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Postmonsoon groundwater quality of Keonjhar urban area, India for drinking and domestic use

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ABSTRACT

This study evaluates the post-monsoon groundwater quality of Keonjhar urban area, Odisha, a region famous for rich mineral resources, significantly influenced by mining activities. A total of sixty-six groundwater samples were collected during 2022 and analysed for major physico-chemical parameters following standard methods. The results indicate that groundwater is slightly acidic to moderately alkaline (pH: 6.2–8.3) and predominantly falls under hard to very hard categories. Hydrochemical facies analysis using Piper trilinear diagram reveals dominance of Ca–Mg–HCO_3 type, followed by Ca–Mg–Cl–SO_4 type. Comparison with BIS (2012) drinking water standards shows that most parameters are within permissible limits, except iron and fluoride, which exceed limits in several locations. Approximately 32% of samples show fluoride concentrations above 1.5 mg/l, while more than half of the analyzed samples exceed permissible iron limits. The study highlights that groundwater is generally suitable for domestic use with appropriate treatment; however, fluoride and iron contamination pose significant challenges for safe drinking water. Regular monitoring and targeted mitigation strategies are recommended.

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1. Introduction

Water is one of the most vital resources for the sustenance of humans, plants and other living beings. Safe potable water is absolutely essential for healthy living. From the dawn of civilization, people have depended on groundwater which is the ultimate and most suitable fresh water resource for human consumption. As the population increases, the demand of water for domestic, agricultural and industrial uses increases too. When these demands exceed the naturally renewable supply, water shortage occurs in the area. According to the World Health Organization (WHO, 2004), drinking water must be free of chemicals and microbial contaminations which are harmful to human health.

Physico-chemical analysis of water is very important in public health studies as the quality of groundwater plays an important role. Previous study on the quality of groundwater in Keonjhar city for agricultural use has found severity of nitrate contamination (Madhav et al., 2020). The present work is to study the quality of groundwater of Keonjhar urban agglomeration in post monsoon period to assess its suitability for drinking and domestic use.

2. Study area

Keonjhar district, situated in the northern border of Odisha, is bounded by latitudes 21° 01′ N and 22° 10′ N and longitudes 85° 11′ E and 86° 22′ E. The district is bounded by Singhbhum district of Jharkhand in north, Mayurbhanj and Baleswar districts in east, Jajpur and Dhenkanal districts in south and Sundargarh district in west. The study area comprises Keonjhar town and its environ extending from 21° 35′ 30″ N to 21° 41′ 30″ N latitude and 85° 33′ E to 85° 41′ E longitude covering an area of around 150 km^2. Keonjhar area experiences tropical to subtropical climate

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with temperature ranging from 45° C to 10° C and average annual rainfall of 1530 mm from south west monsoon.The area is mainly drained by river Aradei, a small tributary of Baitarani River. The drainage pattern is mostly dendritic in nature.

3. Geology

The area consists of several major lithologic groups ranging in age from Archaean to Proterozoic. According to general geological succession of rocks given by Saha et al. (1988), Singhbhum Granite of Archaean age (3.3 Ga) forms the basement of the area. It is overlain by quartzitic sandstone, BHJ, BHQ and mafic lava belonging to Iron Ore Group. These are intruded by basic intrusives known as Newer dolerite (1.6–0.95 Ga). These geological formations suggest high runoff and low infiltration, resulting in a higher density of streams and rivers (CGWB, 2020).

4. Hydrogeology

Groundwater occurs both under unconfined as well as semiconfined to confined conditions in the area. The unconfined or phreatic aquifers constitute the weathered regolith zone of the hard rocks from which groundwater is extracted through dugwells or shallow tubewells. The semiconfined and confined aquifers comprise of deep seated intersecting fracture system in the crystalline hard rocks. According to study conducted by CGWB (1996), there are two major sets of lineaments and dykes in the area trending NW–SE and NE–SW respectively which control the occurrence and movement of groundwater. The relatively younger NW–SE trending set constitutes the prominent conduits for groundwater occurrence and the yield from borewells located in this zone is very high. In contrast, the yield from borewells in the vicinity of NE–SW dykes and lineament is relatively poor.

5. Materials and Methods

Sixty-six groundwater samples from dug wells, tubewells and borewells in use (Table 1), were collected covering the entire study area (Fig. 1) during post monsoon period of 2022 following standard sampling procedure. These were analyzed for physico-chemical parameters following American Public Health Association (APHA, 2005) guidelines. Electrical conductivity (EC) and pH of the water samples were measured by digital meters in the field immediately after sampling. Total dissolved solids (TDS) values were calculated by multiplying electrical conductivity (EC) with 0.64 following the guidelines proposed by USGS (Hem, 1985) for natural water. Total Hardness (TH), Total Alkalinity (TA), Ca^{2+}, ${CO_3}^{2-}$, ${HCO_3}^{-}$ and Cl^{-} were determined by volumetric titrations. Mg^{2+} was calculated from TH and Ca^{2+} by employing standard equation. Na^{+} and K^{+} were estimated by Systronics make flame photometer 128 and ${SO_4}^{2-}$ by Systronics make Double beam spectrophotometer 2203 in the Geochemical Laboratory, Dept. of Geology, Utkal University. Fluoride (F^{-}) concentration was measured through Ion-selective Electrode Method in the Chemical laboratory of Central Groundwater Board, Bhubaneswar. Iron concentration was measured by ICP-AES in CSIR-IMMT laboratory, Bhubaneswar.

6. Results and Discussions

The summary of chemical analysis of postmonsoon groundwater samples of study area is presented in Table 2. The major parameters responsible for drinking and domestic use are discussed below.

Hydrogen Ion Concentration (pH)

pH is the total hydrogen ion concentration value in water which indicates whether a solution is acidic, neutral and basic. Overall, the groundwater is slightly acidic to moderately alkaline in nature with pH value ranging from 6.2 to 8.3 (average 7.25)

Electrical Conductivity (EC)

EC measures the ability of water to conduct an electrical current. The conductivity of water is affected by temperature and is directly related to the amount of dissolved mineral content. It is the inverse of the electrical resistance of one cubic centimeter of a material at the standard temperature of 25°C. EC value ranges from 137 to 1554 microsiemens/cm (µS/cm) [average 778.27 µS/cm] in post-monsoon season, 2022. The highest value of EC is observed near St. Xavier high school.

Total Dissolved Solid (TDS)

TDS is an essential quality parameter of groundwater. It includes inorganic salts such as HCO_3,

Table 1. Location and well type of groundwater samples of the study area.

Sample No.	Location	Well type
1	**ATOPUR**	TW
2		BW
3	**BADAHALA**	DW
4		TW
5	**BADULIGHERA**	TW
6	**BAMPUR**	TW
7		BW
8	**BANIAPAT**	DW
9		TW
10	**BIRABARPUR**	TW
11	**BUSSTAND**	TW
12	**CAPITAL HOSPITAL**	TW
13	**CHAKA**	DW
14		TW
15	**CHANDPOSI**	DW
16		TW
17	**COLLECTOR OFFICE**	TW
18	**D.D AUTO COLLEGE**	TW
19	**DIMBO**	DW
20		TW
21	**D.N HIGH SCHOOL**	TW
22	**FILM HALL**	DW
23	**GANDHI CHAKA**	TW
24	**GOVINDPUR**	TW
25	**GAMARIA**	TW
26	**JAGANNATHPUR**	DW
27		TW
28	**JAIL ROAD**	BW
29	**KASHIPUR**	BW
30		DW
31	**KAMARGUDA**	BW
32		DW
33	**KHASAPITHA**	DW
34		TW
35	**KHOLAPA**	DW
36		TW
38	**MANDUA**	TW
39	**MINING ROAD**	DW
40		TW
41	**NARANPUR**	DW
42		TW
43		BW
44	**NEW COLONY**	DW
45		TW
46	**OLD TOWN**	TW
47	**SATASINGHA**	TW
48	**SRI AUROBINDO SCHOOL**	BW
49	**ST.XAVIER HIGH SCHOOL**	BW
50		TW
51	**TAHSIL OFFICE**	TW
52	**TOWN GIRLS' HIGH SCHOOL**	TW
53	**KIMBHIRIDOL**	BW
54	**NUASAHI**	TW
55	**MACHIBANDHA**	TW
56	**NUAGAN**	DW
57	**DHRUPADA**	DW
58	**KHANTAPARA**	DW
59	**BALIAGUDA**	TW
60	**DANARDANPUR**	DW
61	**SHRIPUR**	TW
62	**NELUNG**	TW
63	**SANKARPUR**	DW
64	**BALISAHI**	DW
65	**TENTULINADA**	DW
66	**NAIGAN**	TW

TW = Tube well, BW = Bore well, DW = Dug well.

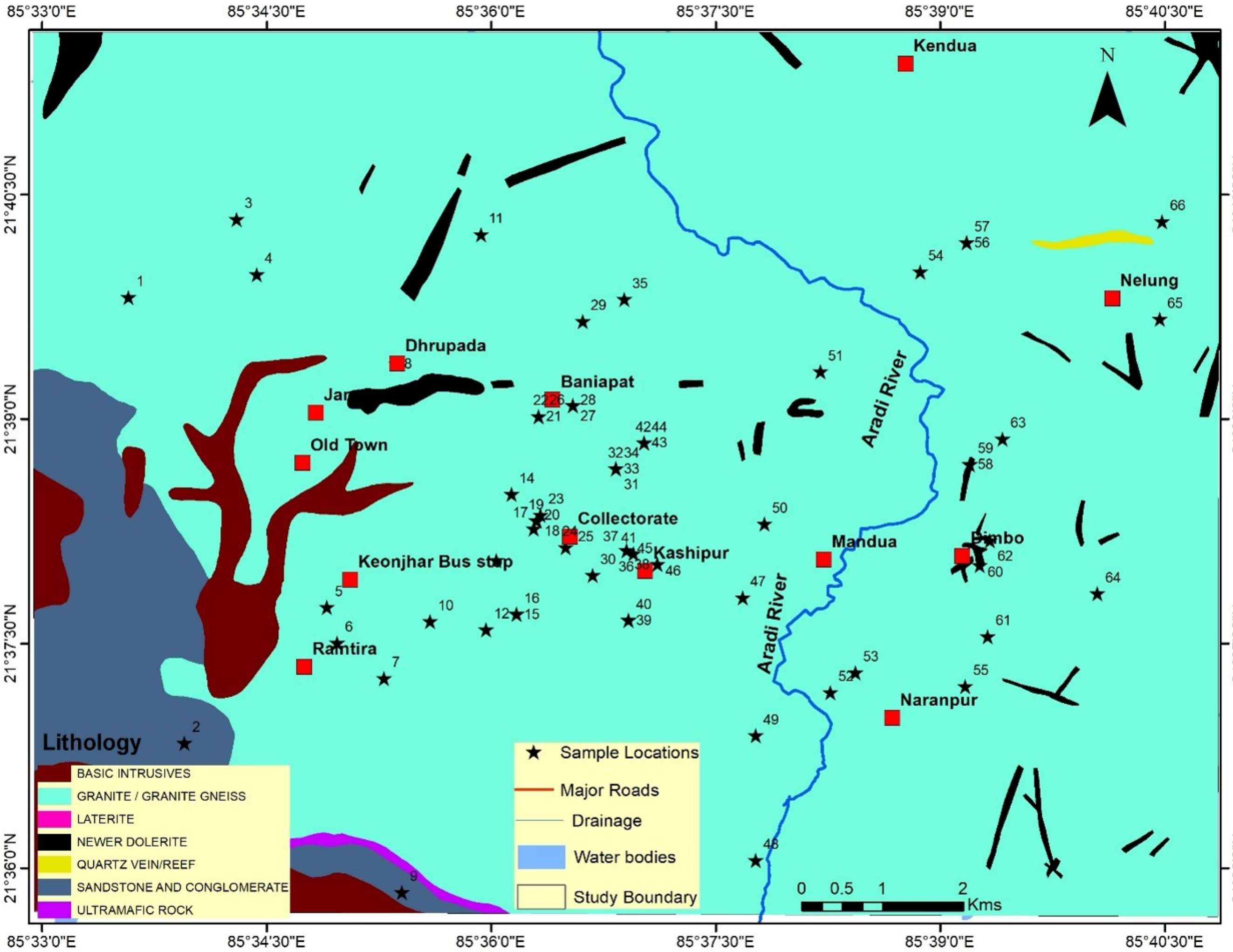


Fig. 1. Map of Keonjhar area showing groundwater sample locations.

Table 2. Comparison of postmonsoon groundwater samples of Keonjhar area with BIS (2012) drinking water standards.

Parameters	Unit	Minimum	Maximum	Mean	BIS (2012)		No. of samples below permissible limit	No. of samples above permissible limit
					Acceptable Limit	Permissible limit		
pH		6.2	8.3	7.25	6.5	8.5	66	NIL_
EC	μS/cm	137	1554	845.5	–	-_	__	__
TDS	mg/l	88	995	541.5	500	2000	66	NIL
Cl^-	mg/l	35	490	262.5	250	1000	66	NIL
HCO_3^{2-}	mg/l	110	390	250	200	600	66	NIL
SO_4^{2-}	mg/l	0	38	19	200	400	66	NIL
Na^+	mg/l	3.3	111.47	57.38	–	200	66	NIL
K^+	mg/l	0.01	7.35	3.68	–	-	66	NIL
Mg^{2+}	mg/l	2.43	100	51.21	30	100	66_	NIL_
Ca^{2+}	mg/l	10	220	115	75	200	66	NIL
TH	mg/l	110	840	475	200	600	61	5
F^-	mg/l	0.11	4.8	2.45	1	1.5	45	21
Fe	mg/l	0.02	0.69	0.3	0.3	0.3	14	17

Cl, SO_4, NO_3, Ca, Mg, Na, and K along with a small amount of dissolved organic matter. TDS values range from 87.68 to 994.56 mg/l (average 498.11 mg/l). The highest value of TDS is observed near St. Xavier high school.

Chloride (Cl)

The Cl concentration is high in groundwater due to leaching of some evaporate minerals like halite that will contribute significant amount of Na and Cl to groundwater. In the present study Cl value ranges from 35 to 490 mg/l (average 140.23 mg/l). The highest contamination of Cl is observed near the St. Xavier high school.

Fluoride (F)

The concentration of fluoride in the study area ranges from 0.11–4.8 mg/l. As many as twenty one (32%) groundwater samples were found to contain fluoride greater than the maximum permissible limit of 1.5 mg/l for drinking use (BIS, 2012). Fluoride up to 1.5 mg/l is beneficial for reducing dental cavities in children during calcification period (Srinivasa Rao, 1997). If water with fluoride concentration above 1.5 mg/l is consumed for a prolonged period, it can cause acute to chronic dental fluorosis, resulting in discolored teeth ranging from yellow to brown (Brindha et al., 2011).

The elevated fluoride concentration in groundwater is likely controlled by geogenic processes, particularly the dissolution of fluoride-bearing minerals such as fluorapatite in granitic and metamorphic rocks.

Iron

Iron is a vital constituent of water. The presence of excess iron in water gives bad taste. Anaemia caused by absence of iron is the commonest nutritional deficiency in the world. Higher amount of iron causes diseases like gastroenteritis and skin pigmentation. Abnormally higher amount of iron affects the vital organs and the disease is named as haemochromatosis. It also leaves strains marks on laundry and layers of stain on plumbing. The rate of flow of water decreases as the iron settles down in the dispersal system. The acceptable as well as the permissible limit of iron in drinking water as per BIS (2012) specifications is 0.3 mg/l.

Out of thirty-one samples analysed for iron, only fourteen (45%) samples are within acceptable and permissible limit whereas majority of samples (55%) are above the maximum permissible limit. High iron concentrations may be attributed to reductive dissolution of iron-bearing minerals present in the Iron Ore Group formations.

The spatial distribution of pH, TDS, Cl, F and Fe in the groundwater of study area are shown in Fig. 2.

6.1. Drinking and Domestic Use

Drinking and domestic consumption are the most important fields of water use. Drinking water standards have been enunciated by Bureau of Indian Standards (BIS, 2012) on the lines of World Health Organization (WHO, 2004). On comparison with BIS (2012) drinking water standards, it is found that all chemical parameters except fluoride and iron are within permissible limit in the groundwater of study area (Table 2).

Hardness of water is due to the presence of divalent metallic cations out of which Ca^{2+} and Mg^{2+} are the most important (Todd, 1980). These ions react with soap to form precipitates making water unsuitable for washing clothes. Further, the precipitates from hard water leave incrustation on cook wares and water taps. The hardness classification of water (Sawyer and Mc Carty, 1967) is given in Table 3. The results show that majority (52%) of the groundwater samples of the study area come under very hard category followed by 45% under hard category and only 3% under moderately hard category. None of the samples is classified under soft category.

Table 3. Hardness classification of groundwater of Keonjhar area after Sawyer and Mc Carty (1967).

Hardness (mg/l) as CaCO3	Water Class	Number of samples
0–75	Soft	0
75–150	Moderately hard	2
150–300	Hard	30
> 300	Very hard	34

Thus, the groundwater is suitable for domestic use with water-softening measures and can be made fit for drinking through appropriate treatment (use of iron filter and defluoridation).

6.2. Hydrochemical classification of Groundwater

Piper Trilinear Diagram

Hydrochemical facies analysis is a valuable tool to trace the chemical history of groundwater. It involves the classification of groundwater by determining its chemical composition and plotting the data in Piper's trilinear diagram, introduced by Piper (1944). This diagram is useful in identifying the major hydrochemical facies by plotting the major ions in two base triangles for cations and anions, which are then projected on to the central diamond field. The chemical data of sixty-six groundwater samples have been plotted on the Piper diagram (Fig. 3). It shows that the post monsoon groundwater facies of Keonjhar area are Ca–Mg–HCO_3 and Ca–Mg–Cl–SO_4 in descending order. The hydrochemical facies dominated by Ca–Mg–HCO_3 type indicates recharge from fresh meteoric water, while the presence of Ca–Mg–Cl–SO_4 type

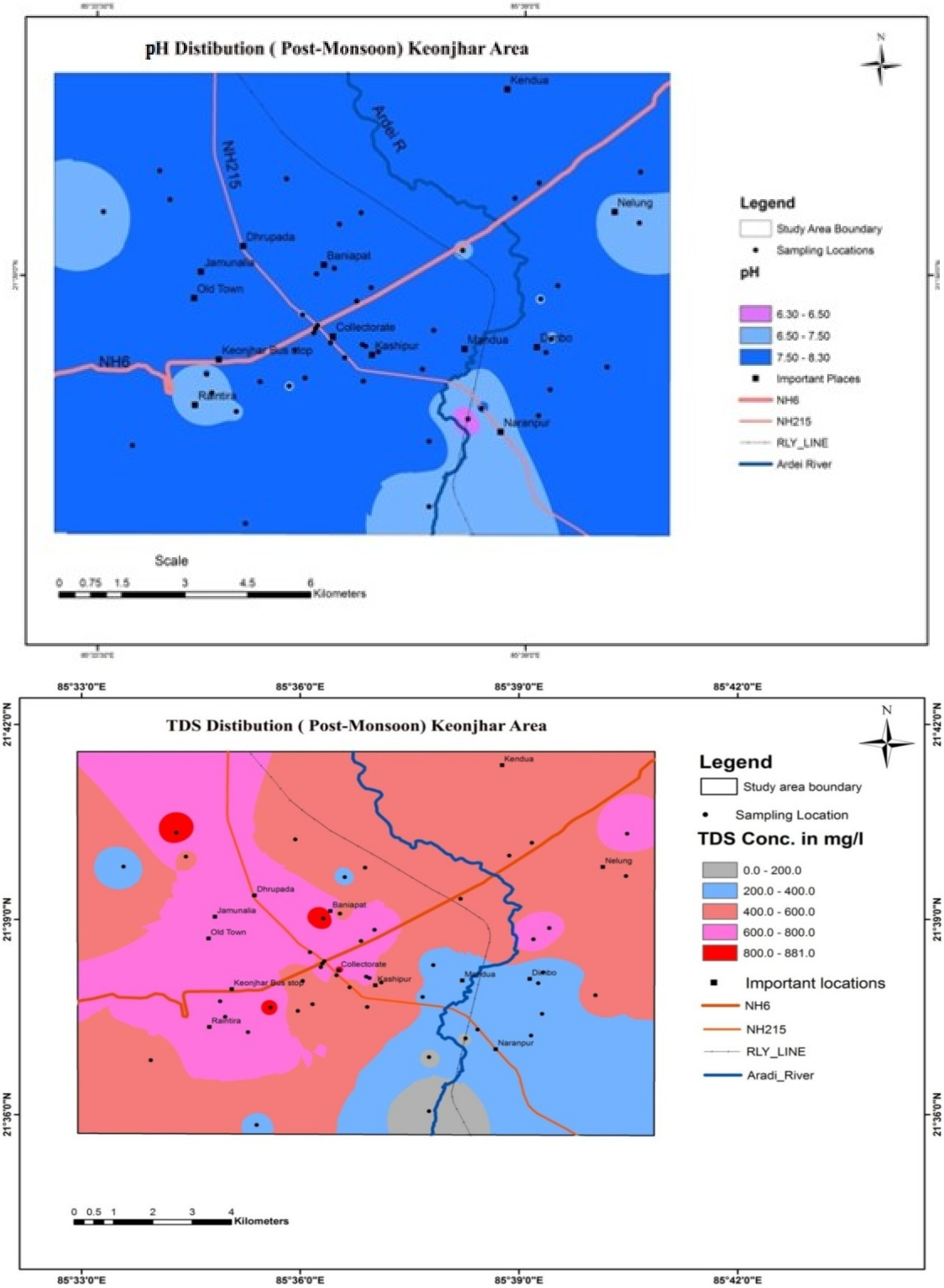
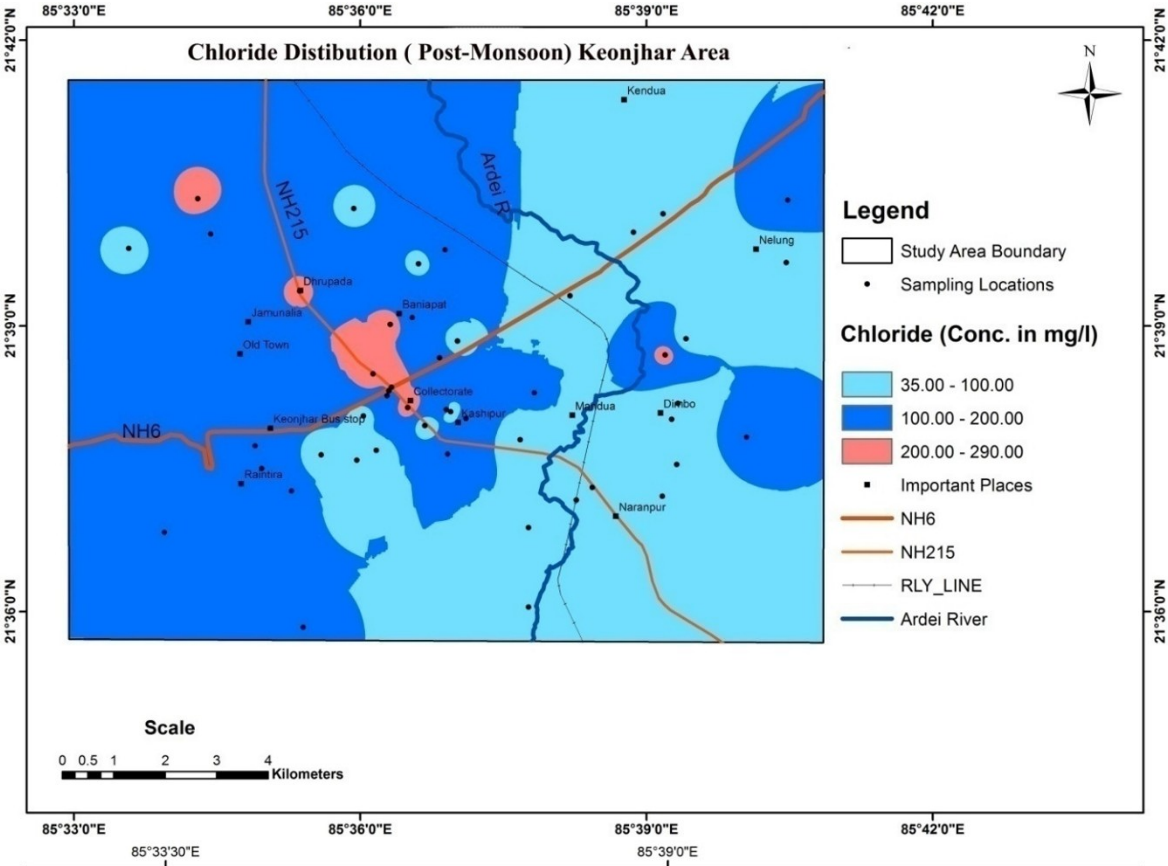
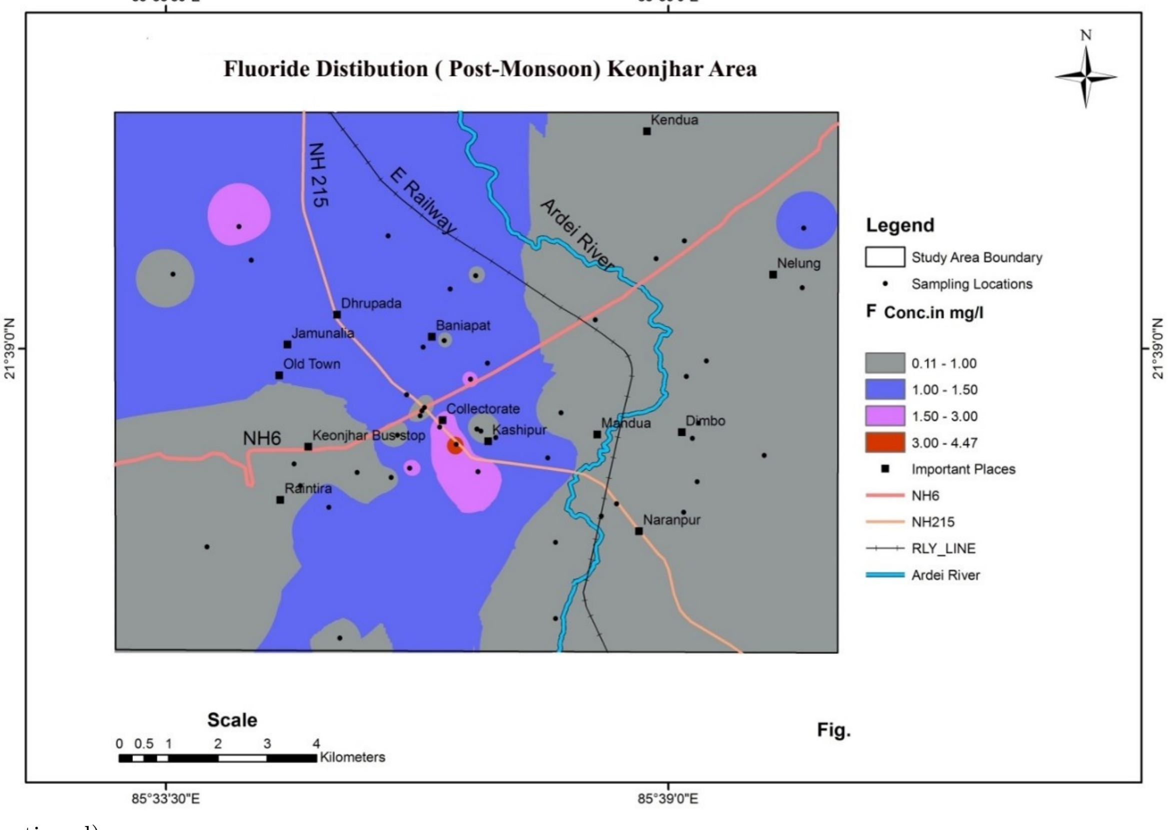


Fig. 2. Spatial distribution of selected chemical parameters in the groundwater of study area.





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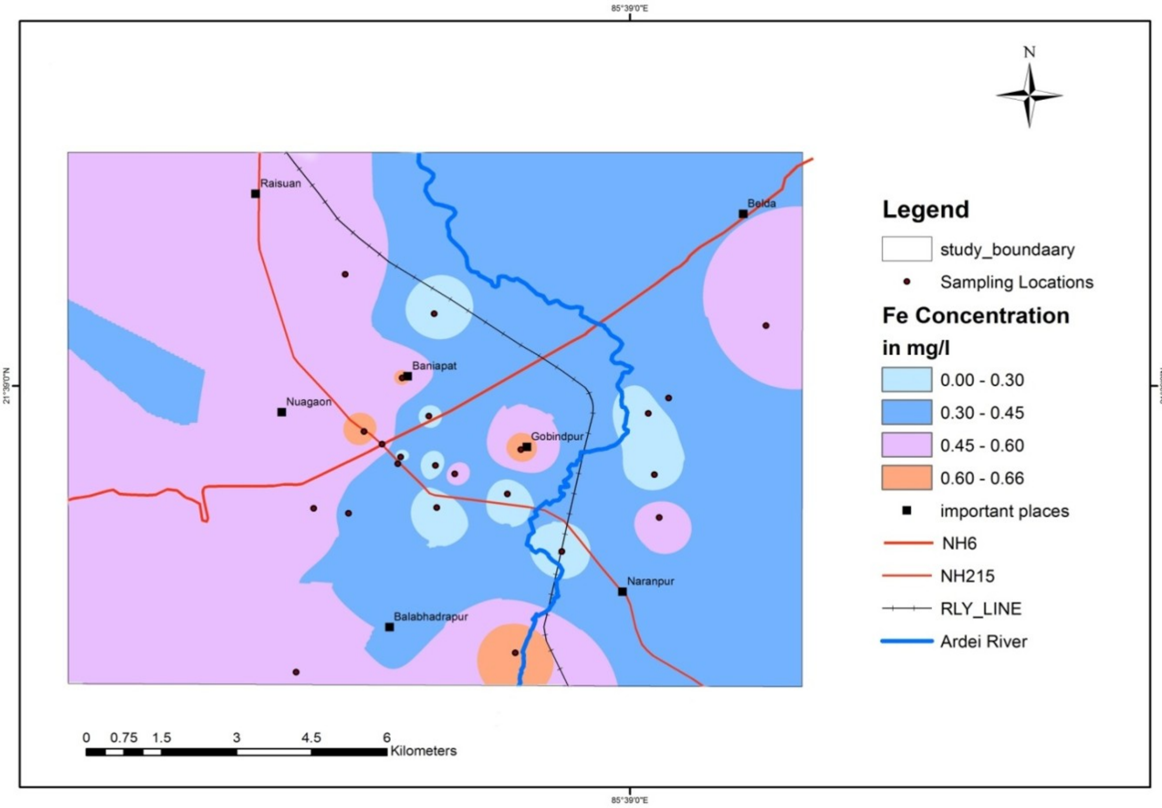

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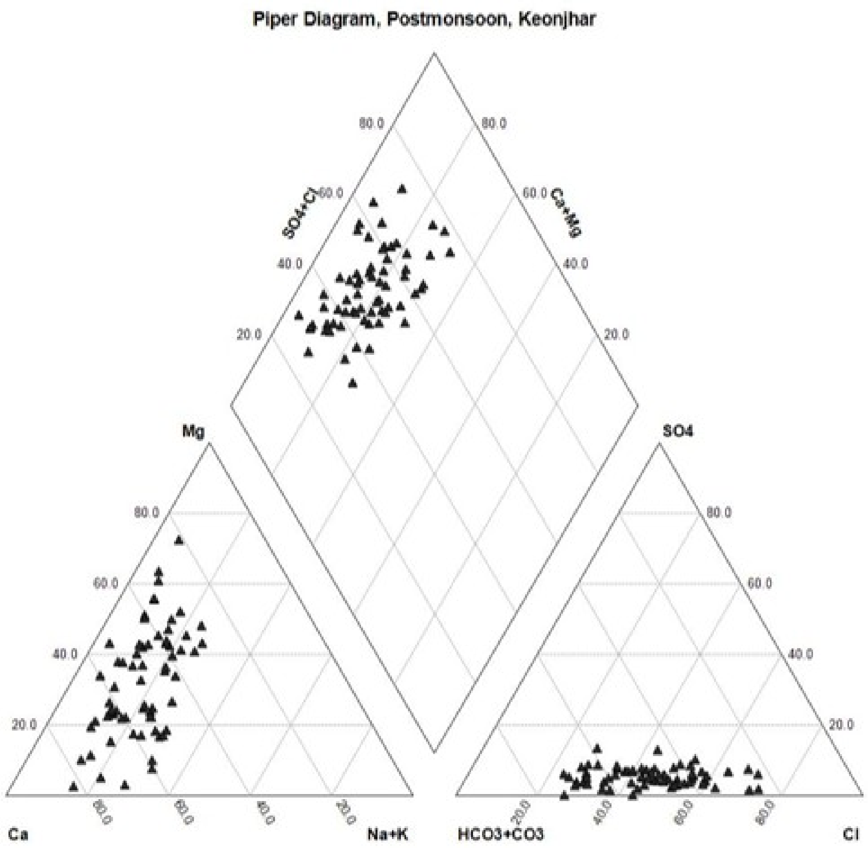

Fig. 3. Piper diagram of groundwater samples of Keonjhar area in post monsoon period.

suggests localized influence of mineral dissolution and anthropogenic inputs. Further, in post monsoon period, alkaline earth dominates alkalis and weak acids dominate strong acids compared to dominance of alkaline earths and strong acids in pre monsoon period (Sahoo, 2026). The relatively lower concentrations of strong acids (Cl and SO_4) during post-monsoon season reflect dilution effects due to recharge.

7. Conclusions

The study reveals that groundwater quality in Keonjhar urban area is largely controlled by geological formations and seasonal recharge processes. While most physico-chemical parameters fall within permissible limits for drinking purposes, elevated concentrations of fluoride and iron pose significant health concerns. The groundwater is predominantly hard to very hard, requiring softening treatment before domestic use. Hydrochemical analysis indicates dominance of Ca–Mg–HCO_3 facies, reflecting recharge from precipitation with limited anthropogenic influence. Although the groundwater is generally suitable for drinking purposes, it requires appropriate treatment, particularly in areas affected by iron and fluoride contamination. Identification of contamination sources, implementation of defluoridation and iron removal techniques, and periodic monitoring are essential for sustainable groundwater management in the region.

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CRediT statement

Sahoo, B.: Sample Collection, Analysis, Data curation and Graphical presentation

Pattanaik, D.S.: Supervision, Data interpretation, Writing manuscript and editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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