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Mathematical Computation of Weighted Arithmetic Water Quality Index of Jui Dam of Jalna District, Maharashtra

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ABSTRACT

Application of water quality index is a useful method in assessing the suitability of water for various beneficial uses. The objective of this study was to know the water quality index of the surface water of Jui dam. For calculating the water quality index parameters namely, pH, total dissolved solids, total hardness, total alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate and fluorides were considered. Weighted arithmetic water quality index method was used to find surface water quality index.

KEYWORDS: *Water quality parameters, water quality Index, Jui dam, Jalna, Maharashtra*.

INTRODUCTION

Due to rapid growth of population, urbanization, industrialization, and agriculture activities, all water resources are under stress. It is important to assess the health of water bodies to develop strategies to improve water resource and watershed management. Most ecosystems around the planet are experiencing problems associated with water scarcity and quality. In other words, water resources are at risk. Natural processes and anthropogenic activities influence water quality, causing degradation in surface and groundwater and affecting their potential use for human and animal consumption, agriculture, recreation, industry, and others (Simeonov et al, 2003; Sánchez et al, 2007; UN-Water, 2010; Aher and Deshpande, 2011; Deshpande and Aher, 2012; Zhang et al, 2012; Varade et al, 2014; Orozco et al, 2017; Aher, et al., 2017; Aher and Dhumal, 2017; Aher and Gaikwad, 2017; Wagh et al, 2018; Dhumal and Aher, 2019; Dangi, et al, 2018; Dhumal, 2021). The assessment of drinking water quality using water quality index (WQI) 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; Tiwari and Mishra, 1985; Singh 1992; Mishra and Patel 2001; Naik and Purohit, 2001;

Chaterjee, and Raziuddin, 2002; Papatheodorou et al, 2006; Yogendra and Puttaiah, 2008; Alobaidy et al., 2010; Latha and Rao, 2010; Boyacioglu, 2010; Jiang, and Yan, 2010; Ketata et al., 2012; Jagadeeswari and Ramesh, 2012; Bozdag, and Gocmez, 2013; Ravikumar et al, 2013; Tyagi et al., 2013; Sheikhy et al, 2014; Boah et al, 2015; Li, 2016; Krishan et al., 2016; Shah and Joshi, 2017; Sridharan and Nathan, 2017; Bidhuri, and Khan, 2020; Deshpande et al., 2020; Aher, et al, 2020). Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers as it is an important parameter for the assessment and management of surface/ground waters.

Hence, the present work has been carried out to know the water quality index (WQI) of the surface water of Jui dam. Jui River which is an important tributary of Khelha River, the dam located at Danapur of Bhokardan block of Jalna district, Maharashtra and built in the year 1960 for irrigation purposes having gross storage capacity is about 9.75 million m^3, with total command area 3296 ha. The Jui dam Irrigated near about 2163 ha, the 2.02 million m^3 water is usage for drinking purpose whereas 1.15 million m3 water usage for agricultural purpose. The geological formations of the area are of Cretaceous to Eocene age represented by a succession of basaltic lava flows. Major part of the area is covered by Aa type flow and compound Pahoehoe type. The different flows are separated by red bole beds of varying thickness.

MATERIALS AND METHODS

The surface water samples collected from the Jui irrigation dam in a one litre pre-cleaned polyethylene bottles. The physicochemical analyses encompassing estimation of major cations calcium magnesium, sodium and potassium anions bicarbonate, chloride, sulphate, nitrate and fluoride besides general parameters such as pH, total dissolved solid and total hardness. In situ parameters like pH, total dissolved solid was measured immediately in the field immediately after sampling. The standard analytical procedures as recommended by the APHA (2015) were employed in the present study. The hydrogen ion concentration (pH), total dissolved solids (TDS) were measured using digital portable meters. Calcium, magnesium bicarbonate and chloride were analysed by volumetric titration methods, sodium and potassium were measured using the flame photometer, sulphate, nitrate and fluoride were determined by spectrophotometric technique. The WQI provides a comprehensive picture of the quality of surface/ground water for most domestic uses. WQI is defined as a rating that reflects the composite influence of different water quality parameters (Sahu and Sikdar, 2008). WQI is calculated from the point of view of the suitability of surface and/or groundwater for human consumption. Hence, for calculating the WQI in the present study, 12 parameters namely, pH, total dissolved solids, total hardness, bicarbonate, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate and fluorides have been considered.

There were three steps for computing WQI of a water sample (US EPA 2009):

- Obtain measurements on individual water quality indicators
- Transform measurements into subindex values to represent them on a common scale
- aggregate the individual subindex values into an overall WQI value.

Horton (1965) used the arithmetic aggregation function for the WQI. 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) was used which involve the following steps:

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

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

Where,

$$K = \frac{1}{1/S_1 + 1/S_2 + 1/S_3 + \ldots\ldots + 1/Sn} = \frac{1}{\sum \frac{1}{S_n}}$$

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

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

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:

$$q_{pH} = \frac{V_{pH} - 7}{8.5 - 7} X\ 100 \quad (3)$$

where VpH = observed value of pH.

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

$$WQI = \sum_{n=1}^{n} q_n w_n / \sum_{n=1}^{n} w_n \quad (4)$$

water quality index (WQI) was computed to evaluate the groundwater suitability for drinking purposes. For computing WQI, the above three steps are involved in WQI calculation, the computed WQI values are than categorized into five classes, excellent, good, poor, very poor and unsuitable for drinking purposes. The table 1 shows classification of water quality, based on its water quality index values.

Table 1: Classification of water quality based on WQI

Sr. No.	WQI 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

Table 2: Calculation of surface water quality index (WQI) of Jui dam

Parameter	Standards Values (S_n)	$1/S_n$	$\sum 1/S_n$	K=$1/\sum 1/S_n$)	W_n=K/S_n	V_o	V_n	V_n/S_n	$Q_n = V_n / S_n x100$	W_nQ_n
pH	8.5	0.118	1.296	0.7717	0.0908	7	7.48	0.32	32	2.90
TDS	500	0.002	1.296	0.7717	0.0015	0	871	1.742	174.2	0.26
TH	200	0.005	1.296	0.7717	0.0039	0	544	2.72	272	1.04
HCO3	200	0.005	1.296	0.7717	0.0039	0	325	1.625	162.5	0.627
Cl	250	0.004	1.296	0.7717	0.0031	0	320	1.28	128	0.39
SO4	200	0.005	1.296	0.7717	0.0039	0	44	0.22	22	0.08
NO3	45	0.022	1.296	0.7717	0.0171	0	36	0.800	80	1.37
F	1	1	1.296	0.7717	0.7717	0	0.43	0.43	43	33.18
Ca	75	0.013	1.296	0.7717	0.0103	0	104	1.387	138.67	1.42
Mg	30	0.033	1.296	0.7717	0.0257	0	41	1.367	136.67	3.51
Na	200	0.005	1.296	0.7717	0.0039	0	108	0.54	54	0.20
K	12	0.083	1.296	0.7717	0.0643	0	23	1.9167	191.66	12.32
Sum		1.296			1					57.36

RESULTS AND DISCUSSION

Suitability for drinking purpose

Water quality index was computed to evaluate the groundwater 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, 2017; Aher et al, 2020a; Deshpande et al, 2020; Dhumal, 2021). The surface water quality index has been classified into (i) Excellent water (WQI <25), (ii) Good water (WQI 26 - 50), (iii) Poor water (WQI 51 – 75), (iv) Very poor water (WQI 76 - 100) and (v) Unsuitable for drinking purpose (WQI >100) (Table 1).

The table 2 gives the mean concentration values (V_n) of the twelve selected physico-chemical parameters of water samples collected in a post-monsoon season of 2020, standard drinking water values (S_n) according to World Health Organisation (WHO, 2011) and Bureau of Indian Standards (BIS, 2012), unit weights (W_n), water quality rating (Q_n) and $W_n Q_n$. The water quality index (WQI) was then calculated using the weighted arithmetic index formula as follows:

$$WQI = \frac{\sum_{n=1}^{n} q_n w_n}{\sum_{n=1}^{n} w_n} = \frac{57.36}{1} = 57.36$$

Based on the water quality index, this value (57.36) falls within 51-75 of the classification indicating poor category for drinking purposes.

Suitability of water for irrigation

The water used for irrigation is an important factor in productivity of crop, its yield and quality of irrigated crops. The continuous use of poor quality water without drainage and soil management may lead to saline and sodic soil, particularly in clayey soils. Suitability of water for irrigation has been assessed on the basis of distribution of chloride, TDS, sodium absorption ratio (SAR) and residual sodium carbonate (RSC) etc. The water has been classified based on various recommended norms.

Total dissolved solids (TDS)

The water suitability for irrigation on the basis of the total dissolved solids has been assessed using Scofileds (1933) classification. The water classified based on TDS into three classes, namely class I (<700), class II (700–2000) and class III (>2000). The study shows that dam water falls under class II and is suitable for irrigation.

Chloride (Cl)

Suitability of water on the basis of chloride concentration is considered as per the classification based on Scofields (1933). The result of the analysis shows that water is suitable for irrigation.

Sodium Absorption Ratio (SAR)

Sodium Absorption Ratio (SAR) is an expression pertaining to cation make up of water and soil solution and is used for characterizing the sodium hazard of irrigation water. SAR value is used to calculate the degree to which irrigation water tends to enter into cation exchange section in the soil. The main problem with high sodium concentration is its effect on soil permeability. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. The higher value of SAR indicates soil structure damage. The sodium adsorption ratio values for each water sample were calculated by using equation given by Richard (1954). Sodium adsorption ratios for dam are less than 10 indicate excellent quality for irrigation (Table 3) and all the samples fall in excellent (S1) category.

Soluble Sodium Percent (SSP)

The SSP values less than 50 or equal to 50 indicates good quality water and if it is more than 50 indicates the unsuitable water quality for irrigation. The SSP value for the dam water is less than 50 and indicates good quality water for irrigation purpose (Table 3).

Residual Sodium Carbonate (RSC)

The quantity of bicarbonate and carbonate in excess of alkaline sediments (Ca and Mg) also influence the suitability of water for irrigation purposes. When the sum of carbonates and bicarbonates is in excess of calcium and magnesium, there may be possibility of complete precipitation of Ca and Mg (Raghunath, 1987; Deshpande and Aher, 2011; Aher et al, 2019). Residual sodium carbonate (RSC) is considered to be superior to SAR as a measure of sodicity particularly at low salinity levels. In water having high concentration of bicarbonates, there is tendency for calcium and magnesium to precipitate as carbonates. To qualify this effect, an experimental parameter termed as residual sodium carbonate can be calculated. Water having less than 1.25 or equal to 1.25 epm of RSC is safe water for irrigation purpose, water is having less than 1.25 to 2.5 epm of RSC is marginally suitable for irrigation purpose whereas water having more than 2.5 epm of RSC is not suitable for irrigation purposes. Based on RSC values, dam water showing the values less than 1.25 and are safe for irrigation (Table 3).

Kelly's Ratio (KR)

Sodium measured against Ca and Mg is used to calculate Kelley's ratio. (Kelley, 1940;

Paliwal, 1972). A Kelley's ratio (KR) of more than one indicates an excess level of sodium in waters. Hence, waters with a Kelley's ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation. Kelley's ratio (KR) of the dam water sample indicating that water is suitable for irrigation.

Table 3: Classification of groundwater on the basis of SAR, SSP and RSC

Parameter	Range	Water Class	Concentration in dam
SAR (after Richard)	< 10	Excellent (S1)	2.27 (Excellent)
	10–18	Good (S2)	
	18–26	Doubtful (S3)	
	> 26	Unsuitable (S4)	
SSP	<50	Good	4.70(Good)
	>50	Bad	
RSC after Richard (1954)	<1.25	Good	-3.23 (Good)
	1.25–2.50	Doubtful	
	> 2.5	Unsuitable	
KR	<1	Suitable	0.55 (Suitable)
	>1	Unsuitable	

CONCLUSION

Water quality index technique used to assess the suitability of surface water Jui dam for drinking purposes illustrated that water belongs to poor water category for drinking purpose whereas it is suitable for the irrigation purpose. The high-water quality index (WQI) values are mainly due to the presence of higher concentration of total dissolved solids and chloride in the surface water, therefore, the analysis revealed that the surface water needs some degree of treatment before usage for drinking purpose furthermore it is recommended that the water quality at Jui dam is continually monitored for several years in order to confirm the findings of this short-term study.

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