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Research Article

SPATIAL DISTRIBUTION OF NITRATE IN GULBARGA TALUK, KARNATAKA, INDIA

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A R T I C L E I N F O

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A B S T R A C T

Nitrate is one such pollutant which is added in excess to groundwater by anthropogenic activity at many places in the world. According to Bureau of Indian Standards (BIS) the maximum permissible limit of nitrate in groundwater for drinking purpose in India is 45 mg/l. Anything in excess of this my cause methemoglobinemia commonly known as 'blue baby disease'. Spatial distribution of nitrate was studied for Gulbarga Taluk using GIS. The present study shows that the nitrate contamination in Gulbarga Taluk is ranged between 15 and 137 mg/l with a median value of 66.1 mg/l. The study also revealed that the major section of the taluk is having nitrate concentration higher than the permissible limits. The high concentrations are associated with agricultural activity practiced at these areas centred around major water bodies. The author suggests practicing sustainable agricultural practices in the area and use of water purifiers to eliminate nitrate from drinking water.

INTRODUCTION

Groundwater is an important source of drinking water especially in the rural areas. It is reported that about 70% of the Indian population is dependent on groundwater. Groundwater may interact with the solids and gases present in the aquifers and may get contaminated. Anthropogenic activities further enhance the contamination levels by adding pollutants in excess and leads to many problems. Nitrate is one such pollutant which is added in excess to groundwater by anthropogenic activity at many places in the world. There are different forms of nitrogen compounds occur in the earth such as organic nitrogen, ammonia nitrogen, nitrite and nitrate. Nitrate is an end product of nitrogen decomposition cycle of the organic matter and is stable. Nitrate contamination is a serious concern all over the world as it causes some serious health implications. The major proven effect of nitrate contamination is methemoglobinemia (Mutewekil M Obeidat *et al*., 2007). According to Bureau of Indian Standards (BIS) the maximum permissible limit of nitrate in groundwater for drinking purpose in India is 45 mg/l (Bureau of Indian Standards, 2012). Groundwater with nitrate concentration exceeding the threshold of 13 mg/l nitrate which is referred as human affected value (HAV) is considered due to human activities (Mutewekil M Obeidat *et al*., 2007). Excess nitrate is found in top soil in rural and agriculture areas and the average nitrate concentration in groundwater in rural areas is five to seven times higher (Reddy *et al*., 2011). Geographic Information System (GIS) is a computer system for capturing, storing, managing and displaying geographic data. By harnessing its enormous analytical powers it can be extensively used for decision making in several areas including groundwater studies. In groundwater studies GIS has been used widely for many purposes but not much for establishing the spatial relationship between pollution level and its source (P. Balakrishnan *et al*., 2011). Hence, it is intended to study the occurrence of nitrate in groundwater and its spatial distribution in Gulbarga Taluk.

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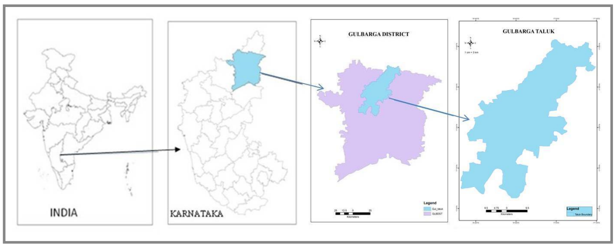
STUDY AREA

Gulbarga is situated in the semi arid region of peninsular India and declared as one of the chronic drought affected areas of Karnataka state. Map 1, shows the location of the study area. Gulbarga taluk is extended between the latitudes N17^{O}2'30" and N17^{O}41'43" and longitudes E76^{O}36'10" and E77^{O}9'52" comprising a geographical area of 1741 sq km. The mean elevation of the study area is about 450m above MSL. As per the 2011 census of India the total population of Gulbarga taluk is 829830. Annual temperature range for Gulbarga taluk is 19^{O}C during winter and 46^{O}C during summer.

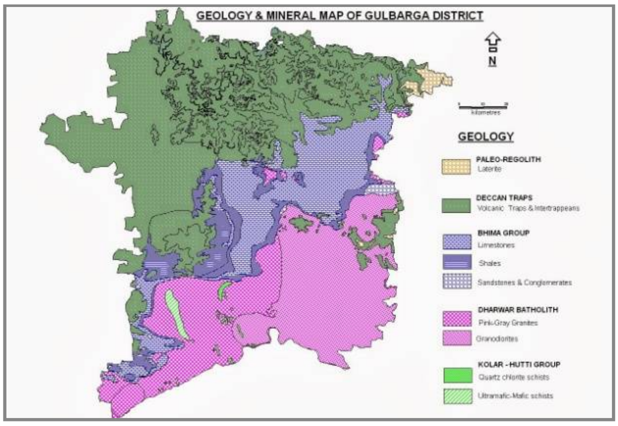


Map 1 Location of the study area; Gulbarga Taluk.

Annual average rainfall is about 750mm and most of it precipitates during monsoon season.

Geology of the Study Area

The Gulbarga District is covered by the rock types ranging from Archean to Recent. The entire area of the Gulbarga taluk is predominant by basaltic lava flows except a small area in the south where limestone are deposited. Basaltic lava flows belong to the Deccan traps of Deccan volcanic province and limestone belongs to the Bhima group of rocks. The major rock types of sedimentary formations of Bhima group are conglomerate, sandstones, shales and limestone. Limestone are fractured and sheared due to tectonic disturbances are exposed subhorizontally with a local northward dip of less than 5^{O} overlying the Archean basement rocks and are traversed by pegmatite veins filled with fluorite associated minerals (S. Sumalatha *et al.*, 1999; Vivek S Kale *et al.*, 1990). A part of the present study area at the southern portion is covered by these limestones which are inter-bedded with shales. Map 2, shows the geology of the Gulbarga district.

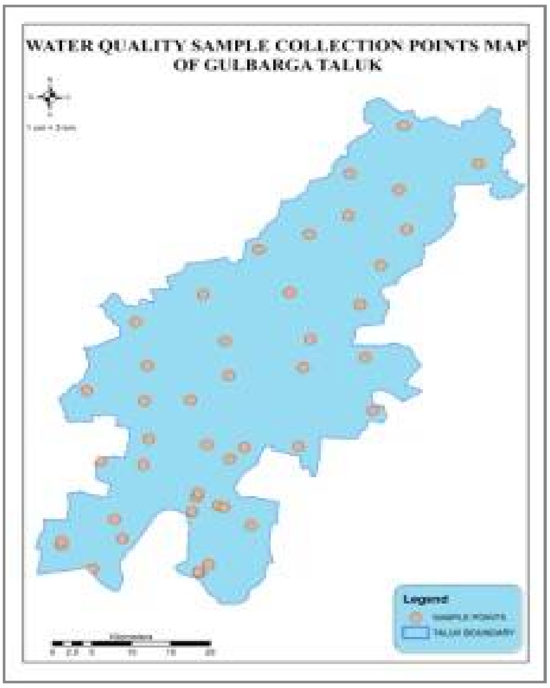


Map 2 Geology of Gulbarga District

METHODOLOGY

A total of 46 samples are collected from both bore wells as well as dug wells from different villages. Standard procedures of the sample collection are followed for the collection of groundwater samples. Samples are collected in 1 litre PVC cans. The cans are thoroughly washed and rinsed twice with the water of sample collecting wells before filling to the brim. Care has been taken to avoid presence of any air gap in the sample cans. Sample cans are properly sealed first with airtight cork and then closed with a cap. Samples are properly labelled and date and location are mentioned on it for future reference. Such collected water samples are sent to the laboratory for the groundwater quality analysis immediately and are analysed within 24 hours.

ArcGIS 10.5 Evaluation version is used for the present study. GIS is a powerful tool to analyse distribution of elements through different techniques. The location of the sample collection wells are obtained by using a handheld Garmin GPS instrument. GPS technology enhances the spatial accuracy of the data integrated in the GIS environment. Using the GPS data the well location map is created. Map 3, shows the locations of the groundwater sample collecting points in the Gulbarga Taluk.



Map 3 Location of the groundwater sample collecting points.

The non spatial data of water quality is tabulated in the excel file which is linked to the spatial data in the GIS environment. The integrated spatial and non spatial database is used for the generation of spatial distribution map of concentration of nitrate and other physicochemical parameters. Elemental distribution maps are delineated using the interpolation technique by adopting the Inverse Distance Weighted (IDW) approach which uses the data of the neighbouring wells. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. The closer a point is to the centre of the cell being estimated, the more influence, or weight; it has in the averaging process (Muzafar N. Teli *et al*., 2014). Finally, various thematic maps for nitrate and other physicochemical parameters are created and used for the analysis of spatial distribution of nitrate in Gulbarga Taluk.

RESULTS AND DISCUSSION

Various thematic maps for nitrate and other parameters are created using the IDW interpolation technique to study the spatial distribution of nitrate and its relation with some of the other parameters in Gulbarga Taluk. Table 1, shows the sampling locations along with some of the other groundwater quality parameters of the study area with its acceptable and permissible limits along with few statistical parameters.

A total of 46 samples are collected, out of which two samples are collected from dug well and the rest are from bore wells. Figure 1, shows the bar graph of concentration of nitrate in groundwater in Gulbarga Taluk. The present study shows the nitrate concentration in Gulbarga Taluk ranged between 15 and 137 mg/l with an average value of 58.91 mg/l. Map 4, shows the thematic map generated for nitrate using the IDW method in the study area. Such prepared map is used for the inference of spatial distribution of nitrate in Gulbarga Taluk.

Table 1 Sampling locations along with some of the groundwater quality parameters of the study area with its acceptable and permissible limits.

sample No	Location	Type of well	Elevation	Cl mg/L	NO3 mg/L	Cl/NO3
	Acceptable Limit			**250**	**45**	
	Permissible Limit			**1000**	**45**	
1	Khanadal	BW	426.11	207.02	70	2.96
2	Itaga	BW	405.08	60.97	69	0.88
3	Farhatabad	BW	381.30	402.71	70.2	5.74
4	Farhatabad	BW	384.96	181.50	75	2.42
5	H Saradagi	BW	382.83	73.13	23	3.18
6	H Saradagi	DW	383.44	62.39	69.05	0.90
7	Tilgul	BW	397.15	49.63	70.5	0.70
8	Tilgul	DW	401.12	43.96	73.6	0.60
9	H Kirangi	BW	420.93	52.46	75.2	0.70
10	Firozabad	BW	379.48	153.14	25.2	6.08
11	Firozabad	BW	386.49	153.14	65	2.36
12	Firozabad	BW	396.85	140.38	67.2	2.09
13	Sarana Saradgi	BW	433.73	653.69	134.7	4.85
14	H Haroti	BW	419.40	174.41	90	1.94
15	Kadani	BW	418.19	300.60	35	8.59
16	Minajagi	BW	406.30	49.63	16	3.10
17	Garur	BW	403.25	418.30	32	13.07
18	Bidanur	BW	390.14	56.72	20	2.84
19	Kavalagi cross	BW	414.22	34.03	18	1.89
20	Jogur	BW	389.23	63.81	110	0.58
21	Jogur	BW	409.04	233.97	117	2.00
22	Herur	BW	398.37	174.41	34.5	5.06
23	Basavapattana	BW	388.62	36.87	117.05	0.31
24	Panigaon	BW	418.19	148.89	112	1.33
25	Sultanpur	BW	473.96	155.98	137	1.14
26	Jambaga	BW	504.75	367.20	132	2.78
27	Babalad	BW	473.35	131.87	35	3.77
28	Mahagaon	BW	432.21	130.45	22	5.93
29	Navadagi	BW	466.95	333.23	31.9	10.45
30	Okali	BW	470.31	83.66	17.5	4.78
31	Dongargaon	BW	573.02	35.45	19.2	1.85
32	Sauntha	BW	537.06	187.17	115	1.63
33	Antapnala	BW	484.94	53.88	15.8	3.41
34	Jeevanagi	BW	431.90	311.96	115	2.71
35	Nagur	BW	437.69	70.90	17.4	4.07
36	Pattana	BW	517.55	126.20	44	2.87
37	Melakunda	BW	455.68	73.32	15.5	4.73
38	Savalagi	BW	457.50	184.34	15	12.29
39	Aurad	BW	452.32	195.68	22	8.89
40	Harasur	BW	460.86	273.67	75	3.65
41	Bhopal Tegnur	BW	406.60	360.17	82	4.39
42	Khaja Kotnur	BW	428.55	141.80	72	1.97
43	Hagaraga	BW	458.42	144.63	15.52	9.32
44	Sannur	BW	439.83	131.87	82	1.61
45	Nandur B	BW	438.91	219.79	17.5	12.56
46	Gulbarga City	BW	464.52	256.65	22.5	11.41
	Total		19901.31	7895.64	2710.02	
	Average		432.64	171.64	58.91	
	Median		423.52	146.76	66.10	
	Max		573.02	653.69	137.00	
	Min		379.48	34.03	15.00	
	StDev		43.62	127.89	39.09	

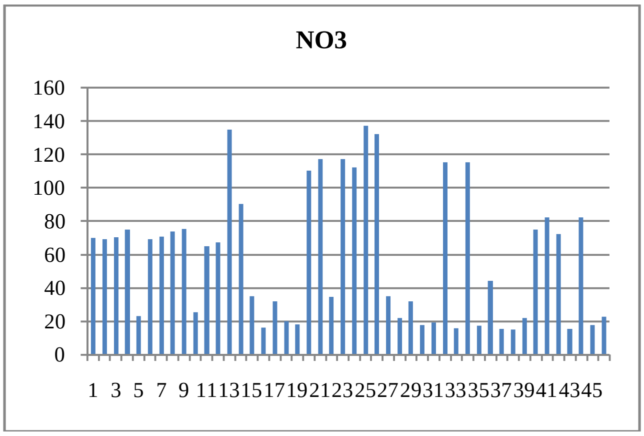
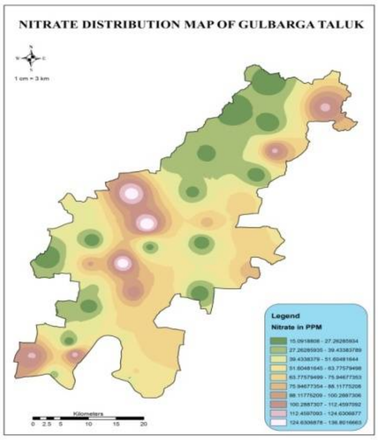


Figure 1 Concentration of nitrate in Gulbarga Taluk.



Map 4 Spatial distribution of nitrate in Gulbarga Taluk.

The spatial map of nitrate concentration shows that the highest concentration of nitrate is occurring at the central portion of the taluk and a couple of pockets at the north and south. In overall, almost the entire taluk except a small portion in the north and few sporadically distributed patches at west and east are having the nitrate concentration higher than the permissible limits. It could be observed that the higher concentration areas are the one where intensive agricultural activity is seen and associated with major water bodies. In Gulbarga Taluk, agriculture can be seen associated with three water bodies such as Bhima River near the southern part, Bennithora River at the centre and Mullamdri River at the north. Apart from these, agriculture is also practiced using groundwater and other water bodies like ponds. This observation suggests that the nitrate contamination observed in the groundwater could be associated with agricultural activity. In intensive agricultural areas, the fertilizers are considered as the principle contributors of nitrate to groundwater (Pawar & Shaik, 1995). The commonly applied inorganic fertilizers in India are urea (nitrogen = 46.6%), superphosphate, potash where urea and potash are highly soluble in water. The urea is completely soluble in water and undergoes changes due to biological activity and is converted to nitrate through ammonium carbonate. Part of the nitrogen fertilizer is absorbed by the plants and the remaining may leached down to groundwater (Pawar & Shaik 1995). The other possible sources of nitrate in rural and agricultural areas could be animal waste, agricultural waste, septic tanks, animal feedlots (Reddy *et al*., 2011; Brindha *et al*., 2012; Bilgehan Nas and Ali Berktay, 2006).

It has been observed from the present study that out of 46 samples 24 samples show higher concentrations of nitrate exceeding the permissible limit of 45 mg/l prescribed by the Indian standard bureau (Bureau of Indian Standards, 2012). Similar reports of nitrate are available where nitrate is ranging between 13 and 252 mg/l for Gulbarga city (Abdul Saleem and Dandigi, 2012). In the present study, the concentration of nitrate in the bore well located in the Gulbarga city is 22.5 mg/l. Occurrence of nitrate in groundwater is dependent on number of factors such as soil, depth, residence time, aquifer geology to name a few. Excess nitrate is found in top soil in rural and agricultural areas (Reddy *et al*., 2011). Generally, dug wells are less deep than the bore wells. Several studies of nitrate contamination have reported that nitrate is predominantly high in shallow water table wells than deep water table wells (Pawar and Shaik, 1995; Reddy *et al*., 2011; Mary Ward *et al*., 2005; Wolfgang and Rolf, 1989). Pawar and Shaik (1995) reported higher concentration of nitrate from dug wells in basaltic terrain (Pawar & Shaik 1995). Similarly, the two dug wells of the study area showed the concentration of nitrate values of 69.05 and 73.6 mg/l which is close to the median value of 66.10 mg/l. Contradicting to the above statement, in the present study it has been found that even the deep bore wells are having the high concentration of nitrate. The lowest value among these bore wells is 15 mg/l and the highest value is 137 mg/l. The reason for the occurrence of high concentration of nitrate even in deep wells could be attributed to intensive agricultural activity and geology of the area. Along with the percolating rain water or irrigation water, nitrate easily gets into groundwater. In hard rock environments such as basaltic terrain of the present study, nitrate reaches the deeper water table due to rapid migration of groundwater through permeable fractures (Reddy *et al*., 2011).

The studies made for nitrate contaminations showed that the concentration of chloride is also high along with high concentration of nitrate in the agricultural areas (Dong *et al*., 2007; Pawar and Shaik, 1995). Chloride ion is a natural form of chlorine and soluble in water. The major sources of chloride in natural water are sedimentary rocks. A small part of the present study area in the south is predominated by sedimentary rocks. The reason for the higher concentration of nitrate in this area may be due to the presence of limestone and intensive agricultural activity. The majority of the study area is covered by igneous rock basalt. Igneous rocks contribute only a fraction of total chloride and especially chloride is not a constituent of water in the basalt (Pawar and Shaik 1995; Biswajeet and Saied, 2011). The possible source of chloride in these environments is anthropogenic activity. The possible sources are fertilizers, industrial and domestic wastewater (Biwajeet and Saied, 2011; Pawar and Shaik, 1995). High concentration of chloride is noticed in some of the wells but except one bore well all samples showed concentration of chloride within the permissible limits. The concentration of chloride in the present study area range between 34 and 653 mg/l with a median of 146 mg/l. A comparative study is made to correlation between nitrate with chloride. Table 2, shows the correlation matrix for nitrate with chloride in the study area. Figure 2, shows the linear correlation graph for the nitrate with chloride.

Table 2 Correlation matrix for nitrate with chloride

Elements	Cl mg/L	NO3 mg/L
Cl mg/L	1	
NO3 mg/L	0.991912	1

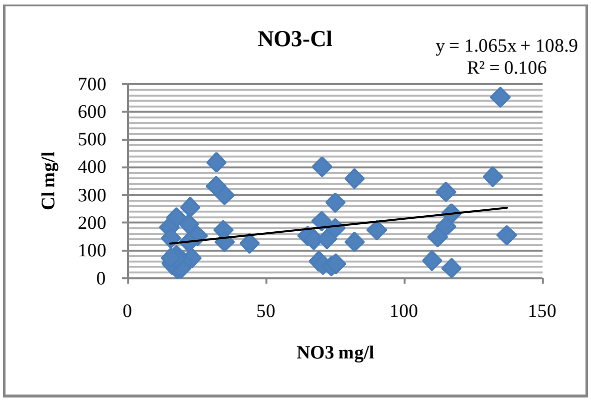


Figure 2 Scatter plot for correlation of nitrate with chloride.

The Cl/NO3 ratio for groundwater samples from the study area showed the variation ranging from 0.31 to 13.07. A positive correlation is observed between nitrate and chloride with r = 0.99192 and P = 1.70617E-46. In few samples high concentration of nitrate is noticed along with low nitrate concentration (Gulbarga city) indicating that the source of chloride may be due to the domestic activity. Hence, it can be inferred that the source of chloride could be fertilizers rich in Cl^- like KCl as well as the other source like domestic waste water. In conclusion, the spatial extent of the nitrate contamination in the study area shown by the spatial map coupled with landuse activity and correlation study establishes that the source of nitrate contamination in the study area could be agricultural source.

Effects

Nitrate concentration above 45 mg/l could be fatal for humans and 100 mg/l for livestock (Bureau of Indian Standards, 2012; Tredoux *et al*., 2000; WRC, 2009). The adverse effects of nitrate contamination are more effective to the infants less than 6 months old. The major proven effect of nitrate contamination is methemoglobinemia which is commonly known as 'blue baby disease' (Mutewekil M Obeidat *et al*., 2007, Spalding and Exner, 1993; Brindha *et al*., 2012). The other effects are enlargement of thyroid, 15 types of cancer, two kinds of birth defects, hypertension, stomach cancer, dizziness, abdominal disorder, vomiting, weaknesses, high rate of pulptation, mental disorder, affect centaral nervous system (Reddy *et al*., 2011; Brindha *et al*., 2012, Baalousha, 2008; Hassan *et al*., 2012).

The excess concentration of nitrate also affect the livestocks. Young animals can also get affected by nitrate the same way as human babies. Loss of livestocks are reported from Namibia and South Africa, livesotcks have been known to abort foetus (Tredoux *et al*., 2000; WRC, 2009; Baalousha, 2008). Further, it also causes eutrophication in water bodies (Brindha *et al*., 2012).

CONCLUSION

The study demonstrated that the GIS could be effectively employed to understand the spatial distribution of nitrate. The present study shows that the nitrate contamination in Gulbarga Taluk is ranged between 15 and 137 mg/l with a median value of 66.1 mg/l. The study also revealed that the major section of the taluk is having nitrate concentration higher than the permissible limits. About 52% of the collected samples showed nitrate concentration higher than the permissible limits. The concentration of nitrate is high in both dug well and as well as bore well. The geological factors may be the cause for deeper percolation of nitrate in deep bore wells. The highest concentrations are observed at the central region of the taluk and a couple of patches at the north and south. The high concentrations are associated with agricultural activity practiced at these areas centred around major water bodies. Groundwater highly contaminated with nitrate may affect health of human beings as well as livestocks in the study area. The author suggests practicing sustainable agricultural practices in the area and use of water purifiers to eliminate nitrate from drinking water.

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