

Spatial and Temporal Mapping of Groundwater Quality using GIS based Water Quality Index (A Case Study of SIPCOT-Perundurai, Erode, Tamil Nadu, India)

S. Durgadevagi, R. Annadurai and Mohan Meenu

Department of Civil Engineering, SRM University, SRM Nagar, Potheri, Kattankulathur - 603203, Kancheepuram District, Tamil Nadu, India; durgadevagi@ktr.srmuniv.ac.in, ddanirudh@gmail.com, annadurai.r@ktr.srmuniv.ac.in, meenakshi.mohan31@gmail.com

Abstract

Groundwater is an important source of drinking water especially in rural areas of Tamil Nadu. Over exploitation of groundwater for industrial use has become a major challenge. Therefore, it is very important to assess the quality of groundwater. The present study is about the geostatistical analysis of groundwater quality for SIPCOT Industrial estate, Perundurai, Erode, where Groundwater is the main source of water for drinking and irrigation purpose. The aim of the study is to map the current situation of groundwater quality in the study area. The groundwater samples collected from 35 wells in and around the SIPCOT industrial estate are used for this purpose. The major water quality parameters such as pH, EC, TDS, TA, TH, Ca, Mg, Na, K, F, Sulfates, Nitrites, Nitrates, Chlorine, Carbonate, Bicarbonate, Sodium absorption ratio, Residual sodium carbonate, and Sodium have been estimated for all the samples and the results were compared with the BIS standards. The spatial distribution map of these groundwater quality parameters were derived and integrated with WQI through GIS. GIS is used as a tool for analysis of spatial distribution of water quality. The resultant map shows the Water quality index for both pre monsoon and post monsoon season of the study area.

Keywords: BIS Standards, GIS, Groundwater Quality, Spatial Variation, Water Quality Index

1. Introduction

Water is the most important, in shaping the land and regulating the climate. Due to uneven spatial and temporal distribution of rainfall and due to improper management of water disposal practices, the development activities of the society are totally depends on the groundwater resources². Due to anthropogenic activities and improper waste disposal the surface water bodies the groundwater is subjected to various sources of contamination¹⁷. According to WHO organization about 85% of all the diseases in human beings are caused by water²³.

The quality of water is generally defined in terms of its physical, chemical and biological parameters and

measured as Water Quality Index (WQI) to assess water portability¹¹. WQI is the tool used to identify the standard of water based on several water quality parameters; hence groundwater quality map is very helpful for evaluating portability of groundwater and to indicate of potential environmental health problems⁸.

Geographical Information System (GIS) is used as a tool to assess the groundwater quality by means of water quality parameters overlay analysis. The objective of the paper is to explore the groundwater data through spatial data analysis and mapping of the spatial variability of groundwater hydrochemistry. The study will also evaluate the geostatistical methods to interpolate the groundwa-

*Author for correspondence

ter parameters. In this study the geostatistical analyst of ArcGIS is used for data investigation.

2. Study Area

In Tamil Nadu, Erode is famous for its textile industries situated in the center part of Tamil Nadu. Perundurai is a developing town because of the advent of SIPCOT which is fully supported by Tamil Nadu Government. The exact location of the study area lies between 77°30'55" E and 11°15'22"N to between 77°35'32"E and 11°11'41" N. The study area comes under the Toposheets 58E/8, 58E/9, 58E/11 and 58 E/12. The key plan of the study area is shown in Figure 1.

It is located in NH-47 between Salem and Coimbatore. SIPCOT consist of 109 industries in which 71 are textile industries 6 chemical industries and 32 other general type industries. A lot of textile industries were relocated from Tirupur to Perundurai. Most of the villages around SPICOT depend on agriculture lands the sources of irrigation are streams, tanks and wells. Ground water plays a major role for irrigation and domestic use.

3. Materials and Methodology

The methodology adopted in this study includes field data collection, laboratory testing of samples and assessment of groundwater quality using Water Quality Index. An overview of the methodology adopted for this study is presented as a flow chart in Figure 2.

3.1 Sample Collection

A total of 35 number of sample location are selected based on the study area map that is 6 wells are selected in 2kms, 8 wells between 2 to 5kms, 10 wells between 5 to 7kms and 9 wells between 7 to 10kms radius from SIPCOT industrial estate totally 35 numbers of water samples from bore wells, open wells and tanks were collected for both post-monsoon and pre-monsoon seasons. The location of sample wells is shown in Figure 3.

The groundwater samples were analyzed for different physio - chemical parameters such as pH, EC, TDS, TA, TH, Ca, Mg, Na, K, F, Sulfates, Nitrites, Nitrates, Chlorine, Carbon, Hydrogen Carbonate, Sodium absorption ratio, Residual sodium carbonate, and Sodium are tested using standard testing procedure and the physic-chemical anal-

ysis was carried out as per the standard methods and the results where compared with the BIS standards³.

4. Results and Discussion

Groundwater quality indicates the quality of water used for different purposes, water quality index of the present water body is established from important various physicochemical parameters in different seasons¹¹. The season wise water quality index was calculated for both pre monsoon and post monsoon season and the values are shown in the Table 1 and 2.

4.1 Water Quality Parameters

The spatial distributions for fifteen parameters as shown in the table are determined and the maximum and minimum values of each parameter are identified to calculate the Water Quality Index for the study area. The value of pH range between 8.05-8.9 during pre-monsoon season and 8.2-8.8 during post monsoon season, the average value of pH shows in most of the placed the water is alkaline. Figure 4 shows the spatial distribution of pH in the study area shows that the concentration of pH value is less only in north part. The value of EC varies from 630-5210 ppm for pre monsoon and 926-3950 ppm for post monsoon, as shown in Figure 5.

TDS varies from 360.6-3315 for pre monsoon and 591-2516 for post monsoon season. Figure 7 shows that spatial distribution of Total Alkalinity of water in the study area, it various from 201-621.5 for pre monsoon season and 205-586.6 for post monsoon season, concentration of TDS is high in the southern region. It is proved that the TDS in groundwater is high due to presence of industrial waste. Figure 8 shows that spatial distribution of Total Hardness of water, it various from 71.25-152.5for pre monsoon season and 48.33-650 for post monsoon season; high concentration of TH is obtained in the southern part. TH was less in edges of the northern part. Figure 9 shows that spatial distribution of calcium, it various from 22.67-60 for pre monsoon season and 28.5-61 for post monsoon season, concentration of calcium is high in the southern part of the study area.

Figure 10 shows that spatial distribution of magnesium in the study area it various from 36-121.5 for pre monsoon season and 42.8-70.5 for post monsoon season; concentration of magnesium is high in the north part.

Sodium varies from 29-745 for pre monsoon season and 35-506 for post monsoon season; concentration of sodium is high in more than half of the study area. Figure 11 shows that spatial distribution of sodium in the study area, it varies from 29-745 for pre monsoon season and 35-506 for post monsoon season; concentration of sodium is high in more than half of the study area.

Figure 13 shows that spatial distribution of fluoride varies from 0.645-1.73 for pre monsoon season and 0.543-1.2 for post monsoon season; concentration of fluoride is high in northern part of the study area, and medium concentration of fluoride is obtained only in the center part of the study area. Figure 14 shows that spatial distribution of carbonate varies from 5.2-60 for pre monsoon season and 9.80-66 for post monsoon season, concentration of sodium is high in the south western part of the study area, Figure 15 shows that spatial distribution of carbonate varies from 199.6-666.9 for pre monsoon season and 208.7-718.3 for post monsoon season, concentration of bicarbonate is high in the south eastern part of the study area.

Figure 16 shows that spatial distribution of Nitrate varies from 10.5-108 for pre monsoon season and 9.94-62 for post monsoon season, concentration of nitrate is high in the southern part of the study area. Figure 17 shows that spatial distribution of SAR varies from 0.86-11 for pre monsoon season and 0.9-12.7 for post monsoon season, concentration of SAR is high in the southern part of the study area.

4.2 Water Quality Index (WQI)

WQI is calculated and the weighted overlay was done. The spatial distribution of WQI for pre monsoon was shown in Figure 18, it shows that the complete study area is under the southern part and some of the northern part the study area is found as very high risk zone. The area around 5 km from the SIPCOT is in high risk zone and the area in 7 km radius is in moderate risk zone. The spatial distribution of WQI for post monsoon was shown in Figure 19, this map shows the study area in moderate and high risk zone of pollution. From this we can assess the quality of groundwater during pre-monsoon and post monsoon season.

5. Conclusion

Water quality is dependent on the type of the contamination added and nature of mineral present at the particular

bore well location². Monitoring of the water quality is done by collecting samples and analysis of physicochemical characteristics of water samples at different locations of the study area. The spatial distribution map of TDS, TA, TH, Chloride, Fluoride, Potassium and PH were not within the permissible limit throughout the study area. The spatial distribution map of all parameters illustrates that 45% of the study area is under very high risk zone and 53% of the study area is in High and moderate risk

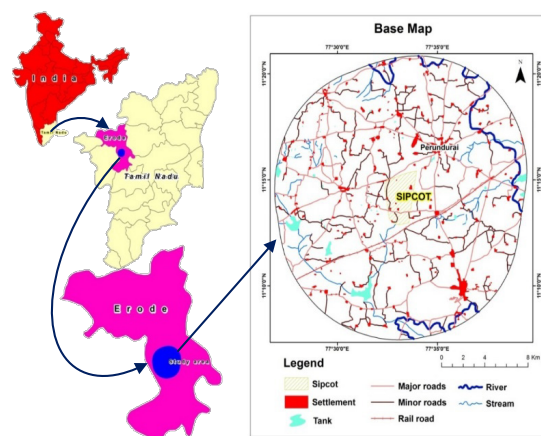


Figure 1. Key map showing the location of the study area.

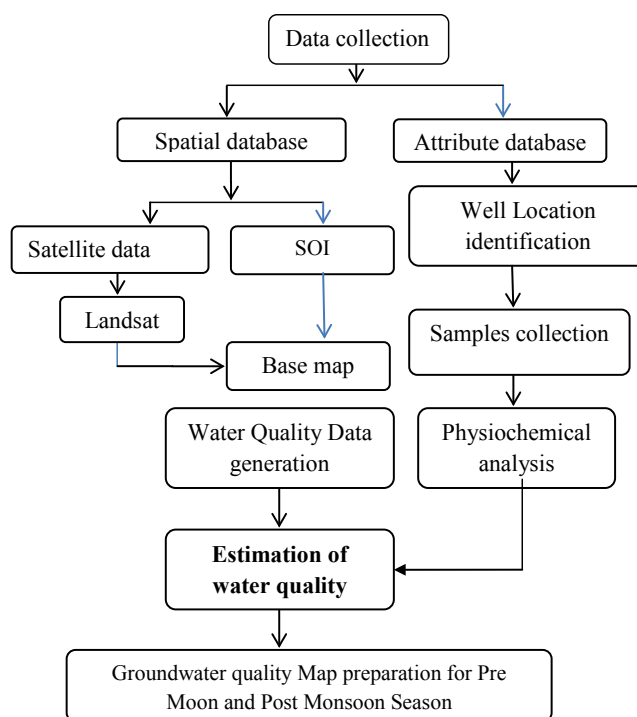


Figure 2. Flow chart showing the methodology adopted in this study.

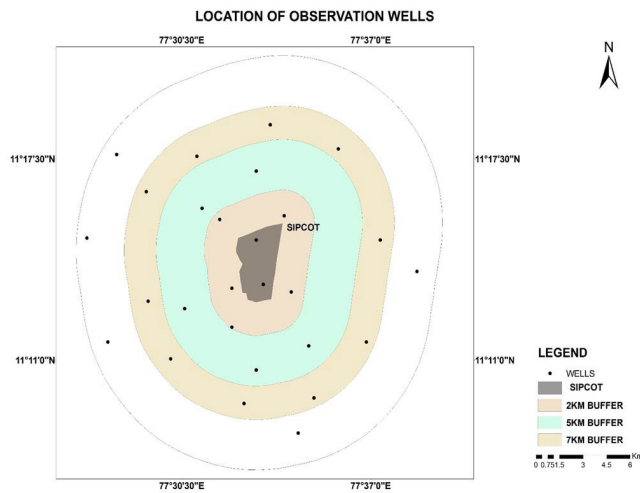


Figure 3. Location map of Observation wells.

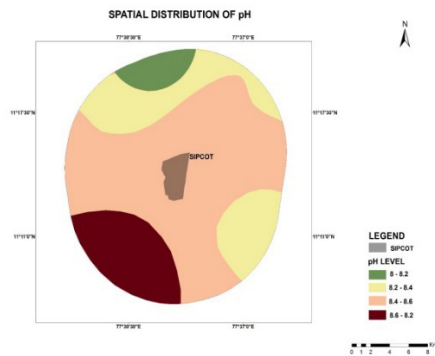


Figure 4. pH

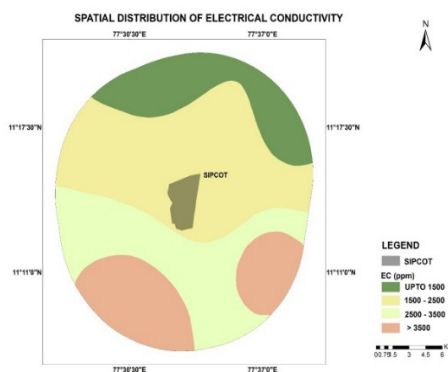


Figure 5. EC

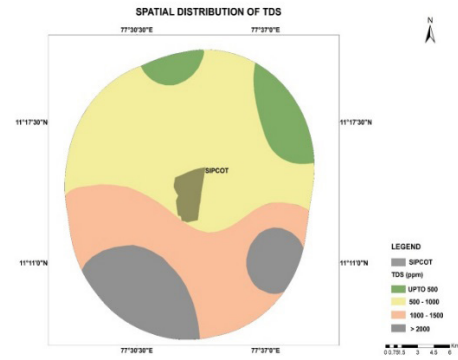


Figure 6. TDS

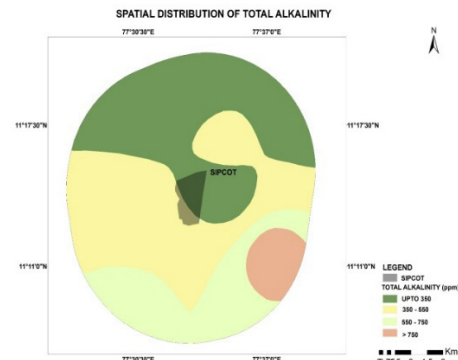


Figure 7. TA

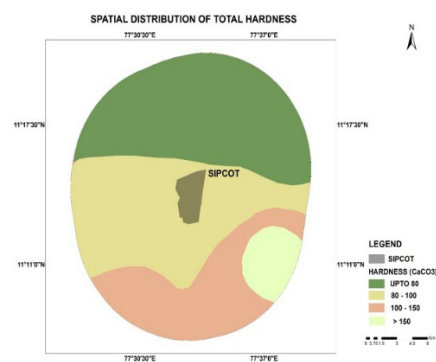


Figure 8. of TH

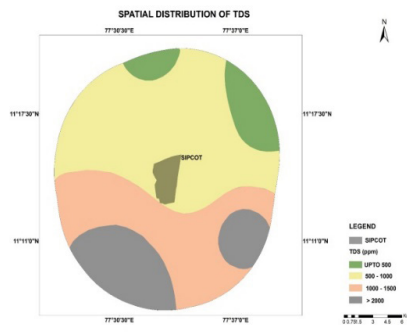


Figure 9. Calcium

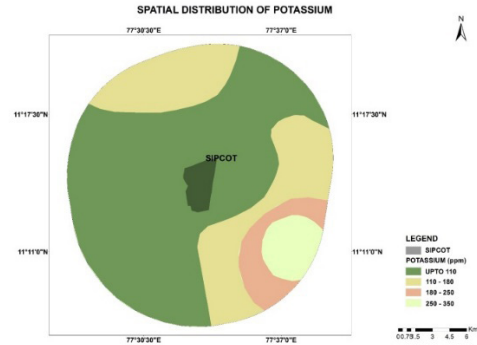


Figure 12. Potassium

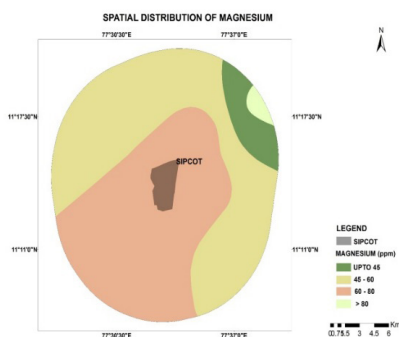


Figure 10. Magnesium

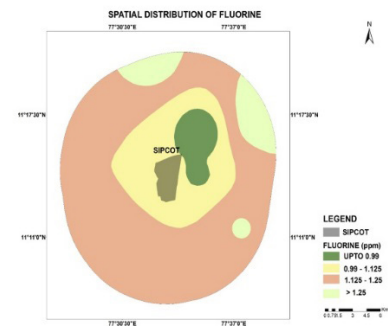


Figure 13. Fluorine

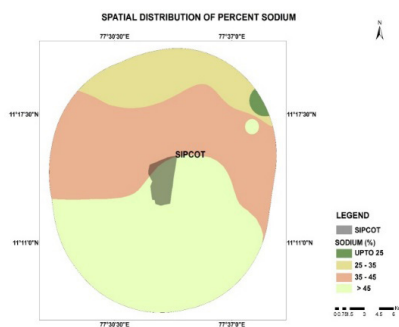


Figure 11. Sodium

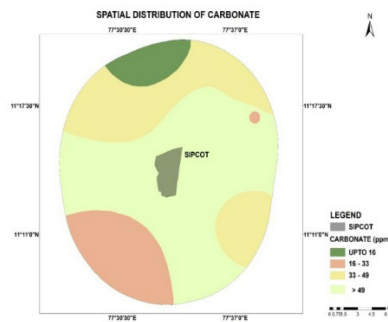


Figure 14. Carbonate

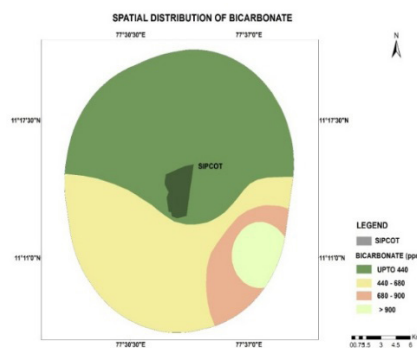


Figure 15. Bicarbonate

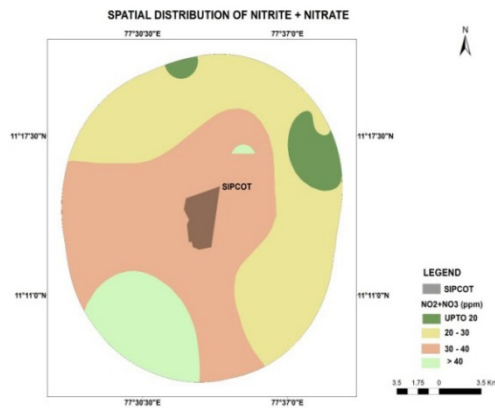


Figure 16. Nitrate

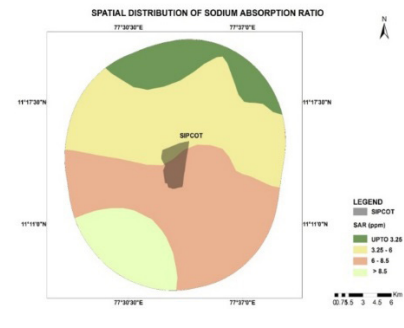


Figure 17. SAR

Table 1. Water Quality Index Value for Pre Monsoon

S.NO	Parameters	Observed value	Standard value (Si)	Unit weight (Wi)	Quality rating (Qi)	(Wi)(Qi)
1	pH	8.05	8.5	0.219	70	15.33
2	EC	630	700	0.371	90	33.39
3	TDS	360.6	500	0.0037	72.12	0.27
4	TA	201	120	0.0155	167.5	2.60
5	TH	71.25	300	0.0062	23.75	0.15
6	Calcium	22.67	75	0.025	30.23	0.76
7	Magnesium	36	30	0.061	120	7.32
8	Sodium	29	60	0.005	48.33	0.24
9	Potassium	38.75	100	0.003	38.75	0.12
10	Sulphate	33.66	150	0.01236	22.44	0.28
11	Nitrates	10.5	45	0.0412	23.33	0.96
12	Chlorine	41.3	250	0.0074	16.52	0.12
13	Carbonate	5.2	20	0.005	26	0.13
14	Bicarbonate	199.6	400	0.002	49.9	0.10
15	SAR	0.86	10	0.01667	8.6	0.14
				$\Sigma W_i = 0.79$	$\Sigma Q_i = 807.47$	$\Sigma W_i Q_i = 61.90$
$WQI = \Sigma W_i Q_i / \Sigma W_i = 61.90 / 0.79 = 77.95$						

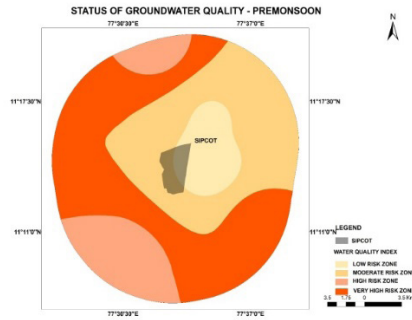


Figure 18. WQI for Pre monsoon.

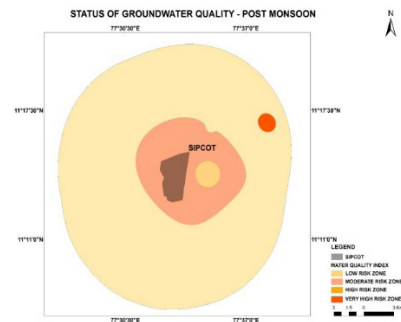


Figure 19. WQI for Post monsoon.

Table 2. Water Quality Index Value for Post Monsoon

S.NO	Parameters	Observed value	Standard value (Si)	Unit weight (Wi)	Quality rating (Qi)	(Wi)(Qi)
1	pH	8.2	8.5	0.219	100	21.90
2	EC	926	700	0.371	132.29	49.08
3	TDS	591	500	0.0037	118.20	0.44
4	TA	205	120	0.0155	170.83	2.65
5	TH	48.33	300	0.0062	16.11	0.10
6	Calcium	28.5	75	0.025	38.00	0.95
7	Magnesium	42.8	30	0.061	142.67	8.70
8	Sodium	35	60	0.005	58.33	0.29
9	Potassium	41	100	0.003	41.00	0.12
10	Sulphate	66.33	150	0.01236	44.22	0.55
11	Nitrites, Nitrates	9.94	45	0.0412	22.09	0.91
12	Chlorine	89	250	0.0074	35.60	0.26
13	Carbonate	9.8	20	0.005	49.00	0.25
14	Bicarbonate	208.7	400	0.002	52.18	0.10
15	SAR	0.9	10	0.01667	9.00	0.15
				$\Sigma W_i=0.79$	$\Sigma Q_i=1029.51$	$\Sigma W_i Q_i=86.45$

$$WQI = \Sigma W_i Q_i / \Sigma W_i = 86.45/0.79 = 108.87$$

zone. Thus the spatial distribution maps of various quality parameters are used to identify the quality of the groundwater in the study area. The WQI values varies from 77.95 – 108.87, which shows that the study area is in very high risk zone.

This study shows the use of GIS integrated with analytical data and WQI to assess the groundwater quality⁵. WQI helps us to understand the status of groundwater in the study area. It also helps us to understand whether the overall quality of groundwater body poses a potential threat to various uses of water. Regions of low groundwater quality should be targeted for more detailed investigation and to take immediate remedial measure. To safe grade the groundwater.

6. References

1. Ambasht RS. Ecosystem study of a tropical pond in related to primary production of different vegetation zones. *Hydrobiologia*. 1971; 12:57-61.
2. Arslan H. Spatial and temporal mapping groundwater salinity using ordinary kriging and indicator kriging: The case of Bafra Plain, Turkey. *Agricultural Water Management*. 2012; 113:57-63.
3. APHA. Washington D.C.: American Public Health Association: Standard methods for the examination of water and wastewater. 1998.
4. BIS. New Delhi: Bureau of Indian Standards: Indian standards specifications for drinking water IS: 10500. 2003.
5. Engel BA, Navulur KCS. The role of geographical information systems in groundwater Engineering. Boca Raton, CRC: Delleur JW (ed.) The handbook of groundwater engineering. 1999; p.703-18.
6. Nas B, Berkay A. Groundwater quality mapping in urban groundwater using GIS. *Environ. Monitor. Assess*. 2010; 160(1-4):215-27.
7. Byun DH. The AHP approach for selecting an automobile purchase model. *Information and Management*. 2001; 38:289-97.
8. Chatterjee C and Raziuddin M. Determination of water quality index (WQI) of a degraded river in asanol Industrial area, Raniganj, Burdwan, West Bengal. *Nature, Environment and pollution Technology*. 2002; 1(2):181-89.
9. Choi MW. Tokyo: The Tokyo Press: A hydrological study of the groundwater in Nasu, Tochigi Prefecture. 1976; p. 21-39.
10. Collect C. Geographic Information system Needs and Software Boston, USA: Kluwer Academic Publishers: *Geographical Information System in Hydrology*, 1st Edition. 1996.
11. Dahiya S and Kaur A. Assessment of physical and Chemical characteristics of underground water in rural areas of Tosham subdivision, Bhiwani-Haryana. *International Journal of Environment and Pollution*. 1999; (4):281-88.
12. Delgado C, Pacheco J, Cabrea A, Baltlori E, Orellana R and Baustista F. Quality of groundwater for irrigation in tropical karst environment; the case of Yucatan, Mexico. *Agricultural Waste Management*. 2010; 97:1423-33.
13. Ghosh A and George JP. Studies on the abiotic factors and zooplankton in a polluted urban reservoir hussain sagar, Hyderabad: Impact on water quality and Embryonic development of fishes. *Indian Journal of Environment and health*. 1989; 31:49-59.
14. Guruprasad B. Assessment of water quality in canals of Krishna delta area of Andra Pradesh, *Nature of Environment and pollution Technology*. 2005; (4):521-23.
15. Horten RK. An Index number for rating water quality. *J. Water poll. cont. Fed*. 1965; 37(3):300-6.
16. Hiyama T, Suzuki Y. Groundwater in the Nasuno basin – spatial and seasonal changes in water quality in Japan, *Hydrol. J Jap Assoc Hydro SCS*. 1991; 21(3):143-54.
17. Joseph K. An integrated approach for management of TDS in reactive dyeing effluents. Hyderabad: International conference on Industrial pollution and Control Technology.
18. Naik S and Puohit KM. Physico-chemical analysis of some community ponds of Rourkela. *Indian Journal of Environmental Protection*. 1996; 16(9):679-84.
19. Raviprakash S and Rao GK. The chemistry of ground water in paravada area with regards to their suitability for domestic and irrigational purposes. *Indian Journal of Geochemistry*. 1989; 4:39-54.
20. Shomar B, Fakher SA and Yahyal A. Assessment of Groundwater quality in the Gaza strip, Palestine using GIS mapping. *Journal Water Resource and Protection*. 2010; 2:93-104.
21. Srinivasamoorthy, Nanthakumar C, Vasanthavigar M. Groundwater quality assessment from a hard rock terrain, Selam district of Tamil nadu. *Arabian J. Geoscience*. 2009; p. 112-15.
22. Tiwari TN and Mishra M. A preliminary assignment of water quality index of major indian rivers. *Indian Journal of Environmental Protection*. 1985; 5(4):276-79.
23. WHO. Geneva, Switzerland: World Health Organization: *International Standards for Drinking Water*. 1992.