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PIG: A NUMERICAL INDEX FOR DISSEMINATION OF GROUNDWATER CONTAMINATION ZONES OF RURAL AREA OF JODHPUR, RAJASTHAN (INDIA)

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ABSTRACT

To evaluate water contamination, a pollution index of groundwater (PIG) is proposed. The PIG assesses the state of water quality measure concentrations in relation to the respective drinking water quality requirements. The validity of the proposed index was confirmed by selecting data on groundwater quality in the rural area of Jodhpur, Rajasthan. The calculated index from the research area ranges from 0.186 to 2.126. The indicator categorizes pollution levels as inconsequential (PIG: <1.0), low (PIG: 1.0 to 1.5), moderate (PIG: 2.0 to 2.5), and very high (PIG: > 2.5) **[1]**.

Keywords: Pollution index of groundwater, water contamination, Groundwater quality

INTRODUCTION

Earth is often referred to as the "Blue Planet" and the "Wet Planet." Seas cover most of the Earth's surface, as viewed from orbit by an astronaut gazing down. Water covers more than 70% of the world's surface, with 20% freshwater and 97.3% ocean. Water flows continuously between the Earth and the atmosphere. As a result, it is part of the "Hydrological Cycle." Water is a necessary component of our life support system. When it comes to the variable and growing contamination of groundwater in tropical regions, groundwater is crucial **[2]**.

Groundwater is the primary source of drinking water in most parts of India. It supplies approximately 88% of the clean drinking water in rural regions where the population is dispersed and the infrastructure necessary for the treatment and transportation of surface water is limited **[3]**.

The quality of groundwater in a certain location is determined by physical, chemical, and microbiological parameters **[4]**. Geological elements such as artificial activities such as agricultural practices and the rise of urban industrial complex **[5-6]**. Control the development and quality of groundwater. Groundwater quality, on the other hand, has an impact on human health and societal well-being **[7]**.

According to the World Health Organization (WHO), the majority (80%) of human illnesses worldwide are caused by contaminated water **[8, 9]**. Furthermore, low irrigation water quality degrades the physical characteristics of the soil, thereby affecting crop production **[10]**. As a result, assessing groundwater health is critical for identifying primary groundwater pollutants. This will allow planners and other stakeholders to take the necessary steps to ensure groundwater quality for human consumption and other purposes **[11]**.

Groundwater is essential in agriculture for the irrigation of crops cultivated during the dry season and crop watering. Groundwater sources, according to estimates, contribute approximately 45% of the irrigation water required. Because of rapid population growth and urbanization, groundwater quality is increasingly threatened by agricultural pesticides and the dumping of municipal and industrial pollutants.

Pollution that enters the subsurface environment may lie undiscovered for many years before being distributed across significant areas of the groundwater aquifer and rendering the groundwater resources unsuitable for human consumption and other purposes, according to estimates.

There has been relatively little systematic study on the effects of fluoride on plants in India. The effect of fluoride applied to soil and sprayed onto plant leaves on various Eco physiological and biochemical parameters in plants must be extensively and methodically investigated. Because of the harmful impacts of nitrate contamination in water, authorities in various countries have set limits for nitrate levels in drinking water. The primary concern with fertilizer application in this area has been identified as the rapid transfer of dissolved nitrates into the groundwater table and subsequent pollution of this water source. This has many health consequences, including an increase in neonatal mortality **[12]**.

METHODOLOGY

Sampling techniques: Twenty water samples were collected from various sites across the Jodhpur region. These water sources are commonly used in the home, including for drinking. A composite sampling technique **[13]** was used to collect water samples from a specific location.

All samples were collected in high-density polypropylene vials. In all cases, the plastic bottles were properly sterilized. Bottles were cleaned with diluted nitric acid first and then with double-distilled water before being used to collect samples.

The research used analytical reagent (AR) grade chemicals. Proper procedures and approaches have been employed for collection, preservation, analysis, and interpretation **[14]**.

Figure 1: Map Shows India, Rajasthan locating Jodhpur [15]

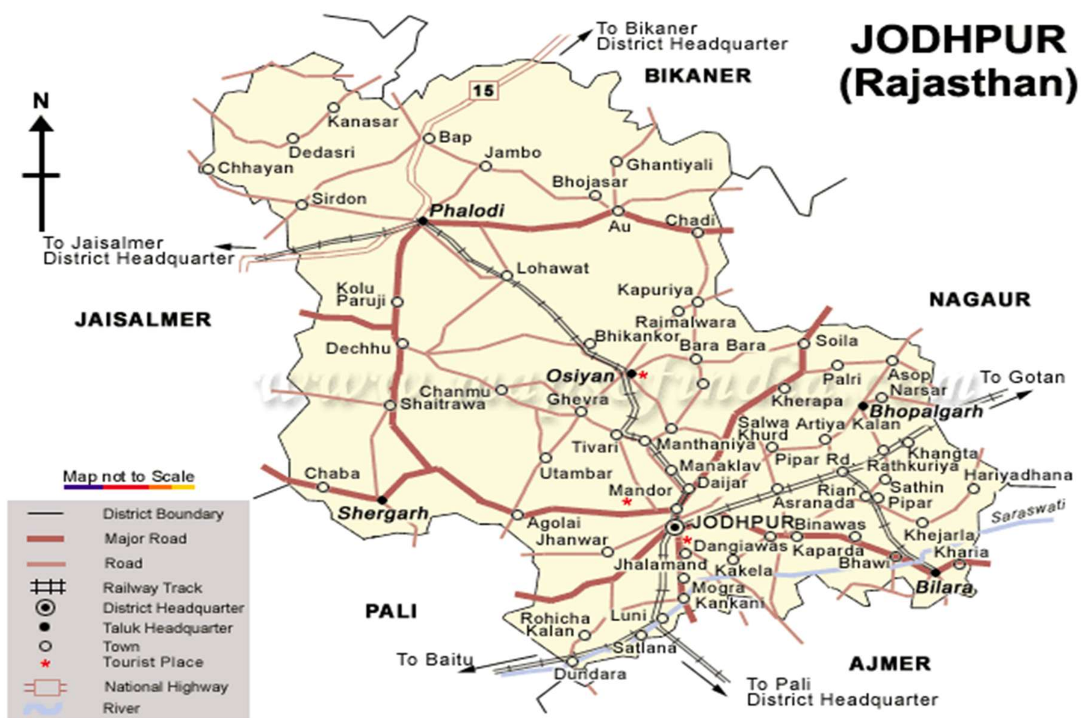

Figure 2: Map of Jodhpur district [15]

Figure 3: Map showing the sample stations of 20 different places [16]

ANALYSIS METHOD

Pollution Index of Groundwater

The groundwater pollution index is a numerical scale that quantifies the level of contamination. This indicates the combined effect of different water quality measures on drinking water quality. The algorithm for computing the PIG is as follows

Step I: Relative weight

A relative weight (Rw) for each water quality measure is allotted, considering its impact on human health. The range of the numerical magnitude of Rw is between 1 and 5. For example, the value of 5 of Rw is assigned to pH, TDS, SO_4^{2-}, NO_3^- and F^- ,4 to Na^+ and Cl^-, 3 to HCO_3^- ; 2 to Ca^{2+} and Mg^{2+}; and 1 to K^+ **(Table 1)**. A minimum Rw value of 1 corresponds to the lowest significant role, whereas a maximum Rw value of 5 reflects the highest significant role in health **[17]**.

Step II: Weight parameter

To compute the exact impact of each water quality measure on overall water quality **(Table 1)**, the weight parameter (Wp) for each water quality measure is established. [Equation (1)]. It is the ratio of each water quality measure's Rw to the total of all relative weights (∑ Rw) **[18]**.

$$\mathbf{Wp} = \frac{\mathbf{Rw}}{\sum \mathbf{Rw}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Table 1: The relative weight (Rw) and weight parameter (Wp) of each parameter with the standard values reported by WHO [19]

Water Quality Parameter (mg/l)	Guideline values	Relative weight (Rw)	Parameter weight (Wp)
K^+	12	1	0.0357
Mg^{2+}	150	2	0.0714
Ca^{2+}	200	2	0.0714
Cl^-	200	4	0.1428
Na^+	145	4	0.1428
SO_4^{2-}	400	5	0.1786
TDS	500	5	0.1786
NO_3^-	45	5	0.1786
SUM (∑)		28	

Step III: Status of concentration

The concentration (Sc) of the water quality measure of each water sample is evaluated in relation to its drinking water quality standard [Equation (2)]. Sc is calculated by dividing the concentration (C) of each water quality indicator in a water sample by the drinking water quality standard (Ds).

$$Sc = \frac{C}{Ds} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Table 2: Status of concentration (Sc)

Sr. No.	TDS	K^+	Ca^{2+}	Mg^{2+}	Na^+	SO_4^{2-}	Cl^-	NO_3^-
S1	0.558	0.016	0.083	0.049	0.268	0.021	0.231	7.755
S2	0.416	0.01	0.021	0.0144	0.246	0.008	0.128	5.888
S3	0.482	0.011	0.01	0.016	0.289	0.009	0.14	6.422
S4	0.904	0	0.021	0.011	0.046	0	0.025	0.333
S5	0.31	0.008	0.068	0.005	0.088	0.006	0.084	6.266
S6	0.27	0.008	0.008	0.012	0.06	0.006	0.058	0.777
S7	0.678	0.016	0.13	0.106	0.328	0.036	0.329	4.644
S8	0.766	0.016	0.2	0.128	0.236	0.039	0.35	8.466
S9	0.328	0.012	0.01	0.012	0.214	0.007	0.147	2.533
S10	0.622	0	0.031	0.008	0.019	0	0.026	0.355
S11	0.22	0	0.034	0.01	0.092	0.005	0.071	1.511
S12	0.48	0.01	0.058	0.002	0.248	0.013	0.167	1.111
S13	0.35	0.008	0.051	0.016	0.087	0.008	0.129	1.133
S14	1.112	0	0.036	0.009	0.04	0	0.051	4.244
S15	0.502	0.012	0.08	0.018	0.148	0.012	0.147	11.11
S16	1.082	0	0.035	0.006	0.042	0	0.049	1.066
S17	0.22	0	0.028	0.004	0.105	0	0.08	1.066
S18	0.958	0	0.01	0.013	0.051	0	0.023	0.488
S19	1.096	0	0.016	0.006	0.044	0	0.024	0.622
S20	0.434	0.008	0.013	0.049	0.193	0.007	0.124	2.866

Step IV: Overall water quality

To calculate the overall water quality, multiply the Wp of each water quality metric by the corresponding Sc [Ow; Equation (3)]. This indicates the number of times Wp is increased in relation to the concentration of each water quality metric **(Table 3)**.

$$Ow = Wp \times Sc \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Step V: Pollution index of groundwater

The groundwater contamination index is calculated [Equation (4)] by summing all values of Ow supplied by all water quality measurements of each water sample (Ow, **Table 3**).

$$PIG = \sum Ow \quad \ldots\ldots\ldots (4)$$

Table 3: Discrimination of Jodhpur Region Samples into Graded Pollution Zone, Using the Pollution Index of Groundwater (PIG)

Sr. No.	TDS	K^+	Ca^{2+}	Mg^{2+}	Na^+	SO_4^{2-}	Cl^-	NO_3^-	PIG
OW1	0.099	0.005	0.005	0.003	0.038	0.003	0.032	1.385	1.57
OW2	0.074	0.003	0.001	0.001	0.035	0.001	0.018	1.051	1.184
OW3	0.086	0.003	0.007	0.001	0.041	0.001	0.019	1.146	1.304
OW4	0.161	0	0.001	0.007	0.006	0	0.003	0.059	0.237
OW5	0.055	0.002	0.004	0.003	0.012	0.001	0.011	1.119	1.207
OW6	0.048	0.002	0.005	0.008	0.008	0.001	0.008	0.138	0.218
OW7	0.121	0.005	0.009	0.007	0.046	0.006	0.046	0.829	1.069
OW8	0.136	0.005	0.014	0.009	0.033	0.006	0.049	1.512	1.764
OW9	0.058	0.004	0.007	0.008	0.03	0.001	0.02	0.452	0.58
OW10	0.111	0	0.002	0.005	0.002	0	0.003	0.063	0.186
OW11	0.039	0	0.002	0.007	0.013	0.008	0.01	0.269	0.348
OW12	0.085	0.003	0.004	0.001	0.035	0.002	0.023	0.198	0.351
OW13	0.062	0.002	0.003	0.001	0.012	0.001	0.018	0.202	0.301
OW14	0.198	0	0.002	0.006	0.005	0	0.007	0.757	0.975
OW15	0.089	0.004	0.005	0.001	0.021	0.002	0.02	1.984	2.126
OW16	0.193	0	0.002	0.004	0.005	0	0.006	0.19	0.4
OW17	0.039	0	0.001	0.002	0.014	0	0.011	0.19	0.257
OW18	0.171	0	0.007	0.009	0.007	0	0.003	0.087	0.284
OW19	0.195	0	0.001	0.004	0.006	0	0.003	0.111	0.32
OW20	0.077	0.002	0.009	0.003	0.027	0.001	0.017	0.511	0.647

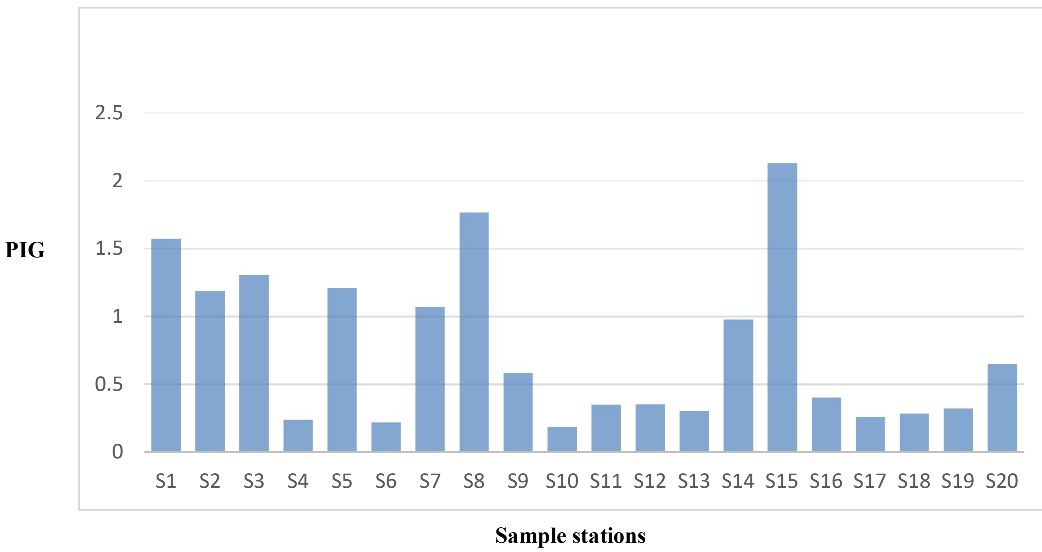

Figure 4: Bar graph indicates the value of PIG with sample stations

Step VI: Classification of PIG

If the concentrations of water quality parameters in a given water sample are the same as those in drinkable water, the health effects of such water quality may be insignificant. Considering this, the calculated value of PIG for such water quality is 1.0. Therefore, if PIG is less than 1.0, it may be regarded as a non-pollution index; however, if it is greater than 1.0, it can be considered the contribution of increased concentrations of water quality measurements into groundwater caused by pollution entering an aquifer. Knowledge base for the intensity of the PIG.

Table 4: Quality index of pollution with respect to PIG Value

Range	Quality
PIG < 1.0	Insignificant pollution
1.0< PIG < 1.5	Low pollution
1.5 < PIG < 2.0	Moderate pollution
2.0 < PIG < 2.5	High pollution
PIG > 2.5	Very High pollution

If Ow is greater than 0.1 (which is 10% of the value of 1.0 for PIG), the relative contribution of the concentration of the water quality measure of each water sample is considered. This provides a clear picture of the effects of contamination on the groundwater system. If several water quality measures are taken using this approach, the value of PIG is 1.0 because the categorization of PIG is dependent on the water quality requirements authorized for drinking purposes. As a result, the categorization of PIG would be the same for each test area's evaluation of groundwater pollution.

RESULTS

Table 5 lists the physicochemical parameters. TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, and NO_3^- were among them, and the mean concentrations of significant cation and anion ions were in the order NO_3^- >TDS > Na^{+} > Cl^{-} > Ca^{2+} > Mg^{2+} > SO_4^{2-} > K^{+}. PIG Groundwater Quality Assessment the PIG is a trustworthy index for assessing groundwater wells in the research region. This index **[20]** was calculated using physicochemical variables.

The computed values of the groundwater contamination index varied from 0.186 to 2.126. According to the PIG value assessment, 65%, 20%, 10%, and 5% of the groundwater samples fell into the Insignificant pollution, Low, Moderate, and High pollution categories, with no extremely high pollution **[21]**.

This value (Ow) is regarded as a contributor to groundwater contamination by each parameter. As a result, the bigger the value of Ow, the greater its contribution. **Table 3** shows that the ions Nitrate and TDS have the greatest influence on the value of Ow, and hence these two parameters were the major contributors to groundwater contamination among other ions. Sulfate and potassium ions, on the other hand, contribute the least to pollution **[22]**.

CONCLUSION

The Jodhpur region has been selected as the site for a case study to distribute groundwater pollution zones utilizing the proposed PIG. This is a basic universal categorization tool for explaining the state of water quality measure concentrations about the water quality standard allowed for consumption. The recommended index based on the research field ranges from 0.186 to 2.126. The geochemical ratios of Na^{+}: Cl^{-}, HCO_3^- Cl^{-},

Na^{+}: Ca^{2+}, and Mg^{2+}: Ca^{2+} support this. As the index is confirmed, the study sheds light on the need to implement corrective actions at every given location to limit polluting activities.

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