© 2018 IJSRST | Volume 4 | Issue 5 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

GIS based Water Quality Index Method for Groundwater Quality Assessment– Using Hydro Geochemical Data: Karur District, Tamil Nadu, India

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ABSTRACT

The two important criteria needed for the healthy life of human being at this moment are the adequate supply of drinking water with safety in its quality. In order to satisfy the quality of drinking water, the Hydro geologists have made detailed studies and brought out certain standards for quality thresholds for almost all the elements dissolved in groundwater that is being used by humans. Further, several studies have also been made on determining the groundwater quality of certain areas through conventionally analyzing the hydro chemical data derived through groundwater samples. A GIS based attempt has been made for the first time in the state of Tamil Nadu to evaluate and characterize the quality of groundwater in Karur District through Water Quality Index (WQI) method, for drinking purpose. GIS and WQI method had been applied to visualize the spatial pattern of the groundwater quality in the study area. A total of 32 pre- (July-2012) and post monsoon (Janauary-2013) groundwater geochemical samples were collected and analyzed for major cations and anions. It is very clear from the study that the chemical composition of groundwater in the study area has strong influence by effective weathering and leaching action of feldspar bearing rocks and along with anthropogenic activities like direct disposal of industrial effluents and the use of phosphatic fertilizers in urban environments. The results from the present study area showed a higher WQI, indicating the deteriorated nature of the groundwater quality. The WQI designed for the pre-monsoon period exhibited poor quality in greater percentage when compared with the post-monsoon period. This had indicated that the over exploitation and anthropogenic events such as, the release of wastes from industries, leftover use of manures and insecticides for agriculture and improper dumping of domestic wastes into the potential river systems. Majority of the groundwater chemical parameters are higher during pre-monsoon than the post-monsoon. The effect of rain fall in monsoon and successive natural groundwater recharge in to the aquifer leads to dilution of the groundwater. From this study, the potential of GIS tool in handling, analyzing and mapping the hydro chemical parameters, and the methodology in determining the WQI are dealt in detail.

Keywords: GIS, Water Quality Index, Pre-and Post-Monsoon Water Quality.

I. INTRODUCTION

Groundwater is a precious and most important natural resource essential for human's life. It occurs approximately in all weathered, porous and pervious geological formations beneath the earth surface. Water quality is one of the most significant matters in groundwater studies.

Groundwater quality depends on the quality of rejuvenated water, rainfall, surface water, lithology and on sub-surface geochemical processes. Progressive changes in the origin and anthropogenic activity may cause periodic changes in groundwater quality. Various geo-statistical concepts are used for the understanding of complex hydro chemical data sets which allows a better understanding of the water quality factors [10, 25& 5].

[19] stated that the mixing of high salinity caused from surface contamination sources such as irrigation return flow, domestic waste water and septic tank effluents with existing water followed by ion exchange reaction process and rock water interaction are responsible for groundwater chemistry.

[13] Studied the suitability assessment and mapping of groundwater quality for drinking purposes using water quality index in Rawalpindi and Islamabad area. [6] Carried out study to evaluate and characterize groundwater quality using Geographical Information System (GIS), water quality index method and Multi-Criteria Decision Analysis (MCDA) Techniques.

The study area, Karur district, Tamil Nadu, a hard rock terrain receives major part of rainfall from northeast monsoon. The local population largely depends on ground water resources for their farming and developmental activities as the area are with limited surface water bodies.

The study area is dominated by local human activities and agricultural activities, the rest by industries manufacturing, dying, bleaching, and bus body building which dispose industrial and hazardous wastes nearby agricultural lands which pose a very major risk to the adjoining groundwater environments. There is no methodical rationalized publication or record accessible for groundwater quality for the study area. Hence, the assessment of groundwater quality is significant for the area development and for safer and further civilization through establishing databases for planning future water resources development strategies.

The key aim of the current effort deals with the matter of using GIS in groundwater quality evaluation in an inclusive and integrated way, by way of that combines the focus effect of diverse chemical elements in groundwater aquifer operating GIS multi-conditional layering capability according to the allowable Bureau of Indian Standards (BIS) standards.

II. STUDY AREA

The study area, Karur district, is located in the Central part of Tamil Nadu state, India, which is bounded in the North by Namakkal district, in the West by Tiruppur district, in the Southeast by Dindigul district and in the East and Northeast by Tiruchirappalli district (Figure. 1 Can u provide continuity to some of the major rivers shown in ur area?). The study area is located in between North latitudes 10o 30' 00" and 11o 05' 00" and East longitudes77°45' 00" and 78°35' 00". The region covering an area of 2900 sq.km is supporting a population of 9.35 lakhs (1991 Census).

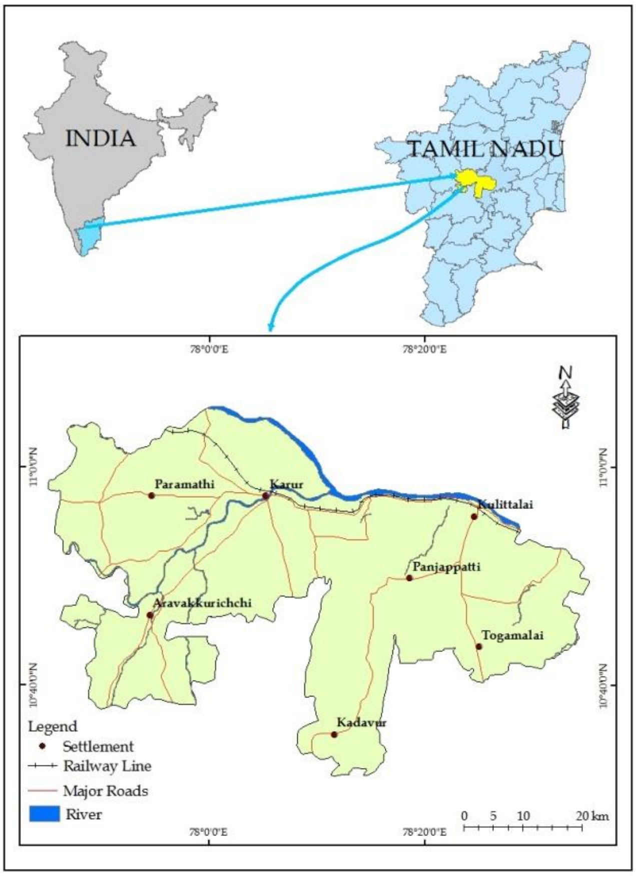

Figure 1. Study Area – Karur District

III. GEOLOGY OF THE STUDY AREA

The lithology map was digitized for the study area in GIS environment from the District Resource Map (1995) published by the Geological Survey of India. The IRS P6 LISS III image was used to update the lithology map and cross-checked and finalized after a field work (Fig. 2). The study area has eleven types of lithological units. The youngest Alluvium belongs to Quaternary period covering an area of about 152.83 sq.km (5.2% of the study area) is found on either sides all along the river beds of Amaravathi and Cauvery. The Amphibolite belongs to Sathyamangalam group is located as two small patches northeast of Aravakkurchi. The Granite and Garnet Granulite belonging to post magmatic acid intrusive are seen sporadically in the study area. The Pink Migmatite covering about 1.2% of the study area is seen mostly as concentrated patches around Kadavur Ultramafic intrusive. Almost the entire study area (85.5%)is covered by Hornblende–Biotite Gneiss belongs to Migmatite Complex. The Ultramafics belongs to ultramafic intrusive, consist of Amphibolite and Norite Gabbro are located within the Kadavur basin. The Pyroxene Granulite, Charnockite, Calc Granulite and Limestone belong to Charnockite Group, Quartizite and Garnet-Sillimanite Gneiss belong to Khondalite group are also available in the study area. All these groups of rocks are belonging to Archaean era.

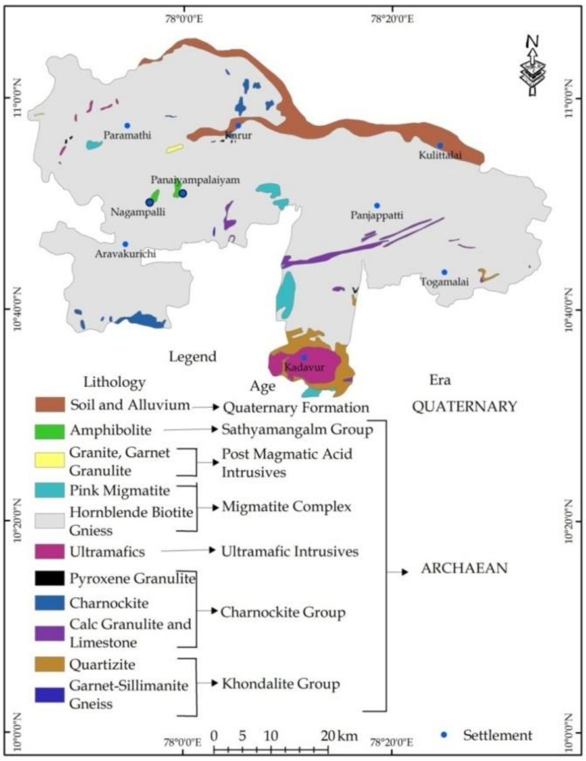

Figure 2. Lithology Map

IV. METHODS AND MATERIAL

Collection of Groundwater Quality Parameters

Thirty two groundwater geochemical data of pre-monsoon (July-2012) and post-monsoon (January-2013) were collected from the Groundwater Division, Surface and Groundwater Data Centre, Public Works Department, Chennai. Using the location details of the said data, the groundwater sampling locations were plotted in GIS (Fig. 3) and the hydro geochemical data such as pH, total dissolved solids, NO3, Ca, Mg. Na, K, Cl, SO4, CO3, HCO3, F and pH have been entered in the attribute table. The concentrations of the various chemical parameters are expressed in milligram per liter, except pH. The simple statistical analysis of the above chemical parameters is shown in Table 1.

V. WATER QUALITY INDEX (WQI)

In order to review the combined impact of different water quality parameters on drinking criteria,the water quality index has been devised. Water quality index is computed to reduce the large amount of water quality data to a single numerical value. Water quality index reflects the compound influence of different water quality parameters on the overall quality of water in the region.

Water Quality Index (WQI) is a very consistent, useful and well-organized method for assessing and communicating the information on the overall quality of water of an area. The purpose of WQI helps in deciding the suitability of groundwater sources for its intended purpose [1, 12&8].

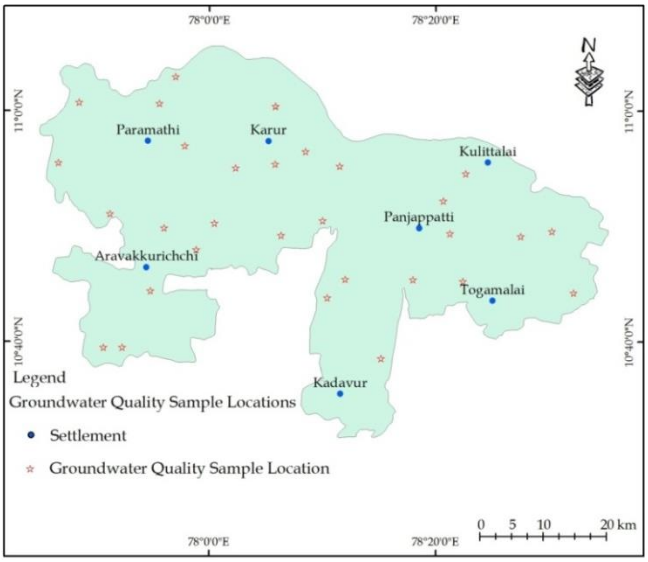

Figure 3. Groundwater Quality Sample Location Map

Table 1. Statistics of Groundwater Chemical Parameters for Pre-& Post-Monsoon

Parameters in (mg/l)	Pre-monsoon values				Post-monsoon values			
	Min.	Max.	Avg.	Std. Dev.	Min.	Max.	Avg.	Std. Dev.
TDS	280	3030	999	677	304	3367	906	995
NO_3	0	38	12	8	1	43	15	10
Ca	12	344	76	91	16	160	47	35
Mg	29	656	123	120	19	340	78	71
Na	32	762	234	186	23	1488	223	271
K	2	54	15	13	1	66	25	18
Cl	78	2014	537	514	50	2779	410	545
SO_4	12	413	127	116	6	1340	131	249
CO_3	0	24	7	9	0	30	11	11
HCO_3	104	451	249	73	79	567	261	118
F	0.1	1.6	0.8	0.4	0.3	2.5	1.0	0.57
pH	7.6	8.8	8.3	0.3	8.0	8.9	8.4	0.24

Where: TDS – Total Dissolved Solids, NO3 - Nitrate, Ca - Calcium, Mg - Magnesium, Na - Sodium, K - Potassium, Cl - Chloride, SO4 - Sulphate, CO3 - , HCO3 – Bicarbonate, Fe – Iron, pH, Min. – Minimum, Max. – Maximum, Avg. – Average & Std. – Standard Deviation.

[2] Analyzed the groundwater quality using water quality index in the Volta region, Ghana. The results indicated that the groundwater from the study area was good for drinking purposes. Many workers of International and National level have concluded that the use of GIS and WQI method could present useful information for water quality estimation [4, 21& 15]. [18] Used water quality index technique to review the fitness of surface water in Sankey tank and Mallathahalli Lake of Bangalore, India for domestic and irrigation purposes. [14] Calculated the groundwater quality index at Bhandara District. This study demonstrated that the water quality was worsening in the post-monsoon season.

[17] Developed WQI model for the groundwater in Tirupur district, South India and they found groundwater is deteriorated in many locations in the study area. [7] Evaluated WQI for Araniar River Basin, India. The study revealed that 90.24% and 73.46 % of the basin area possess good quality drinking water during the post and pre-monsoon seasons, correspondingly. [9] Applied WQI method for groundwater quality evaluation, Anna Nagar, part of Chennai City, India and outcome showed that the samples are falling under excellent to good category and suitable for drinking water purposes.

The standards for drinking purposes as recommended by Bureau of Indian Standards have been considered for the calculation of water quality index. For computing water quality index, three steps were followed [12, 3, 26& 28].

In the first step, each of the 10 factors (pH, Ca, Mg, Na, K, Cl, NO3, F, TDS and SO4) have been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 2).

The maximum weight of 5 has been assigned to the parameters like Nitrate, Total Dissolved Solids, Chloride, Fluoride, and Sulfate due to their main importance in water quality assessment [24]. Potassium was given minimum weight of 2 as it plays less significant role in water quality assessment. Other parameters like Calcium, Magnesium, Sodium, and Potassium were allotted weights between 1 and 5 depending on their importance in water quality determination.

In the second step, the relative weight (Wi) is computed using the following equation:

$$Wi = wi / \sum_{i=1}^{n} wi$$

Where,

Wi = The relative weight

Wi = The weight of each parameter and n = The number of parameters

Table 2. Weight and Relative Weight of each of the Chemical Parameters

S.No	**Parameters**	**Bureau of Indian Standards Maximum Desirable limit**	**Weight (wi)**	**Relative Weight** $Wi = \frac{wi}{\sum_{i=1}^{n} wi}$
1	pH	6.5-8.5	4	0.095
2	Ca (mg/l)	200	3	0.071
3	Mg (mg/l)	100	3	0.071
4	Na (mg/l)	200	4	0.095
5	K (mg/l)	10	2	0.047

6	Cl (mg/l)	250	5	0.119
7	NO_3 (mg/l)	45	5	0.119
8	Fe(mg/l)	1.5	5	0.119
9	TDS (mg/l)	500	5	0.119
10	SO_4 (mg/l)	200	5	0.119
		Total	42	0.974

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration foreach sample by its respective standard according to the guidelines laid down in the Bureau of Indian Standards and the result is multiplied by 100.

$$qi = (Ci/Si)*100$$

Where, qi is the quality rating, and Ciis the concentration of each chemical parameter in each water sample in milligrams per liter. Si is the Indian drinking water standard for each chemical parameter in milligrams per liter according to the guidelines of the Bureau of Indian Standards.

For computing the water quality index, the SI is initially assessed for each chemical parameter, which is then used for determining the water quality index as per the following equation:

$$SIi = Wi*qi$$

$$WQI = \sum SIi$$

Where,

SIi is the sub-index of i^{th} parameter

qi is the scoring based on the concentration of ith parameter.

Water quality types, were determined on the basis of water quality index. The computed water quality index values are classified into five types [16, 26, 11, 20 & 23] as shown in Table 3.

Table 3. Classification of Groundwater Samples According to Water Quality Index

S.No	Range	Type of water
1.	>50	Excellent water quality
2.	51-100	Good water quality
3.	101-200	Poor water quality
4.	201-300	Very poor water quality
5	>300	Water unsuitable for

VI. RESULTS AND DISCUSSION

The areal extent of pre- and post- monsoon water quality indexes were presented in (Figs. 4, 5 and Table 4). The same has indicated that during the post monsoon period, 18% of groundwater samples represented "excellent water quality" and 56% indicated "good water quality" which are located along Kadavur, Aravakkurichchi, Panjappatti, Kulithalai and Paramathi. Further, 25% of the samples showed "poor water quality", and 1% shows "very poor water quality" which are located along Karur and Togamalai areas. In Togamalai area, the poor quality exists in northern region during pre-monsoon period. But during the post-monsoon period the water quality deteriorated for a larger areal extent and this may be due to dissolution of the salts from soil both on the surface formed due to evaporation which are dissolved during infiltration and the chemical constituents from the subsurface soil.

During pre-monsoon period, 44% shows "good water" and53% shows "poor water". The remaining 3% of samples showed "very poor water" located in and around Paramathi, Kulithalai and Aravakkurichchi areas. The Pre-monsoon samples exhibit poor quality in greater percentage (56%) when compared with post monsoon. This may be due to effective discharge of ions, excess use of groundwater, direct discharge of effluents, and agricultural impact.

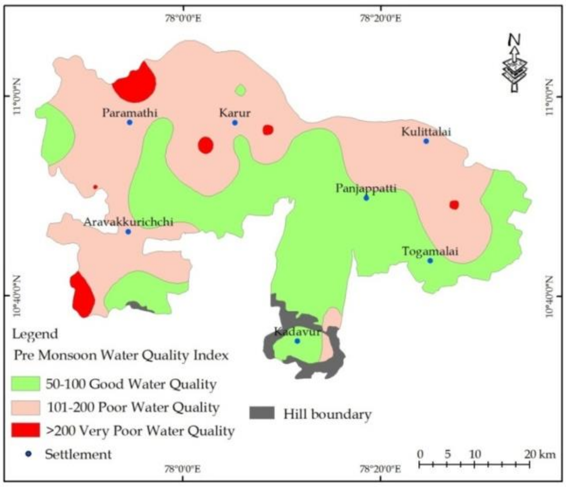

Figure 4. Pre Monsoon Water Quality Index Map

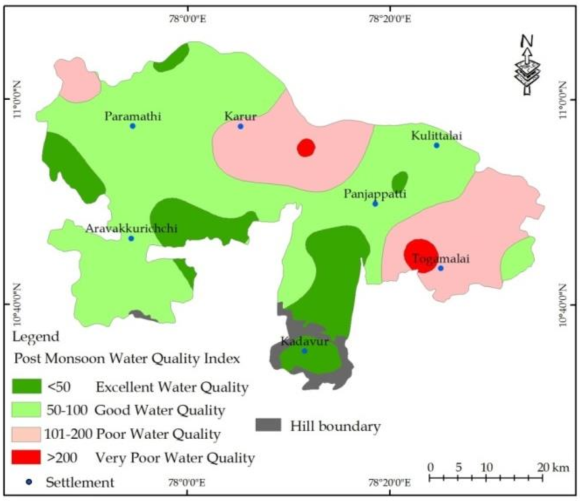

Figure 5. Post Monsoon Water Quality Index Map

Table 5. Areal Extent of Pre-&Post-Monsoon Ground Water Quality Index

S.No	Water Quality Index	Pre Monsoon Area (km2)	Pre Monsoon Area %	Post Monsoon Area (km2)	Post Monsoon Area %
1.	Excellent water quality	Nil	Nil	514	18
2.	Good water quality	1297	44	1643	56
3.	Poor water quality	1554	53	732	25
4.	Very poor water quality	76	3	37	1
5.	Water unsuitable for drinking purposes	Nil	Nil	Nil	Nil

VII. CONCLUSION

The present study was carried out to evaluate and characterize the quality of groundwater, generally for drinking purpose in the study area. GIS based water quality index method had been applied to visualize the change in the spatial pattern of the groundwater quality in the study area.

The water quality index calculated for the pre-monsoon period exhibited poor quality in greater percentage when compared with the post-monsoon period. This had indicated that the over exploitation, dissolution and concentration of rock salts and anthropogenic activities such as, the discharge of effluents from industries, excess use of fertilizers and pesticides for agriculture and improper dumping of domestic wastes into the potential river systems.

The post-monsoon water quality index map revealed that in most of the study area, the water quality improves due to natural recharge. In the areas where the natural recharge is ineffective, it is suggested for designing suitable artificial recharge structures so as to improve the groundwater potential both qualitatively and quantitatively.

The developed groundwater quality index map in this study is straightforward to comprehend and communicate information regarding water quality to the beneficiaries and local management which will make possible the proper consumption and management of groundwater. The methodology adopted in this study can easily be applied to other area for the improvement and formulation of capable groundwater utilization and management policy to make sure proper utilization and to evade groundwater quality deprivation. Hence, from this study, it is clearly established that the GIS and water quality index method are the potential tools for handling and mapping of hydro chemical parameters, determining the water quality and suggesting remedial measures properly.

VIII. ACKNOWLEDGEMENT

Authors wish to thank S.M.Ramasamy, Distinguished Professor, Alagappa University, Karaikudi, India and C.J. Kumanan, Former Professor & Head, Centre for Remote Sensing, Bharathidasan University, Tiruchirappalli, India for their constant encouragement to carry out this research work.

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