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Determination of Water Quality Index and Suitability of Groundwater at Dudhwada Village at Padra Industrial Area, Vadodara, Gujarat

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Abstract—**The approach of the study is to calculate the water quality index of the peri-urban area in seasonal basis of Vadodara district to ensure the utilization of groundwater for domestic, agricultural, and industrial purposes. The focus of study the deal with environmental parameters of groundwater at this area. We are various approach to assess the water quality of groundwater and its suitability based on the results obtained. In this study, various parameters were assessed for evaluating the groundwater quality include Colour, pH, Total Alkalinity (as CaCO3), Ammonical 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.**

Index Terms—**Water Quality Index, seasonal variance, Aquifers, Peri-urban, groundwater**

I. INTRODUCTION

Water is a useful resource for every living creature on Earth. Water is the most distinctive feature and a necessity for everyone. Water is required for every activity, from drinking to agriculture and industrialization. In India, groundwater is the single largest source of drinking water and is withdrawn from various sources like wells, tube wells, hand pumps, and submersible pumps. This is easily reachable and accessible, and is considered less polluted as compared to surface water like ponds, rivers, lake, canals, and other manmade reservoir, however, cleaning groundwater is more difficult compared to surface water once contaminated as required a lot of resources and expenses. Water demand is increasing day by day due to urbanization, infrastructure development, industrialization, population growth, and agricultural activity, which

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directly impacts the exploitation of groundwater. Disposal of untreated sewage in the soak pit in the urban area directly impacts the groundwater, and small-scale industries are releasing the untreated effluent on bare land, which is later mixed with rainwater and recharges the groundwater. Based on various studies, heavy metals are carcinogenic as they create various health-related issues in persons once injected through water or the food chain, and long-term exposure causes issues related to the kidney, liver, nervous system, and cancer. In the past, researchers have verified the use of groundwater quality for the detection WQI, which provides the overall pollution level of groundwater aquifers.

II. MATERIAL AND METHOD

During the study, Dudhawada villages were selected for seasonal variation. The current study aims to evaluate groundwater samples from the selected area and verify the WQI. Padra, Karkhadi, and Jambusar are the oldest GIDCs in the Vadodara region. Various industries are situated in the nearby Dudhawada village, including chemicals, pharmaceuticals, agrochemicals, and pigments. Groundwater used by villagers for agriculture activity is having red color and pageant smell, along with various significant issues. The water used by the public in the study region for different purposes is polluted, and the public is experiencing severe health issues. As a result, this study aims to provide an overview of actual groundwater quality. Measurements of quantitative parameters in groundwater serve as a milestone to address basic environmental problems based on the IS standard/ WHO. Various researchers' assessments of groundwater quality in peri-urban areas revealed that very little work has been done on pollution indices, so this study aims to evaluate the groundwater quality at the sampling area using HPI.
Groundwater quality has been determined by collecting 48 samples in the Peri-urban area of the Vadodara region, for example, from April 2024 to March 2026; however, changes are shown for seasonal basis only. Samples were collected in 1.0-liter clean sample bottles, with proper details like name, location, date, and other necessary information, and analysis was performed at an NABL-approved laboratory according to APHA 23rd Edition

III. LITERATURE REVIEW

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 hydro-geochemical modeling, graphical representations, multivariate statistics, an entropy-based water quality index, and Monte Carlo simulation to evaluate groundwater quality and associated health hazards

IV. METHODOLOGY

One of the simplest 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 groundwater quality to the concerned citizens and policymakers. It thus becomes an important parameter for the assessment of groundwater quality. 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 (wi) 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 (Wi) is computed from the following equation;

$$Wi = \frac{wi}{\sum_{ni=l} Wi} \qquad N = \text{no of Parameter}$$

3- In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each sample (Ci) by its respective standard (Si) 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 each 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-indices of all parameters at a location,

$$WQI = \sum SI$$

Table 1 Water Quality Index (WQI) and Status of Groundwater Quality (Chatterjee and Raziuddin 2002)

Table 1: Drinking water standard 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

V- RESULTS AND DISCUSSION

A total of 48 Samples collected between April 2024 to march 2026 from two locations of Dudhawada village, Vadodara district and later analyzed in an NABL-approved laboratory for their physicochemical parameters including Colour, pH, Total Alkalinity (as CaCO3), Ammonical 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. Based on the calculation method of the WQI, groundwater sample were failed and need treatment for using any kind of application.

Table 2: Seasonal variation of the physicochemical parameters of the water body

Sr. No	Parameters	Summer Season (May' 2025)	Rainy Season (August' 26)	Winter Season (October' 26)
1	Color	4434.00	3278.00	4231.00
2	pH@25C	6.73	6.98	6.70
3	Total Alkalinity (as $CaCO_3$)	255.73	215.23	265.67
4	Ammonical Nitrogen	8.02	9.24	8.25
5	Electrical Conductivity	8543.23	7897.34	8609.28
6	Chloride	2897.67	2897.23	2886.78
7	Fluoride	0.00	0.00	0.00
8	Turbidity	54.27	51.45	56.78
9	Total Dissolved Solids	4048.49	3978.28	4232.45
10	Nitrate	0.00	0.00	0.00
11	Sulphate	582.96	531.23	576.89
12	Calcium	244.76	216.56	245.49
13	Sodium	497.45	523.43	496.67
14	Potassium	53.89	54.78	54.56
15	Magnessium	621.77	627.38	618.78
16	Total Hardness	3186.78	3276.34	3278.00
17	Nickle (as Ni)	0.03	0.03	0.00
18	Copper (as Cu)	0.63	0.53	0.59
19	Lead (as Pb)	0.01	0.01	0.00
20	Total Arsenic (as As)	0.17	0.16	0.00
21	Chromium (as Cr6+)	0.01	0.02	0.15
22	Cadmium	0.00	0.00	0.00
23	Selenium	0.00	0.00	0.05
24	Mercury (as Hg)	0.00	0.00	0.00
25	Cobalt	0.00	0.00	0.05

Table 3: Calculation of Water Quality Index in Summer Season

Parameter	Standard (Si)	Dudhwada Result (ci)	wi	Wi	qi=ci/Si*100	SI=Wi* qi
Color	5	4434.00	3	0.0222	88680.000	1970.667
pH@25C	6.5	6.73	4	0.0296	103.538	3.068
Total Alkalinity (as $CaCO_3$)	200	255.73	3	0.0222	127.865	2.841
Ammonical Nitrogen	0.5	8.02	4	0.0296	1604.000	47.526
Electrical Conductivity	800	8543.23	2	0.0148	1067.904	15.821
Chloride	250	2897.67	5	0.0370	1159.068	42.928
Fluoride	1	0.00	5	0.0370	0.000	0.000
Turbidity	1	54.27	1	0.0074	5427.000	40.200
Total Dissolved Solids	500	4048.49	5	0.0370	809.698	29.989
Nitrate	45	0.00	5	0.0370	0.000	0.000
Sulphate	200	582.96	4	0.0296	291.480	8.636
Calcium	75	244.76	2	0.0148	326.347	4.835
Sodium	20	497.45	2	0.0148	2487.250	36.848
Potassium	12	53.89	2	0.0148	449.083	6.653
Magnessium	30	621.77	2	0.0148	2072.567	30.705
Total Hardness	200	3186.78	2	0.0148	1593.390	23.606
Nickle (as Ni)	0.02	0.03	4	0.0296	164.000	4.859
Copper (as Cu)	0.05	0.63	4	0.0296	1260.000	37.333
Lead (as Pb)	0.01	0.01	4	0.0296	124.000	3.674
Total Arsenic (as As)	0.01	0.17	5	0.0370	1690.000	62.593
Chromium (as Cr6+)	0.05	0.01	4	0.0296	25.600	0.759
Cadmium	0.003	0.00	4	0.0296	0.000	0.000
Selenium	0.01	0.00	4	0.0296	0.000	0.000
Mercury (as Hg)	0.001	0.00	4	0.0296	0.000	0.000
Cobalt	0.05	0.00	5	0.0370	0.000	0.000
Water Quality Index of Summer Season:						2373.541

Table 4: Calculation of Water Quality Index in Rainy Season

Parameter	Standard (Si)	Dudhwada Result (ci)	wi	Wi	qi=ci/Si*100	SI=Wi* qi
Color	5	3278.00	3	0.0222	65560.000	1456.889
pH@25C	6.5	6.98	4	0.0296	107.385	3.182
Total Alkalinity (as $CaCO_3$)	200	215.23	3	0.0222	107.615	2.391

Ammonical Nitrogen	0.5	9.24	4	0.0296	1848.000	54.756
Electrical Conductivity	800	7897.34	2	0.0148	987.168	14.625
Chloride	250	2897.23	5	0.0370	1158.892	42.922
Fluoride	1	0.00	5	0.0370	0.000	0.000
Turbidity	1	51.45	1	0.0074	5145.000	38.111
Total Dissolved Solids	500	3978.28	5	0.0370	795.656	29.469
Nitrate	45	0.00	5	0.0370	0.000	0.000
Sulphate	200	531.23	4	0.0296	265.615	7.870
Calcium	75	216.56	2	0.0148	288.747	4.278
Sodium	20	523.43	2	0.0148	2617.150	38.773
Potassium	12	54.78	2	0.0148	456.500	6.763
Magnessium	30	627.38	2	0.0148	2091.267	30.982
Total Hardness	200	3276.34	2	0.0148	1638.170	24.269
Nickle (as Ni)	0.02	0.03	4	0.0296	156.000	4.622
Copper (as Cu)	0.05	0.53	4	0.0296	1064.000	31.526
Lead (as Pb)	0.01	0.01	4	0.0296	122.000	3.615
Total Arsenic (as As)	0.01	0.16	5	0.0370	1580.000	58.519
Chromium (as Cr6+)	0.05	0.02	4	0.0296	33.400	0.990
Cadmium	0.003	0.00	4	0.0296	0.000	0.000
Selenium	0.01	0.00	4	0.0296	0.000	0.000
Mercury (as Hg)	0.001	0.00	4	0.0296	0.000	0.000
Cobalt	0.05	0.00	5	0.0370	0.000	0.000
Water Quality Index of Rainy Season:						1854.550

Table 5: Calculation of Water Quality Index in Winter Season

Parameter	Standard (Si)	Dudhwada Result (ci)	wi	Wi	qi=ci/Si*100	SI=Wi* qi
Color	5	4231.00	3	0.0222	84620.000	1880.444
pH@25C	6.5	6.70	4	0.0296	103.077	3.054
Total Alkalinity (as $CaCO_3$)	200	265.67	3	0.0222	132.835	2.952
Ammonical Nitrogen	0.5	8.25	4	0.0296	1650.000	48.889
Electrical Conductivity	800	8609.28	2	0.0148	1076.160	15.943
Chloride	250	2886.78	5	0.0370	1154.712	42.767
Fluoride	1	0.00	5	0.0370	0.000	0.000
Turbidity	1	56.78	1	0.0074	5678.000	42.059

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Total Dissolved Solids	500	4232.45	5	0.0370	846.490	31.351
Nitrate	45	0.00	5	0.0370	0.000	0.000
Sulphate	200	576.89	4	0.0296	288.445	8.547
Calcium	75	245.49	2	0.0148	327.320	4.849
Sodium	20	496.67	2	0.0148	2483.350	36.790
Potassium	12	54.56	2	0.0148	454.667	6.736
Magnessium	30	618.78	2	0.0148	2062.600	30.557
Total Hardness	200	3278.00	2	0.0148	1639.000	24.281
Nickle (as Ni)	0.02	0.00	4	0.0296	0.000	0.000
Copper (as Cu)	0.05	0.59	4	0.0296	1186.000	35.141
Lead (as Pb)	0.01	0.00	4	0.0296	0.000	0.000
Total Arsenic (as As)	0.01	0.00	5	0.0370	0.000	0.000
Chromium (as Cr6+)	0.05	0.15	4	0.0296	290.000	8.593
Cadmium	0.003	0.00	4	0.0296	0.000	0.000
Selenium	0.01	0.05	4	0.0296	456.000	13.511
Mercury (as Hg)	0.001	0.00	4	0.0296	0.000	0.000
Cobalt	0.05	0.05	5	0.0370	95.200	3.526
Water Quality Index of Winter Season:						2239.991

VI. CONCLUSION

Water Quality Index		Outcome of Sample
Excellent (0–25):	Highest quality, suitable for all drinking purposes.	0
Good (26–50):	Slight pollution, acceptable for drinking and domestic use.	0
Poor (51–75):	Moderately polluted, requires treatment before consumption.	0
Very Poor (76–100):	Heavily polluted, not recommended for human consumption.	0
Unsuitable (>100:	Excessively polluted, hazardous, and unsuitable for drinking	3

The analysis result indicates that the quality of Dudhawada villages is highly polluted and requires strict regulatory action to prevent further pollution. Almost every parameters are above the prescribed limit by the WQI as BIS, As the rapid growth of industrialization in said region required proper treatment of effluent at industry side and further secondary treatment by Government common effluent treatment plant for further treatment before release to deep sea.

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