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Assessment of Groundwater Quality in Thanjavur District Using Geo-spatial Techniques

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***Abstract* -- Geo-spatial differences in groundwater quality in the district of Thanjavur located in Tamil Nadu state, India have been considered using GIS techniques. GIS is a tool which is used for assessing groundwater quality information. For this study, water samples were collected from twenty five locations of bore wells as well as dug wells during the year 2012 representing the entire study area. The water samples were analyzed for physic-chemical parameters like pH, TDS, TH, EC, Cl^- and NO_3 using standard techniques in the laboratory and compared with the standards. The groundwater quality and suitability information maps the entire study area has been prepared using GIS spatial analyst technique for all the above parameters. The results derived in this study provide details about monitoring and managing groundwater contamination in the study area. Finally, the study concluded that groundwater quality is impaired by anthropogenic activities, and proper management plan is necessary to protect valuable groundwater resources in Thanjavur district.**

Key words: GIS (Geographic Information System), Water quality and Parameters

I. INTRODUCTION

Groundwater is the most important source of water supply throughout the world. The quality of groundwater is reducing every day due to adverse human activities; residential, industrial and agricultural empowering activities. Pollution of groundwater causes poor drinking water quality, health hazards and high costs for alternative water supplies etc [15]. Evaluation of groundwater quality is a necessary task for management of present and future water quality in Thanjavur District. Groundwater quality is mostly affected by natural geochemical processes such as mineral weathering, dissolution reactions and some anthropogenic activities like agriculture, sewage disposal, mining and industrial wastes etc [9], [14], [8], [5] & [12].

Important parameters in determining the usage of water for drinking and agricultural activities are detection of pH, TDS, TH, EC, Cl^- and NO_3. Dissolved solids are undesirable in water. Dissolved minerals, gases and organic constituents produce aesthetically displeasing colour, tastes and odors. Hardness is defined as the concentration of multivalent metallic cations in solution. Total hardness causes economic loss of water etc. Nitrate contamination is strongly related to land use pattern and reported mainly from surface contamination sources, in humans is causes methemogl obinemia disease resulted from ingestion of high concentration of nitrate in its organic form [2], [10], [13] & [3].

The main aim of this study is to evaluate suitability of groundwater for domestic and irrigational purposes in around Thanjavur district. Geographic Information System (GIS) is an important tool helpful in storing, analyzing and displaying spatial data and using that data for decision making in all fields. Use of GIS technology simplifies the assessment of natural resources and environment contamination, and to prepare maps to assess water quality [7], [4] & [11].

The study aims to recognize the spatial variation of certain quality parameters of groundwater through GIS based on the available physic-chemical data from 25 locations in Thanjavur district. The purposes of this assessment are to study about overview of present groundwater quality, to determine spatial distribution of groundwater quality parameters like pH, TDS, TH, EC, Cl^- and NO_3 and to create groundwater quality zone map for Thanjavur district.

II. STUDY AREA

The study area of the Thanjavur district is located on the east coast of Tamil Nadu. The latitude extension between 9^o51' N and 11^o, 25' N, longitude extension between 78^o, 45'E and 79^o, 45'E, the total geographical area is 3396.57 sq.km. The Thanjavur district consists of eight taluks namely: Thanjavur, Thiruvaiyaru, Orathanadu, Kumbakonam, Thiruvidaimarudur, Papanasam, Pattukottai and Peravoorani. The Thanjavur district is the "Rice Bowl" of Tamil Nadu Thanjavur the head quarter of the district derived is name that a demon by the name of the Thanjan - an asura lends its name to the town of Thanjavur district (Figure 1).

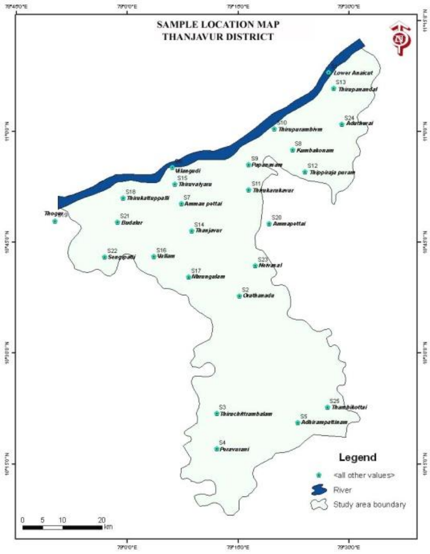

Figure 1: Base Map of the study area, Thanjavur district.

A. Geology

The Geographical Formation of the Thanjavur district is made up of cretaceous tertiary and alluvial deposits. The tertiary alluvial deposits take up the major area. The exposures are only a projection of the long narrow strip occurring in a North West direction from Thanjavur on the north. It's fairly thick sequences of tertiary and older rocks of the southern part. These formations have a very thick literate of silt, clay, calcareous and argillaceous varieties well developed in the district and occupy an area about 96,617 hectare. The best exposures are seen west of "Grant Anicut" Canal and also near Orathanadu. It consists of fertile soil tarraceous soil are well developed in eastern side of the Thanjavur taluk in classified gneisses are highly present in south western part of Thanjavur taluk. The formation mainly consists of sandy clays, unconsolidated sands, and clay bound sands molted clays with twin kankar modules at various horizons.

B. Drainage

This district is enriched with soil resources due to perennial water supply by river Cauvery. It flows through the entire district in different name with its distibutaries and branches viz. Grand Anaicut Canal, Vennar, Pannaiyar, Koraiyar, Vetter, Kodamoritiyar, Thirumalairajanar, Arasalar, Veerasozhanar, Mudikondan, Noolar, Vanjiar, VikramanNattarKirtimanar, Manjalar etc. and all these branch of into a number of small streams. The Cauvery River and its tributaries are the most remarkable features of the district. The river flows from Karnataka state and passes through Dharmapuri, Salem, Erode, Thanjvaur, Trichy, Thiruvarur and Nagapattinam district covering a distance from a spot lying on Brahmagiri mountains on Western ghats at a height of 1320 meters above sea level Cauvery itself is depleted and reduced to the stature of an insignificant stream at its tail and where it joins the Bay of Bengal cauveripattinam about 8 miles of Tranquebar.

C. Climate

The climate of the region in general is that of the Tamil Nadu and is falling in to the four typical seasons. They are

- The cold weather season - From January to February
- The hot weather season - From March to may
- The south west monsoon season - from June to September
- The retreating monsoon.

North east monsoon season - Form October to December

D. Soil

The soil can be classified as,

- Alluvial soil
- Sandy clay

The Cauvery delta generally consists of fine alluvial soil and sand clay are found particularly in most of the areas Red soil is mostly found in the Grand Anaicut command area. A sound of knowledge of soil water and plant relationship is essential improving the irrigation practices and to make the best use of water table. To a certain extent soil governs the land utilization with the varying type and degree of utility of land for different purpose.

E. Agriculture

Thanjavur is predominately on agricultural district. The district is well under the influence of the monsoon. Since the region enjoys a tropical monsoon climate, the temperature and rainfall conditions favour farming activites. The deltaic plain with rich alluvium and with irrigation facilities is predominant in cultivation and latest farming techniques are widely being adopted by most of the farmers. Almost all types of crops have been cultivated throughout the year. Food crop like paddy, the principal crop is grown all round the year other food crops like millets, pulses, oilcrops like copra, gingelly, groundnut cashor, spices-like chilies, coriander cash crops vegetables, fruits and flowers are also cultivated in this district. Almost all types of crops have been cultivated throughout the year. Food crop like paddy, the principal crop is grown all round the year other food crops like millets, pulses, oilcrops like copra, gingelly, groundnut cashor, spices-like chilies, coriander cash crops vegetables, fruits and flowers are also cultivated in this district.

III. MATERIALS AND METHODS

A. Groundwater sample collection and analysis

In this study, 25 wells (dug and bore) were chosen for groundwater sampling based on field survey (Table 1). Groundwater samples were collected during March 2012 and analyzed for six parameters. The groundwater samples were collected in polyethylene containers prewashed with 1:1 HCl and rinsed to four times before sampling using sampling water. Collected samples were elated to laboratory within the same day and stored at 4°C. Samples for laboratory analysis were filtered in the laboratory in the same day through 0.45-μm cellulose membranes prior to the analyses. Groundwater samples for cation analysis were acidified to pH < 2 with several drops of ultrapure HCl in the laboratory. Groundwater samples were analyzed according to the standard methods [1]. Electrical conductivity (EC) and pH were measured in the field immediately after the collection of the samples using portable field meters. In the laboratory, Na is analyzed by flame photometer, and, Cl^- were estimated by titration. Nitrate is analyzed using spectrophotometer. In addition, groundwater quality data were employed to create integrated groundwater quality maps. Chemical composition of the groundwater samples (n = 25) in the study region shows a wide range. The EC in the study region is varied from 280 to 4,780 μS/cm with an average of 1,138 μS/cm (n = 25). The TDS ranged from 154 to 2,587 mg/l with a mean value of 617 mg/l. According to the TDS classification, 16 % of the groundwater samples belong to the brackish type (TDS > 1,000 mg/l), and the remaining comes under freshwater category (TDS < 1,000 mg/l) [6]. Among the dissolved anions, the concentrations of Cl^- and NO_3 lie in between 50 and 1475, 0.5 and 41, respectively. The pH of the groundwater samples in the study area varies from 7.8 to 8.9 with an average value of 8.5 which indicates that the alkaline nature. The electrical conductivity and total hardness values ranged from 75 and 1720, 280 and 4780 respectively. The concentrations of chloride, TDS and Hardness firmly evidence the influences of surface contamination sources such as agricultural activities (irrigation return flow, fertilizers, and farm manure) and domestic waste waters (septic tank leakage, sewage water, etc.) in the study region.

Table 1. GPS co-ordinates of well locations

Well ID No.	Latitude (Easting)	Longitude (Northing)	Location Name
1	11.13333	79.45556	Loweranaicut
2	10.62917	79.25417	Orathanadu
3	10.36389	79.20278	Thiruchitrambalam
4	10.28333	79.20278	Peravurani
5	10.34306	79.38611	Adirampattinam
6	10.91889	79.10278	Vilangudi
7	10.83722	79.12278	Ammanpettai
8	10.95833	79.37417	Kumbakonam
9	10.92500	79.27500	Papanasam
10	11.00556	79.33333	Thirupurambium
11	10.86806	79.27500	Thirukargavur
12	10.90833	79.40278	Thippirajapuram
13	11.09722	79.46667	Thirupanandal
14	10.77556	79.14667	Thanjavur
15	10.88111	79.10833	Thiruvaiyaru
16	10.71833	79.06111	Vallam
17	10.67167	79.13944	Marungulam
18	10.85000	78.99167	Thirukattupalli
19	10.82778	78.80833	Thogur
20	10.79167	79.32111	Ammapettai
21	10.79583	78.97917	Budalur
22	10.71667	78.95000	Sengipalti
23	10.69722	79.29028	Neivasal
24	11.01667	79.48611	Aduthurai
25	10.37778	79.45278	Thambikottai

In this study, we captured the location of all 25 wells with the help of handheld GPS instrument Trimble Juno SD receiver. Based on GPS points data, the well location map prepared by using GPS data integrated with ArcGIS and Surfer software (Figure 1). From these wells, we collected and analyzed groundwater samples for the study area. The water quality data thus obtained forms the non-spatial database. It is stored in excel format and linked with the spatial data by join attribute option with point features in ArcMap. The spatial and the non-spatial database formed are integrated for the generation of spatial distribution maps of the water quality parameters. For spatial interpolation Inverse Distance Weighted (IDW) or spatial analyst tool approach in GIS has been used in the present study to demarcate the locational distribution of groundwater pollutants. Other spatial interpolation techniques include kriging, co-kriging, spline etc. Kriging is based on the presence of a spatial structure where observations close to each other are more alike than those that are far apart (spatial autocorrelation). The 3D surface and wireframe map formed by using surfer software. In this surfer, source file taken from GIS shape file and created blank and grid file. The 3D surface is three dimensional shaded rendering from a grid file. The height of the surface corresponds to the 'z' values of the associated grid node. Denser grids show greater detail on the surface. The wireframes are three dimensional representations of a grid file. Wireframes are created by connection z values along lines of constant 'x' and 'y'. At each 'xy' intersection (grid node), the height of the wireframe is proportional to the z value assigned to that node. The number of columns and rows in the grid file determined the number of x and y lines drawn on the wireframe. Based on six water quality parameters (pH, TDS, TH, EC, Cl^- and NO_3) the quality, 3D and wireframe prepared using above said method.

IV. RESULT AND DISCUSSION

The physico-chemical characteristics of groundwater for all the zones are given in Table 2. Wide range of groundwater samples from 25 different locations were analyzed for their properties. The pH of groundwater samples vary from 7.8 to 8.9 (Figure 2). The Total Dissolved Solids ranged from 154 to 2587 mg/l (Figure 3). The Total hardness of the samples ranged from 75 to 1720 mg/l (Figure 4). The Electrical Conductivity in the study region varied from 280 to 4780 μS/cm (Figure 5). Among the ions Cl^- and NO_3 ranged from 50 to 1475 mg/l and 0.05 to 8 mg/l respectively (Figure 6 and 7).

Zone wise groundwater quality data given in Table 2 indicate that groundwater zones have different ions

Table 2: Physico-chemical parameter analysis during the year 2012

Well ID No.	pH	TDS	TH	EC	Cl^-	NO_3
1	8.6	497	215	890	131	3
2	8.4	355	145	640	124	2
3	8.2	507	225	920	174	1
4	8.4	372	170	660	124	6
5	7.8	792	210	1410	223	4
6	8.5	313	165	580	92	0.05
7	8.5	550	215	980	128	7
8	8.8	336	220	640	106	0.05
9	8.6	540	235	1000	170	3
10	8.8	336	220	640	106	0.05
11	8.9	1046	495	1880	305	3
12	8.8	410	270	810	96	0.05
13	8.6	242	130	460	50	0.05
14	8.7	154	75	280	50	0.05
15	8.2	657	170	1170	184	4
16	8.8	388	200	680	106	7
17	8.2	201	80	320	60	8
18	8.8	282	175	550	53	2
19	8.9	292	165	540	71	0.05
20	8.6	540	235	1000	170	3
21	8.2	1166	750	2040	510	41
22	7.8	2587	1720	4780	1475	31
23	8.1	329	175	640	74	0.05
24	8.9	405	170	760	92	1
25	8.3	2151	1290	4200	1064	3

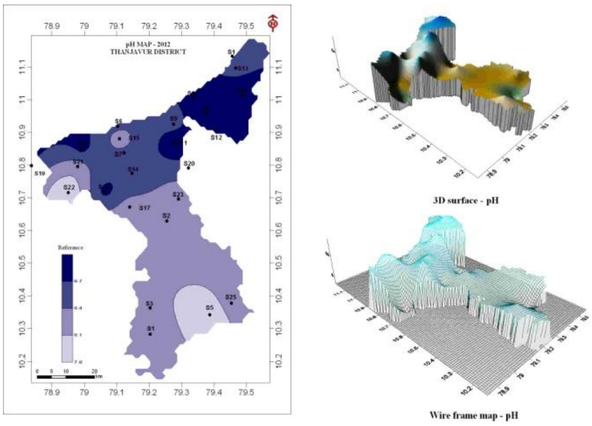

Figure 2: Map shows the quality, 3D surface and wire frame map of pH.

and minerals enriched in it. Nitrate contamination is higher in zones 21 and 22 shows higher values of 41 and 34 mg/l respectively high when compared to other zones and neared to WHO and IS standards (Table 3) of 45 mg/l. Heavier nitrate contamination is due to irrigation practices, soil mineralization and urban contamination the major nitrate contamination in these zones are due to fertilized usage.

Next to Nitrate, Total Dissolved Solids are higher pollutant causing groundwater contamination. The concentration of Total Dissolved Solids in drinking water is usually less than 500 mg/l according to WHO standard. Total Dissolved Solids concentration is higher due to presence of bicarbonates, carbonates, sulphates, chlorides and calcium ions which is originated due to manmade activities. TDS concentration is higher in zone 22 and 25th zone which has 2587 mg/l and 2151 mg/l respectively. Higher TDS concentration causes taste effects laxative effects in human and corrosive action in boilers.

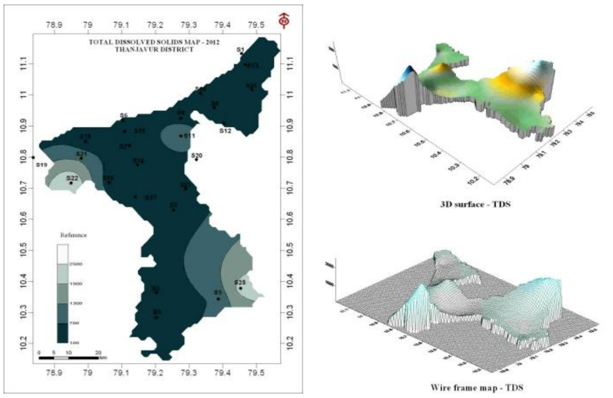

Figure 3: Map shows the quality, 3D surface and wire frame map of TDS

Table 3. Ranges of chemical parameters in study area and compared with WHO & IS for drinking purposes

Sl. No.	Water Quality Parameters	WHO (1993)		IS (10500, 1991)		ID No. of samples exceed the standards	
		Higher accept limit	Maximum allowable limit	Highest desirable limit	Maximum permissible	According to WHO (1993)	According to IS (1991)
1	pH	6.5 - 8.5	8.5	6.5 - 8.5	6.5 - 9.5	1, 8-14, 16, 18-20, 24	Nil
2	TDS	500	1500	500	2000	22, 25	22, 25
3	TH	100	500	300	600	21, 22, 25	21, 22, 25
4	EC	-	-	-	-	-	-
5	Cl^-	200	600	250	1000	22, 25	22, 25
6	NO_3	45	-	45	45	Nil	Nil

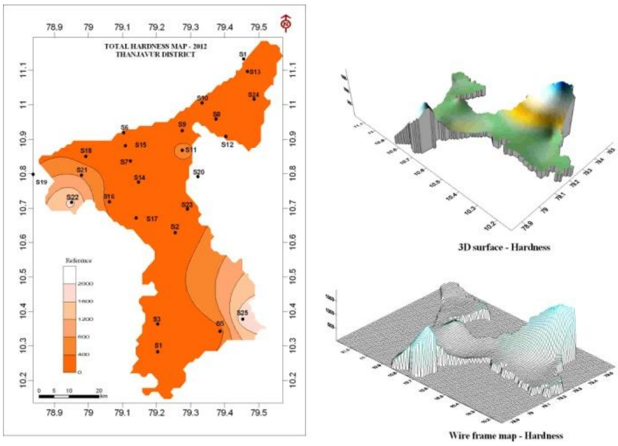

Figure 4: Map shows the quality, 3D surface and wire frame map of EC.

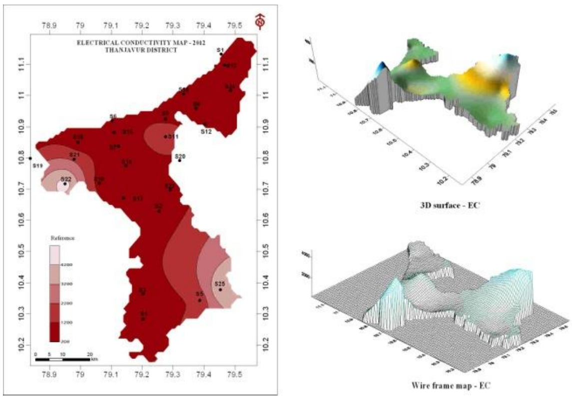

Figure 5: Map shows the quality, 3D surface and wire frame map of TH.

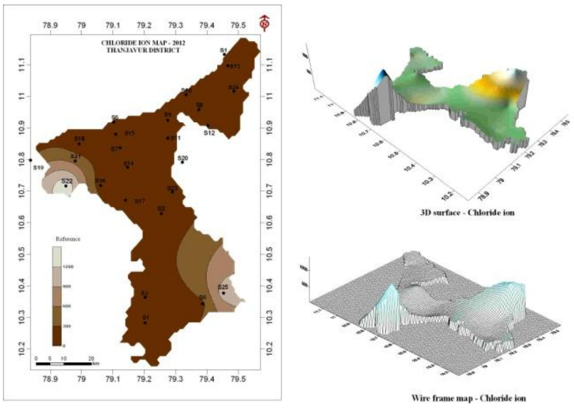

Figure 6: Map shows the quality, 3D surface and wire frame map of Cl^-

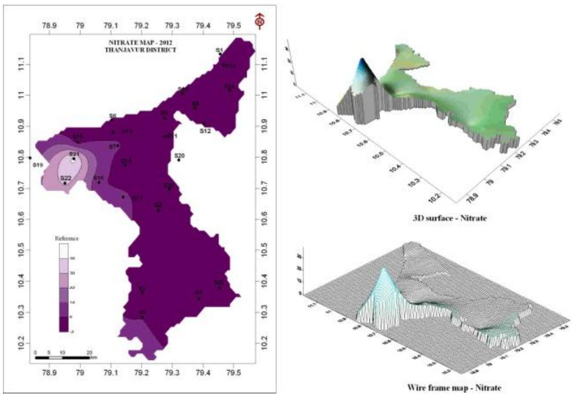

Figure 7: Map shows the quality, 3D surface and wire frame map of NO_3^-

Total hardness is higher in zone in 21, 22 and 25. Hardness is caused mainly due to calcium and magnesium ions based on its combination with carbonates, bicarbonates, chlorides and sulphates. Hardness is classified as temporary and permanent hardness respectively zone 21 had 75 mg/l, zone 22 had 1720 mg/l and in 25th zone 1920 mg/l, which are higher than 500 mg/l of WHO and IS standards.

Chloride is the minor constituent in earth’s crust. Its major source is from rain, industrial, sewage effluent and surface run-off. Chloride concentration is higher in zone 22 and zone 25. Zone 22 had 1475 mg/l and zone 25 had 1064 mg/l respectively. But chloride ion is lower in zone 13 and 14 chloride causes unpleasant taste and odour.

The pH and Electrical conductivity parameter is determining quality of drinking water. pH is caused due to hydrogen ion concentration. Groundwater samples shows pH in the range of 7.8 to 8.9 which is the range of WHO standard, Electrical conductivity of water is essential for determining irrigation suitability of water. EC and Na concentration are important in irrigation purposes, if higher EC means lead to formation of saline soil. Zone 23 shows higher EC of 4780 µS/cm and zone 25 shows EC of 1064 µS/cm respectively.

V. CONCLUSIONS AND RECOMMENDATIONS

The spatial interpolation techniques of groundwater quality in the study region point out that many of the collected samples (zone 21, 21, 23 and 25) are not fulfilling the drinking water quality standards prescribed by the WHO and ISI. This research study achieved the necessity of making the public, local administrator and the government to be attentive on the predicament of poor groundwater quality existing in the area. The government needs to take continuous monitoring, plans for protection of water quality and necessary to develop the groundwater quality improvement methodologies implementation.

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