

Physicochemical Characterization of Groundwater of Ankleshwar Industrial Estate, Bharuch District, Gujarat, India

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Abstract

The present study integrates the groundwater quality, hydrogeological characteristics, contaminant transport, and ecological and human health risk assessment of aquifers of industrial and peri-urban areas of Ankleshwar Industrial Estate, at Ankleshwar Taluka, Bharuch district, Gujarat. Groundwater quality has been determined by collecting 96 samples from April 2024 to March 2026 and subjecting to that comprehensive physico-chemical analysis, for calculating water quality index as per the weighted arithmetic method, parameter such as Colour, pH, Total Alkalinity (as CaCO₃), Ammonical Nitrogen, Electrical Conductivity, Chloride, Fluoride, Turbidity, Total Dissolved Solids, Nitrate, Sulphate, Calcium, Sodium, Potassium, Magnesium, Total Hardness, Nickel (as Ni), Copper (as Cu), Lead (as Pb), Total Arsenic (as As), Total Chromium (as Cr⁶⁺), Cadmium, Selenium, Mercury (as Hg), and Cobalt were considered. The study also shows that contamination of the groundwater has ecological and human health implications. No Samples were defined as excellent for human drinking purposes. . Thus groundwater at Ankleshwar is needs pre-treatment before drinking.

Keywords: Evaluation Method, physicochemical analysis, Water quality index, weighted arithmetic analysis

I. INTRODUCTION

The drinking water is an essential for every living creature on Earth. Surface water bodies are an easy source of water supply for drinking and domestic purposes after treatment, however nowadays they are also polluted due to untreated industrial effluent discharge into such water bodies, and which is directly and indirectly affects the groundwater qualities. Groundwater system of Vadodara showed comparatively high level of mineralization and ionic enrichment at Dudhwada-1 and Dudhwada-2. Poor groundwater quality was consistently reported in these areas indicating that groundwater flow pathways may allow dissolved contaminants to move and concentrate in the local groundwater. The chloride, total hardness, sulphate, magnesium, electrical conductivity and TDS concentrations are high, and strongly suggest high levels of dissolved ions. Anthropogenic inputs from industrial activities and peri-urban activities can be coupled with extended groundwater/rock interaction that may lead to such patterns. The spatial clustering of poor quality groundwater at certain sites also implies that low-lying areas, drainage pathways and local recharge areas could be preferential pathways for transport and accumulation of contaminants.

Many scholar has worked on these topics as **Farzana et al. (2025)** looked into the quality of groundwater in Ishwardi Upazila, a peri-urban area in Bangladesh, where there wasn't much previous data on drinking water safety. They gathered 35 samples from deep tube wells and tested for things like pH, EC, TDS, and various metals. Using atomic absorption spectroscopy, they found that levels of bicarbonate, iron, and manganese often went beyond the safe limits set by Bangladesh, **Ravi Kant Dubey et.al**, Ground Water Quality and Water Quality Index of Dwarka District of the National Capital of India. **Sridhar et al. (2025)** assessed the seasonal distribution, ecological hazards, and human health implications of uranium and associated heavy metals in groundwater throughout Krishnagiri district, Tamil Nadu, India. The research gathered 42 groundwater samples during the 2024 monsoon and 2025 post-monsoon periods, analyzing physicochemical parameters and elements including uranium, barium, beryllium, bismuth, cesium, copper, gallium, manganese, and strontium by ICP-OES methodology, **Singh et al. (2024)** assessed groundwater quality in the Bathinda area of Punjab, India, where extensive exploitation of groundwater has occurred due to intensive agricultural activities in the semi-arid region. The research evaluated the appropriateness of groundwater for potable use using the Drinking Water Quality Index and investigated non-carcinogenic health concerns linked to fluoride and nitrate exposure in adults and children by oral intake and cutaneous absorption, **Kaur et al. (2023)** analyzed groundwater quality and the pathways of nitrate and fluoride enrichment across various basins in Punjab,

India, utilizing 323 groundwater samples. The research employed hydrogeochemical modeling, graphical representations, multivariate statistics, an entropy-based water quality index, and Monte Carlo simulation to evaluate groundwater quality and associated health hazards, **Siganga (2023)** evaluated groundwater quality in the urban and peri-urban areas of Webuye, Bungoma County, Kenya. The research analyzed pollution determinants, water quality metrics, groundwater susceptibility, and the water quality index utilizing data on precipitation, land utilization, sanitary infrastructure, waste management, well conditions, water depth, and proximity to pollution sources. The results of the analysis had been used to suggest models for predicting water quality. The analysis revealed that the groundwater of the area needs some degree of treatment before consumption based on the WQI result.

II. METHODOLOGY.

simplest and easiest methods to evaluate the water quality condition is by using the water quality index. This procedure provides meaningful summaries of water quality data that are meaningful for both technical and non-technical individuals and organization interest in water quality results. The Water Quality Index is one of the easiest and most effective methods to communicate information on the groundwater quality to concerned citizens and policymakers. The groundwater quality index is the simplest number that expresses the overall quality of water of a certain location based on various water quality parameters. The water quality index was calculated using the weighted arithmetic index used by Sanjib Das et. al. (2014)

Arithmetic Procedure: Computation of the Water Quality Index is mainly done in five steps;

1- Each of the parameters is assigned a weightage factor (w_i) according to its relative importance in the overall quality of water for drinking purposes. The minimum weight of 1 has been assigned to the parameter acidity as it plays an insignificant role in the water quality assessment. Other parameters were assigned a weightage factor between 1 and 5 depending on their importance.

2- In the second step, relative weight (W_i) is computed from the following equation;

$$w_i$$

$$W_i = \frac{w_i}{\sum_{i=1}^N w_i} \quad N = \text{no of Parameter}$$

$$\sum_{i=1}^N w_i$$

3- In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each sample (C_i) by its respective standard (S_i) according to the guideline laid down in the BIS, and the resultant is multiplied by 100.

$$q_i = \frac{C_i}{S_i} \times 100$$

4- In this step, Sub index (SI) of its Parameter is calculated by the following equation;

$$SI = W_i \times q_i$$

5- Finally the water quality index (WQI) is calculated by adding all the sub Index of all parameters at a location,

$$WQI = \sum SI$$

III. RESULT

96 Samples collected between April 2024 to march 2026 from Ankleshwar Industrial Estate area, Ankleshwar Taluka, and later analyzed in NABL approved laboratory for their physico- chemicals parameters such Colour, pH, Total Alkalinity (as CaCO₃), Ammoniacal Nitrogen, Electrical Conductivity, Chloride, Fluoride, Turbidity, Total Dissolved Solids, Nitrate, Sulphate, Calcium, Sodium, Potassium, Magnesium, Total Hardness, Nickle (as Ni), Copper (as Cu), Lead (as Pb), Total Arsenic (as As), Total Chromium (as Cr⁶⁺), Cadmium, Selenium, Mercury (as Hg), and Cobalt, as result shown in the table below

Table 1: Test Parameter of Groundwater samples (March 2026)

Sr No	Parameter	Unit	Method	Water Paramaters as per 10500-2012/WHO	Bharuch toll Naka	Near Dhadhal area	Jetali	Aansar Market
1	Color	Pt Co Scale	APHA	5	16.32	17.29	31.00	18.23
2	pH	-	APHA	6.5- 8.5	7.55	7.47	7.83	8.27
3	Total Alkalinity (as CaCO ₃)	mg/L	APHA	200	220.00	1430.00	1720.00	1720.00
4	Ammonical Nitrogen	mg/L	USPEA	0.5	0.00	0.00	0.00	0.00
5	Electrical Conductivity	μS/cm	APHA	200–800 (μS/cm)	923.10	2631.40	6732.00	3197.40
6	Chloride	mg/L	APHA	250	27.99	344.89	1629.49	1629.49
7	Fluoride	mg/L	USPEA	1	0.00	0.00	0.00	0.00
8	Turbidity	NTU	APHA	1	0.10	0.10	0.20	0.10
9	Total Dissolved Solids	mg/L	APHA	500	475.00	1180.00	3400.00	1460.00
10	Nitrate	mg/L	USPEA	45	0.00	0.00	0.00	0.00
11	Sulphate	mg/L	APHA	200	32.56	196.80	426.40	146.40
12	Calcium	mg/L	In House	75	60.92	64.12	368.73	72.14
13	Sodium	mg/L	In House	20	50.10	242.20	340.90	262.60
14	Potassium	mg/L	In House	12	6.90	20.60	3830.80	26.30
15	Magnesium	mg/L	In House	30	67.06	48.60	262.44	75.33
16	Total Hardness	mg/L	In House	200	428.00	360.00	1999.00	490.00
17	Nickle (as Ni)	mg/L	In House	0.02	0.00	0.00	0.00	0.00
18	Copper (as Cu)	mg/L	In House	0.05	0.00	0.00	0.00	0.00

19	Lead (as Pb)	mg/L	In House	0.01	0.00	0.00	0.00	0.00
20	Total Arsenic (as As)	mg/L	In House	0.01	0.00	0.00	0.00	0.00
21	Total Chromium (as Cr6+)	mg/L	In House	0.05	0.00	0.00	0.00	0.00
22	Cadmium	mg/L	In House	0.003	0.00	0.00	0.00	0.00
23	Selenium	mg/L	In House	0.01	0.00	0.00	0.00	0.00
24	Mercury (as Hg)	mg/L	In House	0.001	0.00	0.00	0.00	0.00
25	Cobalt	mg/L	In House	0.05	0.00	0.00	0.00	0.00

Table 2: Water Quality Standard values and relatives weight of parameter.

Sr. No	Parameters	Standard (Si)	wi	Wi
1	Color	5	3	0.0222
2	pH@25C	6.5	4	0.0296
3	Total Alkalinity (as CaCO ₃)	200	3	0.0222
4	Ammonical Nitrogen	0.5	4	0.0296
5	Electrical Conductivity	800	2	0.0148
6	Chloride	250	5	0.0370
7	Fluoride	1	5	0.0370
8	Turbidity	1	1	0.0074
9	Total Dissolved Solids	500	5	0.0370
10	Nitrate	45	5	0.0370
11	Sulphate	200	4	0.0296
12	Calcium	75	2	0.0148
13	Sodium	20	2	0.0148
14	Potassium	12	2	0.0148
15	Magnessium	30	2	0.0148
16	Total Hardness	200	2	0.0148
17	Nickle (as Ni)	0.02	4	0.0296
18	Copper (as Cu)	0.05	4	0.0296
19	Lead (as Pb)	0.01	4	0.0296
20	Total Arsenic (as As)	0.01	5	0.0370
21	Chromium (as Cr6+)	0.05	4	0.0296
22	Cadmium	0.003	4	0.0296
23	Selenium	0.01	4	0.0296
24	Mercury (as Hg)	0.001	4	0.0296
25	Cobalt	0.05	5	0.0370

Table 3: Location Wise Sample's Water Quality Index (96 Nos Samples Ankleshwar Estate)

Sr. No.	Sample Location	Year 2024-2025					Year 2025-2026				
		Excellent	Good	Poor	Very Poor	Unsuitable	Excellent	Good	Poor	Very Poor	Unsuitable
1	Bharuch Toll Naka	0	3	0	0	9	0	3	0	0	9
2	Dadhal Village	0	0	2	4	6	0	1	2	3	6
3	Jetali Road Village	0	0	0	1	11	0	0	0	0	12
4	Ansar Market	0	0	3	6	2	0	0	7	4	1

Table 4: Water Quality Index for Drinking Purposes (Complete collected samples)

Description of Water Quality Index		Year 2024-2025			Year 2025-2026		
		Total Sample	Sample Result %	Remarks	Total Sample	Sample Result %	Remarks
Excellent (0–25):	Highest quality, suitable for all drinking purposes.	0	0.000%	NO sample selected for drinking purposes	0	0.000%	NO sample selected for drinking purposes
Good (26–50):	Slight pollution, acceptable for drinking and domestic use.	3	6.250%	6.25 % is the permissible limit as per BIS	4	8.333%	8.33 % is the permissible limit as per BIS
Poor (51–75):	Moderately polluted, requires treatment before consumption.	6	12.500%	12.50 % RO/ or other kind of treatment before drinking	9	18.750%	18.750 % RO/ or other kind of treatment before drinking
Very Poor (76–100):	Heavily polluted, not recommended for human consumption.	11	22.917	22.917 % not recommended for drinking at all	7	14.583%	14.583 % not recommended for drinking at all
Unsuitable (>100):	Excessively polluted, hazardous, and unsuitable for drinking	28	58.333	58.333 % Sample are highly polluted	28	58.333%	58.333 % Sample are highly polluted
Total 96 Nos Samples Collected		48	100%		96	100%	

IV. DISCUSSION

The results of the present study have significant implications on groundwater management in the Ankleshwar Industrial Estate area. Results from 96 groundwater samples taken during two years of sampling show that groundwater degradation occurs in a spatially variable and long-term manner. The majority of the samples (58.333%) were unsuitable for potable use as per Water Quality Index (WQI) and none of the samples were recorded as an excellent quality. While the highest level of deterioration was noted in during month of Apr to Jun of both years.

V. CONCLUSION

The study also underlines the importance of risk based groundwater use management. The use of untreated groundwater from identified hotspot areas is not recommended for direct drinking water supplies as a significant percentage of groundwater samples were found to be unsuitable for direct use and several toxic metals were found above their respective reference values. Treatment technologies should be determined by the contaminant profile found at each site. For instance, desalination, reverse osmosis, may be suitable when water quality of the groundwater has high TDS content and high salinity, and softening may be needed when the water quality of the groundwater is highly hard. If heavy metal contamination is present, appropriate adsorption, membrane, and/or precipitation options may be necessary. Importantly, communities relying on groundwater should have access to alternative safe water supplies where treatment is technically and/or economically challenging.

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VIII. CONFLICT OF INTEREST

The Author declare declares no conflict of interest.

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