Evaluation of groundwater contamination for fluoride and nitrate in Nellore Urban Province, Southern India: a special emphasis on human health risk assessment (HHRA)

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Abstract

Groundwater pollution with fluoride and nitrate is one of the most serious issues in coastal regions. Thirty-nine groundwater samples were collected in the current research region and tested for PH, TDS, and EC. Thirty-nine groundwater samples were collected in the current research region and tested for PH, TDS, EC and cations, anions, and hardness. The elevated parameters are EC, PH, TDS, and nitrates. The fluoride fell in the permissible limit in Nellore urban area, nitrate and fluoride exposure health risk calculated by using the US EPA method. From that, the total hazard index (THI) was calculated. The fluoride total hazard index value ranges from 0.15 to 0.95 and that of average 0.45, which fell below < 1, hence no significance on children, women, and men. The nitrate is falling in excess in groundwater. The ranges are 35 mg/l to 72 mg/l, and adverse value is 47.8 mg/l. The total hazard index (THI) of nitrates fell at > 1, which indicates a harmful for the human health. The computed THI affected percentage is the children (100%), women (95%), and men (30%). The nitrate was released in water due to the industrial discharge, septic tanks, manure pools, sewer system, and rock–water interaction. The abundance of the cations and anions is $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ and $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{F}^-$. The Gibbs diagram explains the source of the chemistry; hence, all samples fell in the rock–water interaction area.

Keywords Groundwater · Geochemistry · Nitrate · Fluoride · Total hazard index (THI) · And health hazard risk assessment (HHRA)

Introduction

Groundwater is regarded as a dependable supply of fresh water that is easily available for a variety of human needs, including domestic, industrial, irrigation, fish propagation, and so on. Around 1.5 billion people rely on groundwater for their residential and agricultural needs, either directly or indirectly. However, a number of geogenic pollutants in groundwater have been identified across the world in recent years. Geology, aquifer features, climate, geography, subsurface activities, and different geochemical processes influence groundwater quality (Veeraswamy et al. 2018; Adimalla and

Qian 2021). Water is a better commodity for the survival of both biotic and abiotic (Golla et al. 2020). Groundwater contamination is exceeding in the urban areas due to the increase in population, urbanization, and industrialization and 80% of the rural domestic water needs, and 50% of the urban water needs in India (Sharma 1999; Alimohammadi et al. 2018; Rezvani Ghalhari et al. 2021). During the last few decades, nitrate and fluoride have been one of the burning problems on human health in such as methemoglobinemia, stomach ache and dental, skeletal fluorosis in the developing countries like China and India (Darvishmotevalli et al. 2019; Gevera et al. 2019; Onipe et al. 2020; Aravinthasamy et al. 2020). In urban and rural areas, 80% of the people rely on groundwater only (Muralidhara Reddy and Sunitha 2020).

Nitrate is a chemical pollutant that may be found in modest concentrations in a variety of settings and is the most common chemical contaminant in the world's aquifers. Because of the heavy use of fertilizers, agricultural runoff, trash dumps, and contamination with human or animal wastes, the amount of nitrate in groundwater

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has grown in the previous three decades. Furthermore, through septic systems and leaky municipal sewers, certain nitrogenous chemicals seep into the groundwater. Nitrate pollution of groundwater has become a significant concern in several Indian states. The source of nitrate was extensively used in agriculture fertilizers, oxidizing agents (Hadi Rezaei et al. 2018), and potassium nitrate which are used for glass making (Mirzaei 2015). In soil, fertilizers containing inorganic nitrogen and wastes containing organic nitrogen are first decomposed to give ammonia, which is then oxidized to nitrite and nitrate (Rahmati et al. 2014; Adimalla et al. 2019). The nitrate is taken up by plants during their growth and used in the synthesis of organic nitrogenous compounds. Surplus nitrate readily moves with the groundwater (Yu et al. 2020). Fluoride source, where the hornblende granite schist, mica mineral, apatite, amphibole, and fluorite were available, due to the geogenic influence, rock–water interaction, dissolution process, high residence time, and the groundwater, may be severely polluted (Garg et al. 2009; Narsimha and Sudarshan 2017; Vivian et al. 2019). In the study area, there was no significant effect of fluoride. The study area water is consumed by the people, after completion of purification.

Study area

The study area is Nellore urban area that lies between north latitudes $14^{\circ} 22' 30''$ N and $14^{\circ} 30' 00''$ N and longitudes $79^{\circ} 52' 00''$ E and $80^{\circ} 02' 00''$ E in the south-eastern part of Andhra Pradesh state. Landsat 8 ETM+ satellite data was used for the preparation of location map in Fig. 1. The area is covered by a survey of India Toposheet 57 N/15. It is located on the banks of the Penna River in the Nellore revenue division. It is a municipal corporation and the headquarters of the Nellore district. The city is the fourth most populous settlement of the state well-known for its agriculture and aquaculture. Unconsolidated sediments belonging to the quaternary period occur in the area. A small stretch of Dharwar gneiss and schist occurs in the western part. Tertiary sandstone and conglomerate occur below the quaternary sediments. The Dharwars and sandstones are weathered and lateritized. Gneisses, schists, and quartzite's belonging to the Dharwar supergroup occur as small outcrops, inselbergs, and in good sections near Gudur–Sarvepalli road. Biotite-muscovite schist intruded by veins of smoky quartz occurs at Batlapalem (Fig. 2). The rocks exhibit foliation that trends $N 15^{\circ} W-S 15^{\circ} E$ with steep westerly and easterly

Fig. 1 Location map of the study area

Fig. 2 Geology map of the study area

dip (Nagaraju et al. 2016; Veeraswamy et al. 2018). Tertiary sandstone, consisting of coarse-to-medium-grained feldspathic sandstone, with low easterly dips, is seen in small sections south of Nellore, Anikepalli, and Kantepalli. The sandstone is overlain by a polymictic conglomerate in a canal cutting west of Sarvepalli and in good sections in the surrounding areas.

Materials and methods

The study area is Nellore urban area that lies between north latitudes $14^{\circ} 22' 30''$ N and $14^{\circ} 30' 00''$ N and longitudes $79^{\circ} 52' 00''$ E and $80^{\circ} 02' 00''$ E in the south-eastern part of Andhra Pradesh state (Figs. 1 and 2). The area is covered by a survey of India Toposheet 57 N/15. It is located on the banks of the Penna River in the Nellore revenue division. It is a municipal corporation and the headquarters of the Nellore district (Golla et al. 2020). The city is the fourth most populous settlement of the state well-known for its agriculture and aquaculture. Unconsolidated sediments belonging to the quaternary period occur in the area. A small stretch of Dharwar gneiss and schist

occurs in the western part. Tertiary sandstone and conglomerate occur below the quaternary sediments. The Dharwar and sandstones are weathered and lateritized. Gneisses, schists, and quartzite's belonging to the Dharwar supergroup occur as small outcrops, inselbergs, and in good sections near Gudur–Sarvepalli road. Biotite-muscovite schist intruded by veins of smoky quartz occurs at Batlapalem. The rocks exhibit foliation that trends $N 15^{\circ} W-S 15^{\circ} E$ with steep westerly and easterly dip (Nagaraju et al. 2016; Veeraswamy et al. 2018). Tertiary sandstone, consisting of coarse-to-medium-grained feldspathic sandstone, with low easterly dips, is seen in small sections south of Nellore, Anikepalli, and Kantepalli. The sandstone is overlain by a polymictic conglomerate in a canal cutting west of Sarvepalli and in good sections in the surrounding areas.

Sampling collection

In Nellore urban area, 39 groundwater samples were collected in one-liter polyethylene bottles; before collecting the water samples, bottles have been cleaned with 5% nitric

acid HNO_3 . All these samples were analyzed in the laboratory for major ions (K^+ , Na^+ , Ca^{2+} , Mg^{2+} , HCO_3^- , SO_4^{2-} , and Cl^-), total dissolved solids (TDS), and total hardness (TH). During sample collection, handling, and preservation, standard procedures recommended by the Standard Examination Methods for Drinking Water (BIS 2006 & ICMR) were followed. Among the analyzed chemical parameters, Na^+ and K^+ were determined by a flame photometer (GFU2202); SO_4^{2-} and Cl^- were analyzed by ion chromatography (HPLC2601); Ca^{2+} , Mg^{2+} , HCO_3^- , and CO_3^{2-} were analyzed by titrimetric method; TDS was determined by the method of drying and weighing; and TH was the sum of Ca^{2+} and Mg^{2+} (Table 1). The pH, easily influenced by the external environment, was measured with a portable pH meter on site.

Result and discussion

PH

pH means negative logarithm of hydrogen ion concentration. pH scale is 0 to < 7 for acid, 7– for neutral, and > 7 for basic. In the Nellore urban area, the values range from 7.1 to 9.1 and average is of 8.3. A total of 10% of the samples were not permissible for drinking, and the remaining fell permissible. pH is higher in the rainy season and lower in the dry season and same as in the confined and unconfined aquifer (Agoubi et al. 2013; Petalas and Diamantis 1999; Zhou et al. 2015).

Table 1 Groundwater chemistry of minimum and maximum average values

Parameters	Min	Max	Average	SD	Median	SE
EC	400	2900	765	459.7	650	65.02
pH	7.1	9.7	8.3	0.8	8.1	0.11
TDS	260	1885	497.2	298.8	422.5	42.26
Ca (mg/l)	25	86	45.3	13.1	40	1.86
Mg (mg/l)	10	56	43.7	10.6	45	1.5
Na (mg/l)	30	150	75.7	31.5	70	4.45
K (mg/l)	5	10	7.9	2.4	10	0.34
HCO_3^- (mg/l)	50	336	189	78.9	215	11.15
F (mg/l)	0.1	0.63	0.3	0.2	0.3	0.02
CO_3 (mg/l)	0	0	0	0	0	0
Cl (mg/l)	200	300	240.2	17.9	240	2.53
SO_4 (mg/l)	30	75	46.1	8.8	45	1.24
Hardness	40	305	148.3	73.9	145	10.45
NO_3 (mg/l)	35	72	47.8	7.3	45	1.04
GR I	0.51	0.89	0.7	0.1	0.68	0.01
GR II	0.41	0.73	0.59	0.1	0.61	0.01
EC	400	2900	764.97	459.75	650	65.02

Electrical conductivity (EC)

It is indicated that electricity passes through media and articulated as microsiemens/cm or micromhos/cm (Nagaraju et al. 2015; Balaji et al. 2017). The EC values range from 400 to.

2900 $\mu\text{S}/\text{cm}$, and average value is 765 $\mu\text{S}/\text{cm}$. In the present study area, 81% of samples fell in the good, 16% in doubtful, and 3% in unsuitable (Table 2). The EC values increase in the groundwater due to the dissolution of the mineral content (Jasmin and Mallikarjuna 2013).

Total dissolved solids (TDS)

The TDS ranges from 260 mg/l to 1885 mg/l and an average of 497.2 mg/l. A total of 99% of the samples were falling the fresh according to the Carrol (1962) < 1000 mg/l and the remaining 1% fall in the brackish nature (1000–10000 mg/l) (Monjerezi et al. 2012). Total dissolved solids (TDS) can be attributed mainly due to the addition of ions by weathering and leaching of non-resistant minerals from rocks

Table 2 Classification of electrical conductivity

Excellent	< 250	
Good	250–750	30 (81%)
Doubtful	750–2250	6 (16%)
Unsuitable	> 2250	1 (3%)

(geogenic), although the influence of anthropogenic components prevailing in the study area (Jun et al. 2015).

Total hardness (TH)

The TH ranges from 40 mg/l to 305 mg/l and an average of 148.3 mg/l. Hardness refers to the combination of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions (Subba Rao and Chaudhary 2019). In the present study area, all groundwater samples fell in the < 500 mg/l, and all groundwater samples were within the permissible limit for drinking.

Cations and anions

The concentrations of Na^+ and K^+ in groundwater samples are in the range of 30 to 150 mg/l and 5 to 10 mg/l, respectively. The concentrations of Ca^{2+} and Mg^{2+} are in the range from 25 to 86 mg/l and 10 to 56 mg/l, respectively. The concentrations of HCO_3^- ions are ranged from 50 to 336 mg/l. The concentration of Cl^- and SO_4^{2-} are in the range of 200 to 300 mg/l and 30 to 75 mg/l, respectively. The abundance of the major ions in groundwater is in the following order: $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ and $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{F}^-$. The cations ($\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$) were released due to the rock–water interaction and weathering process. The anions ($\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{F}^-$), chloride released from the household refuse, sulfates released from pesticide and fertilizers, and fluorides released from the disintegration of the hornblende granite schist (Li et al. 2018; Adimalla et al. 2019, Adimalla 2021).

Nitrites and fluoride health hazard risk assessment

Fluoride and nitrite concentrations were higher in groundwater than in surface water (Shirke et al. 2021). Human health hazard indexes were calculated for both oral and dermal. The pollutant concentration in groundwater (C_w), frequency of exposure (IR) in days/year, groundwater ingestion rate (IR) in L/day, exposure duration (ED), average body weight (BW), average exposure time (AT), and average daily exposure dose via groundwater ingestion (mg/kg/day) are calculated as follows:

$$\text{Intake ingestion} = \frac{C_w \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

IR (0.7 L/day for children and 1.5 L/day for adults), EF (365 days/year), ED (12 years for children and 30 years for adults), BW (65, 55, and 18.5 kg for men, females, and

children, respectively), and AT are the standard values for each parameter (4380 days for children and 10,950 days for adults). In the following phase, HQ ingestion is used to estimate fluoride hazards (Eq. 2):

$$\text{HQ ingestion} = \frac{\text{Intake}}{\text{RFD}} \quad (2)$$

The total hazard index (THI) of non-carcinogenic risk is evaluated (Eq. 3) as follows:

$$\text{THI} = \sum_{k=1}^n \text{HQ ingestion} \quad (3)$$

Similarly, the average daily exposure dose via dermal contact of groundwater (mg/kg/day) is calculated as follows (Adimalla 2019):

$$\text{Intake ingestion} = \frac{C_w \times SA \times \text{SAF} \times \text{DAF} \times EF \times ED}{BW \times AT} \quad (4)$$

where C_w is pollutant concentration in groundwater, SA is the exposed skin surface area (1600 cm² for children and 4350 cm² for adults), SAF is the skin adherence factor [0.2 mg (cm² day^{−1})], DAF is the dermal absorption factor (0.001), BW is the average body weight (70 kg for adults and 20 kg for children), and AT is the average time for noncarcinogens (365 days) (Yadav et al. 2018; Adimalla and Qian 2021). The fluoride in study area ranges from 0.1 to 0.63 mg/l and average values 0.3 mg/l. The concentration of fluoride in drinking water is < 1.50 mg/l (BIS 2012); meanwhile, > 1.50 mg/l severely damages dental and skeletal fluorosis (Narsimha and Rajitha 2018, Kundu et al. 2001). In the current study area, the total health hazard index (THI) was calculated at different ages like children, men, and women. There is no significantly affected (0%) oral and dermal contact in the study area, i.e., as shown in Table 3. The nitrites in the study area ranges from 35 mg/l to 75 mg/l, and the average value is 47.8 mg/l. > 45 mg/l in drinking water severely affected human beings' health diseases like methemoglobin. The main causes were geogenic influences like the interaction of the water through the aquifer media and fertilizers, biogeochemical processes, and pesticides (Fang et al. 2007). The total hazard index value is > 1, which severely affects human health (Table 4). In the current study area, 99% of the samples were exceeding the permissible limit. The total hazard index of the various ages was calculated, and the affected percentages were children (100%), women (95%), and men (35%).

Table 3 Fluoride total hazard index

S.No	Fluoride								
	HQ Oral			HQ Dermal			Thi		
	Children	Women	Men	Children	Women	Men	Children	Women	Men
1	0.5	0.38	0.32	2.64E−03	9.96E−04	8.43E−04	0.5	0.38	0.32
2	0.27	0.2	0.17	1.44E−03	5.43E−04	4.60E−04	0.27	0.21	0.17
3	0.72	0.55	0.46	3.84E−03	1.45E−03	1.23E−03	0.72	0.55	0.46
4	0.71	0.53	0.45	3.76E−03	1.42E−03	1.20E−03	0.71	0.54	0.45
5	0.57	0.43	0.37	3.04E−03	1.15E−03	9.70E−04	0.57	0.43	0.37
6	0.95	0.72	0.61	5.04E−03	1.90E−03	1.61E−03	0.95	0.72	0.61
7	0.65	0.49	0.41	3.44E−03	1.30E−03	1.10E−03	0.65	0.49	0.41
8	0.15	0.11	0.1	8.00E−04	3.02E−04	2.55E−04	0.15	0.11	0.1
9	0.47	0.35	0.3	2.48E−03	9.36E−04	7.92E−04	0.47	0.35	0.3
10	0.15	0.11	0.1	8.00E−04	3.02E−04	2.55E−04	0.15	0.11	0.1
11	0.71	0.53	0.45	3.76E−03	1.42E−03	1.20E−03	0.71	0.54	0.45
12	0.45	0.34	0.29	9.23E−05	3.48E−05	2.90E−05	0.45	0.34	0.29
13	0.45	0.34	0.29	4.71E−05	1.78E−05	1.46E−05	0.45	0.34	0.29
14	0.75	0.57	0.48	5.26E−05	1.99E−05	1.61E−05	0.75	0.57	0.48
15	0.75	0.57	0.48	3.96E−05	1.49E−05	1.19E−05	0.75	0.57	0.48
16	0.6	0.45	0.38	2.54E−05	9.58E−06	7.53E−06	0.6	0.45	0.38
17	0.15	0.11	0.1	5.30E−06	2.00E−06	1.55E−06	0.15	0.11	0.1
18	0.15	0.11	0.1	4.55E−06	1.71E−06	1.31E−06	0.15	0.11	0.1
19	0.15	0.11	0.1	3.98E−06	1.50E−06	1.13E−06	0.15	0.11	0.1
20	0.45	0.34	0.29	1.06E−05	4.01E−06	2.98E−06	0.45	0.34	0.29
21	0.15	0.11	0.1	3.19E−06	1.20E−06	8.82E−07	0.15	0.11	0.1
22	0.65	0.49	0.41	1.25E−05	4.70E−06	3.40E−06	0.65	0.49	0.41
23	0.15	0.11	0.1	2.66E−06	1.00E−06	7.16E−07	0.15	0.11	0.1
24	0.47	0.35	0.3	7.61E−06	2.87E−06	2.02E−06	0.47	0.35	0.3
25	0.15	0.11	0.1	2.28E−06	8.60E−07	5.99E−07	0.15	0.11	0.1
26	0.71	0.53	0.45	1.00E−05	3.77E−06	2.59E−06	0.71	0.53	0.45
27	0.45	0.34	0.29	5.99E−06	2.26E−06	1.53E−06	0.45	0.34	0.29
28	0.45	0.34	0.29	5.63E−06	2.13E−06	1.43E−06	0.45	0.34	0.29
29	0.75	0.57	0.48	8.87E−06	3.35E−06	2.22E−06	0.75	0.57	0.48
30	0.75	0.57	0.48	8.40E−06	3.17E−06	2.08E−06	0.75	0.57	0.48
31	0.6	0.45	0.38	6.39E−06	2.41E−06	1.56E−06	0.6	0.45	0.38
32	0.15	0.11	0.1	1.60E−06	6.02E−07	3.90E−07	0.15	0.11	0.1
33	0.15	0.11	0.1	1.60E−06	6.02E−07	3.90E−07	0.15	0.11	0.1
34	0.15	0.11	0.1	1.60E−06	6.02E−07	3.90E−07	0.15	0.11	0.1
35	0.45	0.34	0.29	4.79E−06	1.81E−06	1.17E−06	0.45	0.34	0.29
36	0.15	0.11	0.1	1.60E−06	6.02E−07	3.90E−07	0.15	0.11	0.1
37	0.71	0.53	0.45	7.50E−06	2.83E−06	1.83E−06	0.71	0.53	0.45
Min	0.15	0.11	0.1	0	0	3.90E−07	0.15	0.11	0.1
Max	0.95	0.72	0.61	0.01	0	0	0.95	0.72	0.61
AVG	0.45	0.34	0.29	0	0	0	0.45	0.34	0.29
%Affected	0%	0%	0%	0%	0%	0%	0%	0%	0%

Gibb's diagram

The ratio of $\text{Na} + / (\text{Na} + + \text{Ca}2 +)$ and $\text{Cl}/(\text{Cl} + \text{HCO}_3)$ as a function of TDS is represented by a Gibbs diagram, which

is frequently used to evaluate the functional sources of dissolved chemical components, such as precipitation dominance, rock dominance, and evaporation dominance. Water chemistry is evolved as a result of water–rock interaction

Table 4 Nitrate total hazard index

S.No	Nitrate								
	HQ Oral			HQ Dermal			Thi		
	Children	Women	Men	Children	Women	Men	Children	Women	Men
1	3.09	1.43	1.07	1.10E−02	4.15E−03	3.51E−03	3.105	1.44	1.08
2	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
3	2.25	1.04	0.78	8.00E−03	3.02E−03	2.55E−03	2.25	1.04	0.78
4	3.09	1.43	1.07	1.10E−02	4.15E−03	3.51E−03	3.094	1.44	1.08
5	4.05	1.88	1.41	1.44E−02	5.43E−03	4.60E−03	4.05	1.88	1.41
6	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
7	3.15	1.46	1.09	1.12E−02	4.23E−03	3.58E−03	3.15	1.46	1.1
8	2.98	1.38	1.04	1.06E−02	4.00E−03	3.38E−03	2.981	1.38	1.04
9	3.04	1.41	1.05	1.08E−02	4.07E−03	3.45E−03	3.038	1.41	1.06
10	2.93	1.35	1.02	1.04E−02	3.92E−03	3.32E−03	2.925	1.36	1.02
11	3.21	1.48	1.11	1.14E−02	4.30E−03	3.64E−03	3.206	1.49	1.12
12	3.09	1.43	1.07	1.10E−02	4.15E−03	3.51E−03	3.094	1.44	1.08
13	2.36	1.09	0.82	8.40E−03	3.17E−03	2.68E−03	2.363	1.1	0.82
14	2.25	1.04	0.78	8.00E−03	3.02E−03	2.55E−03	2.25	1.04	0.78
15	2.48	1.15	0.86	8.80E−03	3.32E−03	2.81E−03	2.475	1.15	0.86
16	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
17	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
18	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
19	2.81	1.3	0.98	1.00E−02	3.77E−03	3.19E−03	2.813	1.31	0.98
20	2.25	1.04	0.78	8.00E−03	3.02E−03	2.55E−03	2.25	1.04	0.78
21	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
22	2.42	1.12	0.84	8.60E−03	3.24E−03	2.75E−03	2.419	1.12	0.84
23	2.81	1.3	0.98	1.00E−02	3.77E−03	3.19E−03	2.813	1.31	0.98
24	2.81	1.3	0.98	1.00E−02	3.77E−03	3.19E−03	2.813	1.31	0.98
25	2.81	1.3	0.98	1.00E−02	3.77E−03	3.19E−03	2.813	1.31	0.98
26	3.21	1.48	1.11	1.14E−02	4.30E−03	3.64E−03	3.206	1.49	1.12
27	2.19	1.02	0.76	7.80E−03	2.94E−03	2.49E−03	2.194	1.02	0.76
28	1.97	0.91	0.68	7.00E−03	2.64E−03	2.23E−03	1.969	0.91	0.69
29	2.48	1.15	0.86	8.80E−03	3.32E−03	2.81E−03	2.475	1.15	0.86
30	2.48	1.15	0.86	8.80E−03	3.32E−03	2.81E−03	2.475	1.15	0.86
31	2.48	1.15	0.86	8.80E−03	3.32E−03	2.81E−03	2.475	1.15	0.86
32	2.25	1.04	0.78	8.00E−03	3.02E−03	2.55E−03	2.25	1.04	0.78
33	2.25	1.04	0.78	8.00E−03	3.02E−03	2.55E−03	2.25	1.04	0.78
34	2.53	1.17	0.88	9.00E−03	3.40E−03	2.87E−03	2.531	1.18	0.88
35	2.36	1.09	0.82	8.40E−03	3.17E−03	2.68E−03	2.363	1.1	0.82
36	3.09	1.43	1.07	1.10E−02	4.15E−03	3.51E−03	3.094	1.44	1.08
37	3.09	1.43	1.07	1.10E−02	4.15E−03	3.51E−03	3.094	1.44	1.08
Min	1.97	0.91	0.68	7.00E−03	2.64E−03	2.23E−03	1.97	0.91	0.69
Max	4.05	1.88	1.41	1.44E−02	5.43E−03	4.60E−03	4.05	1.88	1.41
AVG	2.69	1.24	0.93	9.56E−03	3.61E−03	3.05E−03	2.69	1.25	0.94
%Affected	30%	30%	22%	0%	0%	0%	100%	97%	32%

and aquifer material, which was further affected by the evaporation process. One of the most important elements impacting groundwater quality is its geological location. The Gibbs diagram explains about the origin source of the

chemical elements in the groundwater. This diagram plotted x-axis ($(Na + K) / (Na + K + CA)$) and y-axis TDS values. All the groundwater samples were fallen on the rock–water interaction area.

Conclusion

One of the most pressing issues in Nellore's urban region has been fluoride and nitrate contamination. The increased concentration geochemical parameters were PH, EC, TDS, and nitrate, with 10% of groundwater samples above the drinking water acceptable limit. Fluoride in the study area fell in the permissible limit and the total health index on human beings the various stages. All the THI values are < 1; therefore, there is no significance in the study area population. **A total of 99% nitrates** in groundwater samples were exceeding the permissible limit. The total hazard index of the various ages was calculated, and the affected percentages were children (100%), women (95%), and men (35%). The nitrate and fluoride were released due to the rock–water interaction, nitrification processes, fertilizer, pesticides, and dissolution of the mineral deposit like fluorite apatite, rock-like hornblende granite schist, and mica schist. The Gibbs diagram explains the origin source of chemical elements in the study area. Overall, from this research, the study area population severely fell in a problem with nitrate contamination, and fluoride has no significant effect. These researches suggest that before consumption of the water, proper treatment is necessary.

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Data Availability The raw data are obtained from NRSC Bhuvan and USGS website (<https://bhuvan.nrsc.gov.in/> and <https://earthexplorer.usgs.gov/>) which is available free of cost, and the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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