Geostatistical approach using Kriging for assessing spatial distribution of ground water nitrate in proximity to a solid waste dump site, Rohtak city, Haryana, India.

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ABSTRACT

The purpose of this investigation was to assess the quantitative spatial distribution of nitrate in ground water in the vicinity of the municipal solid waste dump site of Rohtak city in India. A requirement of Municipal Solid Waste Rule 2016 is the regular monitoring of ground water quality in the vicinity of MSW dumpsites. The quality of ground water was determined by taking samples from 44 tube wells and hand pumps within a radius of 1.2 km from the center of the dumpsite. The location of the water sources were obtained using a global positioning system receiver using a hand held receiver. Spatial interpolation methods are frequently used to estimate values of physical or chemical constitution in location where they are not measured. The geostatistical analyst module of Arc GIS was used for data analysis for the distribution of ground water quality in terms of nitrate quantity. The ordinary kriging method was used to produce the spatial pattern of nitrate in ground water of the study area. The result of ordinary kriging interpolation show that highest nitrate levels are situated near the dumpsite and concentration decreases with distance from the centre. However the decrease is not uniform in all directions. The nitrate levels ranged from 6 to 238mg/l. Result were compared to World Health Organisation, Environmental Protection Agency and Central Pollution Control Board standards for ground water quality.

Key words- GIS, nitrate, kriging, municipal solid waste, dumpsite.

1. Introduction-

Ground water is significant natural resource which can be used as alternative to surface water for industrial, irrigation and drinking purpose [1,2]. Most of drinking water sources has been contaminated by numerous type of human activities such as residential, municipal, commercial, industrial and agricultural usage [3]. The municipal solid waste normally termed as “garbage” is an inevitable byproduct of human activity which is disposed through dumping. Solid waste land filling is the most common method of solid waste disposal. The landfill site nearer to Rohtak is open dumpsites, because the open dumpsites are low operating costs and lack of expertise and equipment provided no systems for leachate collections [4]. Open dumps are unsightly, unsanitary, and generally smelly. They attract scavenging animals, rats, insects, pigs and other pests [5]. Surface water percolating through the trash can dissolve out or leach harmful chemicals that are then carried away from the dumpsites in surface or subsurface runoff. These chemicals may constitute an environmental problem, if the leachate migrates into the ground water. The presence of bore well at the landfill sites to draw ground water threatens to contaminate the ground water [6,7]. The Central Pollution Control Board (CPCB) of India has the standard limit of nitrate at 45 mg/l and there is no relaxation in permissible limit in the absence of alternative source. Consumption of nitrate contaminated water can lead to the accumulation of nitrate to the human body which under acidic condition converted to nitrite. It has long been established that high amounts of nitrate in water can result in diseases such as methemoglobinemia and specific cancers [8,9,10].

Natural resources and environmental concerns, including groundwater, have benefited greatly from the use of GIS. ArcGIS Geostatistical analyst effectively bridges the gap between geostatistics and GIS analysis [11]. Geostatistical analysis has been useful to determine water variables in space and time [12,13]. Geostatistics provides a set of statistical tools for analyzing spatial variability and spatial interpolation. These techniques produce not only prediction surfaces but also error or uncertainty surfaces. Kriging provides the best linear unbiased estimation for spatial interpolation [14,15]. They take into account the spatial autocorrelation in data to create mathematical models of spatial correlation structures. Another advantage of geostatistic is that it provides the means to evaluate the magnitude of the estimation error. The mean square error is a useful rational measure of the reliability of the estimate. It depends only on the variogram and the location of the measurements [16].

Study area-

The site selected is in Rohtak city in the state of Haryana, India Fig.1. Rohtak city situated at a mean sea level of 220 meters. It is located at 70 km North-West of New Delhi at National Highway No.10. It is one of the eight regional centers of National Capital region and 4th largest city of Haryana state. The city is drained by Artificial drain No. 8 which is located at western part of the city and flow from North to South. The climate can be classified as subtropical monsoon, mild & dry winter, hot summer and sub-humid. The normal annual rainfall is 592 mm [17]. There is a great variation in temperature annually, the mean maximum is 40.5^{0}C (May & June), and the mean minimum is 7^{0}C (January) [18]. In 2001 census, its population was 2.9 lac in 2001, followed by 27% increase in 2011 in which population was 3.74 lac. Municipal Corporation Rohtak has landfill site near Bhiwani road situated between villages Sunaria and Jalalpur, near Drain No.8. The dumpsite spans an area of 35.4 acres.

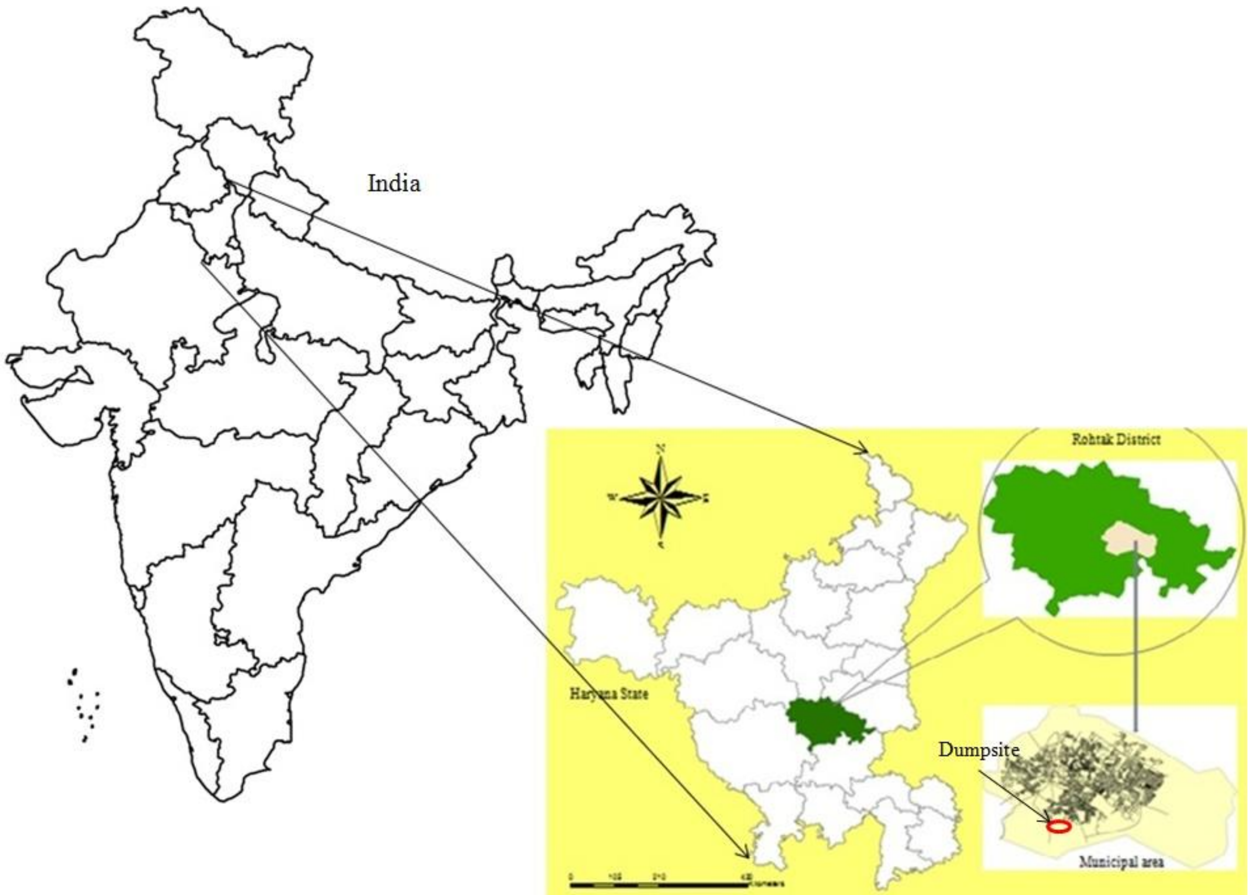

Fig-1. Location map of study area.

2. Materials and methods

Sampling was done along with GPS coordinate during post monsoon season during the month of February (2020). Water samples were collected from hand pump and tub wells situated within a radius of 1.5 Km from dumpsite in amber colored reagent bottles and taken to laboratory for nitrate analysis. UV-Visible spectroscopy standard method was used. UV Spectrophotometer (Dynamica) at wavelength 220 nm and 275 nm.

GIS- Nitrate data of sampling sites was transferred into GIS environment using ArcGIS 10.3. Toposheet (H43W9) used for Georeferencing of cartosat1 imagery. Dumpsite was digitized and then Centroid was generated for sampling site direction and distance in reference to Centroid. Spatial distribution of nitrate concentration of the area of interest has been depicted by converting the point data into thiessen polygons (Fig. 2) and Kriging (Fig. 3) using proximity in analysis tool and interpolate to raster in spatial analyst tool.

Thiessen polygon method is a simple method for defining an area of influence around points and for distributing a property aerially. Euclidean geometry or Theissen polygons generated from a set of sample point, so that any location inside the polygon is closer to that point than any of the other sample points. Theissen polygon is closer to that point than any of the other sample points [19]. In spatial analysis IDW (Inverse Distance Weighted) and Spline interpolation tools are referred to as deterministic interpolation methods because they are directly based on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface. A second family of interpolation methods consists of Geostatistical methods, such as Kriging, which are based on statistical models that include autocorrelation—that is, the statistical relationships among the measured points. Because of this, Geostatistical techniques not only have the capability of producing a prediction surface but also provide some measure of the certainty or accuracy of the predictions [20].

Kriging is similar to IDW in that it weights the surrounding measured values to derive a prediction for an unmeasured location. The general formula for both interpolators is formed as a weighted sum of the data:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Where:

$Z(s_i)$ = the measured value at the i^{th} location

λ_i = an unknown weight for the measured value at the i^{th} location

s_0 = the prediction location

N = the number of measured values

In IDW, the weight, λ_i, depends solely on the distance to the prediction location. However, with the Kriging method, the weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points. To use the spatial arrangement in the weights, the spatial autocorrelation must be quantified. Thus, in ordinary Kriging, the weight, λ_i, depends on a fitted model to the measured points, the distance to the prediction location, and the spatial relationships among the measured values around the prediction location [21,22].

3. Result and discussion

Result of nitrate concentration at the various sampling sites given in Table.1. Result indicates high level of nitrate in the study area. Extremely higher values have been observed near the dumpsite. Sampling sites north of the dumpsite have lower nitrate as compare to sites south of the dumpsite. The Table shows maximum values of nitrate are situated in the south and South-East direction from the dumpsite. Sites along the canal also show high nitrate value. Sites [S14 (98 mg/l)] situated far away from dumpsite as well as were also showing high level of nitrate. Values on western side of drain are higher as compared to those on the eastern side of the drain. The distribution of various sampling sites is given in Fig.3.

The result indicates the detrimental effect of dumpsite leachate percolation in the surrounding ground water. The range of nitrate in the ground water were from 6.00±0.04 mg/l and

238.00±0.03 mg/l. 86.36% sampling sites reported a higher level of nitrate then the permissible limit of 45 mg/l. Sampling site north of dumpsite of dumpsite showed lesser nitrate concentration as compare to sites situated south of dumpsite. On southern side concentration of nitrate decreased with distance from the dumpsite similarly concentration of nitrate on the North West side of drain no.8 was reported less then on the South-East. Nitrate concentration decreased with distance from drain. High concentration of nitrate near the drain were found to be due to discharge of untreated sewage water into the drain at point A. the sewage flow from both upstream and downstream direction and constantly percolate into ground water. It was also observed that farmer were recharging the ground water by installing pumps near the drain and pumping the sewage water into their tube wells situated in their fields situated far away from the drain leading to contamination of the ground water with nitrate.

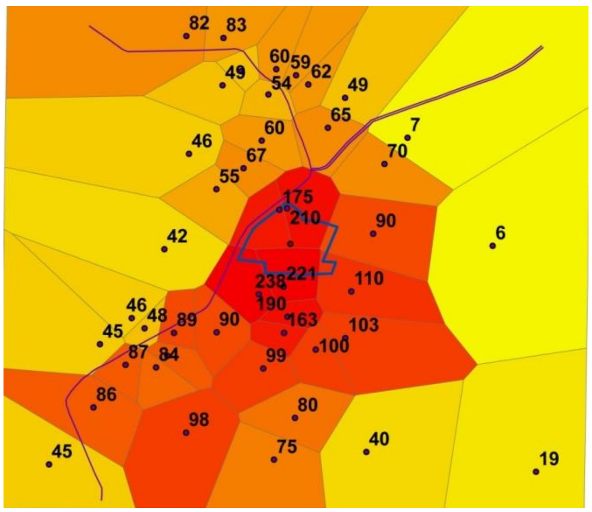

Fig-2. Spatial distribution of nitrate concentration of ground water by Thiessen polygon.

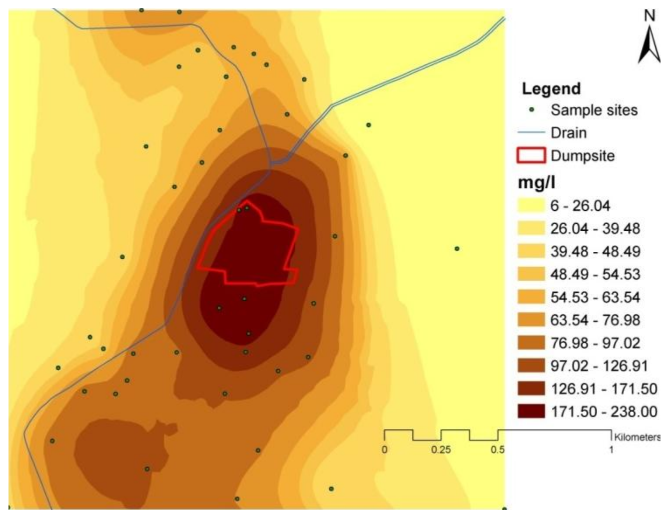

Fig-3. Spatial distribution map of groundwater nitrate concentrations.

From the spatial analysis of the data it is possible that to explain the distribution of the nitrate values on the basis of the direction of flow seems to be from North to South direction of drain. Higher values in the Southern direction of dumpsite and south east direction of drain are due to percolation of nitrate rich leachate and sewage water from dumpsite and drain respectively. Certain higher nitrate values on North West side of drain are probably due to illegal recharge of ground water with sewage from the drain.

Table.1. Nitrate concentration of different sites of Rohtak city.

Sr. No.	*Sample No.*	*Nitrate (mg/l)*	*Direction*
1	S23	6.00±0.04	E
2	S39	7.01±0.02	NE
3	S22	19.00±0.01	SE
4	S21	40.03±0.01	SE
5	S24	42.00±0.05	W
6	S41	45.00±0.04	SW
7	S42	45.01±0.06	SW

8	S28	46.00±0.04	NW
9	S40	46.00±0.05	SW
10	S44	48.00±0.06	SW
11	S43	49.00±0.04	NW
12	S36	49.00±0.05	NE
13	S31	50.00±0.05	NW
14	S33	54.00±0.03	N
15	S25	55.03±0.05	NW
16	S35	59.00±0.02	N
17	S27	60.00±0.01	SE
18	S32	60.02±0.02	N
19	S30	61.00±0.02	NW
20	S34	62.00±0.01	N
21	S29	63.00±0.02	NW
22	S37	65.00±0.05	N
23	S26	67.00±0.01	NW
24	S38	70.00±0.01	NE
25	S20	75.00±0.02	S
26	S17	80.00±0.04	S
27	S12	84.00±0.01	SW
28	S13	86.00±0.02	SW
29	S11	87.00±0.03	SW
30	S10	88.00±0.04	SW
31	S9	89.00±0.05	SW
32	S8	90.03±0.01	SW
33	S3	90.04±0.04	SW
34	S14	98.00±0.01	SW
35	S15	99.00±0.02	S
36	S18	100.00±0.03	SE
37	S19	103.00±0.04	SE
38	S7	110.00±0.02	SE
39	S16	163.00±0.03	S
40	S2	175.00±0.03	N
41	S6	190.03±0.01	S
42	S1	210.00±0.03	N
43	S5	221.00±0.01	S
44	S4	238.00±0.03	S

Table.2 Area of spatial distribution of nitrate in ground water.

Range mg/L	6.00-26.04	26.04-39.48	39.48-48.49	48.49-54.53	54.53-63.54	63.54-76.98	76.98-97.02	97.98-126.91	126.91-171.50	171.50-238.00
Area m^2	189164	20444	386903	573082	272064	1764652	361039	470575	686621	1258593

4. Conclusion-

In this study Theissen polygons and Kriging were generated for analysis of spatial distribution of nitrate concentration in groundwater. It was found that the higher concentration of nitrate in ground water was due to leaching of nitrate from dumpsite as well as direct insertion of drain

No.8 water to recharge the aquifer. Two techniques were used for analysis of spatial distribution of nitrate. Kriging was found to be more exact because it is depend upon spatial relationships among the measured values around the prediction location whereas, in Theissen polygon the area were calculated on the basis of spatial distribution of sampling points.

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