

Statistical Analysis of Groundwater Sample of Bhudoli Village of Neemkathana Block of Sikar India

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Abstract: *The nitrate concentration of groundwater in the Bhudoli village observed is much higher than the BIS (IS 10500: 2012) acceptable limit of 45 mg/L. Total alkalinity, Total Dissolved Solids (TDS), and Total alkalinity of groundwater in the Bhudoli village were observed higher than the BIS (IS 10500: 2012). The fluoride, Chloride, and Sulphate concentration in groundwater are within the BIS (IS 10500: 2012) acceptable limit. It is observed that the quality is better and it is included in the high-quality water villages. The groundwater of Bhudoli village does not show Perfect positive ($r = 1$), perfect negative ($r = -1$), and very high degree ($r = 1- 0.9$) positive/negative correlation. Correlation Analysis reveals that TDS increase in groundwater is associated with nitrate, fluoride, and chloride shows that groundwater aquifer contains metamorphic rocks which contain more soluble minerals having more fluoride. The Aggressive Index of groundwater of Bhudoli village has an AI value of more than 12 indicating the non-corrosive nature of the water. From the statistical analysis of groundwater, it may be concluded that anthropogenic and geogenic factors continuously deteriorate the quality of groundwater. Its suitability for domestic and other purposes is continuously decreasing.*

Keywords: Water, physio-chemical parameters, Water Quality Index, correlation diagram, Aggressive Index, WHO, BIS

1. Introduction

Approximately the world's one-third population uses groundwater for drinking purposes (Nickson *et al.*, 2005). Rajasthan is the driest state of India due to unavailability of surface water source, so groundwater which is overall 91% of total consumption, has an important role for agricultural and human activities. Groundwater is facing the problem of salinity, nitrate and fluoride contamination in most of the villages of the state. Some districts facing major problem due to fluoride and nitrate. It enters in human body and causes mild molting of teeth and its high concentration may act as a carcinogen. Groundwater sources are getting highly polluted through various agencies like agriculture run-outs, industrial effluents, mining activities, sewage etc. due to which groundwater sources have a large change in physico-chemical values. Availability, and quality of both kind surface, and groundwater has been changed, due to urbanization and industrialization. Nitrate contamination of groundwater has also become a health and environmental problem. The geographical and geological setup of Neemkathana is very much affected by Aravali hills and rocks of lime stone, feldspar, dolomite, and quartz etc. There are about 400 mines of different kind of minerals, 40 stone crushers, and sand mining at about 8 sites. Physical impact of sand mining includes reduction of water quality. Mining also affects the level of the water table, a continuous

lowering reported due to mining activities (Karmakar & Das, 2012). Parvizishad *et al.* (2017) give to review the adverse effects and benefits of nitrate and nitrite in drinking water and food on human health. Low concentrations of nitrite and nitrate could have a protective effect on the cardiovascular system, blood pressure regulation and maintaining homeostasis of vessels. High concentrations of nitrate in groundwater in arid, and semi-arid areas are due to agricultural activities, natural vegetation by leguminous species, like acacias, and leaking effluent due to site sanitation (WHO, 2007).

Horton (1965), selected 10 variables to propose the WQI, then after many authors aggregate variables for characterization of the state of water as Water to create a single numeric called, Water Quality Index (Kachroud, 2019). Water Quality Index (WQI): A rating technique that is unique and effective to assess the quality of water (Ahmed, 2021). Correlation matrix is a table which shows correlation coefficient for the used variables in the form of possible pairs. It identifies as well as visualizes the patterns in the large dataset, so seems to be a powerful tool to summarize a huge dataset (CFI Education Inc., 2015 to 2022).

2. Site Selection

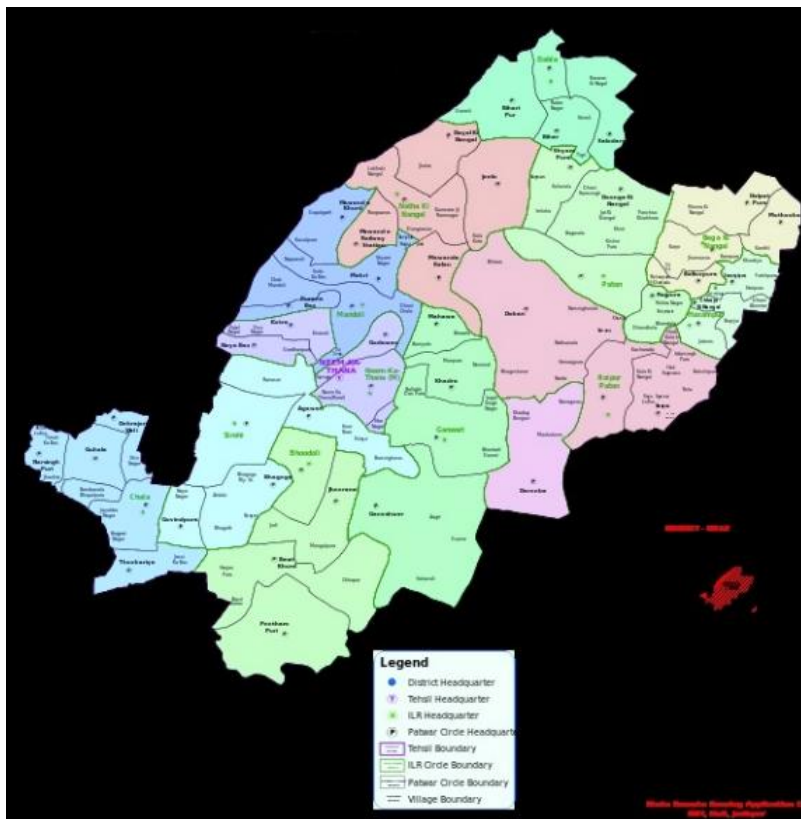


Figure 1: Bhudoli village Neemkathana block (source: election commission)

Geographical location Bhudoli village 27.6937° N, 75.7727° E. The total geographical area of the village is 1471 hectares and the total population of 7,222 people (census2011). Neemkathana is the nearest town to Bhudoli which is 6 km away. Neemkathana block is over-exploited, and the hydrological formation of Bhudoli village is Quartzite. Several open-cast mines are operated by different agencies. Due to unavailability of surface water people of Bhudoli village are dependent on groundwater.

3. Material and Methods

Table 1: List of Parameters and Methods of Determination

Parameters	Methods of determination
pH	pH Meter
TH (mg/l)	EDTA Method
Ca (mg/l)	Titration Method
Mg (mg/l)	Titration Method
TDS (mg/l)	Potentiometric Method
F ⁻ (mg/l)	UV Spectrophotometric Method
SO ₄ ²⁻ (mg/l)	Turbid meter Method
NO ₃ ⁻ (mg/l)	Spectrophotometer

Statistical analysis

This study involves Statistical Analysis for the groundwater samples with the help of following -

Table 2: Water quality classes as per water quality index score (Bathusha & Saseetharan)

S. No.	Water Quality Index	Description
1	<50	Excellent Water
2	50-100	Good Water
3	100-200	Poor Water
4	200-300	Very Poor Water
5	>300	Very Bad/unsuitable for drinking

Table 3: Aggressive Index value and class of groundwater (Yousefi *et al.*, 2018)

Aggressive index (AI)	Aggressive Index Value	Class of water
	AI > 12	Non-aggressive
	10 < AI < 12	Moderately aggressive
	AI < 10	Very aggressive

Table 4: Karl Pearson's Coefficient of correlation (r) variations

Karl Pearson's Coefficient of correlation (r)	
Negative	Positive
Perfectly correlated (-1)	Perfectly correlated (1)
Very high degree (-1 to -0.9)	Very high degree (1 to 0.9)
Sufficiently high degree (-0.9 to -0.75)	Sufficiently high degree (0.9 to 0.75)
Moderate degree (-0.75 to -0.25)	Moderate degree (0.75 to 0.25)
Low degree (-0.25 to 0)	Low degree (0.25 to 0)

Correlation coefficient (r) -Karl Pearson's coefficient, between each pair of Physico-Chemical parameters

Assessment of groundwater of Bhudoli village in Neemkathana block

Groundwater samples of Bhudoli village collected from Month of Aug-2020 to July-2021 and tested for different physico-chemical parameters. The results of physico-chemical parameters shown in the table 4.

Table 4: Water testing data of Bhudoli village in Neemkathana

Water testing of Bhudoli village in Neemkathana block								
Para. Month	pH	Total alkalinity, mg/L	Total hardness, mg/L	Cl ⁻ , mg/L	SO ₄ ²⁻ , mg/L	NO ₃ ⁻ , mg/L	F, mg/L	TDS, mg/L
Aug-20	8.1	350	350	100	26	62	0.91	805
Sept-20	7.2	380	350	90	69	45	0.71	695
Oct-20	8.3	140	150	40	10	2	0.17	220
Nov-20	8	330	510	120	40	67	0.82	745
Dec-20	8	300	280	110	41	64	0.8	775
Jan-21	7.5	380	290	90	37	79	1	730
Feb-21	8.2	390	340	100	39	59	0.9	540
Mar-21	7.6	240	280	90	41	81	0.78	690
Apr-21	7.4	280	170	110	41	85	0.83	680
May-21	8	240	280	90	38	66	0.85	640
Jun-21	7.6	240	280	90	26	73	0.79	675
Jul-21	7.6	280	230	80	43	85	0.86	695

Table 4 includes the testing results for the assessment period of Aug. 2020 to July 2021. BIS (IS 10500:2012) standard is selected for the assessment of the groundwater parameters, which have acceptable, and permissible limits for each parameters, but for nitrate no permissible limit in BIS standard so only acceptable limit is applicable.

pH

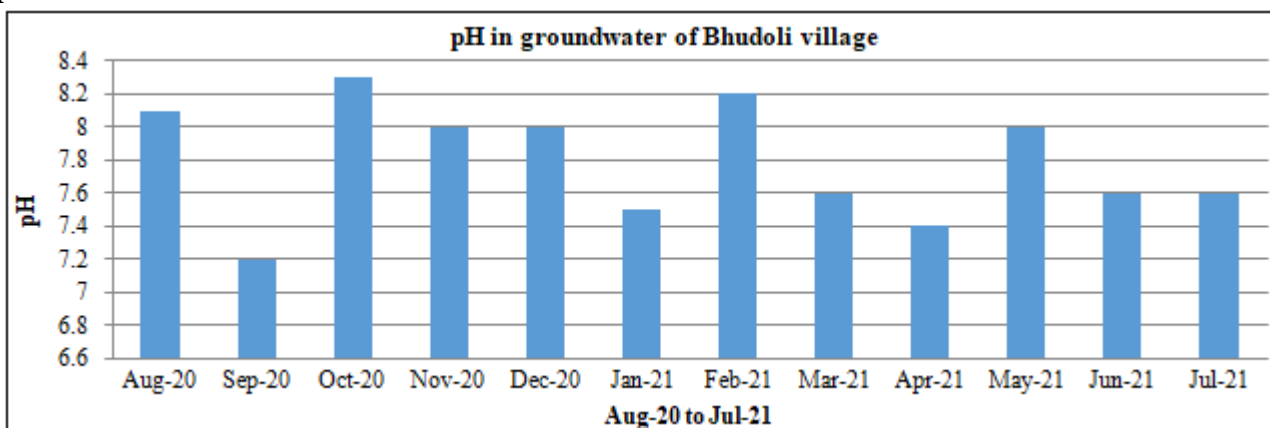


Figure 2: pH of groundwater in Bhudoli village of Neemkathana block

Figure 2 shows the variation of pH value for assessment year from August 2020 to July 2021. The minimum 7.2 observed in month of Sept-2020, and maximum 8.3 observed in the month of Oct-2020. The mean value for the parameter is 7.79, and the standard deviation calculated is 0.35.

Total alkalinity

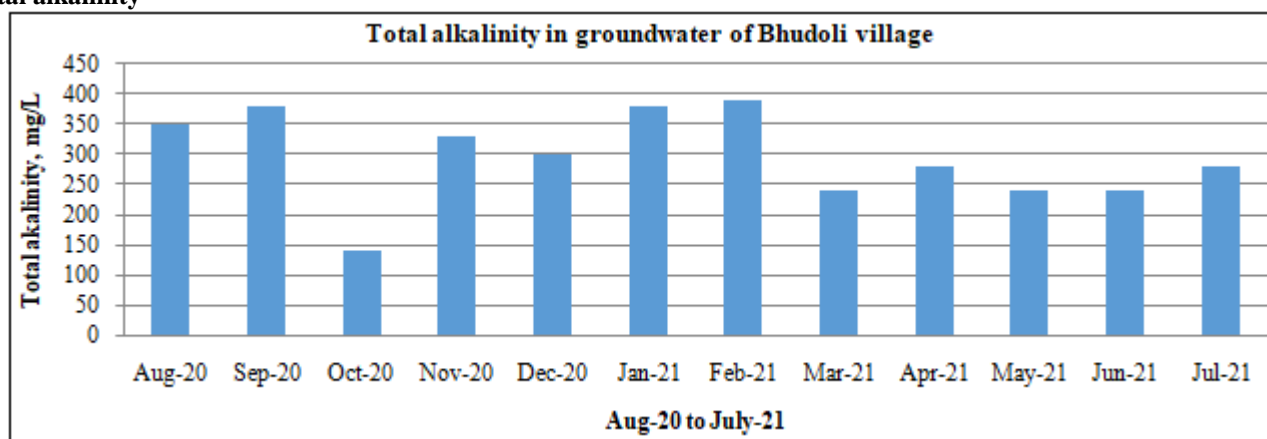


Figure 3: Total alkalinity in groundwater of Bhudoli village in Neemkathana block

Figure 3 shows that range for total alkalinity for the assessment period August 2020 to July 2021 is 140 mg/L-390 mg/L. The maximum 390 mg/L (as CaCO₃) is observed in the month of Feb -2021, and the minimum 140 mg/L is observed in the month of Oct-2020. The mean value for the assessment period of total alkalinity is 296 mg/L, and the standard deviation calculated is 74.64. The total alkalinity of groundwater in the Bhudoli village observed higher than the BIS (IS 10500: 2012) acceptable limit of 200 mg/L (as CaCO₃).

Total hardness

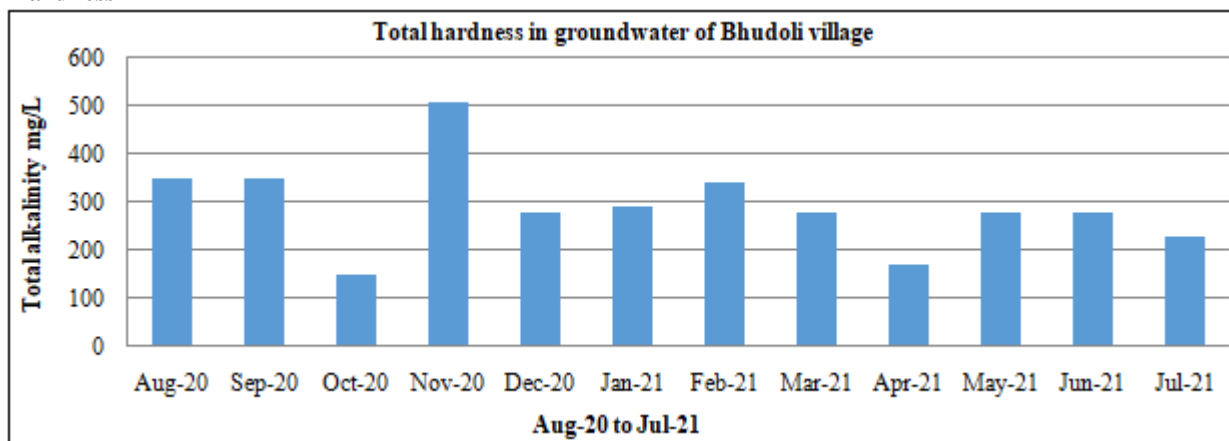


Figure 4: Total hardness in groundwater of Bhudoli village in Neemkathana block

Figure 4 shows that the total hardness (as CaCO₃) variation for the assessment period Aug-2020 to Jul-2021 is 150 mg/L-510 mg/L. The maximum 510 mg/L observed in the month of Nov-2020, and the minimum 150 mg/L is observed in the month of Oct-2020. The mean value is 292.50 mg/L, and the standard deviation calculated is 93.43. Total alkalinity of groundwater in the Bhudoli village observed higher than the BIS (IS 10500: 2012) acceptable limit of 200 mg/L (as CaCO₃).

Chloride

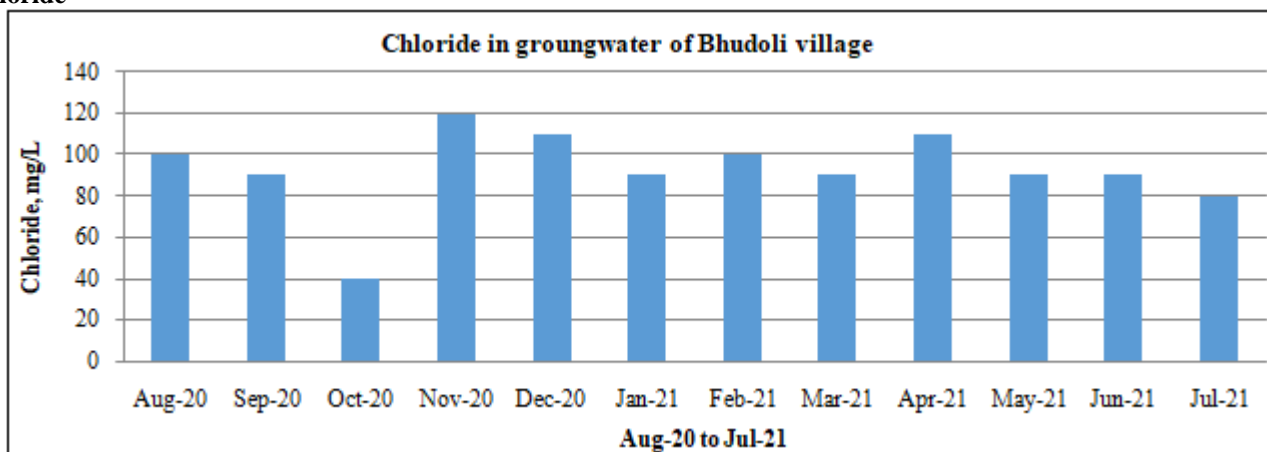


Figure 5: Chloride in groundwater of Bhudoli village in Neemkathana block

Figure 5 shows that the chloride concentration variation for the assessment period Aug-2020 to Jul-2021 is 40 mg/L-120 mg/L. The maximum 120 mg/L observed in the month of Nov-2020 and the minimum concentration 40 mg/L is observed in the month of Oct-2020. The mean value for the chloride concentration is 92 mg/L, and the standard deviation calculated is 20.06. Chloride concentration of groundwater in the Bhudoli village observed is within the BIS (IS 10500: 2012) acceptable limit of 250 mg/L.

Sulphate

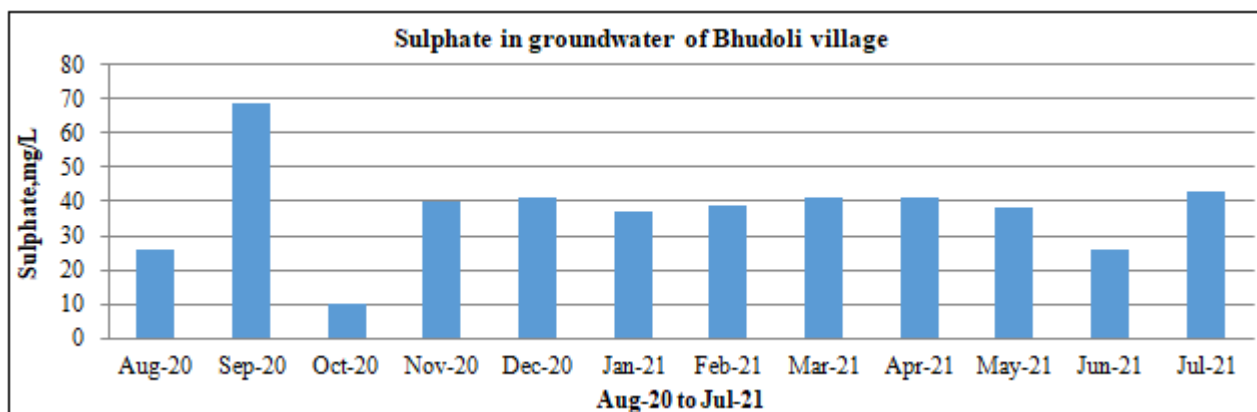


Figure 6: Sulphate in groundwater of Bhudoli village in Neemkathana block

Figure 6 shows that the sulphate concentration variation for the assessment period Aug-2020 to Jul-2021 is 10 mg/L-69 mg/L. The maximum 69 mg/L observed in the month of Sept-2020 and the minimum 10 mg/L is observed in the month of Oct-2020. The mean value for the assessment period is 37 mg/L, and the standard deviation calculated is 13.78. The sulphate concentration in groundwater of Bhudoli village is observed within the BIS (IS 10500: 2012) acceptable limit of 200 mg/L.

Nitrate

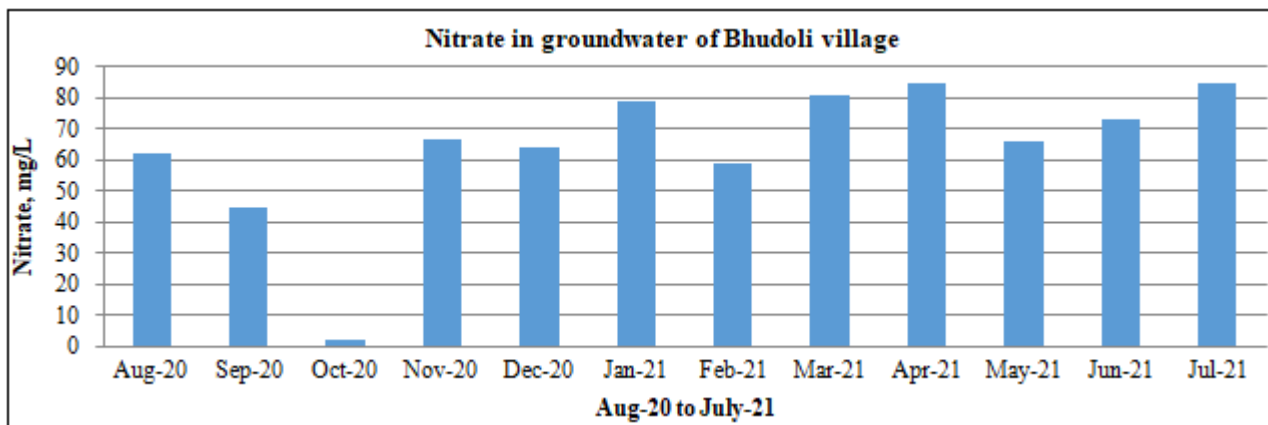


Figure 7: Nitrate in groundwater of Bhudoli village in Neemkathana block

Figure 7 shows that the nitrate concentration variation for the assessment period Aug-2020 to Jul-2021 is 2 mg/L-85 mg/L. The maximum 85 mg/L observed in the month of July-2021, and the minimum 2 mg/L observed in the month of Oct-2020. The mean value observed for nitrate is 64 mg/L, and the standard deviation calculated is 22.81. The nitrate concentration of groundwater in the Bhudoli village observed is much higher than the BIS (IS 10500: 2012) acceptable limit of 45 mg/L.

Fluoride

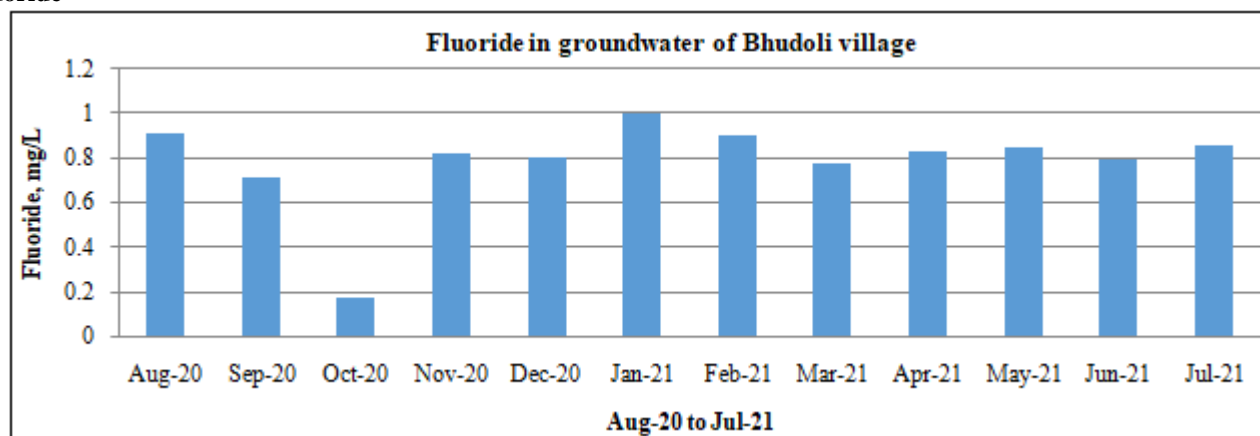


Figure 8: Fluoride in groundwater of Bhudoli village in Neemkathana block

Figure 8 shows that the fluoride concentration variation for the assessment period Aug-20 to Jul-21 is 0.17 mg/L -1.0 mg/L. A maximum 1.0 mg/L observed in the month of Jan-2021, and the minimum 0.17 mg/L is observed in the month of Oct-2021. The mean value of fluoride is 0.79 mg/L, and the standard deviation calculated is 0.21. The fluoride concentration in groundwater of the Bhudoli village observed is within the BIS (IS 10500: 2012) acceptable limit of 1.0 mg/L.

Total Dissolved Solids

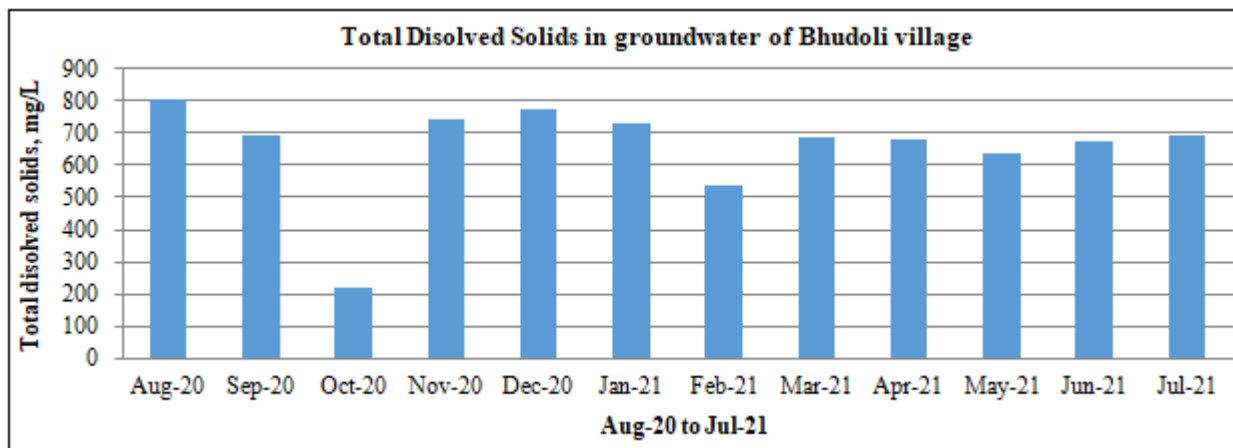


Figure 9: TDS in groundwater of Bhudoli village in Neemkathana block

Figure 9 shows that the Total Dissolved Solids (TDS) variation for the assessment period Aug-20 to Jul-21 is 220 mg/L-805 mg/L. The Maximum 805 mg/L observed in the month of Aug-2020 and the minimum 220 mg/L is observed in the month of Oct-2020. The mean value for the assessment period is 657 mg/L, and the standard deviation calculated is 153.35. Total Dissolved Solids (TDS) observed higher than the BIS (IS 10500: 2012) acceptable limit 500 mg/L.

Water Quality Index Bhudoli Village in Neemkathana

Water quality index value is calculated by the use of weighted arithmetic method for the groundwater samples collected from sample source of Bhudoli village. WQI and class of water are shown in table given below.

Table 5: Water Quality Index and Class of Bhudoli Village in Neemkathana

Water Quality Index and Class of Bhudoli Village in Neemkathana		
Month	Water Quality Index (WQI)	Water Quality Class (WQC)
Aug-20	52.90	Good Water
Sep-20	38.06	Excellent Water

Oct-20	15.96	Excellent Water
Nov-20	48.43	Excellent Water
Dec-20	47.06	Excellent Water
Jan-21	54.45	Good Water
Feb-21	52.96	Good Water
Mar-21	44.29	Excellent Water
Apr-21	45.71	Excellent Water
May-21	49.25	Excellent Water
Jun-21	44.43	Excellent Water
Jul-21	48.26	Excellent Water

The table 5 reveals that the water quality is good or excellent. The Good quality is observed in the months of August, January and February and observed Excellent in other months. It is observed that the quality is better and it is included in the high quality water villages.

Correlation Matrix for groundwater of Bhudoli village in Neemkathana block

Statistical assessment of groundwater with the use of Pearson’s correlation coefficient (r) for the parameters tested during the assessment period Aug-20 to July-21 for Bhudoli village and analysis is given below.

Table 6: Correlation Matrix for groundwater in Bhudoli Village

Correlation Matrix for groundwater in Bhudoli Village								
Parameter	pH	Total alkalinity	Total hardness	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	F ⁻	TDS
pH	1.000							
Total alkalinity	-0.248	1.000						
Total hardness	0.101	0.610	1.000					
Cl ⁻	-0.178	0.621	0.612	1.000				
SO ₄ ²⁻	-0.658	0.600	0.350	0.471	1.000			
NO ₃ ⁻	-0.495	0.353	0.161	0.662	0.367	1.000		
F ⁻	-0.318	0.711	0.431	0.758	0.441	0.859	1.000	
TDS	-0.431	0.596	0.503	0.805	0.522	0.779	0.842	1.000

Table 6 shows the Karl Pearson’s correlation coefficient for the groundwater parameters of Bhudoli. Groundwater of Bhudoli village do not show Perfect positive (r = 1), perfect negative (r = -1), and very high degree (r = 1- 0.9) positive/negative correlation. Some positive correlation coefficient of sufficiently high degree (r = 0.9-0.75) observed for Physico-chemical pair (TDS - Cl⁻), (Cl⁻ - F⁻), (TDS - NO₃⁻), (NO₃⁻ - F⁻), and (TDS - F⁻). Analysis of this trend reveals that TDS increase in groundwater is associated with nitrate, fluoride, and chloride shows that groundwater aquifer contains metamorphic rocks which contain more

soluble minerals having more fluoride. For the moderate degree of relationship, the value of Karl Pearson’s correlation coefficient should be in the range (0.75 -0.25). A moderate degree of positive relationship was observed for (Total alkalinity- F⁻), (Total alkalinity - TDS), (Total alkalinity–Total hardness), (Cl⁻-Total alkalinity), (Total alkalinity -NO₃⁻), (Total alkalinity - SO₄²⁻), (Total hardness - SO₄²⁻), (Total hardness - Cl⁻), (Total hardness - F⁻), (Total hardness -TDS), (SO₄²⁻ - Cl⁻), (NO₃⁻ - Cl⁻), (SO₄²⁻ - F⁻), (SO₄²⁻ -Cl⁻), and (SO₄²⁻ -TDS). For all the remaining pairs of parameters, shows the low degree of a correlation coefficient

observed means a slight change in one parameter of a pair has a very low impact on the concentration of another parameter of the pair, which may be negative or positive.

Aggressive Index For Groundwater Of Neemkathana Block

Table 7: Aggressive Index of groundwater of Neemkathana block

Aggressive Index of groundwater of Bhudoli village of Neemkathana block												
Month	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21
AI Value	13.19	12.32	12.62	13.23	12.92	12.54	13.32	12.43	12.08	12.83	12.43	12.41

Table 7 shows the Aggressive Index of groundwater of Bhudoli village, have the AI value more than 12 for the assessment period of Aug-20 -July 21.

4. Conclusion

Aggressive Index of groundwater is above 12 so it is non corrosive so can be stored and supplied through lead pipes. WQI values have impact of excess nitrate. The nitrate concentration of groundwater in the Bhudoli village observed is much higher than the BIS (IS 10500: 2012) acceptable limit of 45 mg/L. Total alkalinity, Total Dissolved Solids (TDS), Total alkalinity of groundwater also have more concentration than the acceptable limit of BIS. BIS have no permission limit for nitrate as it has more health effects like fluoride. Groundwater quality is continuously deteriorating due to anthropogenic and geogenic factors. It is suggested to the state government to take action regarding contamination of groundwater sources.

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Statistical assessment of groundwater with the use of Aggressive Index (AI) for the parameters tested during the assessment period Aug-20 to July-21 for selected village Bhudoli of Neemkathana block and analysis is given below.

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