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SPATIAL ANALYSIS OF GROUNDWATER QUALITY FOR VIRUDHUNAGAR DISTRICT, TAMIL NADU USING GIS

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Abstract

Groundwater is one of the most impotent natural resources. Groundwater has become a necessary resource over the past decades due to the increase in its usage for drinking, water supply, irrigation and industrial uses etc. Groundwater resources are now facing threats due to anthropogenic activities. The groundwater quality is equally important as that of quantity. Mapping of spatial variability of groundwater quality is of vital importance and it is particularly significant where groundwater is primary source of potable water. The present study has been undertaken to analyze the spatial variability of groundwater quality for Virudhunagar District located in the Tamil Nadu state. Geographical Information System (GIS) is used for the spatial analysis and it is a powerful tool for representation and analysis of spatial information related to water resources. The major water quality parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids, Total hardness, Sulphates, Fluorides and Calcium have been analysed. The spatial variation maps of these groundwater quality parameters were derived and integrated through GIS. The final integrated map shows three priority classes such as High, Medium and Low groundwater quality zones of the study area and provides a guideline for the suitability of groundwater for domestic purposes.

Keywords: GIS, Groundwater, Spatial variation, Water quality

Introduction

Groundwater is a valuable natural resource that is essential for human health, socio-economic development, and functioning of ecosystems (Steube et al, 2009). In India severe water scarcity is becoming common in several parts of the country, especially in arid and semi-arid regions. Due to rapid growth of population and anthropogenic activities, the quality of groundwater is deteriorating day by day. The possibility of groundwater contamination is due to the prevailing drought-prone conditions, the improperly treated and unplanned release of effluents of industry, municipal and domestic into the nearby streams and ponds and the majority usage of groundwater for irrigation are increasing the ionic concentration of the groundwater and making it more saline. Temporal changes in the origin and constitution of the recharged water, hydrological and human factors, may cause periodic changes in groundwater quality. Ascertaining the quality is crucial before its use for various purposes such as drinking, agricultural, recreational and industrial use. Hence monitoring of groundwater quality has become indispensable. The present study attempts to map the spatial variation of groundwater quality parameters for Virudhunagar District using GIS.

GIS is an effective tool for groundwater quality mapping and essential for monitoring the environmental change detection. GIS has been used in the map classification of groundwater quality, based on correlating total dissolved solids (TDS) values with some aquifer characteristics or land use and land cover (Asadi, 2007). Other studies have used GIS as a database system in order to prepare maps of water quality according to concentration values of different chemical constituents. In such studies, GIS is utilized to locate groundwater quality zones suitable for different usages such as irrigation and domestic (Yammani, 2007). Babiker et al. (2007) proposed a GIS-based groundwater quality index method which synthesizes different available water quality data by indexing them numerically relative to the WHO standards.

Virudhunagar District is a water-scarce region and it is under threat due to the excess of dissolved salts like Fluoride and Sulphate etc. The groundwater samples were collected from 6 locations randomly distributed in the study area. The physico-chemical parameters namely pH, Electrical Conductivity (EC), Total Dissolved Solids, Total hardness, Sulphates, Fluorides and Calcium of the samples were analyzed. GIS is used to assess the exiting condition of groundwater quality and stress areas can be identified for further monitoring and management.

Study area

The present study was carried out in Virudhunagar District of Tamil Nadu State. It lies between Latitude $9^0$12'N to $9^0$45'N and Longitude $77^0$24'E to $78^0$18'E. The location of the Study area is shown in Fig.1. Total area of Virudhunagar district is 4243.23 sq. km and the district is divided into 8 Taluks. The district receives the rainfall under the influence of both southwest and northeast monsoons. The Northeast monsoon chiefly contributes to the rainfall in the district. The mean annual rainfall of study area is about 800 mm. The relative humidity is on an average between 65 and 85%. Virudhunagar district is characterised by relatively high level of groundwater development in both hard rock and sedimentary aquifers. Occurrence, movement and storage of groundwater are influenced by lithology, thickness and structure of the rock formation. The presence of black clayey soils has resulted in reduced natural recharge to groundwater system. It has also resulted in water quality problem.

Methodology

The water samples were collected from six wells and tested for physico-chemical parameters are compared with the permissible limits. The major parameters namely pH, Electrical Conductivity (EC), Total Dissolved Solids, Total hardness, Sulphates, Fluorides and Calcium of the samples were analyzed. The base map of the Virudhunagar district is derived from the thematic map collected from Institute of Remote Sensing, Anna University on 1:50,000 scale. The base map was georeferenced and digitized by using MapInfo software and exported to Arc view software for spatial analysis. Spatial interpolation technique through Inverse Distance Weighted (IDW) approach has been used in the present study to delineate the distribution of water pollutants. The Inverse Distance Weighted (IDW) referred to as deterministic interpolation methods because they assign values to locations based on the surrounding measured values and on specified mathematical formulas that determine the smoothness of the resulting surface. Determines the cell values using a linearly weighted combination of a set of sample points and controls the significance of known points upon the interpolated values. This method uses a defined or selected set of sample points for estimating the output grid cell value.

Results and discussion

Groundwater quality maps are useful in assessing the usability of the water for different purposes. The spatial and the attribute database generated are integrated for the generation of spatial variation maps of major water quality parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids, Total hardness, Sulphates, Fluorides and Calcium. Based on these spatial variation maps of major water quality parameters, an Integrated Groundwater quality map of the study area was prepared using GIS. This integrated groundwater quality map helps us to know the existing groundwater condition of the study area.

pH

pH is one of the important parameters of water and determines the acidic and alkaline nature of water. The pH value of water ranged between 7 and 8.3. The pH of the samples was well within the prescribed standards for drinking water. The spatial variation map for pH was prepared and presented in Fig 2.

Electrical Conductivity (EC)

The Electrical Conductivity (EC) was classified in to three ranges (0-2250 μmhos/cm, 2250-3000 μmhos/cm and >3000 μmhos/cm). The spatial variation map for Electrical Conductivity (EC) was prepared and presented in Fig 3. From the map it has been observed that very small portion of the study area, the EC value is within 2250 μmhos/cm. For the Southwest part of the district the Electrical Conductivity (EC) value is in the medium range (2250-3000 μmhos/cm) and the remaining area falls under the poor range (>3000 μmhos/cm) and constitutes major part of the study area.

Total Dissolved Solids (TDS)

The mineral constituents dissolved in water constitute dissolved solids. The total concentration of dissolved minerals in water is a general indication of the over-all suitability of water for many types of uses. The Total Dissolved Solids (TDS) was classified to three ranges (0-500 mg/l, 500-1000 mg/l and >1000 mg/l). The spatial variation map for TDS was prepared based on these ranges and presented in Fig 4. From the spatial variation map it was observed that Northern part of the study area, the TDS value is in the poor range (>1000 mg/l). For the Southwestern part of the study area, the TDS value is in the medium range (500-1000 mg/l) and the smaller portion of the study area has TDS under the good range (0-500 mg/l). water contains less than 500 mg/L of dissolved solids, it is generally satisfactory for domestic use and for many industrial purposes. If the Water with more than 1000mg/L of dissolved solids usually gives disagreeable taste or makes the water unsuitable in other respects.

Total Hardness

Hardness in water is caused primarily by the presence of carbonates and bicarbonates of calcium and magnesium, sulphates, chlorides and nitrates. The Total hardness was classified in to three ranges (0-300 mg/l, 300-600 mg/l and >600 mg/l) and based on these ranges the spatial variation map for total hardness has been obtained and presented in Fig 5. From the map it was observed that for major areas, the total hardness value is in the poor range (300-600 mg/l) and medium range (>600 mg/l) was observed in North Western part of the study area.

Sulphates

Sulphates occur in natural waters at concentration up 50 mg/l and concentration of 1000 mg/l can found in water having contact with certain geological formations such as pyrite, lignite and coal. Sulphates was classified in to three ranges (0-200 mg/l, 200-400 mg/l and >400 mg/l) and based on these ranges the spatial variation map for Sulphates has been obtained and presented in Fig 6. From the spatial variation map, it was observed that Western part of the study area, the Sulphates value is in the good range (0-200 mg/l). For the Central part the Sulphate value is in the medium range (200-400 mg/l) while the considerable portion of North Eastern and Southern part of the Virudhunagar District is under the poor range (>400 mg/l).

Fluorides

Groundwater usually contains fluoride dissolved by geological formation. The desirable limit of Fluorides is 1-1.5 mg/l, beyond this limit the water is considered as poor quality. Based on these range the spatial variation map for Fluorides has been obtained and presented in Fig. 7. From the figure it is evident that major parts of the district have good range (1-1.5 mg/l) of Fluorides. A smaller portion of Southern part of the study area have poor range (<0.97 and >1.55 mg/l) of fluoride contents and also a small part have moderate quality range (0.97-1 mg/l and 1.5-1.55 mg/l).

Calcium

Calcium occurs in water mainly due to the presence of limestone, gypsum and dolomite minerals. Calcium was classified in to three ranges (0-75 mg/l, 75-200 mg/l and >200 mg/l) and based on these ranges the spatial variation map for Calcium has been obtained and presented in Fig 8. From the figure it is evident that major part of the district have moderate range (75-200 mg/l) of Calcium and considerable portion of North eastern part of the district have poor value (>200 mg/l) of Calcium.

Data Integration Using GIS

In this study, the criterion table with suitable ranks and weightages adopted was presented in Table 2. The spatial variation map of major groundwater quality parameters were integrated and integrated groundwater quality map of Virudhunagar District was prepared and shown in Fig 9. The integrated map shows the broad idea about good, moderate and poor groundwater quality zones in the study area. The groundwater quality has been classified quantitatively as good, moderate and poor depending on the final weightage values assigned to polygons in the final layer. From the map, it is evident that the groundwater quality in the Northern part of the study area is in the good condition while the Central part of the study area groundwater quality is in the moderate condition and Southern part of the study area groundwater quality is in poor condition.

Conclusions

Water is an indispensable natural resource on earth. Groundwater is the major source of drinking water in both urban and rural areas. Increasing population and its necessities have lead to the deterioration of surface and subsurface water. Groundwater quality depends on the quality of recharged water, atmospheric precipitation and inland surface water. The groundwater quality is equally important as that of quantity. Assessing and monitoring the quality of groundwater is therefore, important to ensure sustainable safe use of these resources for the various purposes. The present study has been undertaken to analyze the spatial variation of major groundwater quality parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids, Total hardness, Sulphates, Fluorides and Calcium using GIS approach. GIS can provide appropriate platform for convergent analysis of large volume of multi-disciplinary data and decision making for groundwater based studies can be done effectively. The groundwater quality of six wells randomly distributed in Virudhunagar district, Tamil Nadu was selected for the present study. The spatial variation maps of major groundwater quality parameters were prepared and finally all these maps were integrated. The integrated groundwater quality map shows the broad idea about good, moderate and poor groundwater quality zones in the study area. This study demonstrates that the use of GIS could provide useful information for groundwater quality assessment. The results obtained gave the necessity of making the public, local administrator and the government to be aware on the crisis of poor groundwater quality prevailing in the area. The study helps us to understand the quality of the water as well as to develop suitable management practices to protect the groundwater resources.

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Table 1. Criterion table showing Weightages and Ranking assigned for different Water Quality parameters

Sl. No	Criteria	Parameter Range	Ranking	Weightages
1	pH	7 to 7.5	1	20%
		7.5 to 8.5	2	
		>8.5	3	
2	Electrical conductivity (µmhos/cm)	0-2250	1	15%
		2250-3000	2	
		>3000	3	
3	Total Dissolved Solids (mg/l)	0-500	1	15%
		500-1000	2	
		>1000	3	
4	Total Hardness (mg/l)	0-300	1	15%
		300-600	2	
		>600	3	
5	Sulphates (mg/l)	0-200	1	10%
		200-400	2	
		>400	3	
6	Fluorides (mg/l)	1-1.5	1	10%
		<1.5	2	
		>1.5	3	
7	Calcium (mg/l)	0-75	1	15%
		75-200	2	
		>200	3	

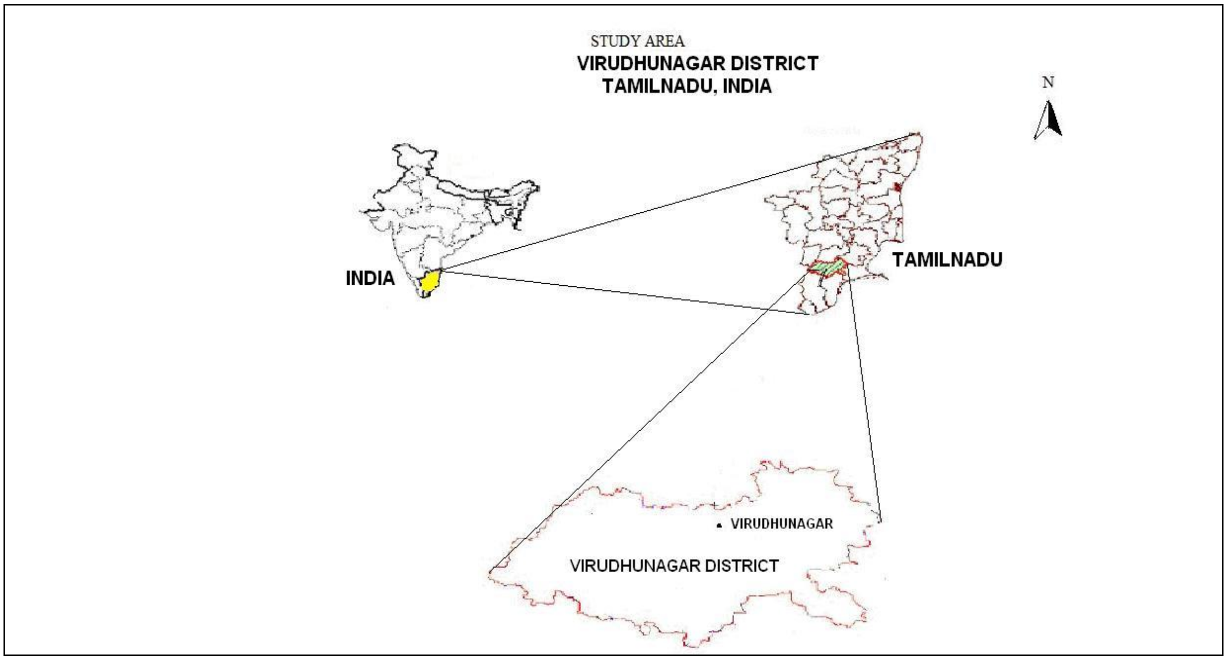

Figure 1. Location map of Study area

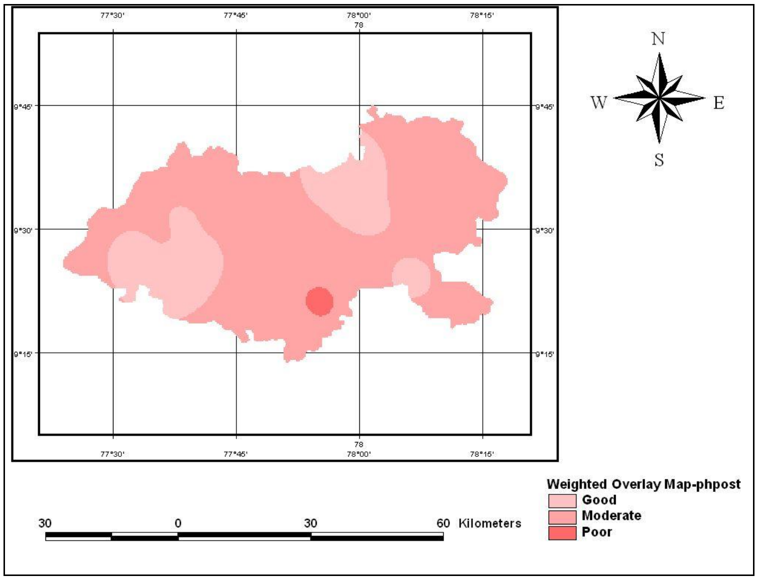

Figure 2. Spatial Variation Map of pH

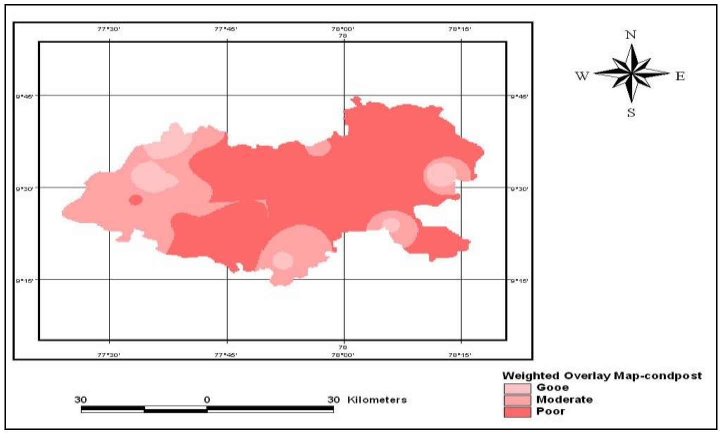

Figure 3. Spatial Variation Map of Electrical Conductivity (EC)

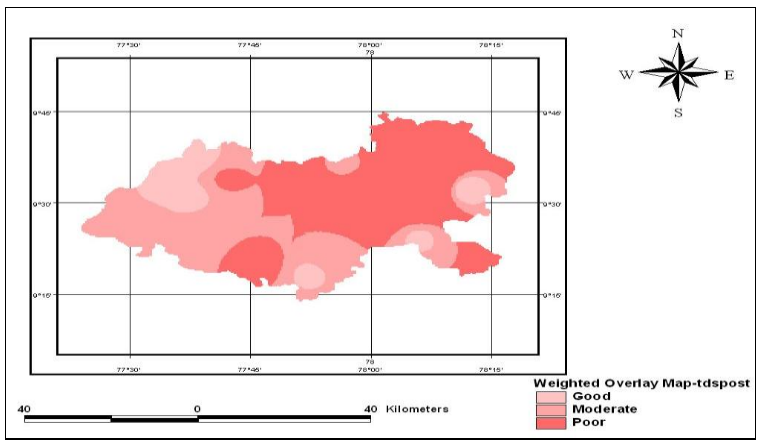

Figure 4. Spatial Variation Map of TDS

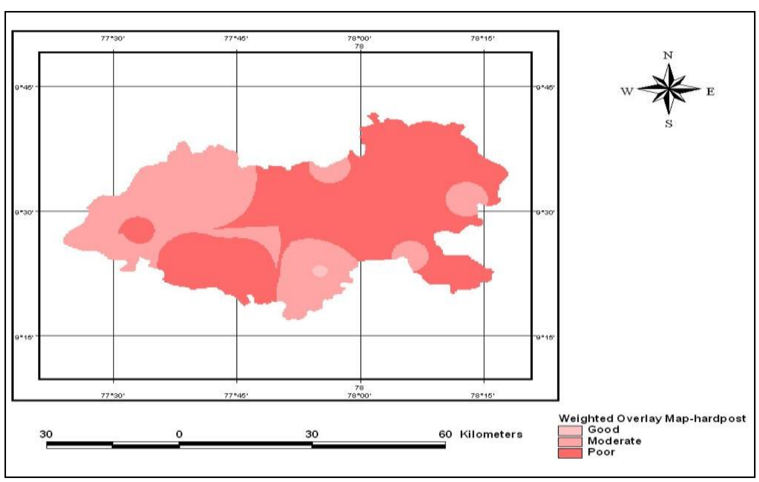

Figure 5. Spatial variation map of Total hardness

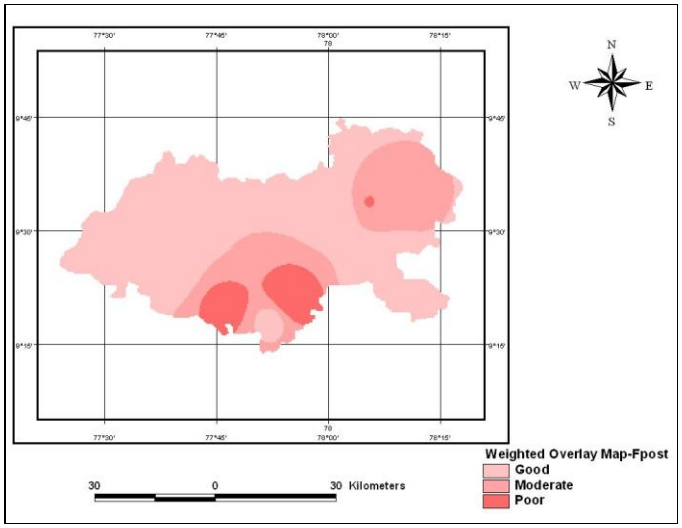

Figure 6. Spatial variation map of Fluoride

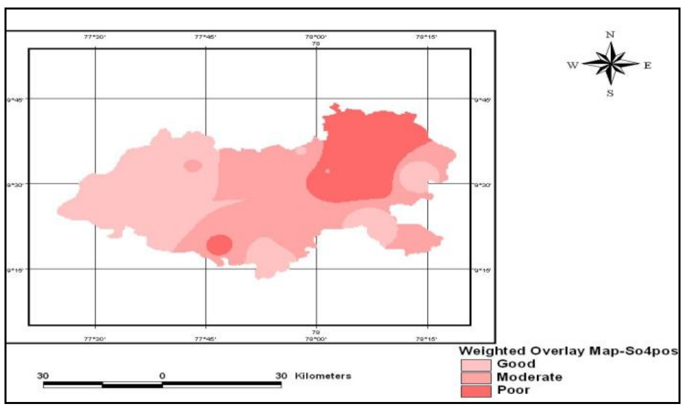

Figure 7. Spatial variation map of Sulphate

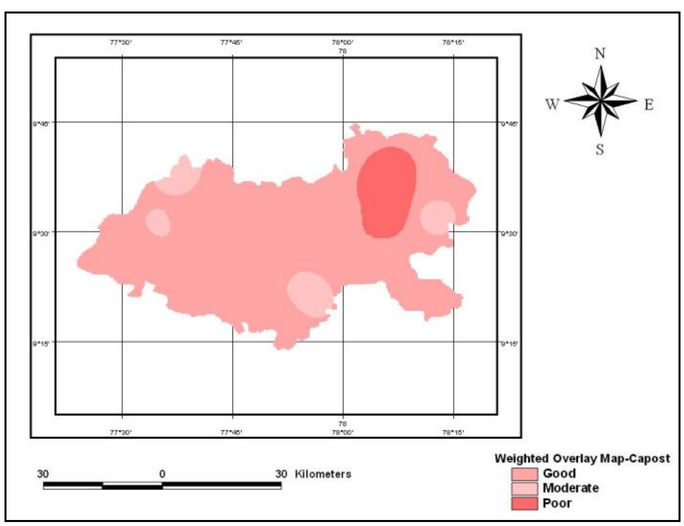

Figure 8. Spatial variation map of Calcium

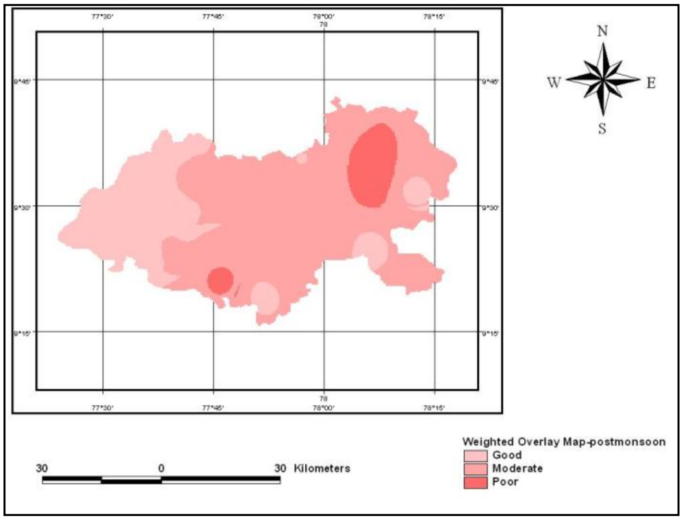

Figure 9. Integrated groundwater quality map of study area