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Groundwater Quality Appraisal through Water Quality Index and Non-Carcinogenic Health Risk Assessment from Nellikal Watershed of Nalgonda District, Telangana, India

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Abstract:- This study described the assessment of groundwater quality using a water quality index (W.Q.I.) and non-carcinogenic health risk due to Nitrate in groundwater from rural habitats of Nellikal watershed of Nalgonda district. Groundwater samples are collected andmeasuredfor pH, E.C., T.D.S., T.H.,and major anions and cations.Results revealed that T.D.S., HCO3- and NO3 concentrations are beyond the WHO permissible limits among the various parameters determined. The groundwater of the study area falls in poor water quality accounts for 35% of samples, and 5.9% of samples are inthe very poor category, according to W.Q.I. The risk assessment demonstrated that hazardous quotient (H.Q.) values are in the range of 0.01-105.70; 0.01-99.10; 0.01-37.75 concerning infants, children and adults, respectively. These data demonstrated that most of the samples (71%) showed HQ>1 together for infants and children suggests a severe health effect on infants and children due to groundwater ingestion from the Nellikal watershed. This investigation recommended that water has to treated before supply for drinking in the study region.

***Keywords**:- Groundwater quality;WHO permissible limits; WQI; Health risk assessment;Nellikal Watershed;Nalgonda; Telangana.*

I. INTRODUCTION

Groundwater is an essential natural resource and currently facing severe pollution, it needs its quality assessment for drinking purposes.Poor groundwater quality has aimpact on human health and the environment, and hence sustainable management of groundwater resources requires great concern (Pant et al. 2017). In semi-arid and arid regions, factors such as uneven precipitation, large evapotranspiration, soil erosion, and frequent human activities have become inconsistent between supply and demand of water resources is exceptionally prominent (Zhang et al., 2018). The characteristics of groundwater chemical evolution are the concentrated reflection of environmental change is of great concern for groundwater resource and ecological quality evolution (Yetis et al., 2019; Wang et al., 2021). Groundwater quality assumes significance to ascertain its suitability for various purposes, and the concentration of multipleparameters should meet the regulatory limits (Subramani et al., 2009; Khatri et al., 2020; Reddy et al. 2019; Vaiphei et al., 2021).Therefore, the quality of groundwater should ensure to protect human and soil health, covering water-borne disease and damage to irrigated crops, respectively (Sarkar and Hassan, 2006; Little et al. 2010; Chaudhary and Satheeshkumar 2018).

Understanding of hydrogeochemical process is helpful in the assessment of groundwater quality (Kadam et al., 2021; Vaiphei et al., 2021).The water quality index (WQI) is capable of complete communication of the water quality data of an area.WQI based maps help understand and raise awareness of groundwater contamination andimpose or suggest suitable water treatment for its usage for drinking purposes and management (Abbasi and Tareen, 2012).In addition, groundwater has become an essential source for tribal habitats and solely depending on their needs of drinking purposes.The uniqueness of this investigation is recognizing the potential factors controlling the groundwater chemistry by combining with groundwater quality data and integrating GIS with WQI approach in a virgin area of Nellikal watershed of Nalgonda district Telangana.This study is a first-of-its-kindthat has immense value for proper groundwater management for drinking utilities.

The objectives of this investigation are to assess the groundwater quality based on the WHO permissible limits, WQI and Health risk assessment methods for its suitability for drinking purposes, a significant water resource for rural habitats

II. MATERIALS AND METHODS

A. Study area

The Nellikal watershedlocated in the Nalgonda district, Telangana The watershed, covering an area of about 120km^2 positioned between latitude 16^{0}34’30”N and 16^{0}40’30”N to longitude 79^{0}18’00”E and 79^{0}27’00”E falling in the Survey of India (SOI) toposheet number 56 P/2 (Fig.1).Mattamvaguflows in Nellikal watershed that further flows into the Krishna River.Nellikal watershed is home to 22,456 inhabitants with an average population density of 189 persons per km2 consisting of 18 villages. It was observed that groundwater levels range between depths of 16 to 30 m bgl (CGWB, 2016). The area is categorized as overexploited due to the large groundwater abstraction for the irrigation of crops, mainly paddy and cotton.

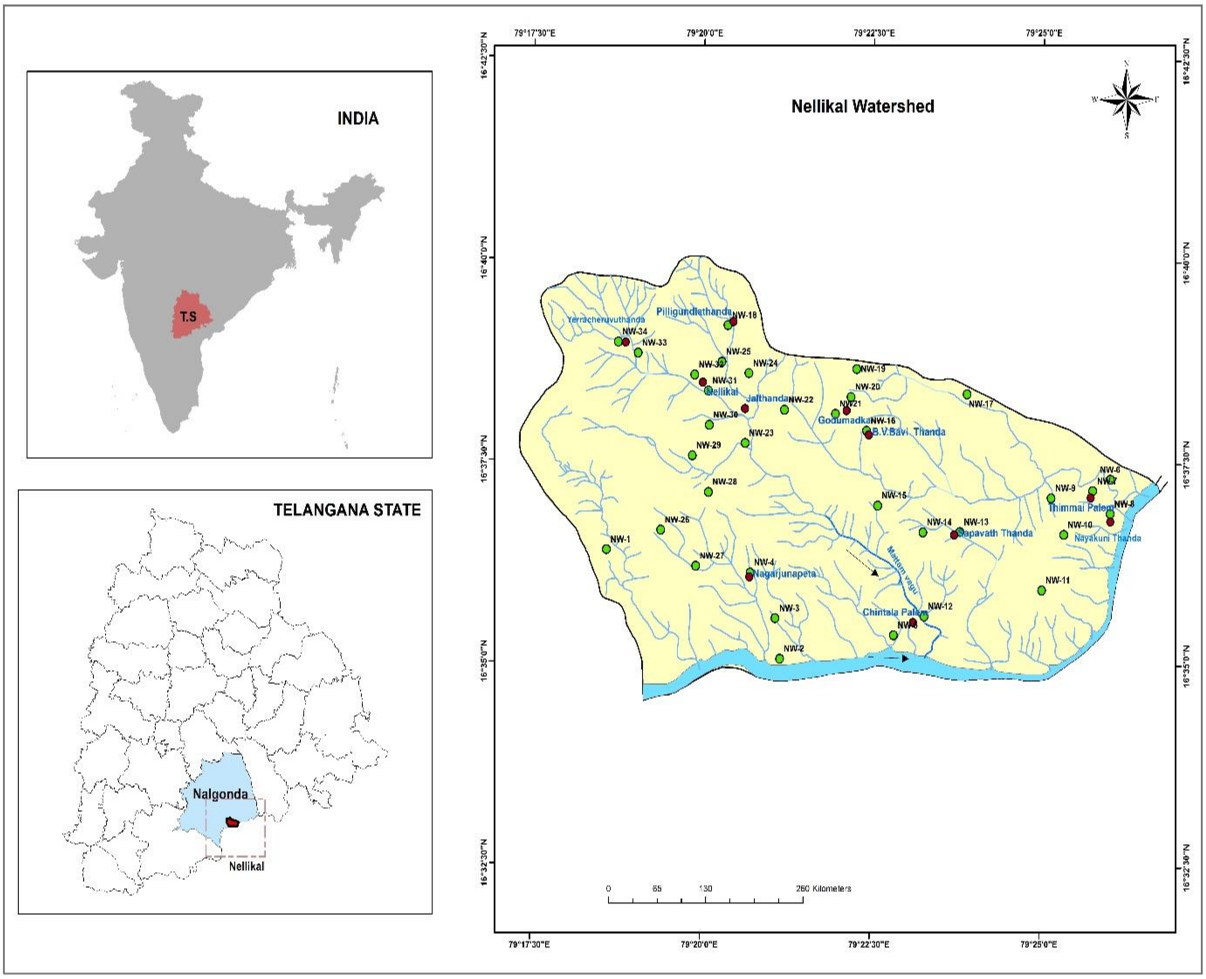

Fig. 1: Location map of Nellikal watershed of Nalgonda district, Telangana along with sampling stations

B. Sampling and analysis

Thirty-four (34) water samples representing groundwater sources were collected randomly to cover the selected study region. These samples were analyzed for physicochemical parameters, major cations, and anions. Water samples are collected in polypropylene bottles following APHA standard methods (APHA, 2017). pH, EC, and TDS were measured immediately after collecting the samples in the field site. Bicarbonate (HCO_3^-) and total hardness (TH) concentrations were determined by the titrimetric method, whereas the Ion chromatography (882 Compact IC plus, Metrohm) method was used for the determination of major ionic concentration in groundwater.

C. Water quality index

Evaluation of groundwater quality through the water quality index (WQI) is a widely used tool that summarizes several water quality parameters into a single proper numerical value (Kurakalva et.al., Kadam et al., 2021; Rawat and Singh, 2018; Vaiphei et al., 2020). It is based on the rank and weight given to the measured parameters. Comprehensive assessment of the groundwater suitability for drinking purposes is carried out using the water quality parameters such as pH, EC, TDS, Ca^{2+}, K^+, Mg^{2+}, Na^+, F^-, Cl^-, NO_3^-, SO_4^{2-}, HCO_3^- andTH and given weight value according to the significance at the study area under evaluation. WQI calculated as below

Relative weight hasbeen calculated as shown in the following equation.

$$W_i = w_i / \sum_{i=1}^{n} w_i \qquad \text{eq. (1)}$$

where, W_i= relative weight
w_i= parameters weight
n= number of parameters

Then quality rating has computed as per the following equation

$$q_i = \frac{C_i}{S_i} * 100 \qquad \text{eq. (2)}$$

where q_i = quality rating
C_i = measure concentration for each parameter (mg/L)
S_i= standard limit for each parameter according to WHO (mg/L)

Later, sub-indices is calculated by multiplying values obtained in eq. (1) &(2)

$$SI_i = W_i * q_i \qquad \text{eq. (3)}$$

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Finally, calculated SI values for every parameter used to calculate WQI by summing all SI values for a particular sample which gives the quality classification according to their range and water types(Kurakalva et al., 2021).

$$WQI = \sum SI_i \qquad \text{eq. (4)}$$

D. Potential health risk assessment

Potential health risk assessment is a significant index used in defining water quality whether it is fit for drinking purposes. It is essential to know how many chemical concentrations are present in drinking water and their long-term health effects due to its consumption. Understanding the harmful health effects due to contaminants via groundwater ingestion is assigned by health risk assessment. Potential health risk assessment calculation helps evaluate health impact on different age groups (Chen et al., 2016; Nadia et al., 2015;Su et al., 2013).The most common health diseases caused by Nitrate are methemoglobinemia/blue baby syndrome, stomach and oesophageal cancer and thyroid hypertrophy (Adimalla 2019).Further, it has been reported that groundwater in granitoid terrain of south India contains high Nitrate, which affects more on child and women health compared to adult men due to consumption of untreated water with high nitrate concentration above permissible value.In this study, a health risk assessment due to nitrate consumption which is present as a dissolved ion in groundwater, was carried out. Health risk assessment has been calculated from the established formulae [eq. (5) and (6)] by measuring daily limit dose (CDI) and hazard quotient (HQ), rate the possibilities of non-carcinogenic impact (USEPA, 2004). The daily intake amount of nitrate present in groundwater can be calculated from the following equations:

$$CDI = \frac{C*DI*F*ED}{BW*AT} \qquad \text{eq. (5)}$$

Here, CDI= daily limit dose (mg/kg/day), C =conc. of nitrate in groundwater (mg/L), DI= ingestion rate (adults, children, infants; 2, 1.5, 0.8 L/day), F= exposure frequency (adults, children, infants; 365 days) ED= exposure duration (adults, children, infants; 40, 10, 1 years), BW= average body weight (adults, children, infants; 70, 20, 10 kg), AT=average time for non-carcinogenic effect (adults, children, infants;14600, 3650, 365 days) (Qasemiel at. 2018).

$$HQ = \frac{CDI}{RfD} \qquad \text{eq. (6)}$$

i.e., Rfd = specific dose reference of a contaminant,

According to the Integrated Risk Information System (IRIS) of USEPA (2012), the permissible dose limit of Nitrate is 1.6 mg/kg/day. If the final value of HQ<1, then there is no impact on human health, but if HQ>1, there is a non-carcinogenic impact on human health, according to USEPA (2012).

III. RESULTS AND DISCUSSION

The summary of groundwater analytical data of theNellikal watershed presented in Table 1and their comparison with WHO guideline values for drinking utility.

A. Groundwater quality based on WHO permissible limits

pH of the groundwater samples iswithinthe allowable limit of WHO (2017) guideline values. However, EC is above permissible limits in 23.5% of samples (Table 1). Besides, most of the groundwater samples (91%) are within permissible limits of <1000 mg/L TDS, and 8.82% of samples are fall in slightly saline (Freeze and Cherry 1979). Around 91.1% of samples are with high HCO3 content beyond the permissible limit of 150mg/L. The spatial distribution of TDS and HCO3 concentrations in groundwater samples of Nellikal watershed is shown in Fig. 2(a) and 2(b).

Among the various anions and cations measured for groundwater samples collected from the study area and their data are shown in Table 2. The nitrate concentration is the most abundant ion next to bicarbonate, and around 44% of the samples are exceeded the WHO permissible limit for drinking (Fig.3 (a). A high nitrate concentration might be due to agriculture fertilizer runoff/leaching as the study region dominates agricultural activities. The spatial variation of nitrate concentrations in groundwater is presented in Fig.3. All other ions are within the permissible limit for drinking purposes. Though fluoride ions in groundwater were found below the permissible limit of WHO (2017) guideline value of 1.5mg/L; however, when the concentration range compared with BIS (2012) permissible limit of 1.0mg/L, and 11.8% of the samples are beyond the permissible limit as shown in Fig.3(b). As the study region falls under the fluoride endemic zone district (i.e., Nalgonda), it is also compared with BIS to be cautious about human health.

Parameters	Units	Min	Max	Ave	Median	SD	WHO 2017 desire limit mg/L	Samples exceeding permissible limit WHO (2017) mg/L	
								No. of samples	% of Samples
Physicochemical									
pH	----	6.40	7.60	7.26	7.28	0.25	6.5-8.5	NIL	NIL
EC	µS/cm	530.00	2290.00	1208.82	1070.00	471.35	750-1500	8	23.5
TDS	mg/L	270.00	1150.00	610.00	545.00	235.77	500-1000	3	8.8
TH	mg/L	9.90	422.75	205.59	195.94	90.26	300-500	Nil	Nil
Alk	mg/L	11.61	552.50	278.12	266.50	116.05	---	Nil	Nil
Anions									
F^-	mg/L	0.07	1.19	0.56	0.53	0.32	0.6-1.5	Nil	Nil
Cl^-	mg/L	18.64	254.90	89.80	72.94	60.71	250-600	Nil	Nil
NO_3^-	mg/L	0.04	396.39	67.93	32.44	88.17	45	15	44.1
SO_4^{2-}	mg/L	17.26	231.53	66.76	55.60	45.76	250-400	Nil	Nil
HCO_3^-	mg/L	109.80	500.20	242.56	231.80	93.18	150	31	91.1
Cations									
Na^+	mg/L	16.19	238.84	76.27	67.39	43.34	50-200	1	2.9
K^+	mg/L	0.67	195.89	16.70	2.77	43.03	12	4	11.8
Ca^{2+}	mg/L	9.90	69.27	37.93	34.25	16.77	75-200	Nil	Nil
Mg^{2+}	mg/L	9.94	67.53	28.10	24.84	15.98	50-150	Nil	Nil

Table 1: Statistical summary of physicochemical parameters, major ions compared with WHO (2017) permissible limits

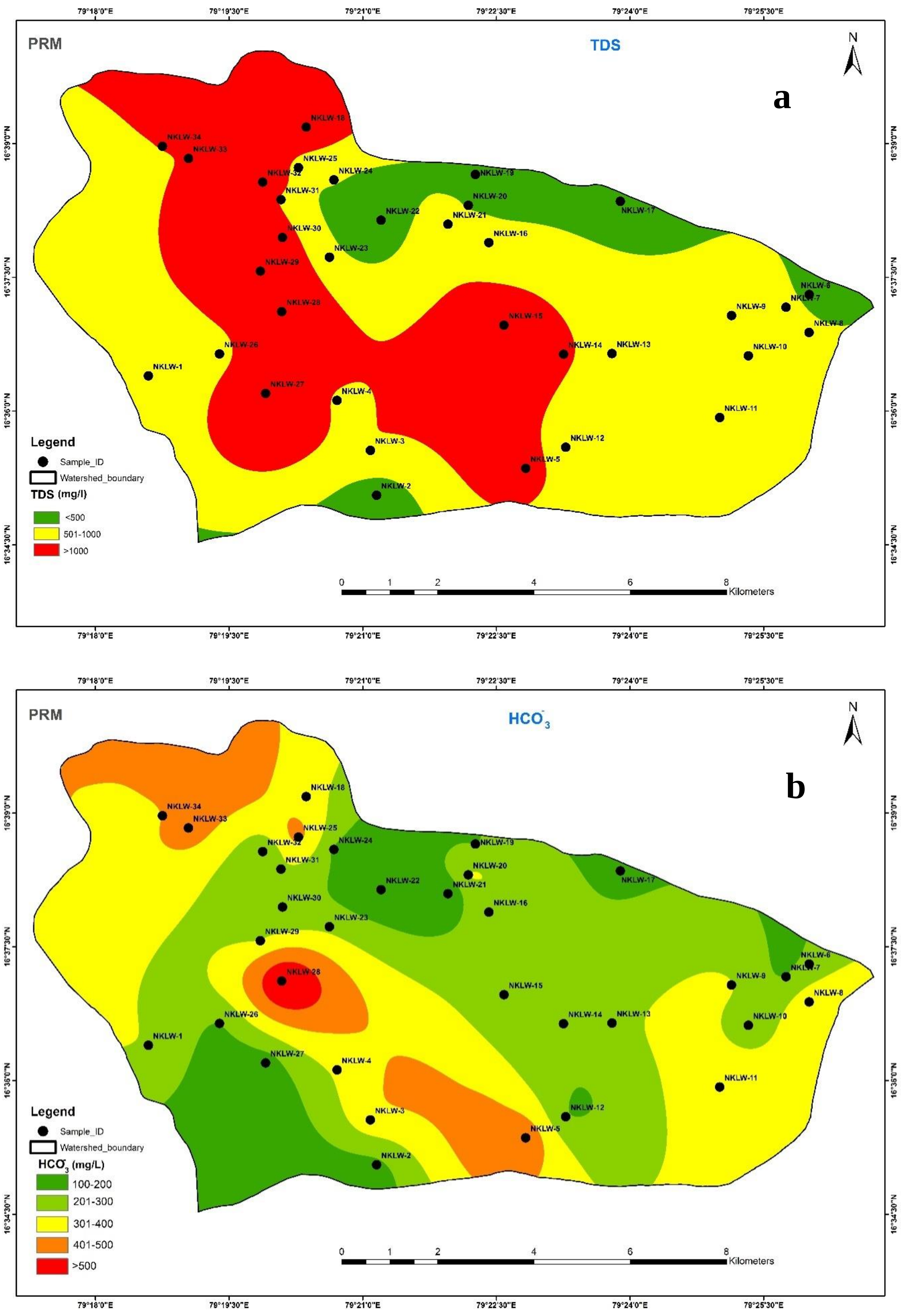

Fig. 2: Spatial distribution maps of (a) TDS, (b) Bicarbonate

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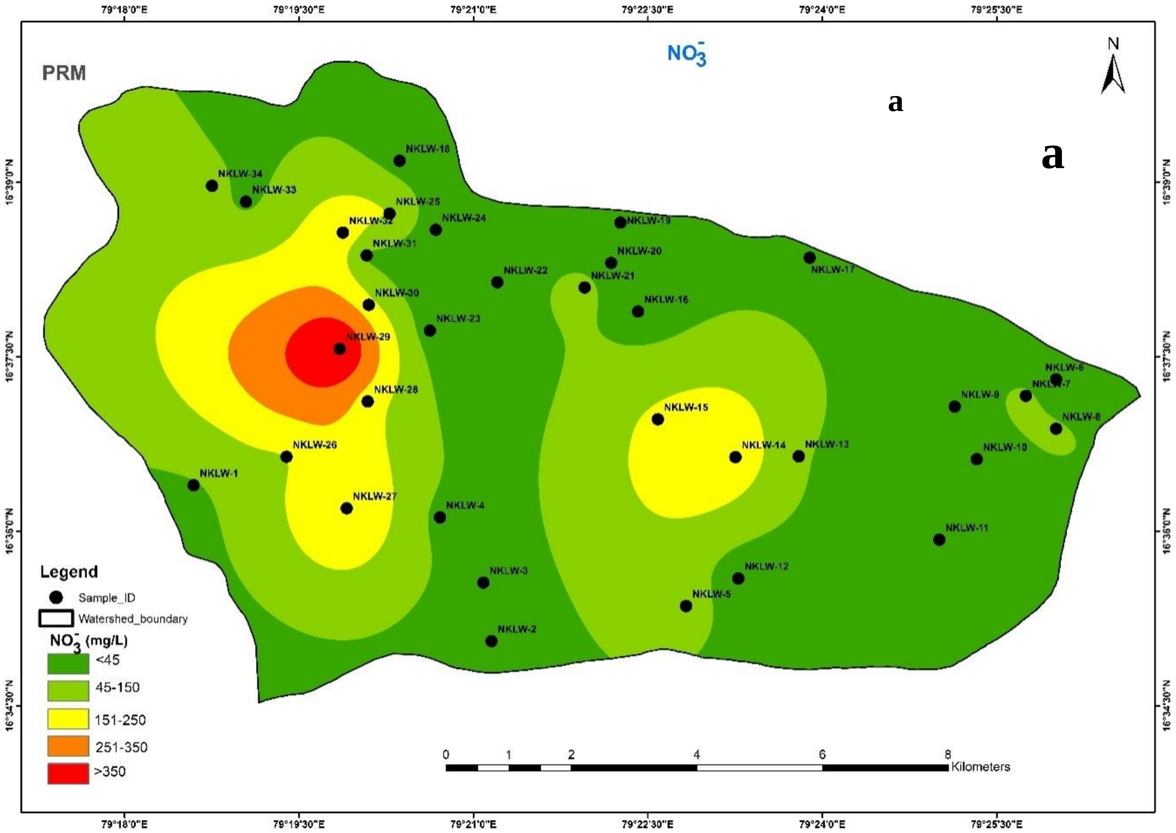

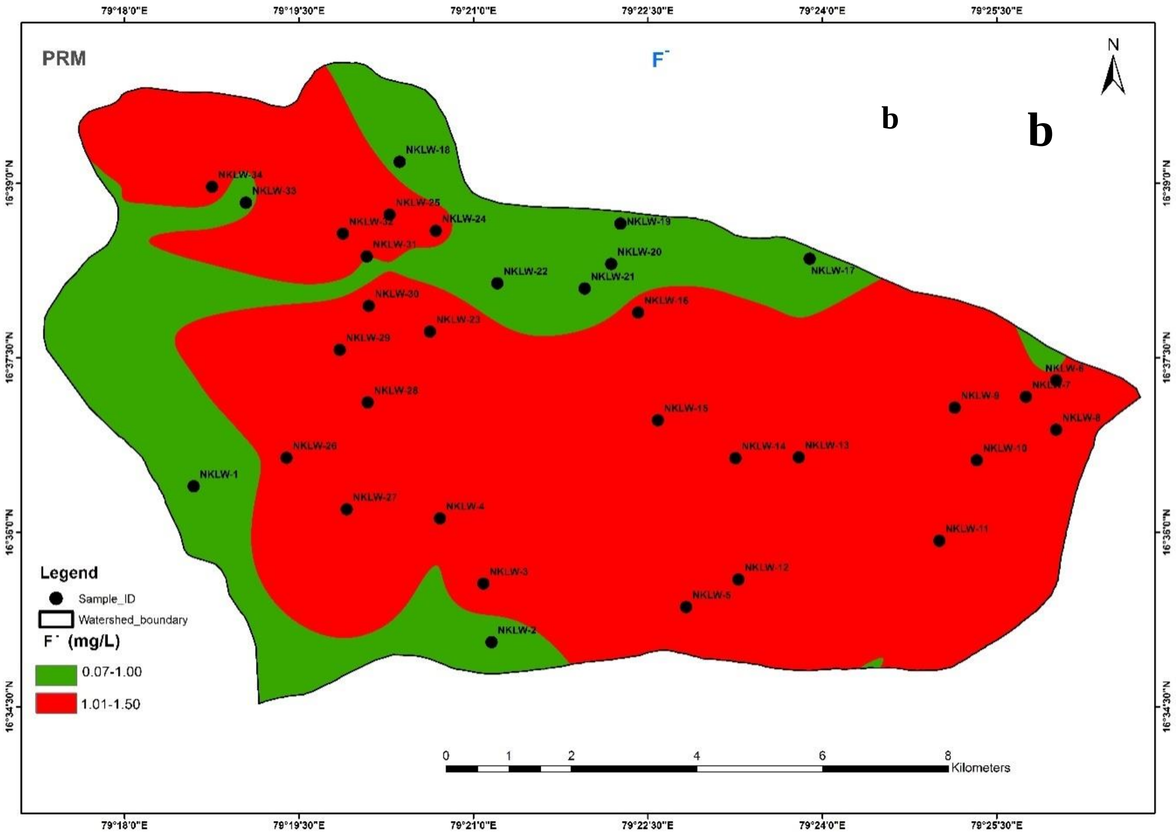

Fig. 3: Spatial distribution maps of (a) Nitrate (b) fluoride in groundwater

B. Water quality assessment using WQI values

Groundwater quality and its suitability for drinking purposes based on water quality index (WQI) spatial variations shown in Figure 4. WQI observed range from 40 to 394. The distribution of WQI in the study area is represented as shown in Fig. 4. This data reveals that35% of samples are falling in the poor category, 6% of samples belong to very poor water type, and none ofthe samples are

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unsuitable for drinking (Fig.5).This further indicates the study area together 41% of the samples are not acceptable for drinking, which needs to be treated prior to supply for drinking purposes.

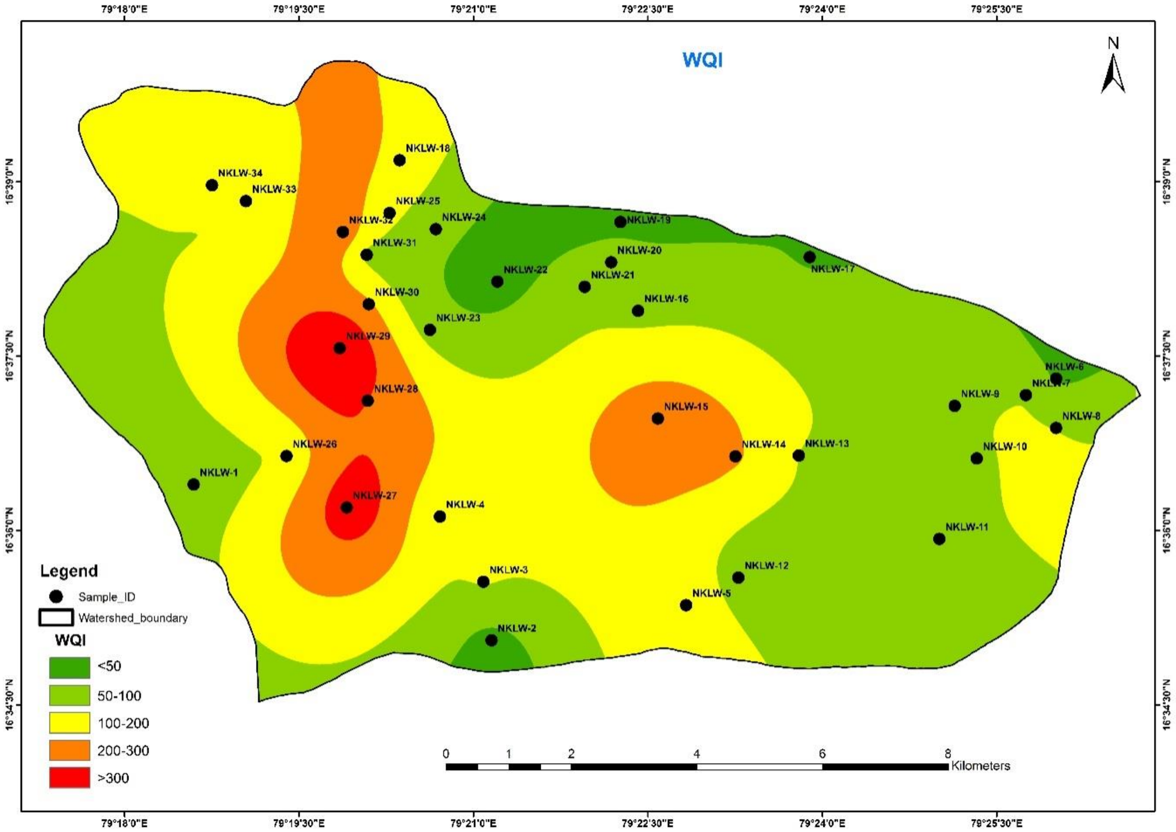

Fig. 4: Spatial variations of WQI values of groundwater in the Nellikal watershed

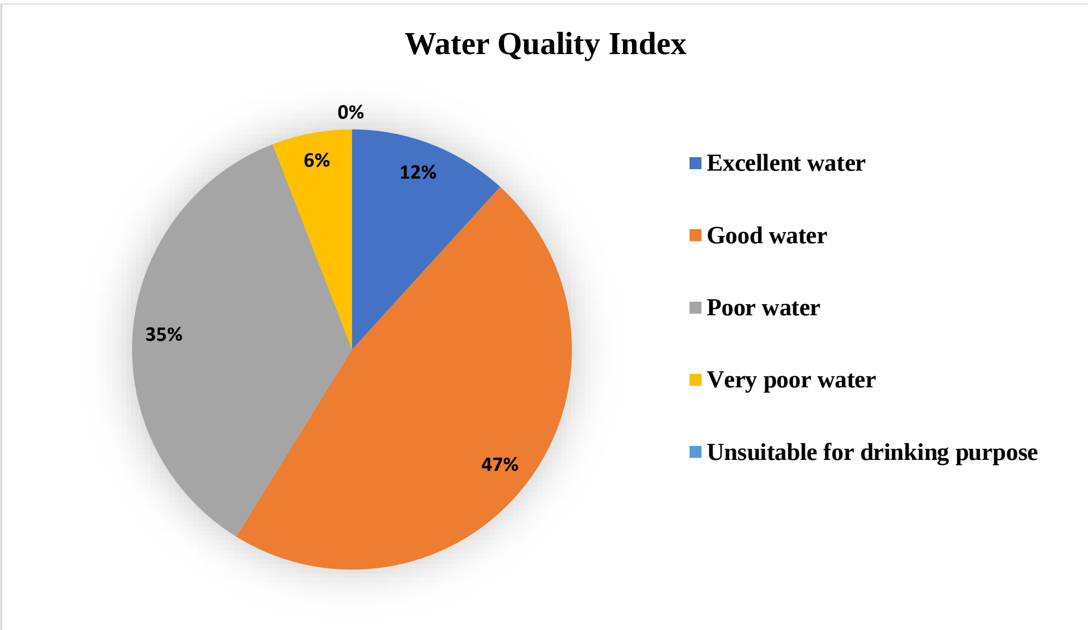

Fig. 5: Distribution of percentage of WQI values of groundwater in the study area

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C. Non-carcinogenic risk assessment of Nitrate

Water quality plays a critical role and deciding factor in human health and wellbeing around the world. The hydrogeochemical studies on groundwater from the Nellikal watershed reveal that elevated concentrations of Nitrate in groundwater is observed. About 44% of the samples in pre-monsoon and 59% of samples in post-monsoon are identified as nitrate concentrations beyond the WHO (2017) permissible limit (i.e. 45mg/L) for drinking purposes (Fig.6). Based on these observations, the health risk assessment of Nitrate in groundwater in the Nellikal watershed is evaluated to safeguard the health of people living in the study region.

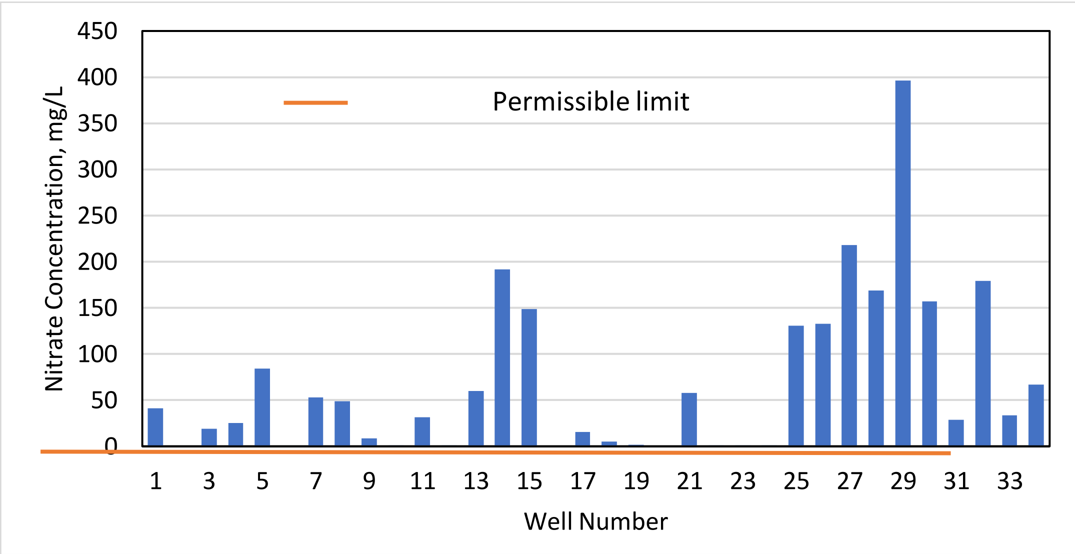

Fig. 6: Nitrate levels in the groundwater of Nellikal watershed

Appraisal of groundwater quality with a focus on Nitrate is a public health concern as the Nellikal watershed belongs to an intensive agricultural region. On the other hand, India is a fundamentally agricultural-based country with irrigation practices that depend on water from river and groundwater resources. Rural habitats depend on groundwater for their livelihood. Further, utilization of groundwater in the agricultural sector also increases due to the scarcity of rains in many regions (Ahmed et al., 2015). In a recent study (Vaiphei and Kurakalva, 2021), it has been reported that nitrate pollution is at risk due to the ingestion of groundwater.

In the present study, the hazard quotient values evaluated from the water quality data are categorized as infants, children and adults. The HQ values found in the range of 0.01-105.70; 0.01-99.10; 0.01-37.75 with respect to infants, children and adults respectively (fig. 7). Around 71% of groundwater samples shown HQ>1 together for infants and children, besides65% for adults. Since the elevated concentration found in the study area, there is a profound health effect on infants and children due to groundwater ingestion from Nellikal watershed.

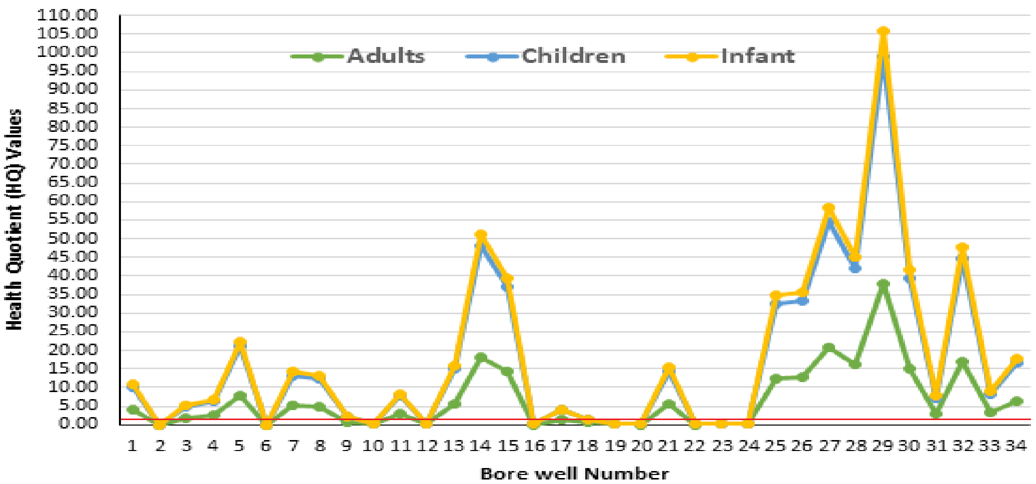

Fig. 7: Scatter plot showing HQ>1 for nitrate concentration in all groundwater samples indicating children

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IV. CONCLUSION

This study summarizes that parameters such as TDS, bicarbonate, and Nitrate are above permissible limits of WHO guideline values for drinking. High levels of Nitrate were found in 44% of the samples, which is unfit for drinking purposes. The enriched nitrate concentration in groundwater might be due to agricultural practices in the region.The groundwater of the study area falls in poor water quality accounts for 35% of samples, and 5.9% of samples are with very poor category as per WQI. Around 71% of groundwater samples showed hazard quotient (HQ) value is >1 together for infants and children, besides 65% for adults are at risk if consumed the water for drinking. Thus, it is suggested treatment of water is essential before supply for drinking use to protect human health.

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- **Conflict of Interest:** Author(s) declares no conflict of interest.

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