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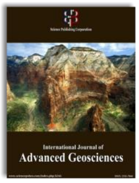

Spatial Assessment of Groundwater Quality with Special Reference to Nitrate Pollution in Raipur City, Chhattisgarh State, India using Geographical Information System

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Abstract

Groundwater quality is one of the most important aspects for sustainable development of social and economic life. In present study, 41 groundwater samples were collected systematically during the pre-monsoon (May 2015) and post-monsoon (December 2015) periods. Nine parameters, i.e. EC, Ca, Mg, Na, K, NO3, SO_4, HCO_3 and Cl were analyzed in the laboratory adapting a standard protocol of APHA, 1995. The analyzed samples were compared with BIS and WHO standard for drinking purpose and spatial distribution map was prepared using Arc GIS Software. In present study, it is found that Ca, Mg, K and NO_3 are above permissible limit and SO4 is above an acceptable limits according to BIS standard. Present study reflecting that main causes of groundwater pollution in study area are anthropogenic activities.

Keywords: *Groundwater Quality; Groundwater Pollution; Groundwater; Raipur City; Chhattisgarh.*

1. Introduction

Groundwater is very essential need for sustainable life on earth surface. Quality of groundwater, to large extent, depends on geogenic as well as anthropogenic activity. There are many causes, which pollute the groundwater varying from septic tanks to industries. Groundwater pollution is difficult to detect and control. Thus, once it is polluted, it is very difficult to rehabilitate its quality. It is estimated that around 37.7 million Indians are affected by waterborne diseases every year, 1.5 million children are estimated to die of diarrhea alone, and 73 million working days are lost due to waterborne disease each year (Khandare 2013).

Contamination of groundwater by nitrate is considered a global problem (Abdulrahman et al. 2009, Jhariya et al. 2012). Nitrate pollution is a rising concern throughout the world that has been regulated through the introduction of several legislations or directives in different countries (Angelopoulos et al. 2008). Nitrates introduced in the groundwater from a variety of sources like agricultural activities, poor sewer system, wastewaters, and industrial activities (Abdulrahman et al. 2009). Nitrate is the most frequently introduced pollutant into the groundwater system (Spalding & Exner 1993, Angelopoulos et al. 2008). Agricultural activities, especially cultivation and fertilization, are principal causes of nitrate contamination on a regional scale and also from poorly treated or untreated human and animal wastes (Hudak 2000, Nolan 2001, Abdulrahman et al. 2009). Nitrate is also a by-product of many industrial processes, including paper and munitions manufacturing industries (Elmidaoui et al. 2001, Abdulrahman et al. 2009). Nitrate is also.

Very mobile in groundwater and tends not to adsorb or precipitate on aquifer solids (Hem 1985, Abdulrahman et al. 2009, Imran 2009, Imran et al. 2010). The adverse health effects of high nitrate levels in drinking water are well documented (Fan et al. 1987, Ward et al. 1994, Fan and Steinberg 1996, Abdulrahman et al. 2009). As per the BIS Standard for drinking water, the maximum desirable limit of Nitrate concentration in ground water is 45 mg/l with no relaxation (BIS, 1991).

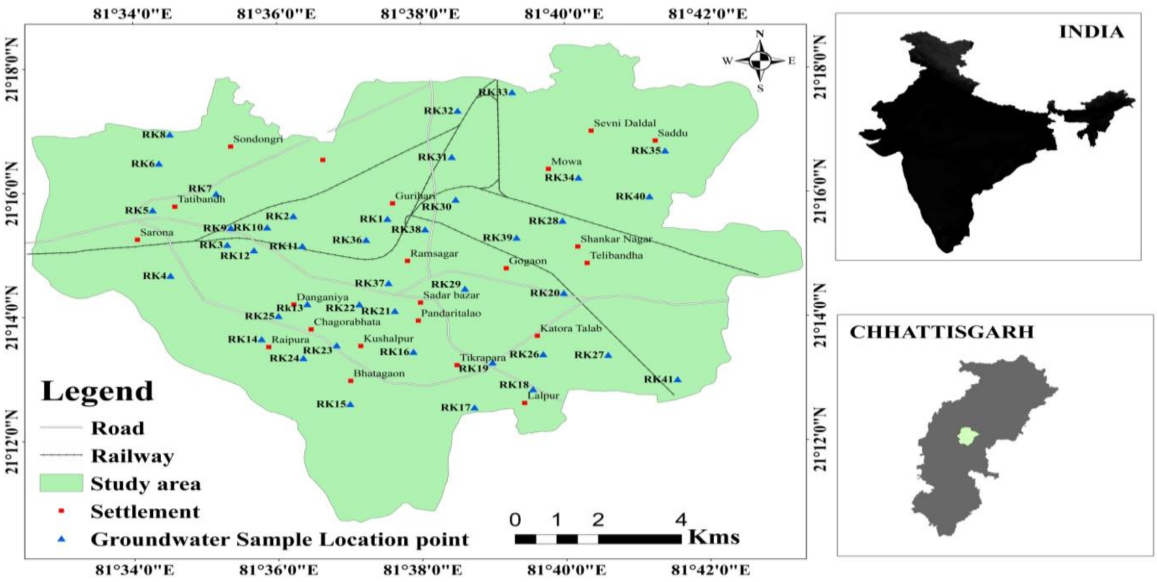
Raipur city is rapidly growing as a result of increase in industrialization and urbanization (Agarwal et al. 2013). The demand of water is increasing, which leads to its overexploitation causing depletion of quantity and deterioration of quality of groundwater. At the same time, Wastes generated from a wide variety of Industries, agricultural and domestic activities. These wastes are dumped into pits, low-lying areas around the city, constituents of which percolates and pollute groundwater. Due to Karstified nature of geologic formation, the groundwater of study area is highly susceptible to pollution. In present paper, groundwater pollution due to anthropogenic activities of Raipur city is studied.

2. Study area

Raipur city is Divisional and District Headquarter, and it is culturally, educationally and economically forward town in the state of Chhattisgarh. Raipur city is situated in western part of Raipur district, Chhattisgarh, India. Study area falls longitude between 81°35' to 81°40' and latitudes between 21°10' to 21°20' under Survey of India (SOI) toposheet no. 64G/11 and 64G/12. Present study area encompassing a geographical area of approximately 150 km^2 covering part of Raipur block of Raipur districts. Location map and groundwater sample location map of the study area is given in Fig. 1.

Raipur has a tropical wet and dry climate, Temperatures remain moderate throughout the year, except March to June, which can be extremely hot. The temperature in April to May sometimes rises above 48 °C (118 °F). These summer months also have dry and hot winds. In summers, the temperature can also go up to 50 °C.

The city receives about 1,300 mm of rainfall, mostly in the monsoon season from late June to early October. Winters last from November to January and are mild, although lows can fall to 8 °C.



3. Methodology

3.1. Collection of groundwater samples

A total 41 groundwater samples were collected from study area during pre-monsoon (May 2015) and post-monsoon (December 2015) periods from different location of study area. Prior to collection of water samples the bottles were thoroughly washed with distilled water in the laboratory. The bottles were rinsed to avoid any possible contamination and every precautionary measure was taken. Methods of collection and analysis of water samples was adopted using standard protocols (APHA, 1995). Then, the samples were sealed, numbered, and were carefully taken to the laboratory for the chemical analysis. Locations of samples were collected using Global Positioning System (GPS).

3.2. Laboratory analysis of groundwater samples

In the present study nine parameters are analyzed viz. EC, Ca, Mg, Na, K, HCO_3, NO_3, SO_4 and Cl. The samples were analyzed in Laboratory of Chhattisgarh Council of Science and Technology (CGCOST), Raipur using standard protocol of APHA (1995). Methods for analysis of parameter are given in Table 1.

Table 1: Methods for Analysis of Parameter

Parameter	Method
EC (Electrical conductivity, µs/cm)	EC meter
Ca (Calcium, mg/l)	EDTA Titration
Mg (Magnesium, mg/l)	Atomic Absorption Spectroscopy (AAS)
Na (Sodium, mg/l)	Flame Photometer
K (Potassium, mg/l)	Flame Photometer
HCO_3 (Bicarbonate, mg/l)	Titration method
NO_3 (Nitrate, mg/l)	UV-vis Spectroscopy
SO_4 (Sulphate, mg/l)	UV-vis Spectroscopy
Cl (Chloride, mg/l)	Titration method

3.3. Groundwater samples analysis

The major drinking water quality parameters along with corresponding permissible limits as per Bureau of Indian Standards (BIS 2003) and its statistics is given in Table 2.

3.4. Geographical Information System (GIS) based analysis

The GIS based analysis of spatial behavior of the groundwater quality in the study area was done using spatial analyst module of Arc GIS 9.3. The Inverse Distance Weighted (IDW) method interpolation techniques was used in the analysis in GIS environment.

Table 2: Statistics of Groundwater Samples and Drinking Water Comparison with Water Quality Standard (BIS, 1991)

Parameters	Minimum		Maximum		Median		SD		Drinking Standard	
	Pre-monsoon	Post- monsoon	Pre- monsoon	Post- monsoon	Pre- monsoon	Post- monsoon	Pre- monsoon	Post- monsoon	AL	PL
EC	535	636	1368	1592	803	1092	182.30	233.62	-	-
Ca	47.4	12.76	260.60	205.81	137.851	114.903	44.51	40.03	75	200
Mg	4.3	6.04	62.62	82.49	28.675	26.4	14.51	20.09	30	-
Na	15.6	18.8	234	159	76.9	47.8	39.42	36.56	50*	200*
K	0.04	0.11	65.5	196.3	7.2	2.6	17.34	35.81	10*	12*
HCO_3	112.2	89.67	528.4	350.62	248.6	175.07	100.13	71.33	300*	600*
NO_3	0	0	120.15	150.26	20	26.0843	25.03	32.611	45	NR
SO_4	14.5	1.2	320.15	280.31	102.11	95.3	67.91	61.03	200	400
Cl	40	50	270	260	140	150	59.11	42.03	250	1000

*WHO standards (BIS standards are not available).

4. Result & discussion

4.1. Spatial analysis

EC: The spatial analysis for two seasons i.e. pre-monsoon and post monsoon is given in Fig. 2 a & b. During pre-monsoon seasons EC is varying from 1368 μs/cm to 535.001 and during post-monsoon season it is varying from 1592 μs/cm to 636.001 μs/cm.

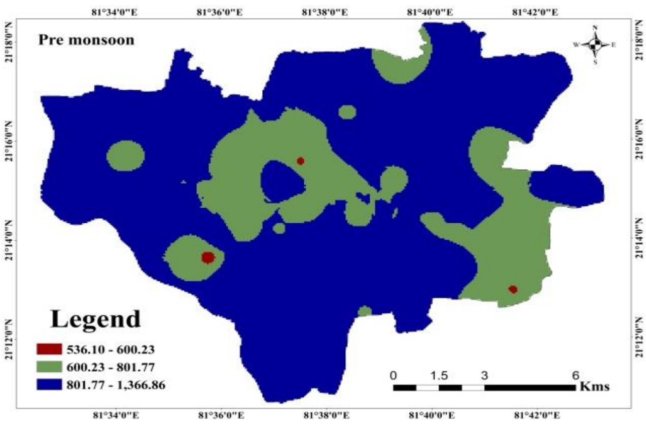


Fig. 2a: Spatial Distribution Map of EC.

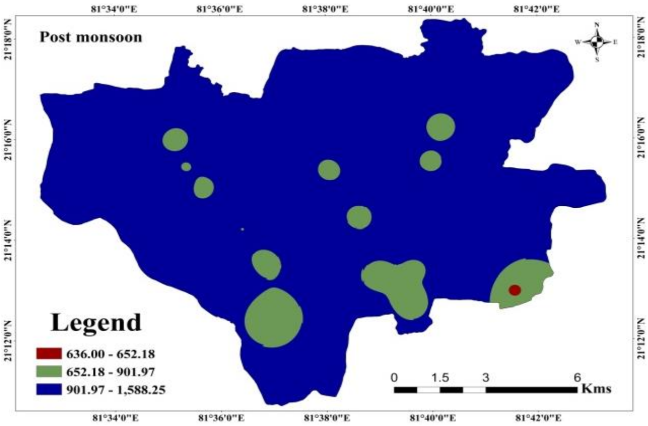


Fig. 2b: Spatial Distribution Map of EC

Ca: The spatial analysis for two seasons i.e. pre-monsoon and post-monsoon is given in Fig.3 a & b. During pre-monsoon seasons Ca is varying from 260.603 mg/l to 47.40 mg/l whereas during post-monsoon periods it is varying from 205 mg/l to 12.76 mg/l.

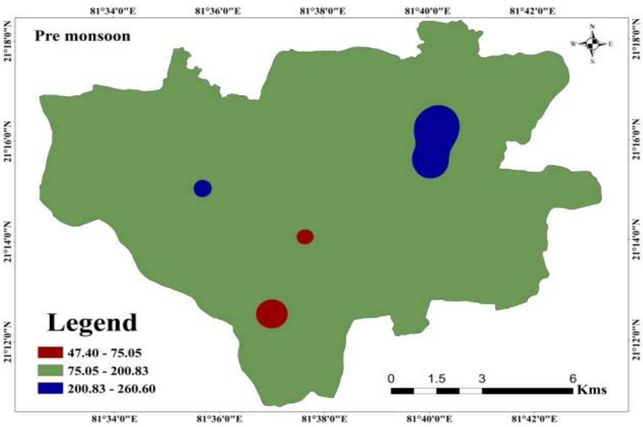


Fig. 3a: Spatial Distribution Map of Ca.

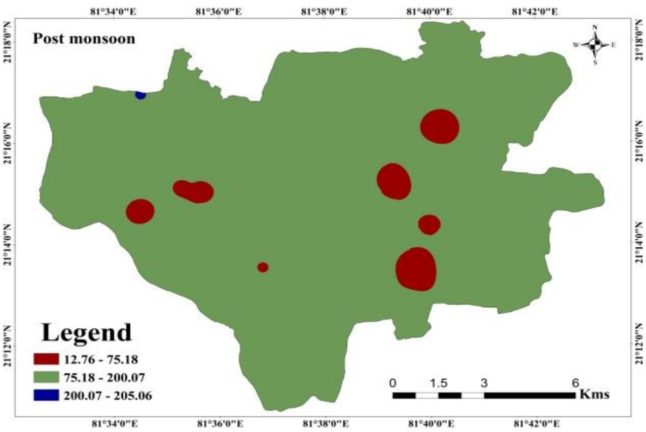


Fig. 3b: Spatial Distribution Map of Ca.

Mg: The spatial analysis for two seasons i.e. pre-monsoon and post monsoon is given in Fig.4 a & b. During pre-monsoon seasons Mg is varying from 62.62 mg/l to 4.39 mg/l and in post monsoon season it is varying from 82.49 mg/l to 6.04 mg/l.

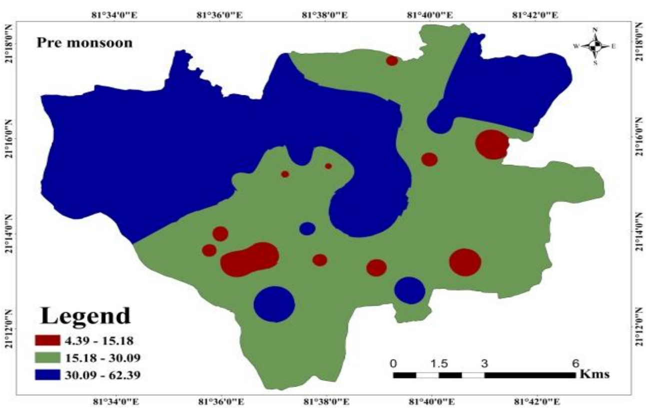


Fig. 4a: Spatial Distribution Map of Mg.

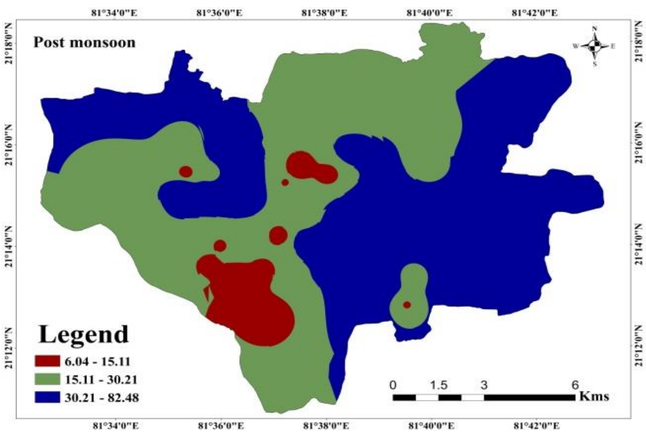


Fig. 4b: Spatial Distribution Map of Mg.

Na: The spatial analysis for two seasons i.e. pre-monsoon and post monsoon is given in Fig.5 a & b. During pre-monsoon seasons Na is varying from 233 mg/l to 15.60 mg/l and in post monsoon season it is varying from 158.99 mg/l to 18.00 mg/l.

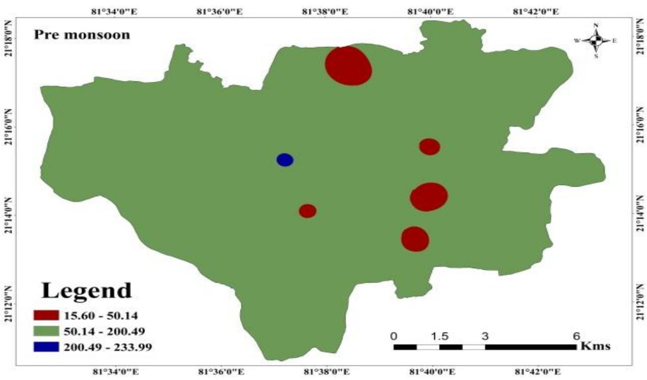


Fig. 5a: Spatial Distribution Map of Na.

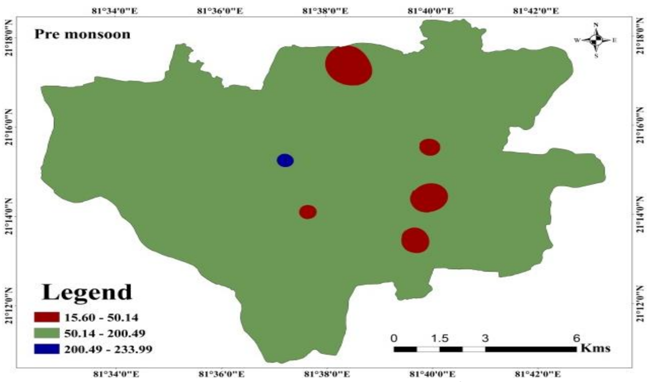


Fig. 5b: Spatial Distribution Map of Na.

K: The spatial analysis for two seasons i.e. pre-monsoon and post monsoon is given in Fig.6 a & b. During pre-monsoon seasons K is varying from 65.5 mg/l to 0.04 mg/l and in post monsoon season it is varying from 196.3 mg/l to 0.11 mg/l.

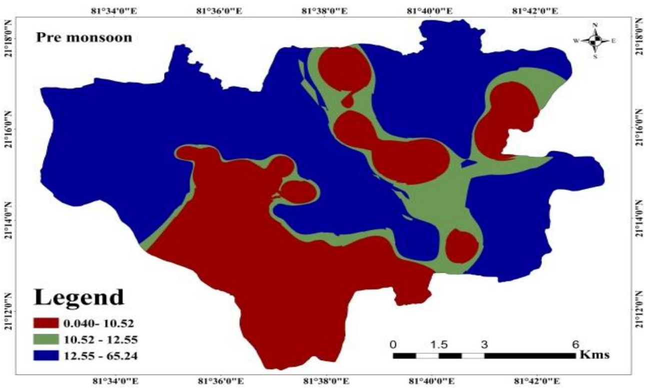


Fig. 6a: Spatial Distribution Map of K.

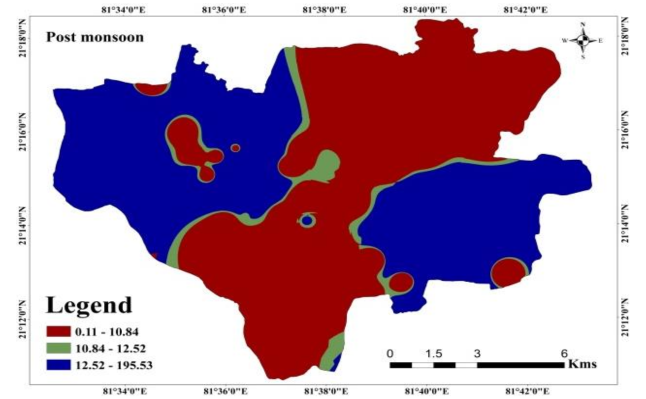


Fig. 6b: Spatial Distribution Map of K.

HCO_3: The spatial analysis for two seasons i.e. pre-monsoon and post monsoon is given in Fig.7a & b. During pre-monsoon seasons HCO_3 is varying from 528.39 mg/l to 112.2 mg/l and in post-monsoon season it is varying from 350.62 mg/l to 89.67 mg/l.

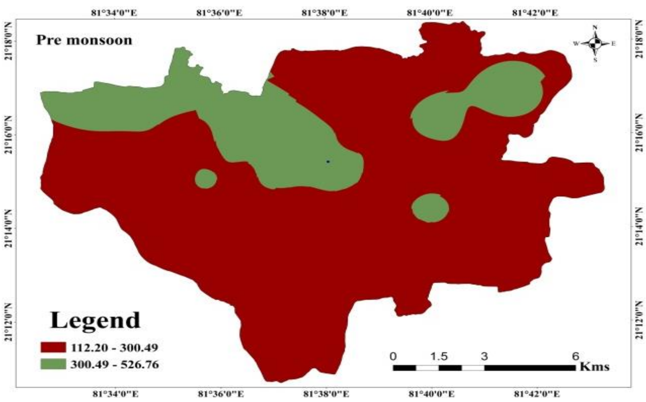


Fig. 7a: Spatial Distribution Map of HCO_3.

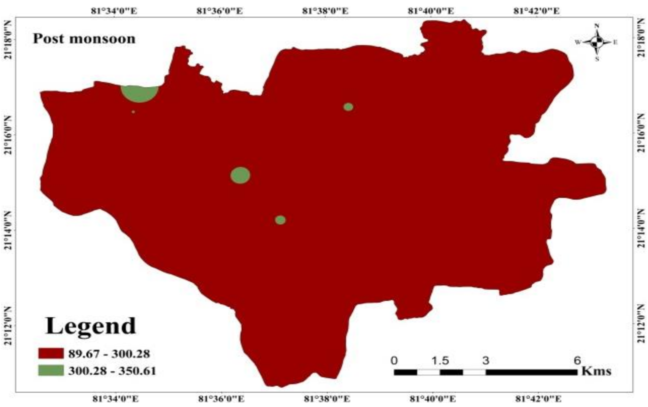


Fig. 7b: Spatial Distribution Map of HCO_3.

NO_3: The spatial analysis for two seasons i.e. pre-monsoon and post monsoon is given in Fig.8 a & b. During pre-monsoon seasons NO_3 is varying from 120.15 mg/l to 0.0002 mg/l and in post monsoon season it is varying from 150.26 mg/l to 5.2 mg/l.

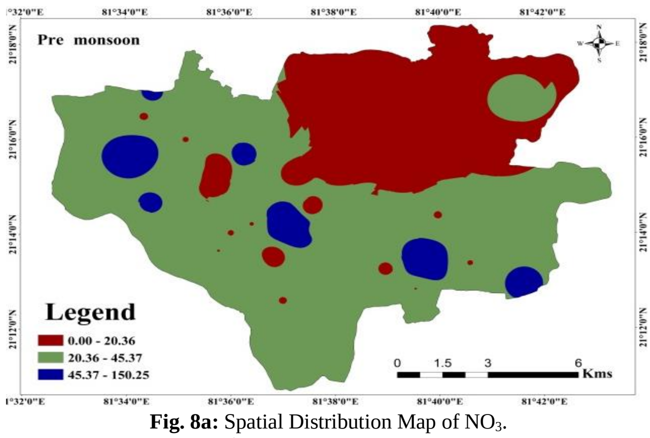


Fig. 8a: Spatial Distribution Map of NO_3.

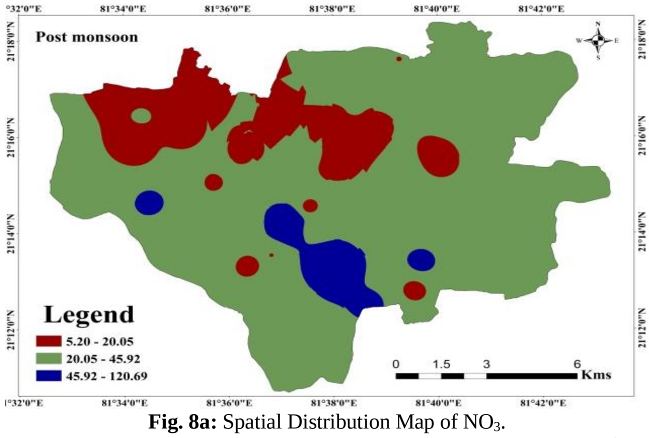


Fig. 8a: Spatial Distribution Map of NO_3.

SO_4: The spatial analysis for two seasons i.e. pre-monsoon and post-monsoon is given in Fig.9 a & b. During pre-monsoon seasons SO_4 is varying from 220.14 mg/l to 2.00 mg/l and in post monsoon season it is varying from 280 mg/l to 1.20 mg/l.

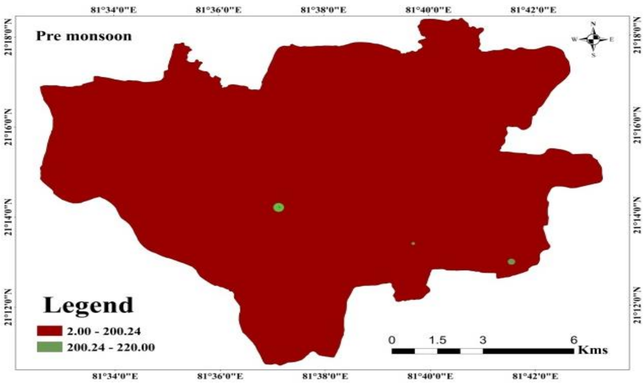


Fig. 9a: Spatial Distribution Map of SO_4.

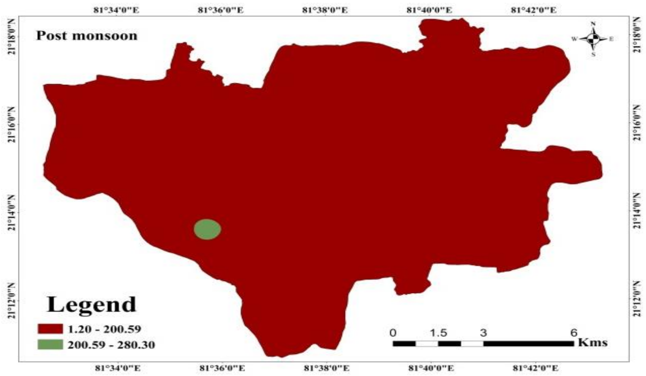


Fig. 9b: Spatial Distribution Map of SO_4.

Cl: The spatial analysis for two periods i.e. pre-monsoon and post monsoon is given in Fig.10 a & b. During pre-monsoon periods Cl is varying from 270 mg/l to 40.002 mg/l and in post monsoon period it is varying from 260 mg/l to 50.002 mg/l.

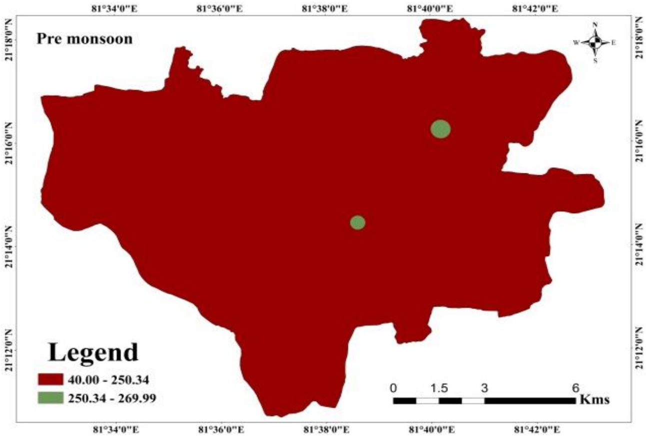


Fig. 10a: Spatial Distribution Map of Cl.

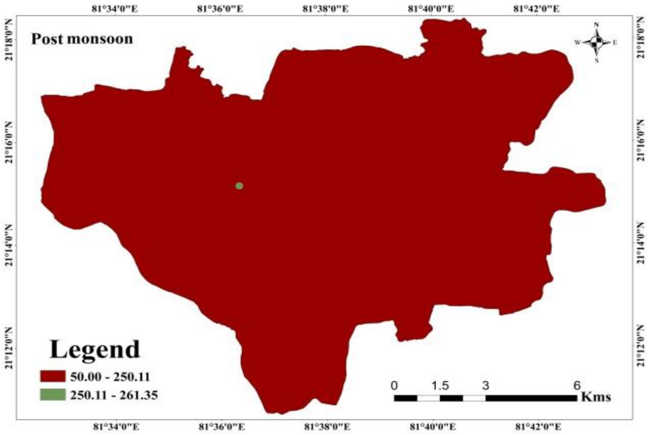


Fig. 10b: Spatial Distribution Map of Cl.

Table 3: Showing Nitrate Concentration of Groundwater Sample

Groundwater sample location code	Pre-monsoon	Post-monsoon	Location
RK 1	20.2	37.8943	Mangal Bazar, Gudhiyari
RK 2	74.3	19.6608	Kota colony, mangal bhavan
RK 3	41	23.12	Dumartalao
RK 4	54.12	50.02	Sarona
RK 5	74.25	20.86643	Tatibandh
RK 6	24.901	19.02	Jarwai
RK 7	20	20.9098	Hirapur
RK 8	74.13	50	Tenduwa
RK 9	49.5776	22.15	Kota
RK 10	0	0	Koteshwar (mandir)
RK 11	21.25	25.3	Saraswati nagar
RK 12	10.16	12.5	Amanaka
RK 13	26.0843	20	Danganiya
RK 14	20.3	28.16	Raipura
RK 15	28.3	20	Bhatagaon
RK 16	45.35	35.6	Mathpurena
RK 17	32.18	40.5	Santoshi nagar
RK 18	20.25	21.5	Lalpur
RK 19	16.3	20	Panchpedi naka
RK 20	20	5.32142	Telibandha
RK 21	45.32	40.12	Purani basti
RK 22	150.26	120.15	Shyam Mandir, samta colony
RK 23	4.11	10.16	Kushalpur talab
RK 24	45.16	40.15	Changhorbatha
RK 25	20	26.2312	DDU nagar
RK 26	120.5	100	New Rajendranagar
RK 27	20	23.5	Purena
RK 28	20	25.12	Paroti nagar
RK 29	45.6	25	Jail
RK 30	12.5	9.9	Fafadih
RK 31	11.59	14.1	WRS colony
RK 32	11.23	14.63	Bhanpuri
RK 33	20	24.1	Industrial Estate, Bhanpuri
RK 34	16.32	20.53	Mowa
RK 35	25.3	30.25	Saddu
RK 36	11	5.2	Ramkund
RK 37	5.5	10.45	Amapara
RK 38	10.58	12.4	Naharpara
RK 39	15.5	20.1177	Rajatalab
RK 40	10.4	12.4	Kachna
RK 41	55.41	50.12	Near energy park

4.2. Groundwater quality

In the study area, nine water quality parameters were analyzed for 41 groundwater samples. It is observed that in study area Ca, Mg, K and NO_3 are above permissible limit and SO_4 is above acceptable limit according to BIS standard. According to BIS standards Ca, K and Mg have no direct influence on human health. It gives adverse effect on domestic use like encrustation on utensils. SO_4 also have no major impact on human health but if its concentration is high in presence of Na and Mg can cause gastrointestinal irritation. SO_4 is also a good indicator of NO_3 concentration in groundwater. The Nitrate ion concentration in study area is found above 45 mg/l i.e. above permissible limit according to BIS standard. The value were compared with the BIS standard and found that in pre-monsoon period twelve sample have high concentration of Nitrate i.e. groundwater sample RK2 (74.3 mg/l), RK 4 (54.12 mg/l), RK 5 (74.25 mg/l), RK 8 (74.13 mg/l), RK 9 (49.57 mg/l), RK 16 (45.35 mg/l), RK 21 (45.32 mg/l), RK 22 (150.26 mg/l), RK 24 (45.16 mg/l) RK 26 (120 mg/l), RK 29 (45.6 mg/l) and RK 41 (55.41 mg/l)and in post- monsoon period five samples were found high concentration, i.e. RK 4 (54.02 mg/l), RK 8 (74.13 mg/l), RK 22 (120.15 mg/l RK 26 (120.5 mg/l), RK 41 (50.12 mg/l) and, which is shown in Fig.11 and Table 3. Concentration of Nitrate was found high during post-monsoon period as compare to a pre-monsoon period which indicating the leaching of sewage and fertilizer by rain water in the study area and in other condition high Nitrate concentration during pre-monsoon and low Nitrate concentration during post-monsoon period indication dilution of Nitrate ion by rain water (Wedland et al. 1994, Jhariya et al. 2012, Khandar 2013). Higher concentration of Nitrate in groundwater is due to anthropogenic activity mainly (Reddy et al. 2009, Jhariya et al. 2012, Khandar 2013). In study area nitrate concentration is mainly found in settlement area, which indicates that anthropogenic activity is main cause of high nitrate concentration in groundwater.

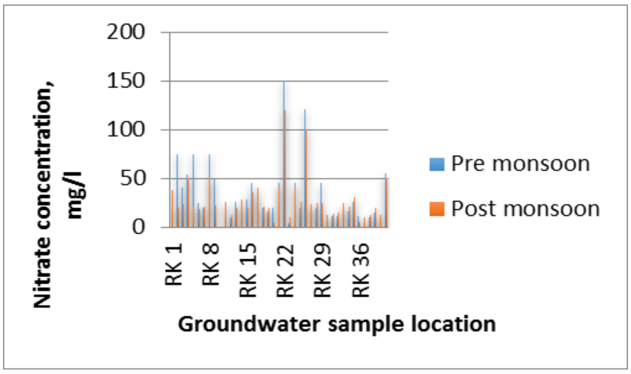


Fig. 11: Graph Showing Seasonal Variation in Nitrate Concentration.

4.3. Source of nitrate pollution

1) There are many sources in environment that contribute to the total nitrate content of natural waters, e.g. atmosphere, geological features, anthropogenic sources, atmospheric nitrogen fixation and soil nitrogen. It has been observed that in sandy soil with low water holding capacity and high permeability, movement of pollutants like nitrate is much quicker than in clayey soil (Jhariya et al. 2012, Khandar 2013).
2) Wastewater in the upper soil layer either from the cesspools or the disposal ponds could infiltrate to the groundwater aquifer. The absence of a sewage system encourages such types of contamination by nitrate (Jhariya et al. 2012, Khandar 2013). Thus, the level of nitrate in groundwater will continue to increase in the sources of contamination. These sources are more dangerous than the leaching ones, because of the daily use of water, which then recharges the aquifer.
3) Nitrate in groundwater can be derived from natural sources or from point sources, such as sewage disposal systems and livestock facilities causes pollution of surface water, ground water and wells through percolation. Waste materials are one of the anthropogenic sources of nitrate contamination of groundwater. Surface water runoff from fertilized farmland and animal feedlots is a major potential source of nitrate contamination. Septic tanks are another example of anthropogenic source nitrogen contamination of the groundwater (Jhariya et al. 2012, Khandar 2013).

4.4. Mechanism of nitrate pollution in groundwater

Nitrogenous materials are rare in the geological record; therefore, occurrence of nitrate in groundwater is normally of anthropogenic nature due to the contact of soil cover with contaminants like wastewater and nitrate fertilizers (Maila et al. 2004, Jhariya et al. 2012). The factors, which contribute to the aquifer contamination, comprise the partially-confined aquifer and the porous and permeable soil cover. Such hydrogeologic circumstances boost the groundwater contamination by allowing a direct contact between the contaminants and groundwater. Aquifers could be contaminated by point sources, leaching sources and biochemical transformation of organic nitrogen compounds acting as an encouraging mechanism enhancing the groundwater contamination, particularly in the point sources by the nitrification process (Maila et al. 2004, Jhariya et al. 2012).

4.5. Effects of High Nitrate concentration

1) Blue-baby Syndrome: Nitrates are especially poisonous to children less than six months of age. Children who ingest nitrate, suffer from a disease known as blue-baby syndrome (Jhariya et al. 2012, Khandar 2013). Cases of blue-baby syndrome usually occur mainly in shallow depth. Often these wells become contaminated when they are dug or bored and are located close to cultivated fields, feedlots, manure lagoons or septic tank. Methemoglobinemia is the condition in the blood which causes infant cyanosis, or blue-baby syndrome. Nitrate reacts with hemoglobin leading to formation of methaemoglobin in which iron is in ferric (III) state, greatly lessening the capacity of the blood to carry oxygen and causing chemical suffocation very young children are susceptible because fetal hemoglobin has a great affinity for nitrite than normal hemoglobin.
2) Stomach and Gastrointestinal Cancer: Nitrate itself is not cancer-causing, but instead acts as a "procarcinogen," i.e. it reacts with other chemicals (amines and amides) to form carcinogenic compounds (N-nitroso) compounds. The physiological studies provide strong support showing the association between nitrate contamination of drinking water and increased cancer rates. N-nitroso compounds have been associated with 15 different types of cancers, including tumors in the bladder, stomach, brain, esophagus, bone and skin, kidney, liver, lung, oral and nasal cavities, pancreas, peripheral nervous system, thyroid, trachea, acute myeleocytic leukemia and T and B cell lymphoma. More than one hundred of these N-nitroso compounds have been tested for carcinogenicity in animals and 75-80% of them have been found to be carcinogens (Jhariya et al. 2012, Khandar 2013).

4.5. Prevention

1) Proper sewage and drainage system.
2) Wells should be established during the height away from the septic tanks and fertilized area and well casing should be properly placed.
3) Water containing high nitrate levels can be safely used for another purpose like bathing, washing utensils and laundry.

4) Heavy vehicles should not allow to run above the septic tank, and drain - pipes (Khandare 2013, Jhariya et al. 2012).
5) Reputable contractor should be hired to pump-out/clean septic tank every 2 to 3 years (Khandare 2013, Jhariya et al. 2012).
6) Social awareness like Residents of rural areas should have their wells tested, especially if pregnant women or infants are consumers of the well water. If the well is contaminated, other water source alternatives should be used and make sure that children should avoid consuming nitrate contaminate water.

5. Conclusion

Present study indicates that the parameters like Ca, Mg, K and NO_3 are above permissible limit and SO_4 is above the acceptable limit according to BIS standard. Nitrate ion concentration in study area is found above 45 mg/l i.e. above permissible limit according to BIS standard. Concentration of Nitrate ion was found high during post-monsoon period as compare to pre-monsoon period which indicating the leaching from sewage and fertilizer by rain water in the study area. In another condition, high Nitrate concentration during pre-monsoon and low Nitrate concentration during post-monsoon period indicating dilution of Nitrate ion by rain water in the study area. The sources of nitrate pollution in the study area are mainly due to anthropogenic activity.

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