Original Article

Bulletin of Pure and Applied Sciences.
Vol. 36 E (Geology), Issue (No.1) 2017: P.1-17
Print version ISSN 0970 4639
Online version ISSN 2320 3234
DOI 10.5958/2320-3234.2017.00001.4

Integration of Groundwater Potential and Irrigation Water Quality at Micro Level in Tannery Polluted Areas

Dr. C. G. Hemamalini*, Dr. M. Krishnaveni**

*Professor, Department of Civil Engineering, Easwari Engineering College, Chennai - 600089, Tamil Nadu, India. **Professor, Department of Civil Engineering, Centre for water Resources, Anna University, Chennai, Tamil Nadu, India.

Abstract

Micro level integration of groundwater potential and quality is essential in severely polluted river basins, to enable efficient extraction, planning of artificial recharge structures for augmentation of groundwater potential and dilution of pollutant load. The objective of the paper is to develop an integrated groundwater potential and quality map, using GIS techniques to identify the locations of water extraction in sub basin level. Ambur sub-basin in Palar River Basin, Tamil Nadu, India were chosen for present study, this basin is affected by tannery effluents for the past 30 years. Groundwater potential map were prepared using geology, geomorphology, lineament, soil, landuse / land cover and slope maps and also based on field survey data on groundwater level and yield. Groundwater quality map for irrigation purpose were prepared based on spatial distribution of electrical conductivity, Sodium Adsorption Ratio, Sodium percentage, Residual Sodium Carbonate and Permeability index. Based on these maps, an integrated overlaid map of groundwater potential and quality were prepared. The integrated map distinctly indicates zones for groundwater extraction, development of artificial recharge structures and adoption of suitable water treatment methods for irrigation at micro level. Pollutant transport model can also be applied, to simulate changes that may happen in the integrated map over the next 20 - 100 years. The results of this study show that the benefits of integrated map for solving the water problems with respect to both quantity and quality for the water managers. It is arrived that the total area of about 29.60 km^2 out of 60 km^2 is suitable for irrigation with respect to both potential and quality.

Keywords: Micro level; Industrial effluent; Irrigation groundwater quality; Groundwater potential; GIS.

Corresponding Author: Dr. C. G. Hemamalini, Professor, Department of Civil Engineering, Easwari Engineering College, Chennai - 600089, Tamilnadu. India

E-mail: cghemamalini72@gmail.com

(Received on 10.02.2017, **Accepted on** 29.05.2017)

1. INTRODUCTION

Micro level identification of zones for groundwater extraction, location of artificial recharge structures for augmentation of groundwater and dilution of pollutant load and adoption of suitable water treatment methods become very important, in river basins severely affected by pollution of groundwater and surface water, scarce rainfall and poor surface water availability (CGWB 2010; Murty and Surender Kumar 2011). Ambur sub basin, in Palar river basin, is the most polluted area due to tannery effluents (Government of Tamil Nadu 1998 and Thangarajan 1999). During the field visits, it was also noticed that tannery effluents are directly let into the Palar river (Fig .1a and Fig.1b), though there is no natural flow in the river. This has been happening for the past 30 years. As a result, groundwater is severely polluted and has become unfit for irrigation and drinking purpose in most of the villages. The situation is compounded by irregular and scanty rainfall in this region for the past 30 years. There are two rain gauge stations namely Ambur and Vaniyambadi rain gauge stations situated north and south of the sub basin. In Ambur, the excess, deficient, normal and scanty rainfall variations arrived are 1005 mm, between 334.7 mm and 669.4 mm, between 669.4 mm and 1005 mm and 334.7 mm respectively. Similarly, in Vaniyambadi, the excess, deficient, normal and scanty rainfall variations arrived are 1041mm, between 347 mm and 694 mm, between 694 mm and 1041 mm and 347 mm respectively.

Occurrence of groundwater varies spatially and temporally based on the physiographic features of the terrain. Delineation of potential zones involves integration of Remote Sensing data with Geographical Information System (GIS) (Saraf and Choudhury 1998; Murthy et.al 2003; Jasrotia et.al 2007; Nagarajan and Sujit Singh 2009). Various thematic maps such as geology, geomorphology, lineament, soil, land use / land cover and slope maps were prepared and these maps were integrated by assigning weights to different criteria in each thematic map using overlay analysis. Finally groundwater potential zones map was arrived. Irrigation groundwater quality map (Asadi et. al 2007, Hemamalini et. al 2010, Islam et.al 2009) was prepared based on parameters required for agriculture (Ayers and Westcot 1985, Sarkar and Hassan 2006, Raihan and Alam 2008, Raghunath 2003, Todd 1980) for Ambur sub-basin.

Fig.1a: Tannery effluent flowing into the Palar river at Vadacheri Crossway

Fig.1b: Tannery Effluent Flowing in the River at Periyavarigam

Groundwater potential map was overlaid on irrigation groundwater quality map to integrate spatially the variations in potential and quality. This integrated map is useful for locating groundwater abstraction points, locating artificial recharge structures, estimation of draft and development of more realistic conceptual model of groundwater system. This map can be used for specific planning and suitable cropping pattern in each village, based on groundwater potential and quality. In simulating groundwater pollutant transport, this integrated map can be used as a tool to validate the results of the simulation model.

Study Area

Ambur sub basin (Fig.2a and Fig 2b) in Palar river basin were taken as study area since there is continuous discharge of treated as well as untreated effluent from tannery industries, resulting in acute shortage of usable surface water and groundwater in this sub basin, for irrigation and drinking purposes. Field investigation in the sub-basin also revealed that in most of the cultivable lands, farmers have either shifted to horticultural crops like coconut or left the farm lands uncultivated due to high level of pollution in groundwater. The Ambur sub basin is delineated from Survey of India toposheets 57L/9, 57L/10, 57L/13 and 57L/14 and it lies in between longitudes 78°33'19" and 78°48'48" East and latitudes 12°39'0.44" and 12°45'19.36" North. It measures 394.4 km^2. The geological formation of the study area shows that it is predominately underlain by Gneissic formation and in few places by Charnockite formation (Thangarajan 1999 and Groundwater Perspectives A Profile of Vellore District, SGSWRO, PWD 1998). Geophysical investigations using electrical resistivity method were conducted at different locations in the sub basin such as in Minnur, Venkatapuram, Vadakarai, Periyankuppam Sengilikuppam, Chinnavarigam, Kadavalam, Mittalam, Chinnapallikuppam, Vinnamangalam, Naickaneri and Chikkanankuppam.

The soil is of type sand and sandy loam soil and clay and clay loam soil. The area has dry climate with average annual rainfall of 775.8 mm, recorded in Ambur rain gauge station and 783.4 mm, recorded in Vaniyambadi rain gauge station for 70 average years. The sub basin falls in Vellore district. There are 492 leather tanning units presently operational in Vellore district and 109 units under closure. This area has 10 common effluent treatment plants (CETP), where 395 tanneries are members and 97 individual effluent treatment plants. The volume of treated effluent from all CETPs in Vellore district disposed into the Palar River is 6945 kl / day, disposed into land is 2105 kl / day and disposed into other water bodies is 3200 kl / day.

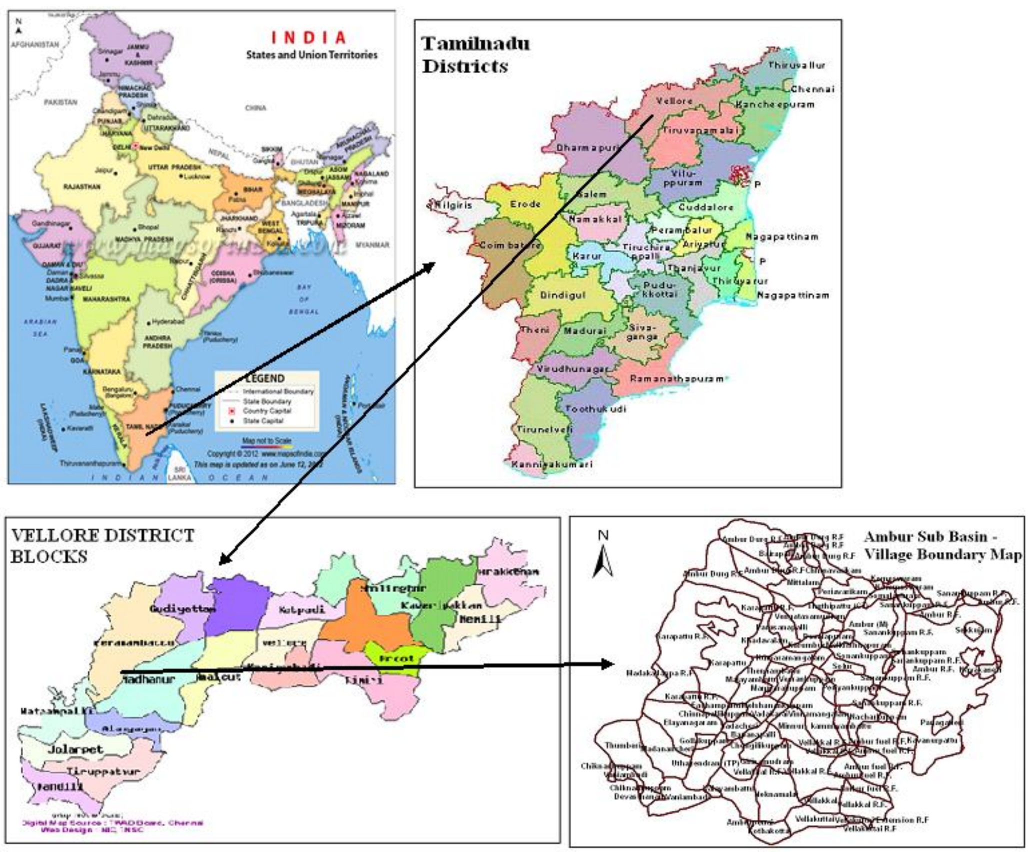


Fig.2a: Location Map of Ambur Sub Basin

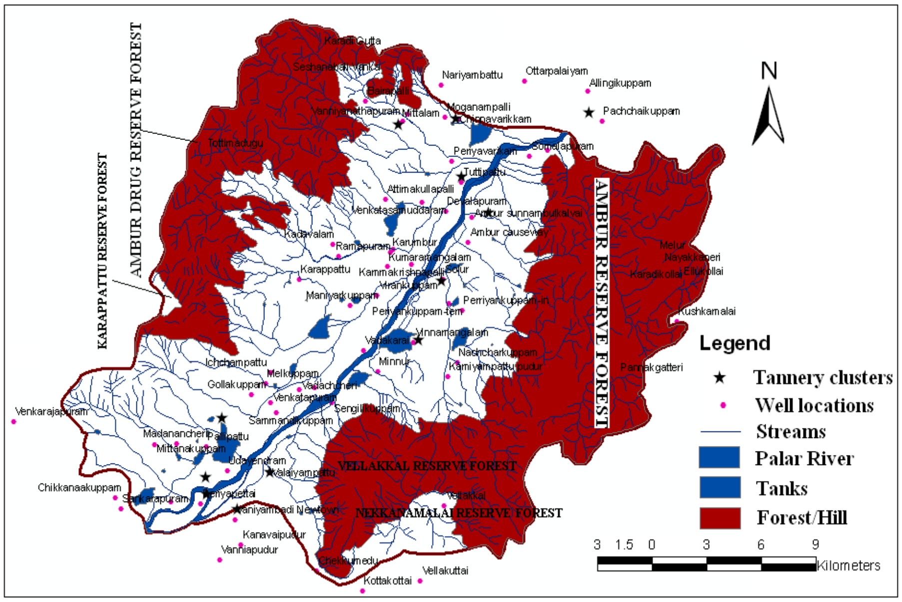


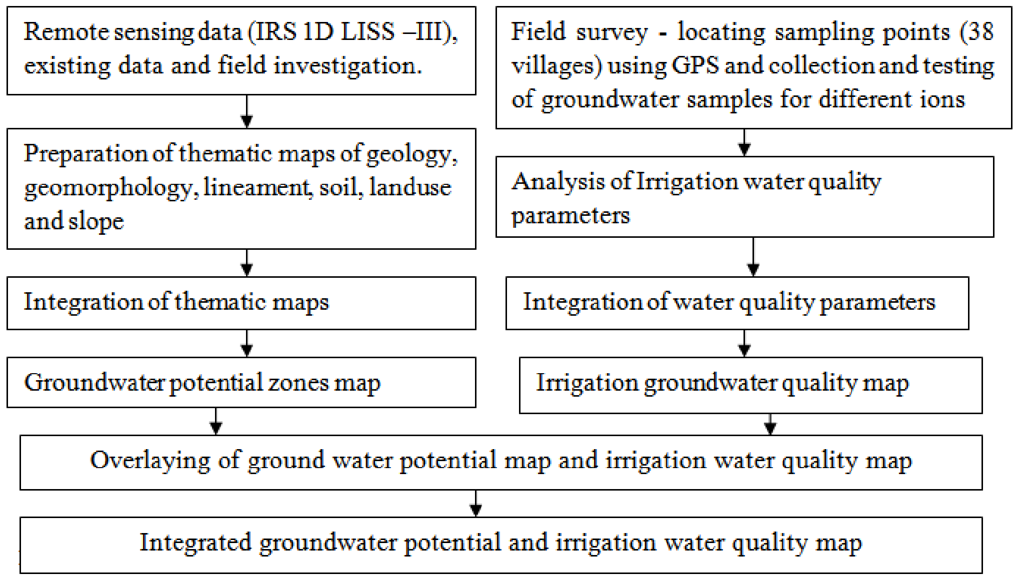
Fig.2b: Physical Map of Ambur Sub Basin

2. METHODOLOGY

Two paths were followed in this study, one for identification of groundwater potential zones and the other path for studying irrigation water quality. This was followed by overlaying of the groundwater potential and quality maps to arrive at integrated groundwater potential and irrigation water quality map. Fig. 3 shows that the methodology adopted to get integrated groundwater potential and quality map for Ambur sub basin.

In the first path, thematic maps (Fig.4-9) of geology, geomorphology, lineament, land use / land cover, soil and slope map were first prepared using remote sensing data (IRS 1D LISS – III) and field investigation. These maps were integrated with suitable weights (Table 1), according to their influence on groundwater potential using overlay technique in GIS and groundwater potential zone map (Nagarajan and Sujit Singh, 2009) (Fig.10) was arrived. The central part of the sub basin consists of Un-consolidated sediments, which are alluvium and fluvial. Other parts of the sub basin are covered with the crystalline Charnockite and Granitic Gneiss of Archaean age. Groundwater occurs under water table conditions in weathered and fractured portions of crystalline rocks.

The different types of geomorphological units identified in this basin are flood plain, pediment with inselberg complex, pediplain weathered / buried, denudation hills, residual hills and structural hills. Flood plain is a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood. This feature has high influence on groundwater potential. Pediment is a gentle inclined erosion surface carved into bedrock covered with fluvial gravel present at the foot of mountains. Pediplain is an extensive erosion surface. Weathered rock buried below the pediplain indicates the presence of groundwater potential in this area.



Lineaments are responsible for infiltration of surface run-off in the sub-surface and also for movement and storage of groundwater. The lineaments are important in rocks, where secondary permeability and porosity resulting from folds, faults and fractures influence weathering and serve as groundwater conduits. The lineament intersection areas are considered as good groundwater potential zones.

The depth of weathering is identified as 18 m to 25 m below ground level in most of the study area and verified during field visits (Fig 11-13). The zone with thick overburden and fractured bedrock are classified as having high groundwater potential.

In terms of groundwater development, low slope shows the presence of high groundwater potential, medium slope depicts the presence of moderate to low groundwater potential and high slope depicts the presence of poor groundwater potential.

In field survey, it was observed that groundwater levels measured in different zones of the study area reveal the different categories of groundwater potential. In Minnur village, the level of groundwater which falls in the category very good is 4 m below ground level. In Chinnavarigam village, the level of groundwater which falls in the category good is 12 m below ground level. In Gollakuppam village, the level of groundwater which falls in the category poor is 18 m below ground level. In Karumbur, the level of groundwater which falls in the category very poor is 24 m below ground level.

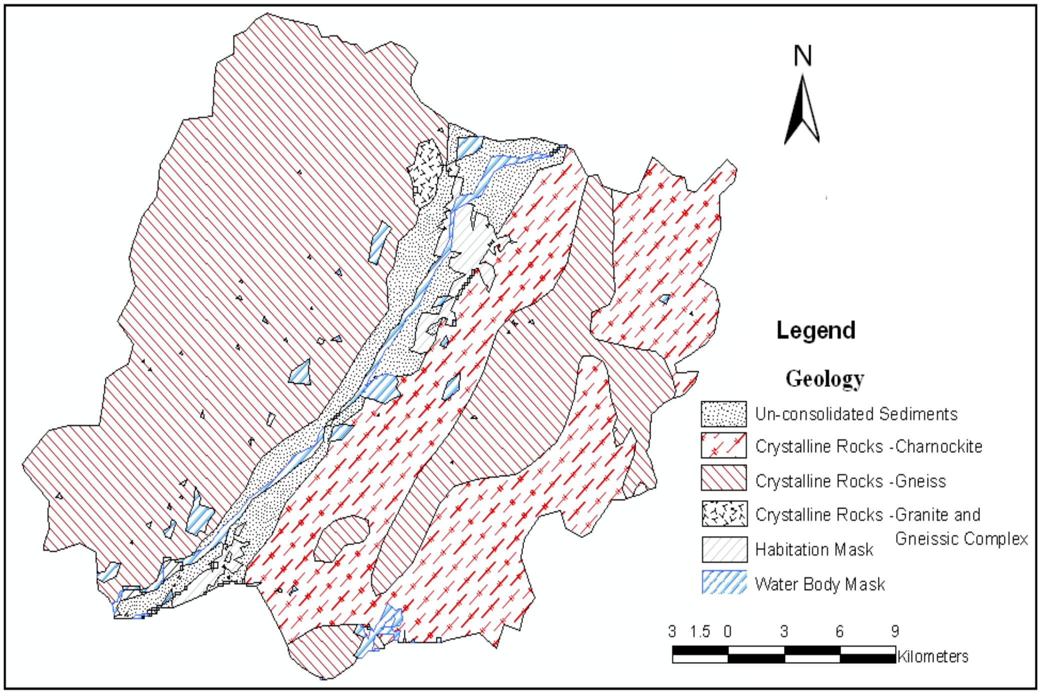


Fig. 4: Geological map of Ambur sub basin

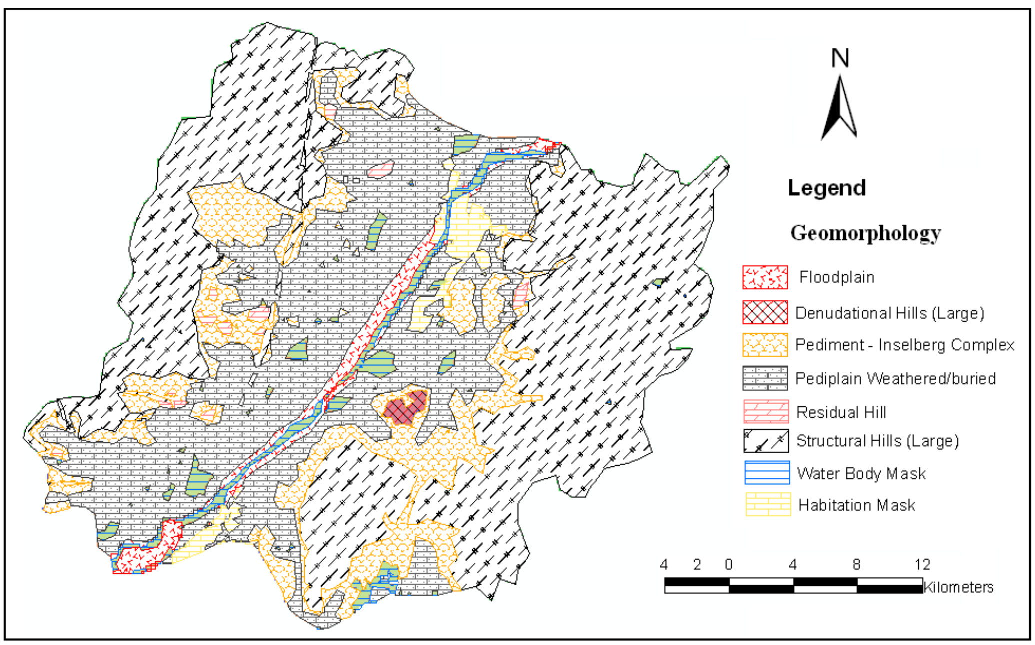


Fig. 5: Geomorphological map of Ambur sub basin

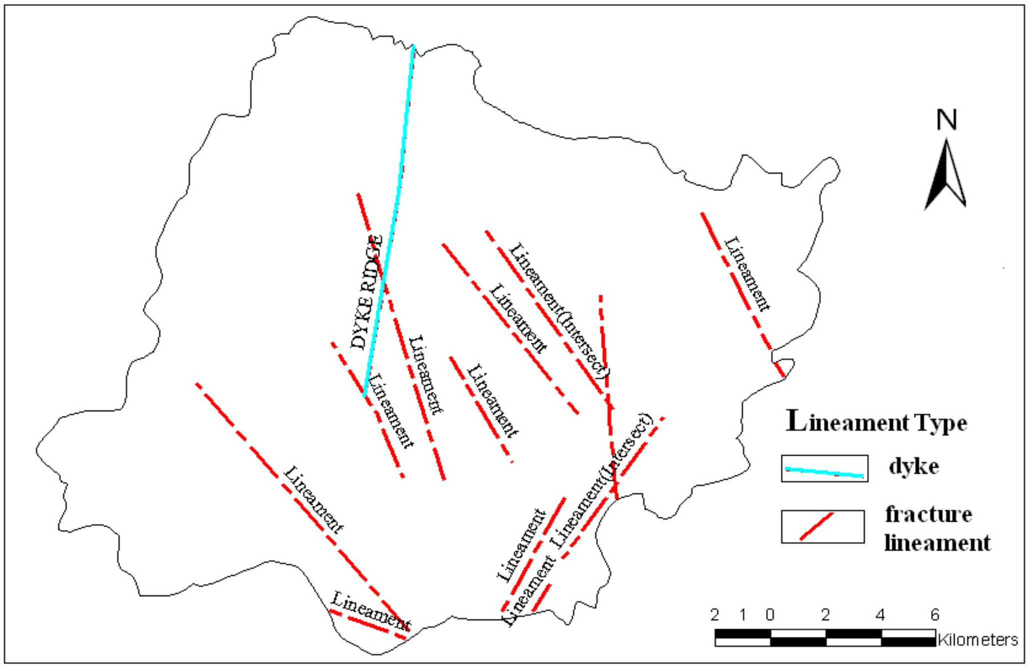


Fig. 6: Lineaments map of Ambur sub basin

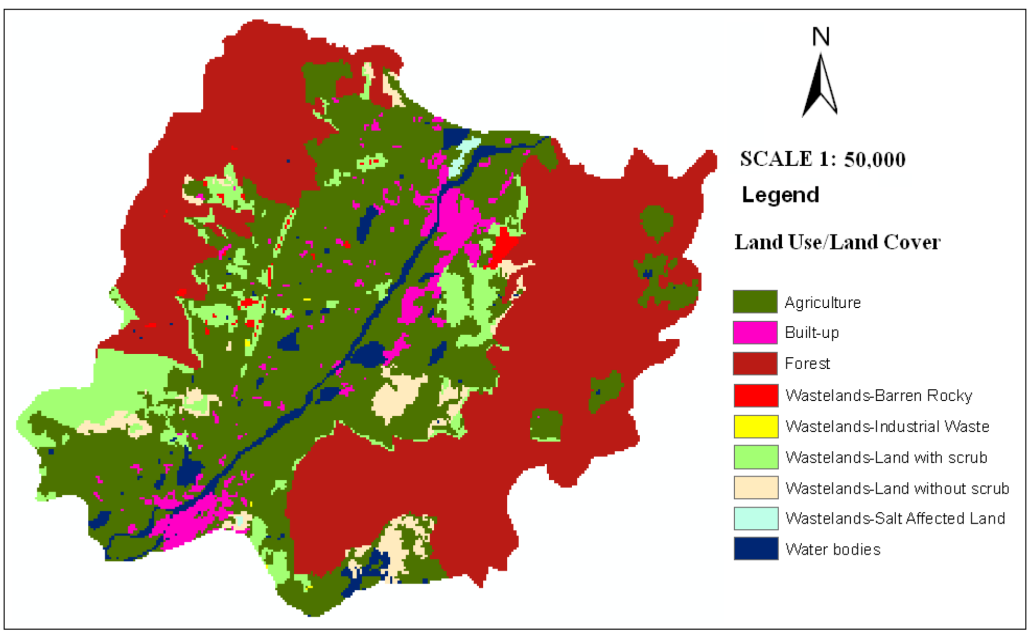


Fig. 7: Land Use / Land Cover map of Ambur sub basin

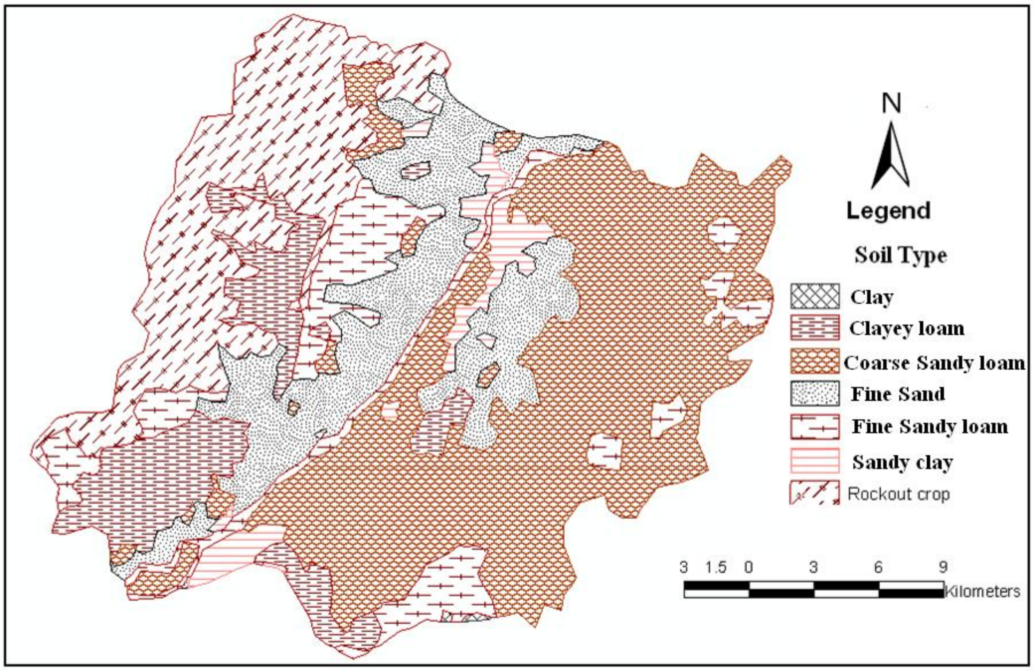


Fig. 8: Soil Map of Ambur sub basin

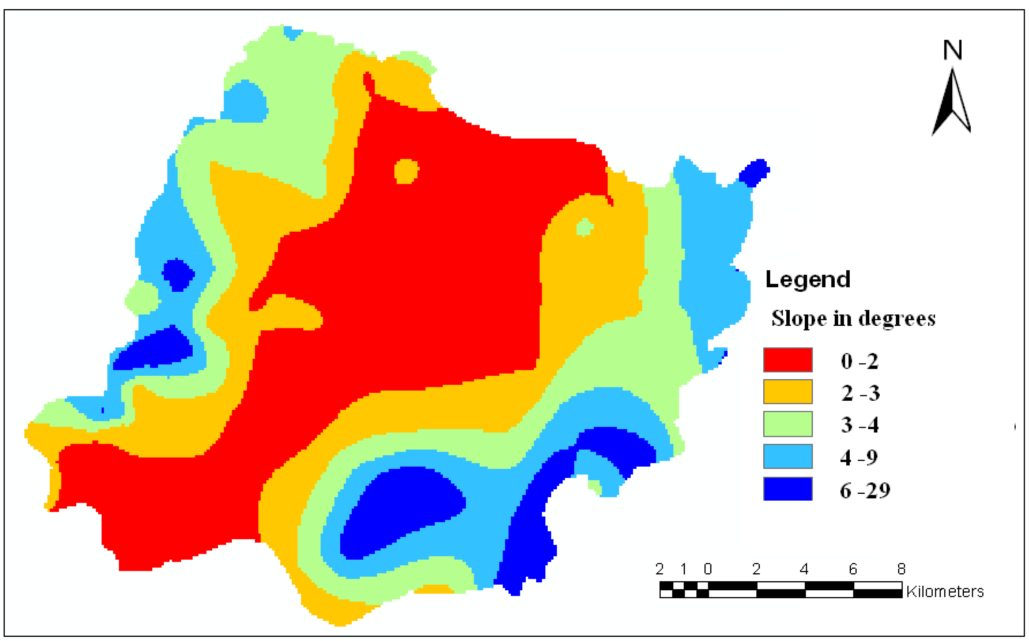


Fig. 9: Slope map of Ambur sub basin

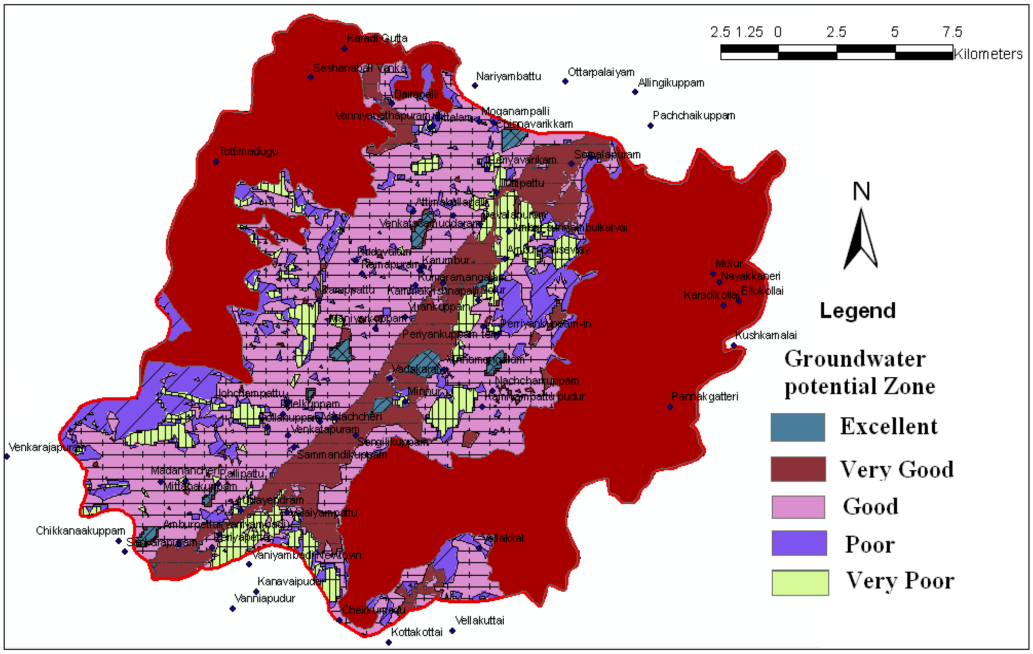


Fig. 10: Groundwater Potential Zone map of Ambur sub basin

Table 1: Weightage assigned for different criteria / feature

S. No.	Theme	Criteria/Feature	Weights assigned for Groundwater Potential
1	Geology	Un-consolidated sediments	2
		Crystalline rock –Charnockite, Gneiss	1
2	Geomorphology	Flood Plain	5
		Pediplains weathered / buried	4
		Pediment – Inselberg Complex	3
		Denudation / Residual hill	2
		Structural Hill	1
3	Lineament	Present	2
		Absent	1
4	Land Use / Land Cover	Water Bodies	5
		Agriculture	4
		Forest	3
		Waste land with and without scrub	2
		Waste land with salt affected	1
		Waste land with Barren rocky	1
		Waste land with Industrial waste	1
5	Soil	Coarse Loamy	5
		Fine Loamy	4
		Fine	3
		Clayey Skeletal	2
		Clayey	1
6	Slope	Very Gentle	5
		Gentle	4
		Moderately Steep	3
		Steep	2
		Very Steep	1

In the second path, 75 sampling sites in Ambur sub-basin were located using GPS. Groundwater samples were collected and tested for irrigation water quality parameters and are shown in Table 2a. In arriving at spatial variability of groundwater quality in Ambur Sub-basin, parameters such as Electrical Conductivity (EC) for salinity hazard, Sodium adsorption ratio (SAR) for alkali hazard or sodium hazard, EC and SAR combined based on US salinity diagram, Residual Soluble Carbonate (RSC), Permeability index (PI), Sodium Percentage (SP), Cl ion toxicity, Kelly's ratio (Ayers and Westcot, 1985, Todd 1980, Raghunath 1987) were considered. These parameters were entered and interpolated using Arc GIS software (Hemamalini et al 2010). Weightage (Table 2) was assigned for each quality parameter based on acceptable or permissible standards for irrigation water quality. These maps were overlaid and integrated by the method of weighted overlay, to arrive at irrigation groundwater quality map (Fig.14) for pre monsoon (2009).

Fig.11: Depth of weathering in the observed well at Periyankuppam village (Long 78.670 Lat 12.752)

Fig. 12: Depth of weathering in the observed well at Sammandhikuppam (Long 78.637 Lat 12.714)

Fig. 13: Water seeping into the well in Vadakarai village (Long 78.673 Lat 12.738)

Table 2a: Groundwater quality parameters for irrigation suitability

S.No	Sampling Location	EC µs/cm	Sodium Absorption Ratio (SAR)	Soluble sodium percentage (Na %)	Permeability Index (PI)	Residual Sodium Carbonate (RSC)	Cl mg/l
1	Chinnakommeshwaram	2150	2	31	48	0	162
2	Allingikuppam	8590	8	54	59	0	1370
3	Ottarpalaiyam	1300	1	26	51	0	122
4	Nariyambattu	4450	1	18	26	0	660
5	Chinnavarikkam	7910	6	47	53	0	1180
6	Mittalam	2670	1	26	58	0	230
7	Attimakullapalli	2640	0	7	28	0	290
8	Karumbur	1090	5	34	39	0	2119
9	Virankuppam	1130	4	40	49	0	2159
10	Kadavalam	4380	6	57	71	1	330
11	Ramapuram	2440	0	11	55	3	160
12	Karappattu	1080	0	16	66	2	80
13	Maniyarkuppam	13400	3	29	36	0	2629
14	Vadakarai	16000	26	82	86	0	2329
15	Venkatapuram	24000	21	72	75	0	3919
16	Gollakuppam	5540	4	51	68	1	550
17	Madanancheri	3800	9	71	83	2	330
18	Mittanakuppam	2580	3	60	95	5	110
19	Chikkanaakuppam	3990	7	66	77	0	510
20	Sankarapuram	5370	10	70	80	0	560
21	Palaiyavaniyambadi	4880	21	91	101	6	420
22	Periyapettai	3560	4	57	77	1	310
23	Amburpettai (vaniyambadi)	3350	3	53	78	1	310
24	Vanniapudur	3950	11	80	93	2	320
25	Kanavaipudur	4040	3	43	60	0	280
26	Vaniyambadi Newtown	3910	4	53	69	0	380
27	Vinnamangalam	8500	6	47	53	0	1300
28	Periyankuppam	4370	2	24	38	0	450
29	Solur	28300	13	52	54	0	4799
30	Ambur	9160	13	70	75	0	660
31	Melur	880	1	19	38	0	120
32	Venkarapuram	1200	1	26	46	0	80

Table 2b: Irrigation water quality parameters and their influence on suitability

S. No	Parameter with unit	Hazard	Acceptable limits for irrigation	Range of values of the examined samples	Irrigation suitability*	Scale value
1	EC in µs/cm	Salinity	<700	-	Excellent	
			700 – 1500	800 – 1500	Very good	1
			1500 – 3000	1501 – 3000	Good	2
			3000 – 5000	3001 – 5000	Poor	3
			>5000	5001 – 12,000	Very poor	4
				12,000 – 28,198	Not suitable	5
2	SAR –Sodium Adsorption Ratio	Sodium (alkali)	<10	<10	Very good	1
			10 – 18	10 – 18	Good	2
			18 – 26	18 – 26	Poor	3
			>26	-		
3	EC and SAR in U.S. Salinity Diagram	Permeability and infiltration	SAR <10 EC 100 – 6000	SAR <10 EC 100 – 6000	Very Good	1
			SAR 10 -18 EC 100 – 6000	SAR 10 -18 EC 100 - 6000	Good	2
			SAR 18 – 26 EC 100 – 6000	SAR 18 – 26 EC 100 – 6000	Poor	3
			SAR >26 EC 100 – 6000	SAR <10,10 - 18, 18 -26 EC >6000	Unsuitable	5
4	Sodium Percentage –Na %	Sodium	< 60%	7 - 60	Very good	1
			60 % – 75 %	61 -75	Good	2
			> 75%	76 - 90	Poor	3
5	Residual Soluble Carbonate -RSC	Toxicity due to carbonates and bicarbonates	<1.25	0 – 1.25	Very good	1
			1.25 – 2.5	1.25 – 2.5	Good	2
			>2.5	2.5 - 6	Poor	3
6	Permeability Index-PI		>75%	76 - 100	Very good	1
			25% - 75%	29 - 75	Good	2
			<25%	-		
7	Chloride -Cl		< 140	< 140	Very good	1
			140 – 350	140 - 350	Good	2
			> 350	> 350	Poor	3

(Classification derived based on IS 11624-1986, classification by State Ground and surface Water resources Data center, Tamil Nadu and adapted from Ayres and Westcot 1985, Raghunath 2003,Todd 1980).

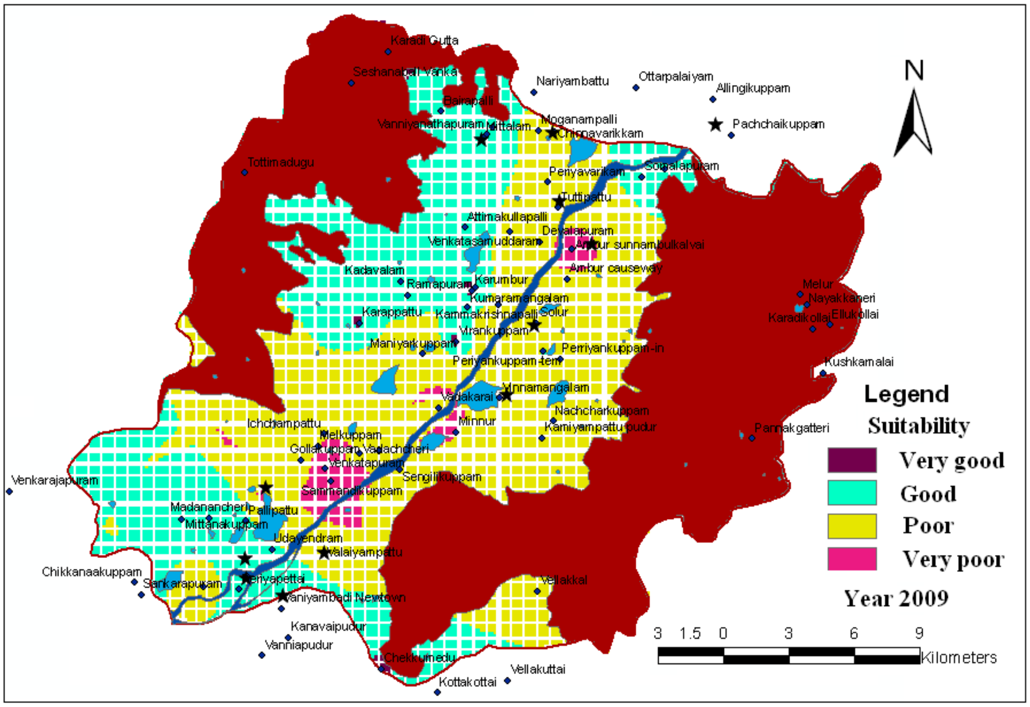


Fig. 14: Integrated Irrigation Groundwater Quality Map of Ambur sub basin

After this stage, the potential map was over laid on groundwater quality map and an integrated potential cum irrigation water quality map (Fig.15) was prepared. From the integrated map, net area available with potential and quality was arrived. This indicates the severity impact of treated and untreated tannery effluent discharge into the sub basin. The results of integrated map were validated for selected sampling sites with corresponding field data.

3. RESULTS AND DISCUSSION

The spatial distribution of irrigation groundwater quality was arrived based on the percentage of area falls in different criteria as shown in Table 3. In this sub basin only 47.9% of area falls under good water quality, covering the criteria good and very good. Table 4 shows that the spatial distribution of groundwater potential. In this sub basin, 44.21% of area falls under good potential, covering the criteria good, very good and excellent. Table 5 shows that the integrated potential cum quality zones for irrigation purpose. The integrated map reveals that a net area of about 60 km^2, constituting about 29.77% of the total area, excluding forest and hills in this sub basin has both potential and quality for irrigation purpose.

Groundwater in the villages with Excellent-Good, Very Good-Very Good, Very Good-Good, Good-Very Good and Good-Good in terms of potential and quality, as indicated in the integrated map, can be optimal sources for extraction. Groundwater in villages with Excellent-Poor, Excellent-Very Poor, Very Good-poor, Very Good-Very Poor, Good-Poor, and Good-Very Poor in terms of potential and quality, as indicated in the integrated map, require water treatment even for irrigation purpose. These villages can grow salt tolerant crops, suitable to the agro-climatic condition of the area, so as to get optimum economic returns. Steps can also be taken in these areas for dilution of pollutant load through percolation with exiting tanks.

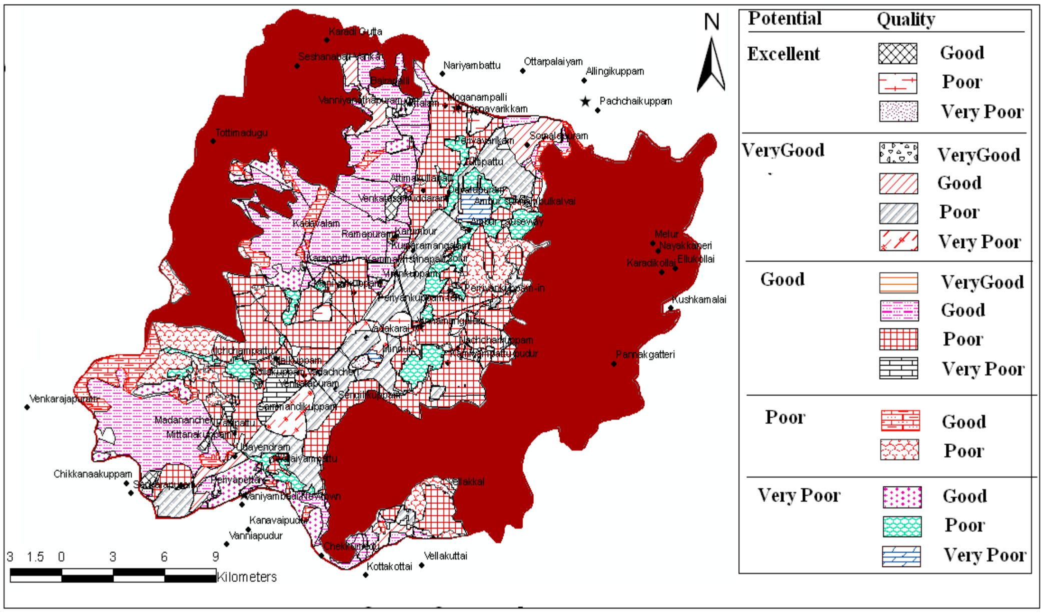


Fig. 15: Integrated Groundwater Potential and Quality Map of map of Ambur sub basin

Table 3: Distribution of area with respect to irrigation groundwater quality

Year	Irrigation quality	Groundwater	% area
2009	Very good		5.92
	Good		41.98
	Moderate		49.82
	Poor		2.28

Table 4: Distribution of area with respect to groundwater potential

Groundwater potential	% area
Excellent	1.06
Very good	9.67
Good	33.45
Poor	49.68
Very poor	6.14

Other areas having poor potential and quality as indicated in the integrated map require augmentation of potential through recharge structures across streams, through percolation with exiting tanks and also dilution of pollutant load through different methods. This integrated map can be used for creating awareness to farmers in these villages on pollution prevention, remedial and improvement measures.

Validation

The results of integrated groundwater potential and quality map were validated with actual field data for some of the villages in the study area. In case of the village Maniyarkuppam, the integrated map indicates good groundwater potential and poor quality. As per the field data, the groundwater level is 7 m below ground level and irrigation groundwater quality parameters are EC = 13400 μs/cm and Cl = 2629 mg/L. In case of the village Venkatapuram, the integrated map indicates good groundwater potential and very poor quality.

As per the field data the groundwater level is 7.3 m below ground level and irrigation groundwater quality parameters are EC = 24000 μs/cm and Cl = 3919 mg/L. In case of the village Chinnakomeswaram, the integrated map indicates poor groundwater potential and good water quality. As per the field data the groundwater level is 12 m below ground level and irrigation groundwater quality parameters are EC = 2150 μs/cm and Cl = 162 mg/L. The affected villages identified from the map are located within tannery clusters.

4. CONCLUSION

Ambur Sub basin which is affected by severe groundwater pollution due to tannery industry for the past 3 decades, compounded by irregular and scanty rainfall and poor surface water flow, is presented. Groundwater in the Ambur sub basin is polluted and has become unfit for agriculture. As a result, the entire cropping pattern has changed in this sub basin, and in some villages agriculture is no longer practiced. The integrated groundwater potential cum quality map using GIS techniques provides inputs for multi pronged approach to groundwater conservation and management. Further to this study, pollutant transport model can be applied in the sub-basin, to simulate changes that may happen in the integrated map over the next 20 to 100 years. Results of such simulation can assist in planning appropriate measures for water resources conservation, pollution prevention and remedial measures for sustainable agriculture. This approach can be adopted in all river basins affected by industrial pollution.

Table 5: Integrated potential cum quality zones for irrigation purpose

Groundwater potential	Irrigation Groundwater quality	Area in Sq. km (Excluding forest / hill)	% Area	Net area with potential and quality
Excellent potential	Good	1.146	0.57%	0.57%
	Poor	2.895	1.44%	Not suitable
	Very poor	0.277	0.14%	Not suitable
Very good potential	Very good	0.0362	0.02%	0.02%
	Good	7.616	3.78%	3.78%
	Poor	26.169	12.98%	Not suitable
	Very poor	4.033	2.00%	Not suitable
Good potential	Very good	0.269	0.13%	0.13%
	Good	50.939	25.27%	25.27%
	Poor	59.202	29.36%	Not suitable
	Very poor	2.836	1.41%	Not suitable
Poor potential	Good	8.404	4.17%	Not exploitable
	Poor	14.779	7.33%	Not exploitable
Very poor potential	Good	8.647	4.29%	Not exploitable
	Poor	12.281	6.09%	Not exploitable
	Very poor	2.082	1.03%	Not exploitable
	Total	**201.611**	**100.00%**	**Net area with potential and quality = 29.77%**

REFERENCES

1. Asadi S.S., Padmaja Vuppala., Anji Reddy. M.(2007).Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India." *Int. J. Environ. Res. Public Health,* 2007, 4(1), 45-52.
2. Ayres, R.S. and D.W. Westcot., (1985).Water Quality for Agriculture. Irrigation and Drainage Paper No. 29. Food and Agriculture Organization of the United Nations. Rome, 1985. pp. 1-117.
3. Groundwater Perspectives A Profile of Vellore District, TamilNadu, State Ground and Surface Water Resources Organisation in Public Works Department, Government of TamilNadu, Chennai-600005, 1998.
4. Groundwater Quality in Shallow Aquifers of India, published by Central Ground Water Board, Ministry of Water Resources, Government of India, Faridabad, India, 2010.
5. Hemamalini. C.G., Krishnaveni. M., Evaluation of groundwater quality of Ambur sub basin through Remote sensing and Geographical Information System", Proceedings of 3rd International Perspective on Current & Future State of Water & Environment, EWRI of ASCE, India, 2010.
6. Islam. M. S. and Shamsad S. Z. K. M., Assessment of Irrigation Water Quality of Bogra district in Bangladesh, J. Agril. Res., December 2009, 34(4): 597-608,
7. Jasrotia A.S., Kumar. R and Saraf. A.K., Delineation of groundwater recharge sites using integrated remote sensing and GIS in Jammu district, India, *International Journal of Remote Sensing*, 2007, Vol. 28, No. 22, 5019–5036.
8. Murthy. K. S. R, Amminedu. E and Venkateswara Rao. V., Integration of thematic maps through GIS for identification of groundwater potential zones, *Journal of the Indian Society of Remote Sensing*, 2003,Vol 31, (No. 3) 197-210.
9. Murty, M.N. and Surender Kumar., India Infrastructure Report 2011, Water Pollution in India, An Economic Appraisal, p. 285, 2011
10. Nagarajan. M and Sujit Singh.(2009). Assessment of Groundwater Potential Zones using GIS Techniques, *Jour. Indian Soc. Remote Sensing*, 2009, Vol. 37, 69 – 77.
11. Raghunath, H.M., Groundwater. Wiley Eastern Limited, 2003, 2nd ed. New Delhi, India. p. 350 -360.
12. Raihan. F., Alam. J. B., Assessment of Groundwater Quality in Sunamganj of Bangladesh, *Iran. J. Environ. Health. Sci. Eng*., 2008, Vol. 5, (No. 3), pp. 155-166
13. Saraf, A.K. and Chaudhary, P.R.(1998).Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharges sites, *International Journal of Remote Sensing*, 1998,Vol. 19, No. 10, 1825- 1841.
14. Sarkar.A.A and.Hassan.A.A.(2006). Water Quality Assessment of a Groundwater Basin in Bangladesh for irrigation Use, *Pakistan Journal of Biological Sciences*, 2006, 9 (9): 1677-1684.
15. Thangarajan, M.(1999). "Modeling Pollutant Migration in the Upper Palar River Basin, Tamil Nadu, India", National Geophysical Research Institute Hyderabad – 500007, India, *Environmental Geology*, Vol. 38, No. 3, 1999.
16. Todd, D.K., Groundwater Hydrology. 2nd ed., John Wiley and Sons Inc. New York, USA. 1980, pp. 280-304.