

Nitrate and Chromium Contamination in Groundwater from Effluent of Tanneries and Drastic Vulnerability Index Map – A Case Study of Ranipet area, Vellore District, Tamilnadu

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Abstract

Objectives: To determine the chromium and nitrate pollutants in groundwater and combined with DRASTIC Maps. **Methods/Statistical analysis:** Thirty five groundwater samples taken from bore and open wells are collected and analyzed by physico-chemical parameter and heavy metals. This groundwater quality data are interconnected with DRASTIC features. **Findings:** From the water quality data, found two major pollutants namely chromium and nitrate due to the presence of tannery industries in the study area causing human health, animals, plants and skin diseases. Using seven features, we assigned three categories such as ranges, ratings and weight to find out DRASTIC index maps ranging from 58 to 699 being very low to very high. These maps are combined with the pollutant values to find out the spatial distribution. **Application/Improvements:** Fully control the groundwater pollution present in the study area that can be adopted for any suitable remedial measures.

Keywords: Chromium, DRASTIC Index, GIS (Geographic Information System), Nitrate, Ranipet Area

1. Introduction

In any nation, Groundwater is one of the most important natural resources, helping as a major source of water to residential, communities, industries and agriculture purposes. The major source of groundwater now becomes the only water source since the limited availability of surface water. Hence, the prevention of groundwater contamination is essential for effective groundwater resource management and vulnerability assessment. The assessment of groundwater vulnerability to pollution has been the subject to severe study during the past years and a variety of methods have been developed. The sim-

plest form of the DRASTIC model includes D-depth of water, R-recharge, A-aquifer media, S-soil, T-topography, I-impact of vadose zone, C-conductivity. The final aim is the development of an integrated method which could successfully predict the specific vulnerability or the pollution risk under intense environmental stress. The selection of this index was based not only on the fact that it constitutes the main contaminant that human activities introduce into the environment of the study area, but also it has been proposed as a representative indicator of groundwater quality degradation. DRASTIC method is more economic and less time consuming to assess a wide range of regional groundwater vulnerability, over-

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coming sloppy, uncontrolled development of land, and undesirable activities. This method was first developed for the US Environmental Protection Agency. Geographic Information System (GIS) is a very efficient tool for analyzing, interpreting, manipulating and incorporating the geological, hydro geological and geomorphologic data¹. The objective of the study area is to determine the nitrate and chromium contamination in groundwater from effluent of tanneries and drastic vulnerability index map.

2. Materials

The current study region is sited in and around Ranipet area is about 154.50 square kilometers and having Latitude N 12°52'30" – 12°57'30" and Longitude E 79°15'00"–79°25'00'. The region mainly includes Ranipet, Walajapet, Arcot and Melvishram and the water source of the study region is mostly Palar River and Ponnai River. In the geological study, this region is having crystals of granite rocks. The Ranipet area is a persistent polluted area and exporting tanned leather. Many industries are processing leather in this area and discharging their effluents on to the open land, surrounding water bodies and into the lakes and river. The effluents were polluting the rivers, lakes and effecting ecological matter and human health².

3. Methodology

The water samples were collected from thirty five different open and tube wells as shown in Figure 1. and were analyzed by physico-chemical parameters and heavy metal like Chromium as per norms. Nitrate and Chromium contamination occurs in bore wells, open wells and industrial waste waters as shown in the Table 1. One of the most widely used models to assess wide range of potential contaminants is DRASTIC index³.

Analysis of groundwater vulnerability in DRASTIC model as referred in Figure 2. This method uses some hydro - geological factors of an area in order to determine the relative groundwater vulnerability to contaminants. DRASTIC includes seven classes – D for water intensity level, R for deep percolation, A for underground layers of rock, S for improvement of soil, T for study area map, I for unsaturated area and C for property of vascular soil. The seven classes are then weighted and ranked, and then are combined to obtain a final ranking value using a groundwater vulnerability algorithm⁴. There are three significant parts: weight, ranges and ratings.

All classes were set to absolute value range between one (lowest factor) to five (highest factor). For each, classes have been ascertained ranges based on its impact on pollution potential. The ratings for each feature has

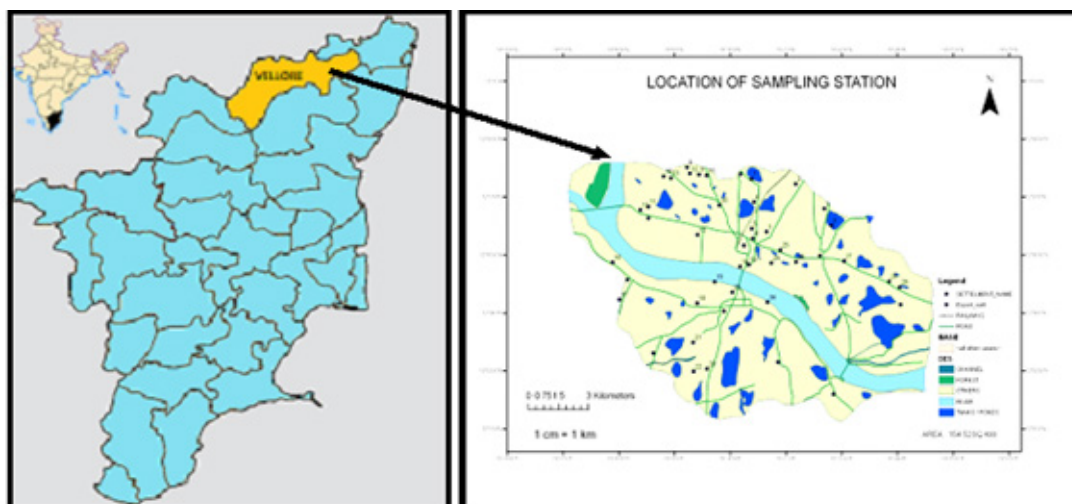


Figure 1. Location of well sampling stations of the study region.

Table 1. Nitrate and Chromium parameters

Well No	Well Type	Nitrate PPM	Chromium PPM	Well No	Well Type	Nitrate PPM	Chromium PPM
1	DW	20	0.2452	19	BW	7	0.2452
2	BW	10	0.1926	20	BW	10	0.3152
3	BW	10	0.1401	21	BW	4	0.1751
4	BW	5	0.1926	22	DW	5	0.1401
5	BW	4	0.1926	23	BW	8	0.0876
6	BW	5	0.2802	24	BW	5	0.0525
7	BW	3	0.4904	25	BW	6	0.1226
8	DW	2	0.4203	26	BW	10	0.1576
9	BW	4	0.3678	27	BW	12	0.0350
10	BW	5	0.3327	28	BW	5	0.1226
11	BW	50	0.3152	29	BW	6	0.1051
12	BW	5	0.2977	30	BW	7	0.1401
13	BW	8	0.3152	31	BW	3	0.1226
14	BW	5	0.3678	32	BW	4	0.1051
15	BW	9	0.5429	33	BW	5	0.0701
16	BW	10	0.4904	34	BW	5	0.1401
17	BW	6	0.2802	35	BW	6	0.0350
18	BW	10	0.2277				

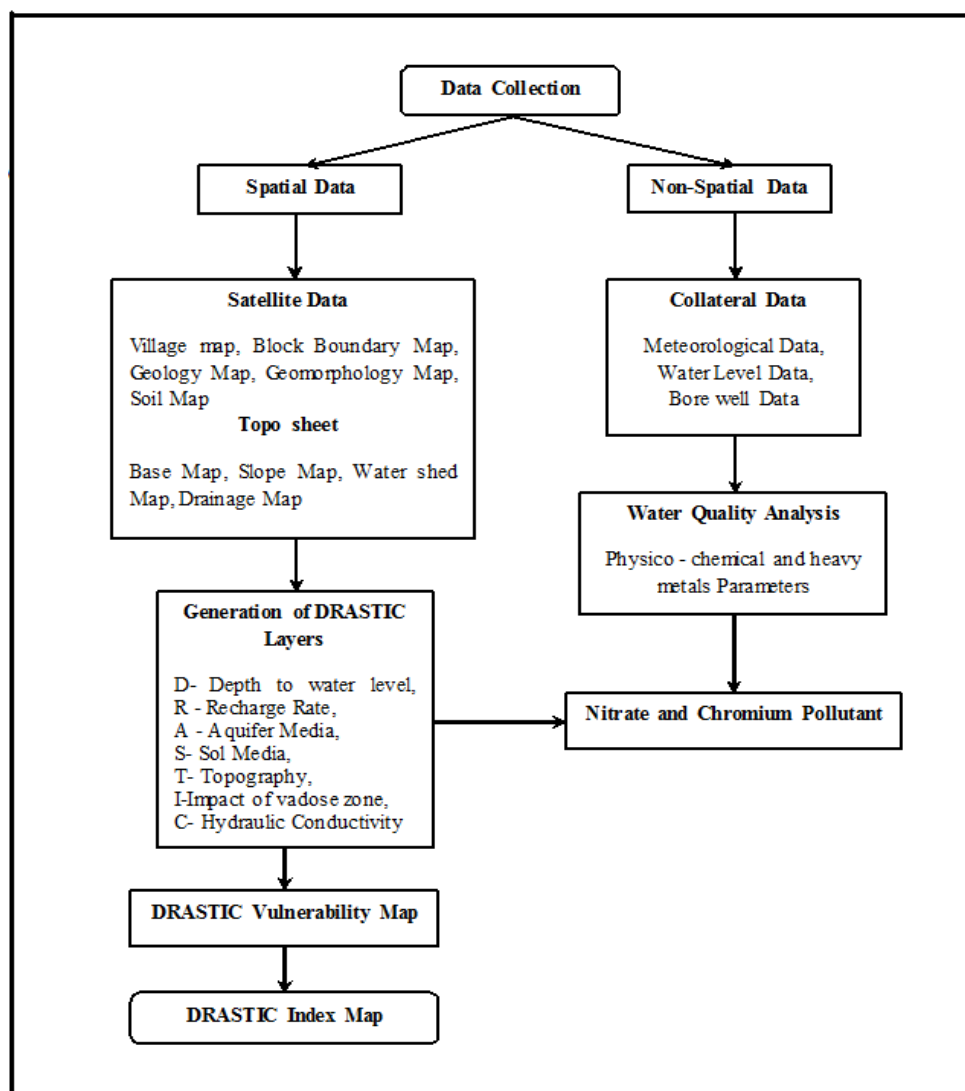


Figure 2. Methodology flowchart for groundwater vulnerability analysis.

been assigned value between 1 and 10, providing a relative assessment between ranges in each feature. To build and manage the database, spatial distribution and Arc GIS map 10.1 (ESRI)⁵ were used. The DRASTIC vulnerability map referred as a composite description of all results from the intersection of thematic maps parameter was combined by overlaying according to the index equation. In order to calibrate the DRASTIC model, chromium and

nitrate concentration were selected as the primary contamination parameter. Thirty five wells were selected for sampling and analysis during the year 2012. The exact position of each well was determined using GPS techniques and measured by spectrophotometer⁶. The highest value of weight which is 5 was the work to water intensity level and unsaturated area due to more contamination

Table 2. Ratings and weight of DRASTIC classes

Sl.No	DRASTIC classes	Ranges	Ratings	Weight	Total Weight
1.	Depth to water level (D)	2.9- 4.5	9	5	45
		4.5 – 8.4	7		35
2.	Natural Recharge Rates (R)	Built Up / Mining / Quarry	1	4	4
		Open / vacant land / scrub land	3		12
		Sandy area	5		20
		Crop land / plantation / fallow land / forest	6		24
		Waterbodies	8		32
3.	Aquifer Media(A)	Charnokite / granite and gneissic complex	3	3	9
		Granite and gneissic complex / fissile hornblende gneiss	4		12
		Gravel,sand,silt	8		24
4.	Soil Media(S)	Tanks / Ponds/ Channel	10	2	20
		Sandy clayloam	9		18
		Sandy clay	8		16
		Loamy sand	7		14
		Sandyloam	6		12
		Clayloam	3		6
		Clay	1		2
5.	Topography (Slope)	0-2	10	1	10
		2-6	9		9
		6-12	5		5
		12-18	3		3
		>18	1		1

Table 2 Continued

6.	Impact of Vadose Zone Media (I)	Tanks / Ponds	1	5	5
		Clay	3		15
		Sandy clay/Loamysand	4		20
		Channel	6		30
		ClayLoam	7		35
		Sandy clayloam	8		40
		Sandy clay	9		45
7.	Hydraulic conductivity(C)	River/Tanks/Ponds	0	3	0
		Sandy clayloam/Clayloam/Sandy loam/Clay	1		3

in ground water. Data of all the features were digitized, changed to raster form and processed.

Groundwater contamination of water level is high for seven features index value and to develop the rating and weight for hydro-geological setting and its parameters⁷. Map Integration with hydro geological factors for moving of groundwater. Ratings and weight of seven features are shown in Table 2.

4. Results and Discussions

In general, the aquifer potential protection increases with depth to water table. The water intensity level range between 2.9 and 8.4m under the subsurface medium and the rating levels were 9 and 7 as the subsurface table is high. The water intensity level map is shown in the Figure 3a.

The rainfall data has been taken from IMD (Indian Meteorological Department), the data has been interpolated using the technique, Inverse Distance Weight (IDW) interpolation in the ArcGIS spatial analyst tool and it is classified as Built Up / Mining / Quarry Open / vacant land

/ scrub land Sandy area Crop land / plantation / fallow land / forest / water bodies. The map for the net recharge is shown in the Figure 3b.

The recharge ratings value lies in the range of 1-8. The different the soil materials are the more the pollution and as the fluid range is very high for applying the rating level of 8. The result of water-resistant environment for Charnokite or granite and gneissic complex is slightly susceptible and ratings value is 3. Granite and gneissic complex / fissile hornblende gneiss, which are permeable rock units have more fluid level and thus, the above rock units was applied the ratings value as 4. The aquifer map is shown in the Figure 3c.

It has significant contact on the progress of the quantity of subsurface water due to infiltration area into the Vadose zone. The rating was assigned from 10 (soil – tanks / ponds / channels) to 1 (clay). The soil media map is shown in the Figure 3d.

However areas with the lower slope withstand water for a longer period of time and hence allow more water to infiltrate (more vulnerable). The range of topography from 0 to greater than 18 and ratings was assigned from

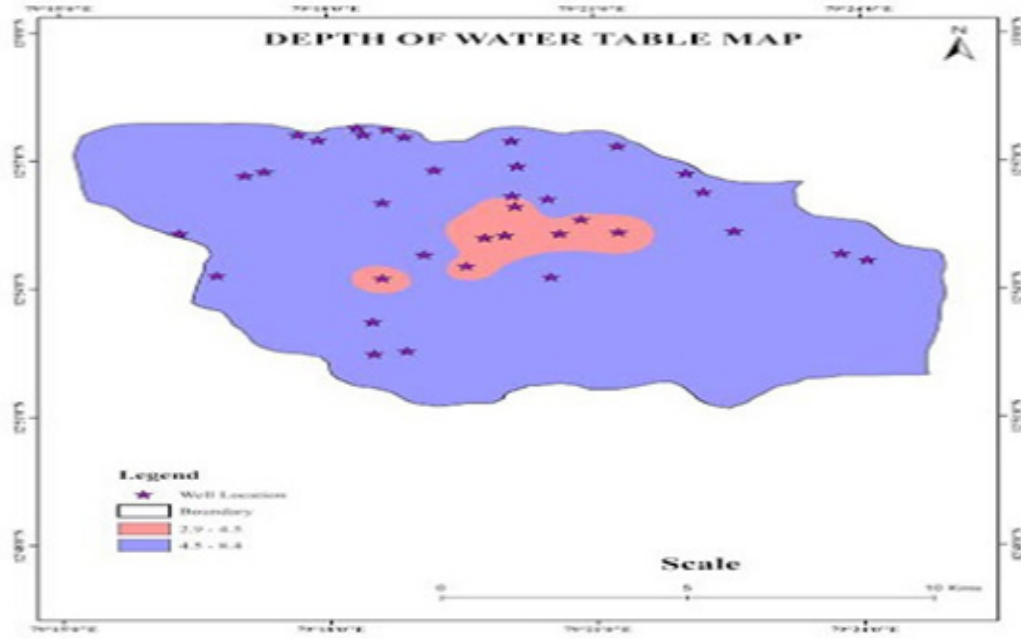


Figure 3a. Depth to the water level of the study area.

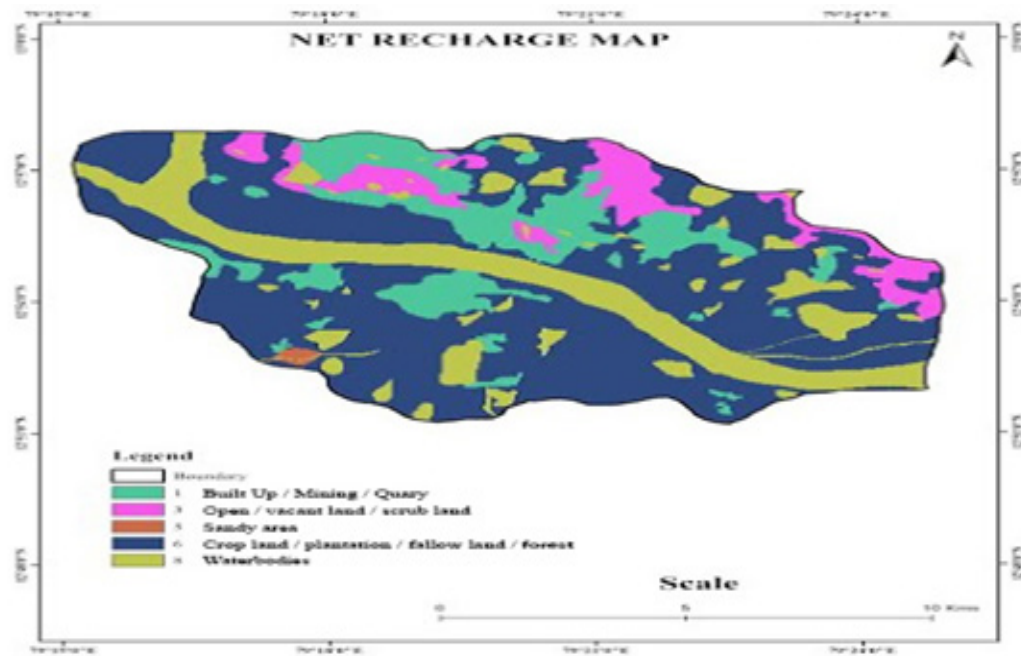


Figure 3b. Net recharge map of the study area.

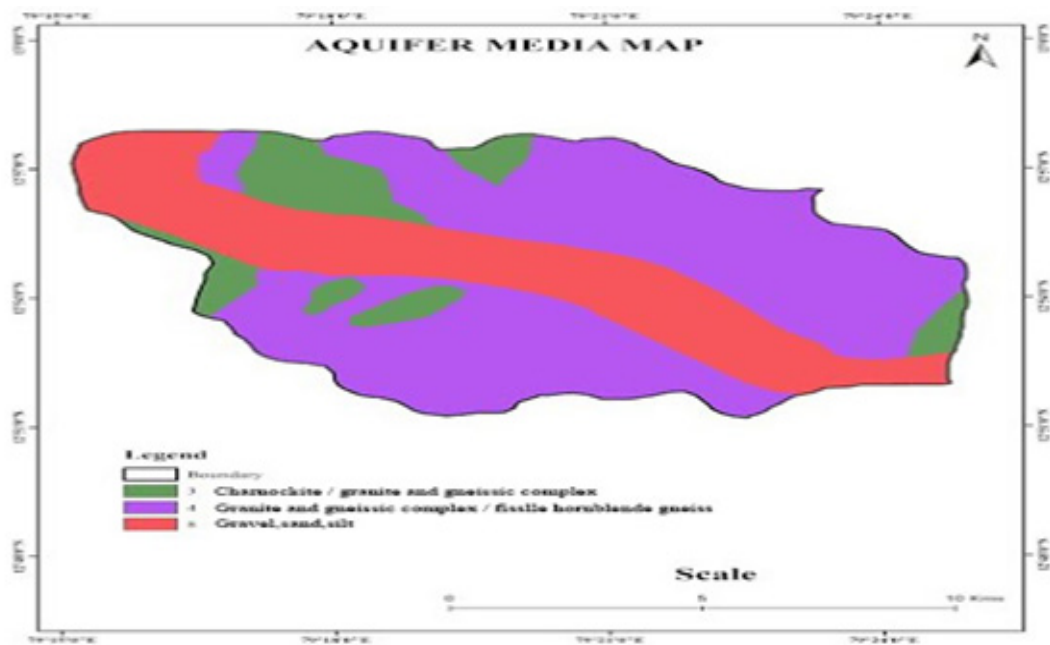


Figure 3c. Aquifer media map of the study area.

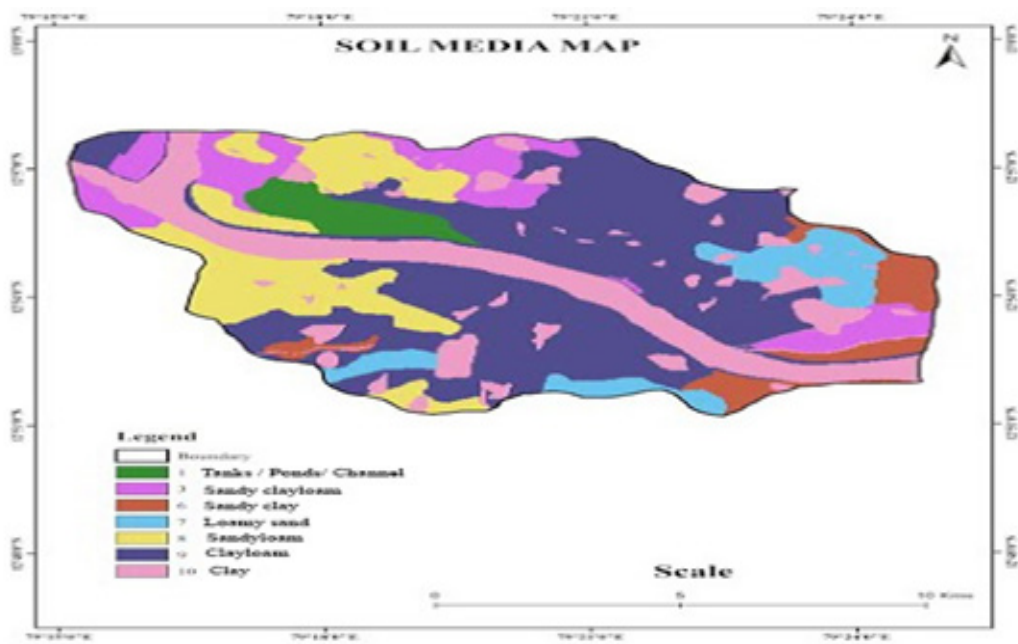


Figure 3d. Soil media map of the study area.

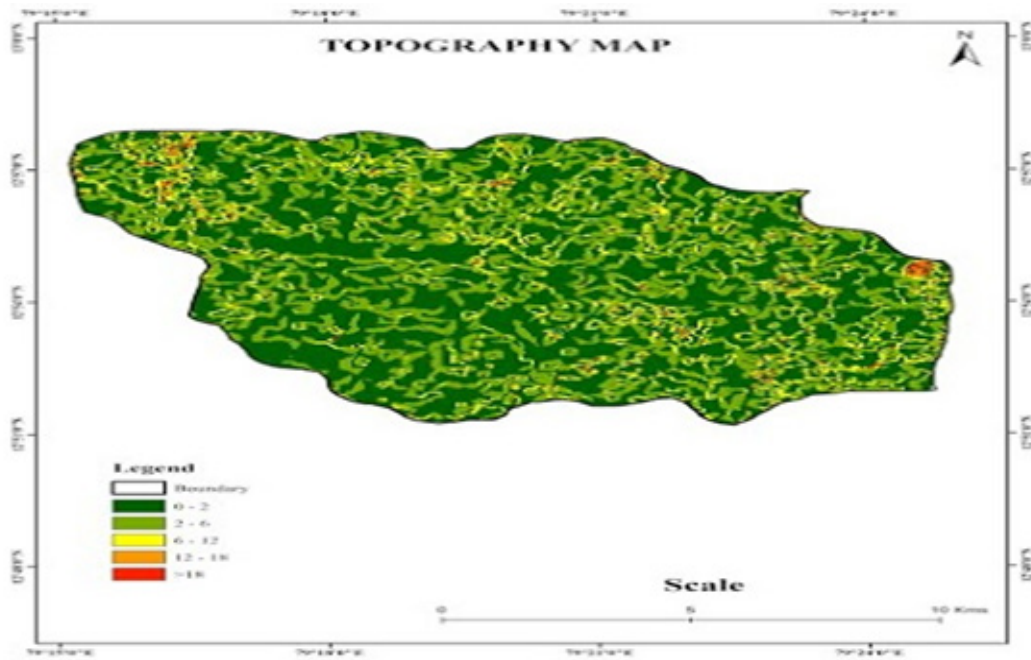


Figure 3e. Topography (Slope) map of the study area.

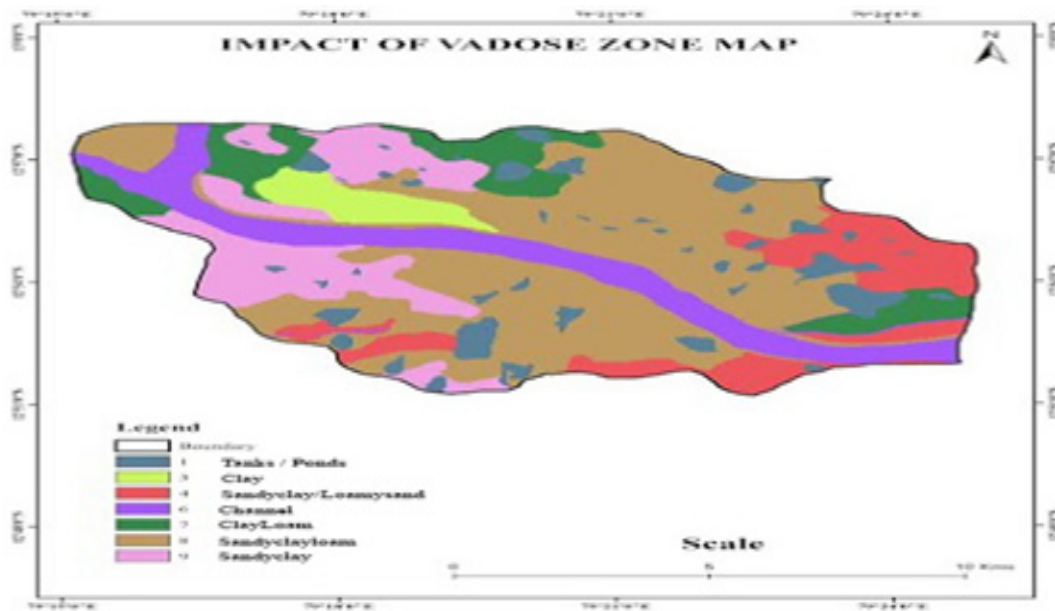


Figure 3f. Impact of vadose zone map of the study area

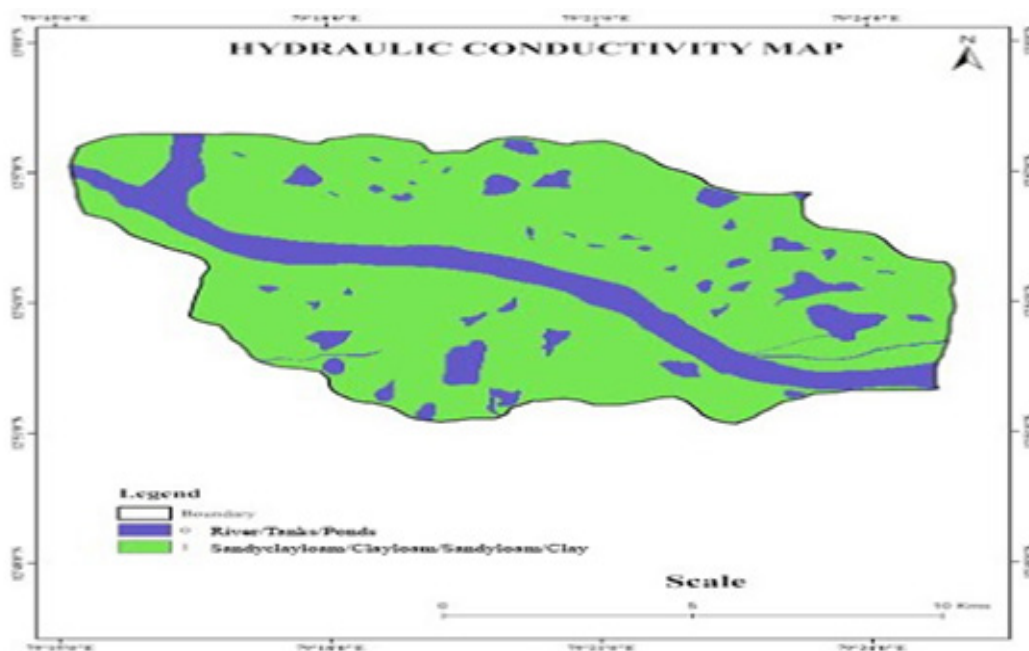


Figure 3g. Hydraulic conductivity map of the study area.

10 to 1. The topography map of the study area is given in the Figure 3e.

Vadose zone controls the passage and attenuation of the contaminated material to the saturated zone. The study area in and around Ranipet consists of clay, sandy clay or loamy sand, channel, clay loam, sandy clay loam and sandy clay. The units such as clay and loam do not have more quantity of groundwater in the vadose zone are less susceptible and the units such as gravel, sandy and limestone having less quantity of groundwater are high susceptible⁹. As per soil units the rating value from one to nine was applied. Vadose zone map is shown in the Figure 3f.

The movement of pollution level is rectified by hydraulic conductivity and ratings value is range between 0-1. The hydraulic conductivity map is shown in the Figure 3g.

Using the seven features layers of ratings and weights the absolute susceptibility map created ranges from 58 – 699. The classification of features are worked out randomly which provided inaccurate consequences which are unreliable. The DRASTIC Method used, produced the map given below showing the areas of very low, low,

Table 3. Drastic index values

VALUE OF DRASTIC INDEX	
Range	Classification
58 - 98	Very Low
98 - 113	Low
113- 128	Moderate
128 - 166	High
166- 699	Very High

moderate, high and very high vulnerability¹⁰. Finally the subsurface region having the properties such as the above the seven features have developed the drastic index values as shown in the Table 3.

The map obtained supported the potential for contamination, especially Chromium. The DRASTIC aquifer vulnerability map is presented in Figure 4, shows the predominant of moderately vulnerability class (shades

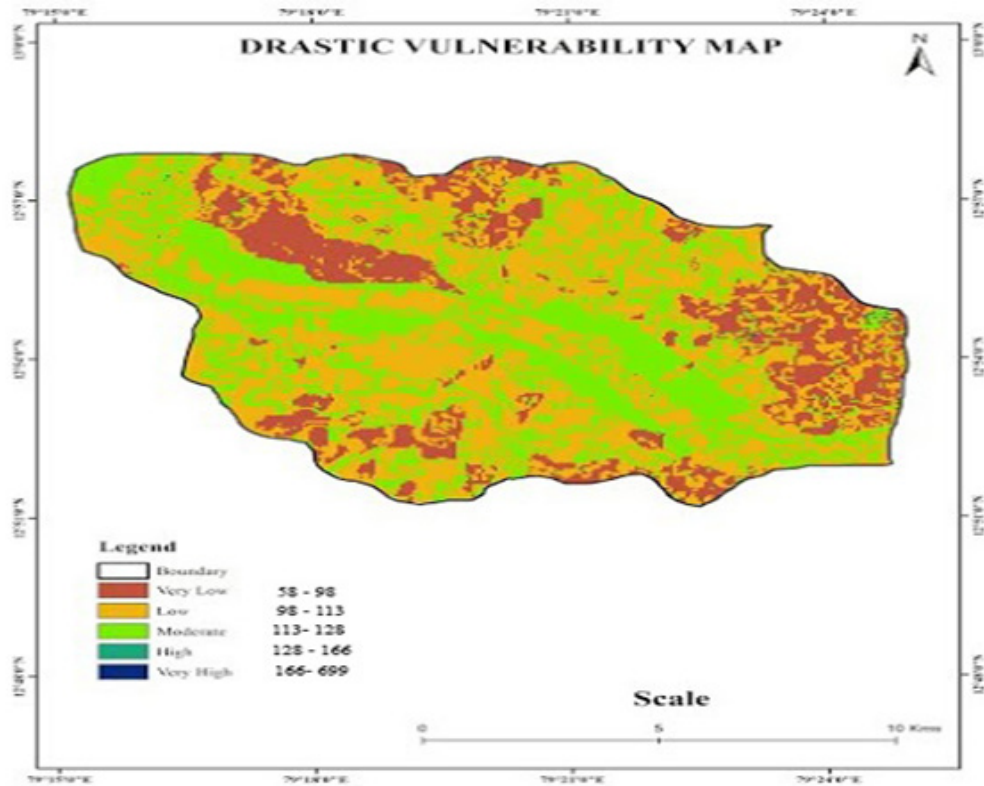


Figure 4. Drastic vulnerability map.

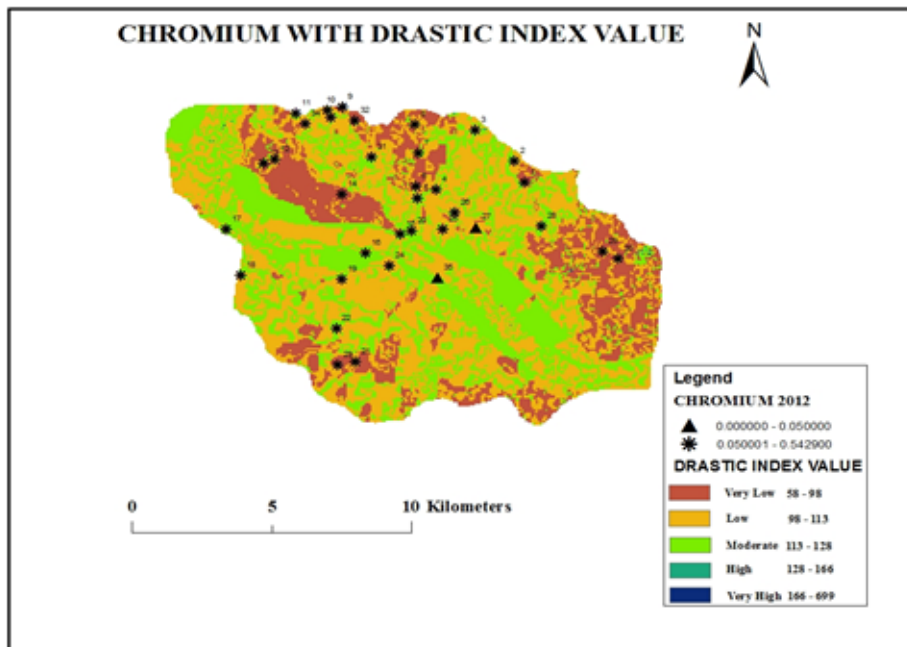


Figure 5. Spatial distribution of groundwater vulnerability score for Chromium.

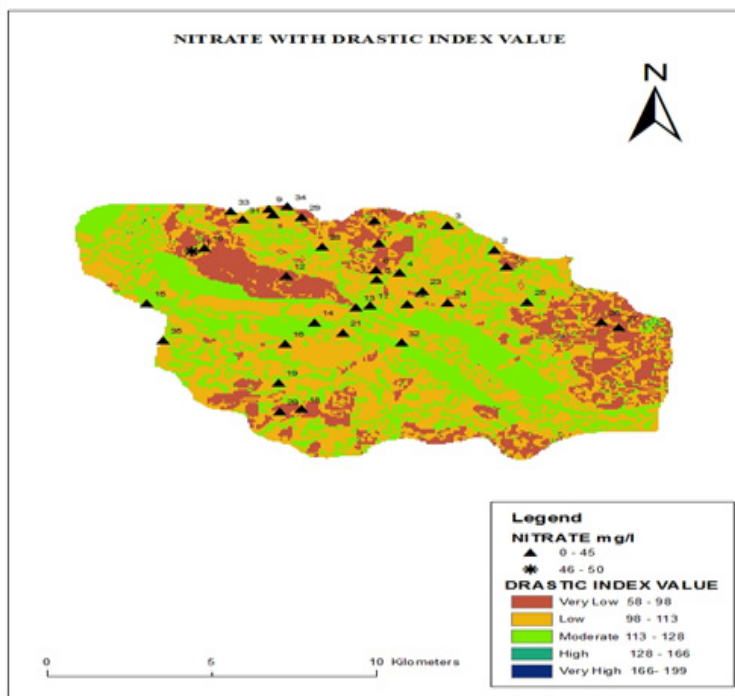


Figure 6. Spatial distribution of groundwater vulnerability score for Nitrate.

of green) and very high vulnerability class (blue shades). This situation is caused by small depth to water potentiated by the presence of sandstone, marl and alluvial rocks, all of which help to increase the infiltration of water into the aquifer as well as increase agricultural activity. Location of wastewater disposal in this region helps to reduce groundwater pollution⁸.

The chromium concentration in groundwater in the study area was more than 0.05 mg/l during November 2012 while the maximum acceptable Chromium concentration for human health is less than 0.05 mg/l according to the World Health Organization. It is well known that if chromium concentration is higher than 0.05 mg/l in groundwater, it indicates anthropogenic contamination⁹. The spatial distribution of groundwater vulnerability score for chromium was presented in Figure 5. Chromium concentration increases about the industrial wastewater disposal location in and around Ranipet area. The nitrate concentration in the study area ranges from 2 – 50 mg/l.

The well no. 11 is more than permissible limit and causes methenoglobinemia in infants. The spatial distribution of groundwater vulnerability score for nitrate was presented in Figure 6. Nitrates generally occur in high levels in some ground waters¹⁰.

5. Conclusion

The DRASTIC vulnerability map represents the study area as classified in five categories: very low (58 - 98), low (98-113), moderate (113 – 128), high (128-166) and very high (166 -699). In the study area, the depth to water was low and the hydraulic conductivity was high, which resulted in an increase in the vulnerability of the aquifer. Because the types of soil in the aquifer media, vadose zone and soil media consist of, clay, sandy clay and sandy loam, the vulnerability may be decreased. The resulting chromium concentration indicated is high in the study area and these parts are more prone to damage. In and

around Ranipet area the soil is highly vulnerable, while the other area such as Melvishram (Vanniyavedu) and Arcot (Mudiyor Illam) are low and moderately vulnerable to groundwater contamination. Nitrate values as shown in well number 11 (Puliyathangal) is more than permissible limit and causes methenoglobinemia in infants.

Comparison of the DRASTIC Index maps with spatial distribution of groundwater vulnerability score for chromium and nitrate mentioned a less quality level. The reason may be due to the flow direction of the groundwater that affected the transport of pollutants. The study area shows that GIS has been applied to prepare various maps of different data layers and that comparing spatial distribution maps are very useful for groundwater management and suggests groundwater remediation for applying suitable method.

6. References

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