International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958, Volume-8, Issue- 4C, December 2018

Evaluation of Groundwater Quality at Eloor, Ernakulam District, Kerala Using GIS

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Abstract— Pollution of groundwater resources is one of the major challenges faced by rapidly developing countries like India. Population explosion, large scale industrialization and urbanization have led to rapid decline in groundwater quality. Traditional methods of assessing groundwater quality like random sampling and analysis has become ineffective and obsolete in providing a comprehensive, complete and accurate picture of the pollution levels in large areas. In this paper, groundwater quality in the industrial belt of Eloor in Ernakulum district of Kerala is evaluated using Geographical Information System based geostatistical methods. Ordinary Kriging method based on spatial autocorrelation is used for predicting the groundwater physico-chemical parameters at unmeasured locations.

Index Terms— Geographical information system, Geostatistical methods, Groundwater pollution, Ordinary kriging.

I. INTRODUCTION

Water is one of the most important natural resources required for sustaining life on Earth. Water in its many forms is required for human health, social and economic well being and development of a nation. It is a vital resource that is becoming increasingly scarce due to rapid increase in population, industrialization, urbanization, climate change and various other anthropogenic activities [9]. Water is present on Earth in many forms; as surface water in rivers, lakes and oceans; as snow and glacial water; as groundwater stored in aquifers and as water vapor in atmosphere. Out of these many sources of water, groundwater is considered as the most dependable source because it is widely available and reliable especially in arid climates and in times of drought and scarcity [6]. About a third of the world's population depends on groundwater for meeting their basic necessities. However, unchecked exposure to large scale pollution and over use has lead to depletion in quality of groundwater resources. This is encountered especially in regions of high population density and industrialization [8].

There are many sources from which groundwater can get polluted. These include natural sources like dissolution of minerals found in soil and rocks and manmade sources like leaching from landfills, application of chemical insecticides and pesticides, industrial discharges and spills etc. The contamination of groundwater leads to ecological degradation, loss of vegetation, pollution of surface water sources and causes adverse effects on human and animal health. Once an aquifer gets contaminated, it is arduous and unfeasible to reverse the effect. Polluted groundwater can cause negative health impacts in humans. Kidney, liver, nerve damages, miscarriages, developmental abnormalities, cancer, poisoning by toxins etc are a few health effects of polluted water. Thus, better management, quality control and monitoring is required to preserve groundwater resources [8]. Conventional methods of monitoring groundwater quality involve construction of monitoring wells and random sampling from bore wells or open wells. These methods are time consuming, expensive and tedious. Alternative methods like spatial mapping of groundwater quality using Geographical Information System has gained momentum in recent years. Since groundwater quality is a spatially varying parameter, mathematical models and spatial analysis can be used to manage groundwater problems. With limited observations or data, manpower, expense and time, GIS based geostatistical methods can be used as an effective tool for obtaining accurate pollution profiles [3]-[9].

Eloor is a river island formed by the tributaries of Periyar river in Ernakulam District of Kerala in India. It is home to the largest industrial belt in Kerala with over 247 small, medium and large scale industries involved in the production of chemicals, fertilizers, insecticides, leather, rubber, metal plating etc. Most of these industries are several decades old and employ the most polluting manufacturing methods. This has lead to widespread pollution of land, water and air in the area. Eloor is considered as one of the most polluted toxic hotspots in India by Greenpeace. A study conducted by Greenpeace in 2003 found that pollution in Eloor has caused harmful effects in health of local population. Eloor ranks 24th in the list of Critically Polluted Areas (CPAs) in the country. There has been a significant increase in respiratory diseases, birth defects, cancer and many other illnesses in the Eloor community. A study conducted in 2007 on the quality of groundwater in Eloor, found that the groundwater quality was poor [2]. Since the detection of alarming levels of pollutants in the wells of Eloor, a large number of people have abandoned their wells or use it for purposes other than drinking, cooking and bathing.

This study aims to study the status of groundwater pollution in Eloor using GIS based geostatistical methods.

II. METHODS AND DATA

A. Study Area

Eloor is a river island occupying an area of 14.21 square kilometers in Ernakulam District of Kerala in India between north latitudes 9º 3´ and 10º 6´ and east longitudes 76º 20´ and 76º 28´. It is formed between two distributaries of the Periyar river [2].

Revised Manuscript Received on June 23, 2018.

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B. Sample Collection and Physico - Chemical Analysis

Thirty groundwater samples were collected from open wells in Eloor from January 2018 to February 2018. Physico – chemical parameters of the collected samples such as pH, temperature, TDS, Chloride, sulphate, iron,nitrate, hardness, COD and lead were analyzed as per APHA methods. Portable pH meter and TDS meter was used to determine pH and TDS respectively. The coordinates of sample points were obtained using handheld GPS.

C. Geostatistical Analysis

Geostatistical methods such as kriging are widely used in fields such as geology, mining, meteorology and earth sciences for mapping spatial variation of parameters based on spatial autocorrelation. Geostatistics uses both mathematical and geostatistical methods to generate continuous surfaces. It can be used not only to predict values at unmeasured locations, but also to determine the uncertainty in the prediction [2].

A GIS database was created to store the analyzed water quality parameters. Geostatistical wizard tool in GIS was used for interpolation of parameters. Before using kriging for interpolation, exploratory data analysis was done to determine the suitability of data for prediction [1]. Kriging method works best if the data is normally distributed. Histograms and Q-Q plots were used to assess the normality of the data. Parameters which did not show a normal distribution were transformed using transformations such as logarithmic and arcsine transformations to make them conform more closely to a normal distribution. Analysis of normal Q-Q plots and histograms showed that all the parameters exhibited normal distribution. However, logarithmic transformation was applied to parameters that showed a decrease in skewness after transformation. Thus, pH, chloride, nitrate and sulfate data were transformed before predictions.

Ordinary Kriging was used for prediction since it was the easiest and most accurate of all the interpolation methods. Semivariograms were used to study the spatial correlation in data and to fit mathematical models for prediction [7]. The semivariogram parameters such as nugget, sill and range were studied to determine the degree of spatial correlation [6]. Three types of models; spherical, exponential and Gaussian were used to for prediction of parameters at unmeasured locations. The best fitting model was selected after cross-validation based on the lowest root mean square error (RMSE). The smallest RMSE value indicates the most accurate prediction [5].This model was then used to generate the output surface or thematic map.

III. RESULTS AND DISCUSSIONS

The results of physico-chemical analysis conducted on thirty groundwater samples are given in Tables I and II. The parameters analyzed include pH, temperature, TDS, chloride, nitrate, hardness, iron, and sulfate.

TABLE I: ANALYSIS OF PH, TDS, TEMPERATURE AND HARDNESS

Sample No	pH	TDS (ppm)	Temperature ˚C	Hardness (mg/L)
1	6.7	200	29.2	186.2
2	6.2	214	28.3	194.3
3	6.0	206	28.8	211.8
4	6.1	211	27.7	205.1
5	6.2	198	27.8	209
6	5.9	185	28.2	214.2
7	6.0	170	28.4	210.8
8	6.9	173	28.7	223.6
9	6.2	198	29	246.6
10	6.3	230	30	243
11	6.2	229	28.1	245.1
12	6.3	225	27.6	268.6
13	6.5	227	29.6	276.5
14	6.9	216	28	267.7
15	7.2	213	26	263.1
16	6.5	205	26.3	269.8
17	6.3	219	26.6	271
18	6.1	223	28	246.4
19	5.7	220	29.2	242.7
20	5.6	236	29.4	255.6
21	5.2	242	28.3	304.2
22	5.6	243	28	311.6
23	5.5	238	28.2	309.9
24	5.4	246	28.2	301.8
25	5.9	242	27.8	283.4
26	5.8	236	28	278.9
27	6.4	227	27.3	248
28	6.1	231	29	251.5
29	6.3	186	28	225
30	6.2	226	29	234.5

TABLE II: ANALYSIS OF CHLORIDE, IRON , NITRATE AND SULPHATE

Sample No	Cl^- (mg/L)	Fe (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)
1	198.6	0.23	16.5	134.2
2	202.3	0.15	19.4	136.4
3	200.1	0.32	16.8	139
4	210.4	0.29	15.5	145.6
5	211.9	0.27	19.3	143.2
6	206.6	0.33	20.1	149.6
7	220.8	0.18	24.3	150.3
8	232.5	0.22	23.8	153.6
9	228.6	0.26	25	149.2
10	240.8	0.31	33.3	156.1
11	252.3	0.36	38.6	163.3
12	228	0.33	37.3	166.1
13	226.1	0.3	36.5	168.8
14	228.3	0.28	44.3	177.6
15	225.1	0.23	50.3	173.8
16	211.5	0.25	48.9	174.2
17	213.8	0.32	52.5	176.5
18	224.8	0.36	48.7	173.6
19	230.2	0.35	46.2	186
20	248.4	0.33	39.6	183.8
21	259.8	0.37	36.7	195.6
22	260.1	0.41	29.5	204.2
23	266.5	0.47	26.6	207.8
24	271.8	0.49	24.7	211.9

25	261.2	0.33	27.3	216.6
26	264.8	0.38	28.3	225
27	258.6	0.3	26.6	203.6
28	238.6	0.32	24.2	223.8
29	216.2	0.28	25.6	164.6
30	235.7	0.33	39.9	145.8

Semivariograms were plotted and best fitting model was selected based on lowest RMSE value. Spherical model was found to be best fitting model for TDS, nitrate, hardness and iron. Gaussian model was found to be best fitting model for temperature, chloride and sulphate. Exponential model was found to be best fitting model for pH. The best fitting semivariogram models for the eight groundwater quality parameters are shown in Fig. 1 to Fig. 8.

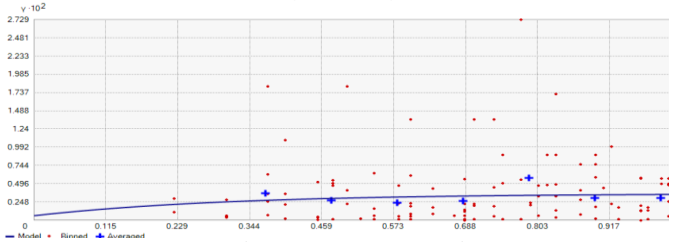

Fig. 1. Best fit semivariogram model for pH

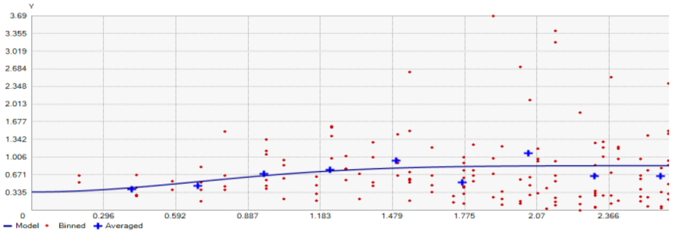

Fig. 2. Best fit semivariogram model for temperature

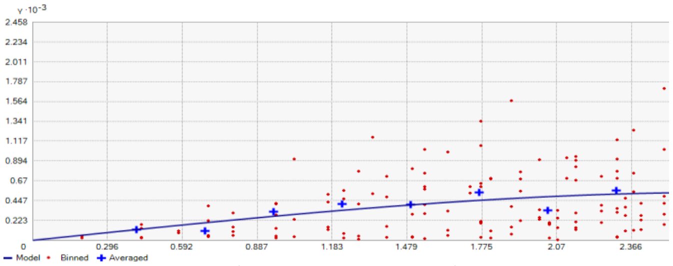

Fig. 3. Best fit semivariogram model for TDS

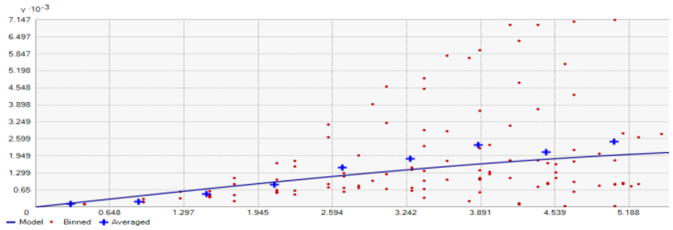

Fig. 4. Best fit semivariogram model for hardness

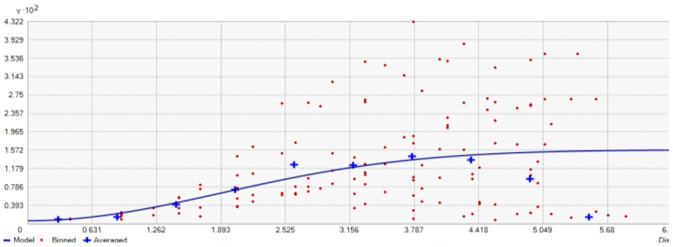

Fig. 5. Best fit semivariogram model for chloride

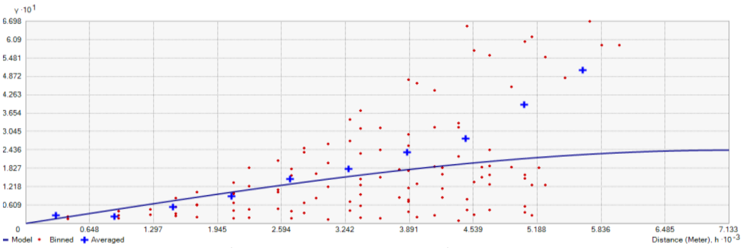

Fig. 6. Best fit semivariogram model for nitrate

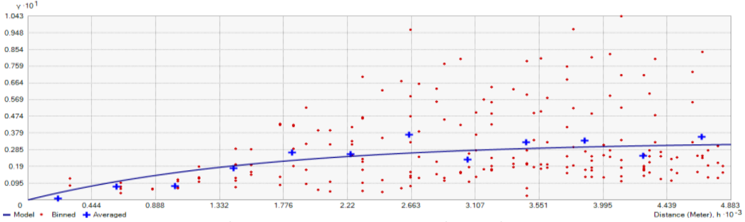

Fig. 7. Best fit semivariogram model for sulfate

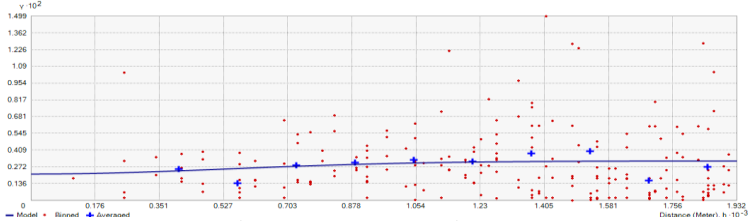

Fig. 8. Best fit semivariogram model for iron

The predicted output surface based on the best fitting models for each of the eight parameters is shown in Fig 9 to Fig 16.

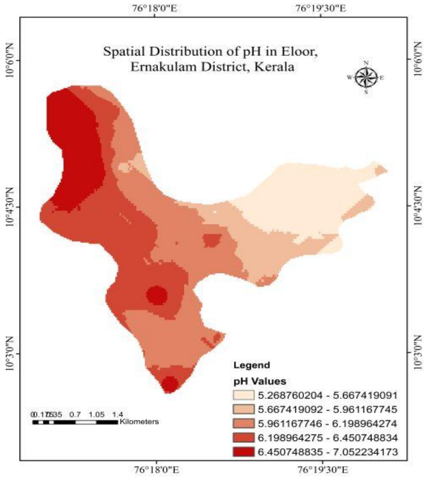

Fig. 9. Predicted map of spatial variation in pH

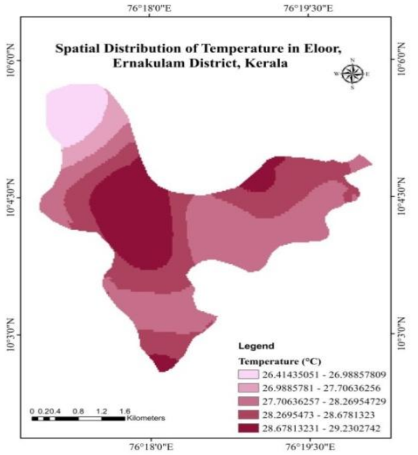

Fig. 10. Prediction map of spatial variation in temperature

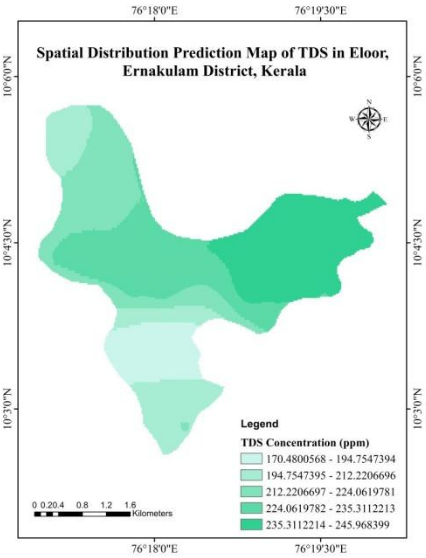

Fig. 11. Prediction map of spatial variation in TDS

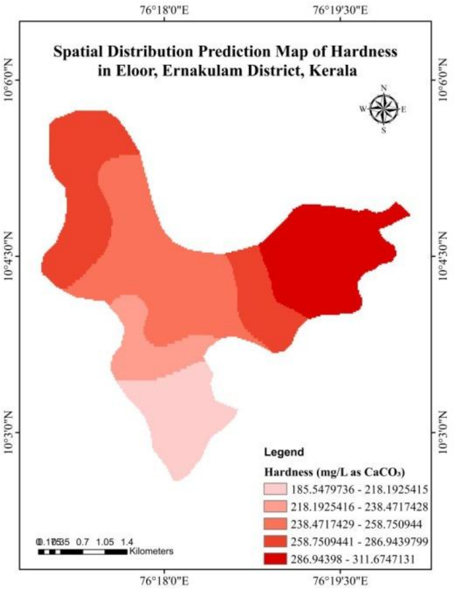

Fig. 14. Prediction map of variation in hardness

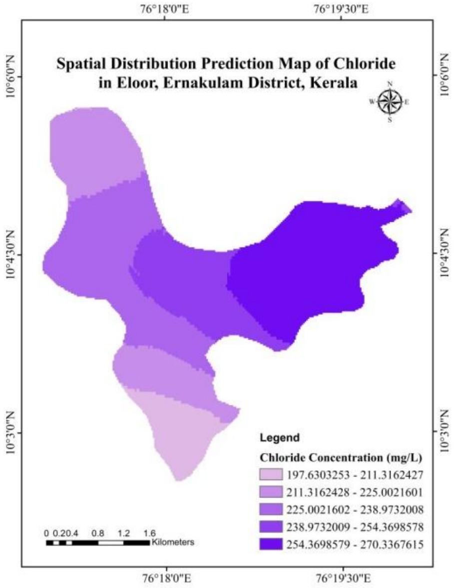

Fig. 12. Prediction map of spatial variation in chloride

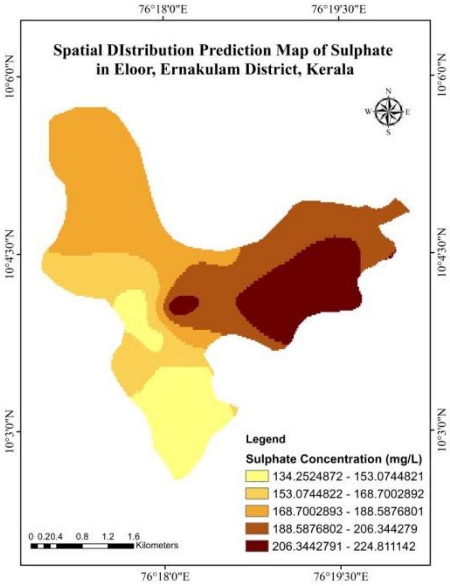

Fig. 15. Prediction map of variation in sulfate

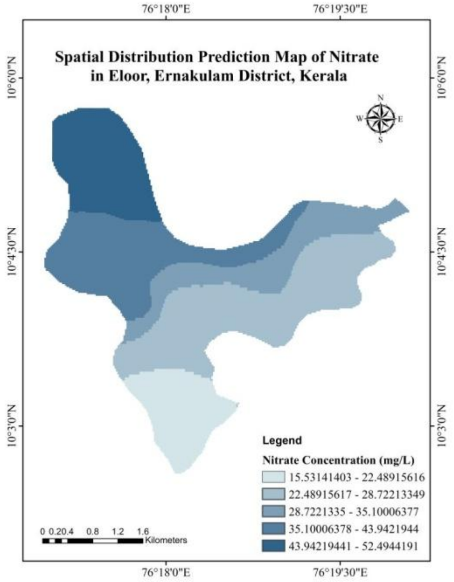

Fig. 13. Prediction map of spatial variation in nitrate

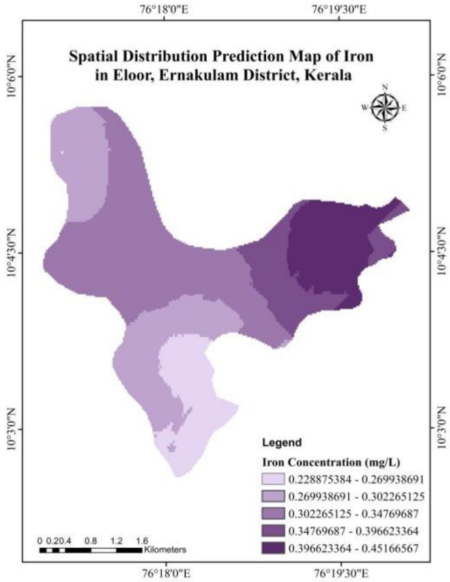

Fig. 16. Prediction map of variation in iron

Groundwater showed high acidity in north eastern parts of Eloor and acidity decreases towards the western and southern regions. Temperature shows irregular variations with higher temperature in the central, southern and eastern parts. TDS showed higher values in the eastern region. However, TDS was within limits in the whole area. Chloride concentration exceeded the desirable limit of 250 mg/L in most of the eastern parts of Eloor. Nitrate concentration was found to be high in the north-western regions of Eloor. The desirable limit of 45 mg/L was exceeded in this area. Hardness exceeded the limit of 200 mg/L in almost all the regions with the highest concentration observed in the eastern and northern regions. Sulfate concentration was found to be within limits except in some parts of the eastern region. The concentration of iron exceeded the desirable limit of 0.3 mg/L in almost all regions.

From the above observations, it was inferred that the groundwater in northern and eastern parts of Eloor are more polluted and unfit for human consumption than the southern regions. This variation may be attributed to the higher density of industries in this region. Using geostatistical methods was found to be a suitable method for predicting concentration of groundwater parameters at unmeasured locations.

ACKNOWLEDGMENT

We are grateful to Dr. Jayanand B., Principal,Govt. Engineering College, Trichur, Dr. Sajikumar N., Professor and Head of Department, Department of Civil Engineering, Govt. Engineering College, Trichur and Dr. Vinod P., project coordinator and PG coordinator, Department of Civil Engineering, Govt. Engineering College, Trichur for their help and support.

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