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Groundwater Quality Index of Dheku River Basin of Maharashtra, India: A Mathematical Approach

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ABSTRACT

An attempt has been made to calculate the Groundwater Quality Index (GWQI) of Dheku river basin in order to assess its suitability for drinking purposes. Samples were assessed for twelve physico-chemical parameters namely pH, Electrical Conductivity, Total Dissolved Solid, Total Hardness, Bicarbonate, Chlorides, Sulphates, Nitrates, Calcium, Magnesium, Sodium, Potassium and Fluoride in post-monsoon season of 2016. Weighted arithmetic water quality index method was used to find groundwater quality index (GWQI). The groundwater quality index varies from 11.93 to 96.05 with mean 41.63 indicating the impact of human activity is the main cause of deterioration in water quality.

KEYWORDS: *Water quality parameters, Groundwater quality Index, Weighted Arithmetic Index Method.*

INTRODUCTION

Groundwater is a valuable natural resource and an imperative part of the hydrological cycle (Brindha and Kavitha, 2015; Verma, et al., 2018). The quality of groundwater in a region is a function of physical, chemical and biological parameters. Groundwater quality is important as well as quantity. Poor quality of water adversely affects plant growth and human health (Todd, 1980; WHO, 1984; Hem, 1991). Groundwater may also be contaminated due to weathering of rock and agro-chemicals used for irrigation. Groundwater is usually used directly in rural water supply without proper treatment and for agricultural practice and human consumption in most parts of India. The industrial wastewater, sewage, sludge, and solid waste are also discharged into the drains. These contaminants enter aquifers and make drinking water polluted (Forstner and Wittman, 1981; Jerome and Anitha, 2010; Ahmad and Mazhar, 2020).

Overgrowing population, industrialization and environmental pollution are the most critical issues. Groundwater is extremely vulnerable and overexploited natural resources in the earth. It is the only primary source of drinking water (Clark et al., 1997; Leduc et al., 2017). Therefore, it is very challenging to meet increased requirements and afford adequate quantity and wholesome quality groundwater to the population (Stevanovic, 2010; Siddha and Sahu, 2020). Geochemical studies of groundwater provide a better understanding of possible changes in quality. Many naturally occurring major, minor and trace elements in drinking water can have a significant effect on human health either through deficiency or excessive intake (Frengstad et al., 2001). Hence, understanding of the processes that control the water quality is needed towards the aim of water-quality control and improvement (Hem, 1991; Subba Rao et al., 2006; Aher and Deshpande, 2015).

Adverse quality conditions increase the investment in irrigation and health, as well as decrease agricultural production. This in turn, reduces agrarian economy and retard improvement in the living conditions of rural people (Deshpande and Aher, 2011, Aher, 2012). In order to keep the health of any system at an optimal level, certain water quality indicators or parameters must be monitored and controlled (Boah, et al., 2015). In order to keep the health of any system at an optimal level, certain water quality indicators or parameters must be monitored and controlled (Boah,.et al, 2015). Groundwater contamination is less common compare to surface water. Human activities such as land-use/cover changes, discharge of contaminated agricultural, geological formation, change in rainfall patterns and infiltration rate affect the groundwater quantity/quality and leads to groundwater pollution (Schot and van der Wal, 1992; Kumari and Rai, 2020).

Groundwater, in contrast, is better in quality, readily available as it exists in virtually all geologic formations and is naturally protected from direct contamination by surface anthropogenic activities (Morris et al. 2003;Prasanna et al. 2011; Deshpande and Aher 2012; Fenta et al., 2015); thus, this shows due emphasis should be given for development of groundwater resources. GWQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters were taken into consideration for the calculation of groundwater quality index (GWQI). The indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and in water quality management. In formulation of water quality index, the relative importance of various parameters depends on intended use of water. Mostly it is done from the point of view of its suitability for human consumption. The Groundwater quality index (GWQI) summarizes large amounts of water quality data into simple terms such as excellent, good, bad, etc. for reporting to managers and the public in a consistent manner (Boyacioglu, 2010).The indices are among the most effective ways to communicate the information on water quality trends for the water quality management (Jagadeeswari and Ramesh, 2012).

GWQI is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues (Tyagi et al.2013; Shah, and Joshi,2017).The assessment of drinking water quality using Groundwater Quality Index (GWQI) is one of the best tools which was developed in the 1970s by the Oregon Department of Environmental Quality to summarize and assessing the status of water quality (Brown et al., 1972; Yogendra and Puttaiah, 2008; Alobaidy et al., 2010; Latha and Rao, 2010; Ketata et al., 2012; Tyagi et al., 2013; Li, 2016; Krishan et al., 2016; Bidhuri, and Khan, 2020).

The objective of this study is to calculate the Groundwater Quality Index (GWQI) of Dheku basin and its suitability for drinking purposes. The study area is in the drainage basin of the Dheku River in Aurangabad district, Maharashtra, India. It covers an area of 410 km^2 and lies between latitudes 12°152 N to 19°552 N and longitudes 74°452 E to 75°002 E. Most rainfall occurs during southwest monsoon (June–September) period. Geologically, the study area consists of Deccan Trap lava flows of upper Cretaceous to Eocene age. The traps are overlain by thin alluvial deposits along the rivers.

MATERIALS AND METHODS

Seventy-four groundwater samples during post-monsoon season 2016 were collected from studyarea. The water samples for most of the chemical parameters were analyzed in lab of Post Graduate Department of Geology, Institute of Science, Aurangabad, Maharashtra, India. The chemical characteristics were determined as per the standard methods for examination of water and wastewater (APHA, 2012). The hydrogen ion concentration (pH), Electrical conductivity (EC) and total dissolved solids (TDS) were measured using digital portable meters. Calcium, magnesium bicarbonate and chloride were analyzed by volumetric titration methods, sodium and potassium were measured using the flame photometer, sulphate, nitrate and fluoride were determined by spectrophotometric technique. Water quality indices are tools to determine conditions of water quality. Creating the GWQI involves three main steps (US EPA 2009): (1) obtain measurements on individual water quality indicators (2) transform measurements into ''subindex'' values to represent them on a common scale (3) aggregate the individual subindex values into an overall GWQI value. Horton (1965) used the arithmetic aggregation function for the GWQI. Brown et al. (1970) also employed basic arithmetic weighting, although without the multiplicative variables.

The calculation of "WQI using Weighed Arithmetic Index method" after Brown et al. (1972) (Table 2) was used which involve the following steps:

Step 1: Calculation of unit weight(W_n) factors for each parameter by using the formula

$W_n = \frac{k}{S_n}$ (1)

Where,

$$K = \frac{1}{1/_{S1} + 1/_{S2} + 1/_{S3} + \cdots \ldots + 1/_{Sn}} = \frac{1}{\sum \frac{1}{S_n}}$$

S_n = standard desirable value for n[th] parameter

On summation of all selected parameters unit weight factor, W_n =1 (unity)

Step 2: Calculate the sub-index (q_n) value by using formula

$q_n = \frac{V_n - V_o}{S_n - V_o} X\ 100$ (2)

V_n is the mean concentration of the nth parameter,
S_n is the standard desirable value of the nth parameter
$V_o$are actual values of the parameter in pure water, generally $V_o = 0$, for most parameters except pH

For pH, the ideal value is 7.0 because of pure water and a permissible value is 8.5.
So, the calculation of quality rating for pH is calculated from the following equation:

$q_{pH} = \frac{V_{pH-7}}{8.5-7} X\ 100$ (3)
where VpH = observed value of pH.

Step 3: Combining step 1 and step 2 GWQI is calculated by the following equation.

$GWQI = \sum_{n=1}^{n} q_n\, w_n / \sum_{n=1}^{n} w_n$ (4)

Groundwater quality index (GWQI) was computed to evaluate the groundwater suitability for drinking purposes. For computing GWQI, the above three steps are involved in GWQI calculation, the computed GWQI values are than categorized into five classes, excellent, good,poor, very poor and unsuitable for drinking purposes. The table 1 gives unit weight(W_n) factors for each parameter and table 2 shows classification of water quality, based on its groundwater quality index values for human consumption use.

Table 1: Relative weight to the water quality parameters

Chemical Parameter	Indian Standards (2012) (S_n)	1/S_n	$\sum 1/S_n$	K=1/$\sum 1/S_n$)	W_n=K/S_n
pH	8.5	0.117	1.295869	0.771683	0.090786
TDS	500	0.002	1.295869	0.771683	0.001543
TH	200	0.005	1.295869	0.771683	0.003858
HCO_3	200	0.005	1.295869	0.771683	0.003858
Cl	250	0.004	1.295869	0.771683	0.003087
SO_4	200	0.005	1.295869	0.771683	0.003858
NO_3	45	0.022	1.295869	0.771683	0.017149
F	1	1.000	1.295869	0.771683	0.771683
Ca	75	0.013	1.295869	0.771683	0.010289
Mg	30	0.033	1.295869	0.771683	0.025723
Na	200	0.005	1.295869	0.771683	0.003858
K	12	0.083	1.295869	0.771683	0.064307
		$\sum$ 1.295			$\sum$1.0000

Table 2: Classification of water quality, based on its quality index (Brown et al. 1972)

Sr.No.	GWQI Values	Water type
1	0-25	Excellent
2	26-50	Good water
3	51-75	Poor water
4	76-100	Very poor water
5	>100	Unsuitable for drinking purpose

RESULTS AND DISCUSSION

Application of GWQI is a useful method in assessing the suitability of water for various beneficial uses. Ground water quality indexes were computed to evaluate the ground water suitability for drinking purposes. It improves understanding of water quality issues by integrating complex data and generating a score that describes water quality status and evaluates water quality trends (Boyacioglu, 2007). Quality of water is very significant to human because it has a direct link with human health and welfare (Shaikh, et al, 2020). The groundwater quality index (GWQI) is an important tool to determine the drinking water quality in urban, rural and industrial area. Groundwater samples (n = 74) and its GWQI values as well as its types are presented in Table 3 and fig .1.

Table 3: GWQI value of the Selected Groundwater Samples

Sample No	GWQI	Classification	Sample No	GWQI	Classification
1	81.69	Very Poor	38	55.05	Poor
2	29.32	Good	39	51.88	Poor
3	21.59	Excellent	40	37.48	Good
4	31.13	Good	41	46.94	Good
5	88.90	Very Poor	42	30.14	Good
6	96.06	Very Poor	43	43.44	Good
7	19.30	Excellent	44	21.00	Excellent
8	83.27	Very Poor	45	38.09	Good
9	23.20	Excellent	46	69.53	Poor
10	17.85	Excellent	47	19.96	Excellent
11	80.44	Very Poor	48	27.66	Good
12	91.83	Very Poor	49	26.18	Good
13	56.87	Poor	50	32.09	Good

14	12.51	Excellent	51	21.00	Excellent
15	63.93	Poor	52	33.69	Good
16	39.35	Good	53	23.33	Excellent
17	52.72	Poor	54	22.46	Excellent
18	54.25	Poor	55	24.64	Excellent
19	20.60	Excellent	56	21.12	Excellent
20	29.10	Good	57	20.09	Excellent
21	49.90	Good	58	50.70	Poor
22	79.74	Very Poor	59	36.06	Good
23	17.20	Excellent	60	34.80	Good
24	11.99	Excellent	61	11.93	Excellent
25	59.19	Poor	62	69.78	Poor
26	23.04	Excellent	63	26.04	Good
27	43.10	Good	64	55.65	Poor
28	21.33	Excellent	65	69.28	Poor
29	21.05	Excellent	66	31.64	Good
30	17.71	Excellent	67	34.91	Good
31	29.40	Good	68	37.54	Good
32	34.74	Good	69	79.83	Very Poor
33	74.30	Poor	70	34.37	Good
34	86.79	Very Poor	71	23.66	Excellent
35	39.18	Good	72	21.08	Excellent
36	88.04	Very Poor	73	17.96	Excellent
37	62.30	Poor	74	27.71	Good

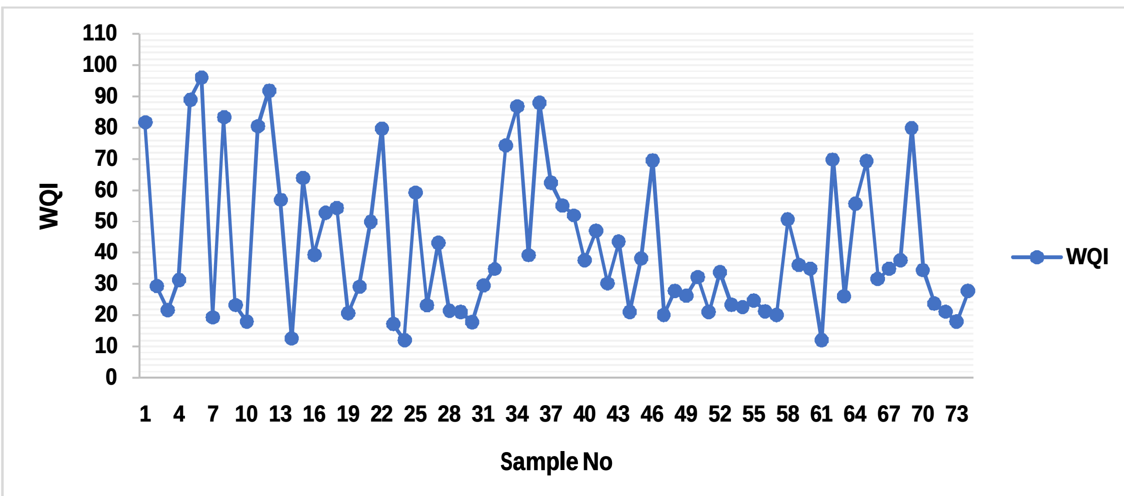

Figure 1: Groundwater quality index (GWQI) values in study area.

In this study, the computed GWQI for Drinking purposes varies from 11.93 to 96.05 with mean value 41.64 in post-monsoon season 2016.The study area has been classified into (i) Excellent water (GWQI <25), (ii) Good water (GWQI 26 - 50), (iii) Poor water (GWQI 51 – 75), (iv) Very poor water (GWQI 76 - 100) and (v) Unsuitable for drinking purpose (GWQI >100) (Table 4 and Fig.2). Based on the groundwater quality index, 32% (24 samples) of the samples fall under excellent category, 35% (26 samples) fall under good category and 19% (14 samples) fall under poor category, and 14% (10 samples) fall under very poor category for drinking purpose (Fig.2).

Table 4: Groundwater quality classification based on WQI value

Sr. No.	GWQI value	Groundwater quality	No of water samples	% of water samples
1	0-25	Excellent	24	32
2	26-50	Good water	26	35
3	51-75	Poor water	14	19
4	76-100	Very poor water	10	14
5	>100	Unsuitable	-	-

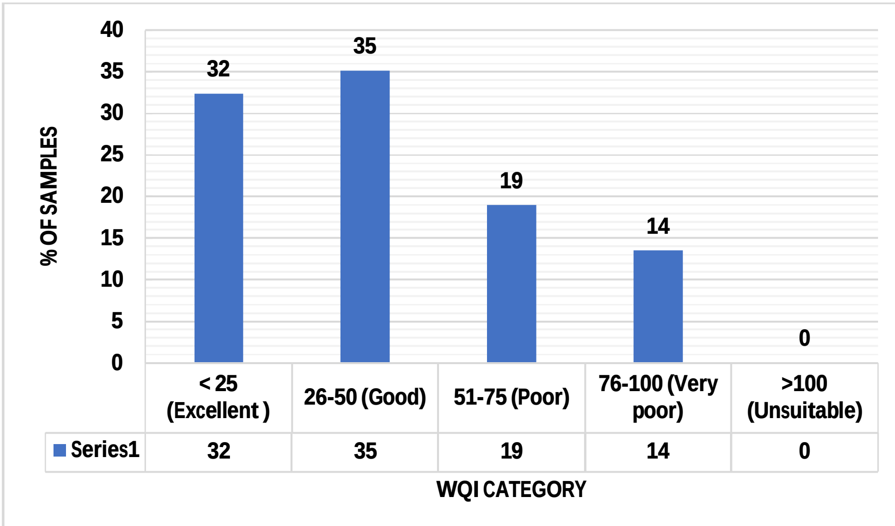

Figure 2: Classification of water by Groundwater Quality Index

CONCLUSION AND RECOMMENDATIONS

The objective of the study was to calculate the Groundwater quality Index (GWQI) of Dheku River basin in order to assess its suitability for drinking purposes. The study suggests that priority should be given to groundwater quality monitoring and its management to protect the groundwater resource from contamination as well as provide technology to make the ground water fit for drinking purposes. GWQI is calculated from the point of view of the suitability of groundwater for human consumption. GWQI of 19% (14 samples) fall under poor category, and 14% (10 samples) fall under very poor category for drinking purpose indicating the impact of human activity is the main cause of deterioration in water quality and must therefore be treated before use to avoid waterborne diseases.

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