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Evaluation of surface water for drinking purpose with seasonality of water quality index

Thamaraiselvi, V. P.[1] and Sr. Nirmala, T.[2]

[1]PG and Research Centre of Zoology, Jeyaraj Annapackiam College for Women, Periyakulam, Mother Teresa Women's University, Kodaikanal, T.N., India
[2]JA College, Periyakulam and Principal of Annai Scholastica Arts and Science College for Women, Pamban, T.N., India

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ABSTRACT

The present investigation was aimed to evaluate the surface water by analysing the physico-chemical parameters in Vaigai reservoir and Pickup dam from February, 2016 to March, 2018. Physical and chemical properties were analyzed using APHA methods and the result of 16 parameters was used for Water Quality Index analysis. It was high in Vaigai reservoir than in Pickup dam. Water of Vaigai reservoir was good except Southwest monsoon I and II, Northeast monsoon I and winter II. Pickup dam quality of water was poor only during Southwest monsoon II and II, Northeast monsoon II. It was good in quality for other seasons. Poor quality of water during monsoon needs care to prevent pollution.

Key words*: Surface water, Physico-chemical parameters, Water Quality Index, Season, Vaigai reservoir and Pickup dam.*

Introduction

The quality of drinking water depends on the surface water. The prime source of surface water is Dam or reservoir. This water is used for drinking, irrigation etc. which has to be monitored. Monitoring of surface water can be done by physico-chemical analysis (Sharma *et al.*, 2011 and Djahed *et al.*, 2016). Water Quality Index (WQI) is recognized as an environmental performance indicator to express the quality of water and evaluate the spatial and temporal water changes by generating a single numerical value which classify water into five categories such as excellent, good, fair, poor and polluted based on the Indian Standards (Janardhana Rao *et al.*, 2016). WQI is one of the most effective tools to monitor the surface as well as ground water pollution and can be used efficiently in the implementation of water quality upgrading programme (Ghosh *et al.*, 2013; Singh and Hussain, 2016). WQI plays a vital role in assessing suitability of water for various uses (Sargaonkar *et al.*, 2008).

Weights assigned to parameters in WQIs are often defined by local water experts and hence WQIs are known to inherit subjectivity. Water Quality Monitoring of Magadi hill range lakes and reservoirs of India was studied by Muniyellappa (2018) and WQ assessment was conceded out through WQI (Thakor *et al.*, 2011; Tyagi *et al.*, 2013; Poonia *et al.*, 2015).

Seasonal variations in quality of water exist in Lake Nasser and it was proved to be a good quality of water after the analysis of physico-chemical parameters (Toufeek and Korium, 2009). Assessment of seasonal variation in water quality of River Rwizi, Uganda was carried out by Ojok *et al.* (2017) and found that water pollution was resulted by domestic and agricultural waste water and industrial efflu-

[1]Research Scholar, [2]Former Principal

ents. These indices are accredited to exhibit annual cycles, trends in water quality at low or high concentrations, spatial and temporal variations in water quality in an efficient and timely manner (Tyagi *et al.*, 2013). Banda and Kumarasamy (2020) evaluated the indices to bring a unified water quality index that is applicable to all the water sheds of a given country (Brown *et al.*, 1970; Abbasi and Abbasi, 2012).

Recently a few researchers tried to use WQI method for giving WQ rating in Tamilnadu (Latha *et al.*, 2002; Palanisamy *et al.*, 2007; Maheswari and Sankar, 2011; Nirmala *et al.*, 2021). In Vaigai Reservoir and its water supply area, the WQI was not made so far. The objective behind this study was to assess water at Vaigai reservoir and Pickup dam to evaluate the pollution in the drinking water.

Materials and Methods

Study area**:** Vaigai river basin covers an area of about 7009.13 km^2 located in Theni district. This dam was established on January 21, 1959. Vaigai basin lies between Latitude of 9^o 15′ – 10^o 20′ N and Longitude of 77^o 10′ - 79^o 15′. Height and length of the reservoir is 33.8 m (111 ft) and 3,560 m (11,680 ft) respectively and its capacity is 174,000,000 m^3. It can store 71 feet of water. Pickup dam is located about 1.5 km downstream of Vaigai Reservoir and it is also known as intake well. It sucks out water from Vaigai River supplied to two purification plants.

Sample collection: In total, 48 water samples were collected in sterilized plastic bottles from these two different selected locations every month on the early hours during March 2016 to February, 2018. Samples were taken to the lab for analysis of the physico-chemical parameters, which was used for WQI analysis. Seasons were classified as summer, Southwest (SW) monsoon, Northeast (NE) monsoon and winter for first year (I) and second year (II). Physico-chemical analysis of water was carried out in the laboratory following the standard meth-ods as prescribed by APHA, (2005) and limited to WHO (2011) standards for drinking water.

Water Quality Index (WQI)

Water quality index was measured by using the

Plate 2. Pickup Dam

equation for WQI as used by Amadi *et al.*, (2017). This method was developed by Brown *et al.*, (1972) followed by Chowdhury *et al.*, (2012). To know the water quality rating and status of the study area, the quality rating developed by Krishnan *et al.*, (1995) was used. Overall water Quality Index was calculated by aggregating quality rating with the unit weight as shown below.

$$WQI = \Sigma Wi * qi \qquad \text{Where } qi = (Ci/Si)*100$$

Ci is mean concentration of parameters; Si is the Indian Standard for Drinking Water Quality (BIS, 2012). Relative Weight (Wi) is calculated by a value inversely proportional to standard value (Si) of each respective parameter. For computing WQI, the sub index (Si) is first determined for each chemical pa-

Plate 1. Vaigai Dam and Reservoir

rameter, as given below:

SIi = Wi x qi

WQI = ΣSIi-n Where, SIi - the sub index of ith parameter, Wi - relative weight of ith parameter, qi - the rating based on concentration of ith parameter, and n - the number of chemical parameters.

WQI values were classified into 5 categories; the water quality is rated as excellent, good, poor, very poor and unsuitable for drinking when the value of the index lies between 0-50, 50-100, 100-200, 200-300 and >300 respectively following grade of water quality by Krishnan *et al.* (1995).

Table 1. Relative Weight of physico-chemical parameters used for analysis with BIS (2012)

Parameters	Weight	Relative Weight	BIS Value
pH	4	0.074074074	6.5
Total Dissolved Solids	4	0.074074074	500
Alkalinity	4	0.074074074	20
Total Hardness	3	0.055555556	200
Calcium	2	0.037037037	75
Magnesium	2	0.037037037	30
Sodium	4	0.074074074	200
Potassium	1	0.018518519	12
Iron	4	0.074074074	0.3
Ammonia	3	0.055555556	1.2
Nitrate	4	0.074074074	45
Chloride	5	0.092592593	250
Fluoride	5	0.092592593	1
Sulphate	4	0.074074074	150
Tidy's test O_2	5	0.092592593	244
Total	**54**	**1**	

Results

Water from the Vaigai Reservoir and Pickup Dam was collected for two years (2016-2018) to analyse the seasonality of WQI. To calculate WQI, physico-chemical parameters such as Turbidity, Total Dissolved Solids, electrical conductivity, pH, Alkalinity, Total hardness, Calcium, Magnesium, Sodium, Potassium, Ammonia, Nitrite, Nitrate, Fluoride, Sulphate, Phosphate and Dissolved Oxygen were analysed first and this value was subjected to WQI analysis. This result has been compared with the water quality rating and grade following Krishnan *et al.* (1995) to find out the status of their WQI value. WQI of Vaigai Reservoir and Pickup Dam, was analysed in four different seasons such as summer I & II, SW monsoon I & II, NE monsoon I & II and winter I & II for 2016-2017 and 2017-2018 respectively.

In Vaigai Reservoir, WQI was ranged from 74 to 119. In 2016-2017, WQI was low during summer1 and high during SW monsoon I (Table 2). When we rate the quality of the same water during summer I, NE monsoon I and winter I, it was good, and poor quality was recorded during SW monsoon I (Table

Table 2. Water Quality Index of Vaigai Reservoir in four different seasons during March, 2016-February, 2018.

Parameters	Si	Wt.	wi	Summer I Sli	Summer II Sli	SWM 1 Sli	SWM 1I Sli	NEM I Sli	NEM II Sli	Winter I Sli	Winter II Sli
Turbidity	1.00	2.00	0.04	50.98	75.82	83.66	96.73	73.20	98.04	61.44	81.05
Total Dissolved Solid	500.0	4.00	0.08	2.82	2.10	2.82	2.01	2.96	2.28	2.54	2.01
Electrical Conductivity	400.0	2.00	0.04	2.52	2.14	2.55	2.24	2.25	2.11	2.38	2.20
PH	6.50	4.00	0.08	9.61	8.61	8.97	8.57	8.93	8.45	8.77	8.69
Total Alkalinity	200.0	4.00	0.08	1.40	1.49	1.67	1.52	1.67	1.33	1.45	1.52
Total Hardness	200.0	3.00	0.06	1.94	2.06	2.26	2.06	2.12	1.85	2.21	1.98
Calcium	75.0	2.00	0.04	0.99	0.99	1.05	0.94	1.05	0.59	0.98	0.78
Magnesium	30.0	2.00	0.04	0.87	1.13	0.78	0.96	0.70	1.13	0.74	1.18
Ammonia	0.50	3.00	0.06	5.88	6.27	8.63	5.10	5.88	5.88	5.88	5.88
Nitrite	1.50	3.00	0.06	1.57	1.74	5.01	2.18	3.49	1.96	3.05	1.74
Nitrate	45.0	4.00	0.08	0.41	0.52	0.29	0.17	0.41	0.23	0.29	0.35
Chloride	250.0	5.00	0.10	1.48	1.31	1.46	1.44	1.23	0.97	1.29	1.23
Fluoride	1.00	5.00	0.10	5.56	4.25	6.54	4.25	5.56	7.52	6.21	5.56
Sulphate	200.0	4.00	0.08	0.17	0.18	0.16	0.17	0.16	0.17	0.19	0.19
Phosphate	0.50	2.00	0.04	3.66	4.44	5.23	3.40	4.18	1.83	4.71	2.61
DO	6.50	2.00	0.04	0.54	0.70	0.60	0.60	0.66	0.58	0.56	0.64
Total				90.40	113.77	131.69	132.34	114.45	134.93	102.67	117.61
WQI				**74.4**	**97.8**	**115.7**	**116.4**	**98.5**	**118.9**	**86.7**	**101.6**

2). While in 2017-2018, WQI was low during summer II and high during NE monsoon II (Table 2). Here The Vaigai Reservoir had good quality of water during summer and poor quality during SW monsoon I, NE monsoon II and winter II. WQI was comparatively high during 2017-2018 than 2016-2017 (Table 2).

WQI of Pickup Dam ranged between 74.4 and 115.4. Quality of water was good in all the seasons during 2016-2018 except Southwest monsoon II and Northeast monsoon II which was poor in quality. It was good during summer II and Winter II but poor quality in SW monsoon II and NE monsoon II (Table 3). WQI was low during summer II and high during NE monsoon II. This water was good during summer I & II and winter I & II, SW monsoon I and poor during SW monsoon II and NE monsoon II (Table 3).

Vaigai Reservoir showed high WQI during SW monsoon I and II and NE monsoon II and low during summer I. In Pickup Dam it was high during SW monsoon II and NE monsoon II and low during winter II. In both the areas, summer I had low WQI (Figure 1). WQI of Vaigai Reservoir showed high and moreover the mean, standard deviation and error value of WQI showed low in Pickup Dam, rainfall mean was high in Vaigai Reservoir followed by Pickup Dam (Table 4). Pearson correlation was carried out to correlate the sites of WQI index between

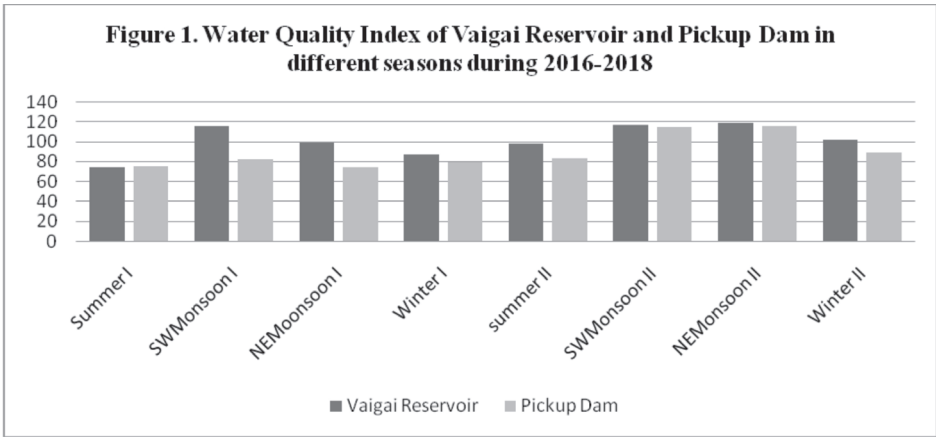

Table 3. Water Quality Index of Pickup Dam in four different seasons during March, 2016-February, 2018

Parameters	Si	Wt.	wi	Summer I Sli	Summer II Sli	SWM 1 Sli	SWM 1I Sli	NEM I Sli	NEM II Sli	Winter I Sli	Winter II Sli
Turbidity	1.00	2.00	0.04	49.67	52.29	52.29	91.50	45.75	88.89	53.59	62.75
Total Dissolved Solid	500	4.00	0.08	2.95	2.38	2.91	2.12	3.08	2.19	2.67	2.47
Electrical Conductivity	400	2.00	0.04	2.64	2.31	2.55	2.26	2.73	2.31	2.36	2.37
PH	6.5	4.00	0.08	8.73	8.61	8.53	8.53	8.49	8.65	8.61	8.77
Total Alkalinity	200	4.00	0.08	1.76	1.23	1.52	1.35	1.50	1.20	1.20	1.31
Total Hardness	200	3.00	0.06	1.86	1.64	1.92	1.91	1.82	2.51	1.85	2.23
Calcium	75	2.00	0.04	1.08	0.98	0.94	0.78	0.85	0.77	1.01	1.03
Magnesium	30	2.00	0.04	0.87	0.83	0.65	0.78	0.52	0.52	0.57	0.78
Ammonia	0.50	3.00	0.06	5.88	9.80	10.20	7.06	5.88	7.45	7.06	7.06
Nitrite	1.50	3.00	0.06	3.92	5.45	5.01	3.05	5.23	3.92	2.83	4.58
Nitrate	45	4.00	0.08	0.03	0.03	0.03	0.04	0.03	0.05	0.04	0.04
Chloride	250	5.00	0.10	1.57	1.37	1.32	1.50	1.31	0.97	1.58	1.15
Fluoride	1	5.00	0.10	6.86	5.56	4.90	3.92	6.86	4.58	5.56	5.56
Sulphate	200	4.00	0.08	0.16	0.17	0.17	0.21	0.17	0.22	0.16	0.20
Phosphate	0.50	2.00	0.04	3.14	5.75	4.97	5.23	5.49	6.54	5.23	4.44
DO	6.50	2.00	0.04	0.58	0.60	0.64	0.52	0.64	0.62	0.58	0.60
Total				91.72	98.99	98.55	130.77	90.36	131.38	94.90	105.32
WQI				75.7	83.0	82.6	114.8	74.4	115.4	78.9	89.3

SWM-Southwest Monsoon, NEM-Northeast Monsoon

Table 4. One-Sample T test and Statistics using compare means value for Water Quality Index, Temperature and Rainfall in four different seasons during March, 2016-February, 2018

	Test Value = 0						Std. Deviation	Std. Error Mean
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference			
					Lower	Upper		
WQI1	18.361	7	.000	101.233	88.19	114.27	15.595	5.514
WQI2	15.202	7	.000	89.249	75.37	103.13	16.605	5.871
R1	4.710	7	.002	52.356	26.07	78.64	31.440	11.116
R2	4.304	7	.004	43.398	19.55	67.24	28.520	10.083
T1	53.000	7	.000	25.194	24.07	26.32	1.345	.475
T2	70.480	7	.000	25.273	24.43	26.12	1.014	.359

WQI - Water Quality Index, R - Rainfall, T - Temperature, 1-Vaigai Reservoir, 2-Pickup Dam.

Vaigai Reservoir and Pickup Dam. These sites were correlated and showed high significance at 0.01 i.e. they are 99% significant. They were related to one another. WQI of Pickup Dam was correlated with Temperature in Vaigai Reservoir at 100% significant. It was also correlated and 95% of significant with rainfall ($p<0.05$, $r=0.989$).

Discussion

Vaigai Reservoir receives water from different sources such as Varushanadu, Periyar main canal via Cumbam valley, Mullai Periyar River, Suruliar, Theniyar, Kotakudiar etc. Due to SW monsoon I rainfall, all wastes were brought into this reservoir that added the index value, and it was lower in summer I. High WQI was recorded during SW monsoon I and II and NE monsoon II due to the poor quality of water which was brought out by erosion of soil and waste on the riverside which ends in reservoir. Study of Nirmala *et al.* (2021) showed that the water of Vaigai Reservoir was excellent for drinking purpose in 2007, poor in 2008 and 2013. In 2016-18 seasonal analysis of WQI indicates that the quality of water was good with "B" grade during Summer I, Winter I and NE monsoon I while it was poor in quality with "C" grade during SW monsoon I and II, NE monsoon II and Winter II (Krishnan *et al.*, 1995).

Vaigai reservoir water quality during 2016-2017 was good but in 2017-2018 it became poor in quality may be due to the accumulation of pollution resulted from domestic waste water, agricultural runoff and industrial effluents which may become unsuitable for drinking as stated by Nirmala *et al.* (2021) and Ojok *et al.* (2017). SW monsoon and NE monsoon seasons showed increase of WQI due to the accumulation of waste during rainy season along with industrial effluent as studied by Reenal *et al.* (2020), Vanitha and Shanmugavelu (2012), and Nirmala *et al.* (2021). The increase of WQI value may be due to entry of different water mass into reservoir as in the study of Toufeek and Korium (2009).

Water quality was poor during 2017-2018 than 2016 - 2017 which showed high WQI value. Study of this is in accordance with the study of Athiyannoor Panchayat water samples from 15 Ponds by Sajitha and Vijayamma (2016). Their report showed that excellent quality of water was in Athiyannoor as the WQI ranges from 6 to 16 where there is no contamination or anthropogenic activities unlike our sites. But in this study WQI ranges from 74 to 119 and it was due to pollution. Pollution in the study sites may be due to distinct sources such as industrial effluents, municipal sewage, industrial impoundments, and diffuse source such as agricultural runoff which includes pesticides, pathogens, fertilizers and organic pollutants. Discharge of sewage water to the Vrishabhavathi River polluted the main water bodies. Like this Byramangala lake is highly polluted because of hammering of sewage and other domestic with high levels of nutrients and low levels of dissolved oxygen in Magadi hill range lakes and reservoirs.

The quality of water rating was good in Pickup Dam except in SW monsoon II and NE monsoon II which was poor in quality (Table 3). This water grade was C during SW monsoon II and NE monsoon II. This may be due to the accumulation of waste into this area by mixing Raj Shree Sugar effluent and Tata coffee effluent into the Vaigai river as

in the study of Jesu *et al.* (2013). This water cannot be used as such during SW monsoon II and NE monsoon II that needs care to be taken to treat before consumption. Water quality was good and fell under "B" grade water as it had the WQI values below 100. The same result was recorded by Nirmala *et al.* (2021) for Vaigai Dam. Poor quality of water was due to direct discharge of effluents along Vaigai and agricultural runoff as in the study of Jasmin and Mallikarjuna (2013). As WQI got increased, it is not potable. Seasonal variations of monsoon may be due to leaching of ions, weathering and ion exchange processes as reported by Thivya *et al.* (2014). If the water is in good quality, a significant amount of water borne diseases could be prevented.

Conclusion

Water Quality Index ranges from 74 to 119. Vaigai Reservoir water quality was good during 2016-2017 but poor during monsoon season and winter of 2017-2018. Pickup Dam water quality was good during summer I and II, winter I and II, SW monsoon I and NE monsoon I whereas SW monsoon II and NE monsoon II were poor quality which needs more care to avoid dumping of wastes and discharge of effluents during these two seasons.

Rainfall and temperature are positively related to WQI. Further, even though it was treated, to maintain good quality of water in all the seasons, continuous monitoring of physico-chemical parameters should be done and WQI must be analysed to find out its potable nature for drinking, cooking and other purposes. Disposal of organic and inorganic pollutants and industrial effluents are added into Vaigai Reservoir. Hence the sources of Vaigai Reservoir also should be taken care by the people and the government to protect this area, from contamination. This quality index should be brought to the notice of the public to monitor effectively by them and to save a better environmental condition.

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