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Assessment of Temporal Status of River Muthirapuzha, Munnar, Central Kerala Based on Water Quality Index

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Abstract

The water quality of river Muthirapuzha in Munnar, Idukki, district, Kerala, India was monitored for two years (February 2014-January 2016). Water Quality Index (WQI) is a widely accepted mathematical expression for understanding the trend in the quality of water bodies. Water samples were analyzed for various physicochemical parameters, such as pH, total dissolved solids, total hardness, total alkalinity, dissolved oxygen, biological oxygen demand, chloride, sulfate, nitrate, and calcium. Based on these ten parameters WQI was calculated. The station-wise and season-wise analysis of WQI revealed that the water of river Muthirapuzha to be good in the upstream and severely polluted towards the downstream. The pollution load was heavy during the pre-monsoon and post-monsoon seasons. The water quality was adversely affected at the middle stream of river Muthirapuzha due to the sewage-disposal from Munnar Township. This study indicated that the anthropogenic and tourism activities during the pre-monsoon and post-monsoon period vigorously affected the water quality of river Muthirapuzha.

Keywords: River Muthirapuzha, Periyar, Water Quality, Water Quality Index, Munnar, Tourism

1. Introduction

Rivers are the backbone of human civilization, being the most significant freshwater source amidst the 96% of global non-potable saline water (Kalaivanan, 2020). As a result, rivers are the primary source of our drinking water needs. Natural and anthropogenic factors have influenced the composition and the quality of river water. The water qualities of aquatic bodies provide vital information on the sustainability of life in these ecosystems. Water quality refers to the physicochemical and biological characteristics of water (Diersing and Nancy, 2009). To keep a healthy water class, certain water quality parameters must be monitored and controlled (Boah *et al.*, 2014). A good number of indices have been developed to summarize water quality data in an easily expressible format (Sutadian *et al.*, 2016). A water quality index is a means to translate a large amount of water quality data into simple terms for reporting to management and the public in a regular manner (Boyacicoglu, 2008). The water quality index (WQI) is a mathematical instrument that provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. It is one of the most effective ways to communicate information on water quality trends to policymakers and implement water quality improvement programmes efficiently (Padmanabha and Belagali, 2007). Muthirapuzha river, a major tributary of River Periyar, central Kerala, India, is experiencing frequent changes in its hydrochemistry and geochemical character (Thomas *et al.*, 2012, 2018). Muthirapuzha river from the main drainage system south of Anamudi, the highest peak of South India. Munnar Township, the famous tourist destination in Kerala (Murugadoss *et al.*, 2016), is sprawling on the banks of this stream. This stream had experienced over flooding due to climate change in recent times. An assessment of the water quality index (WQI) of River Muthirapuzha is attempted in this study, which shall be helpful for effective management of the hill stream habitat and formulating policy decisions on River Muthirapuzha.

2. Materials and Methods

2.1. Study area

The present study was performed to assess the surface water quality in Muthirapuzha River. (9° 57’ 5.7024" to 10° 10’ 20.1432" N; 76° 59’ 01.7736" to 77° 04’ 40.404" E). It originates from Umaya Mala near Anamudi Peak in the Western Ghats and covers a distance of 34 km before joining the Periyar River; twelve sampling stations along this course of the river were identified for this study (Fig.1)

2.2. Water sampling and analysis

Water samples were collected once every four months to assess the seasonal variation in water quality. It was done at about 0.5 m depth from the water surface, in pre-cleaned 2L plastic containers, after rinsing sufficiently in the same water. To determine the water quality index (WQI), ten physicochemical parameters were measured. p^H was measured by portable hand meter(Hanna Instruments-HI98107P) and DO was measured by modified Winkler’s method. The other water quality parameters (TDS, total hardness, total alkalinity, BOD, chloride, sulphate, nitrate, and calcium) were analyzed in the Research Laboratory. Department of Zoology, Mar Ivanios College, Thiruvananthapuram, Kerala. All water quality analyses were carried out as per APHA (2012).

2.3. Water Quality Index:

The calculation of WQI was made using the “Weighed Arithmetic Index” method (Brown *et al.*, 1972). To

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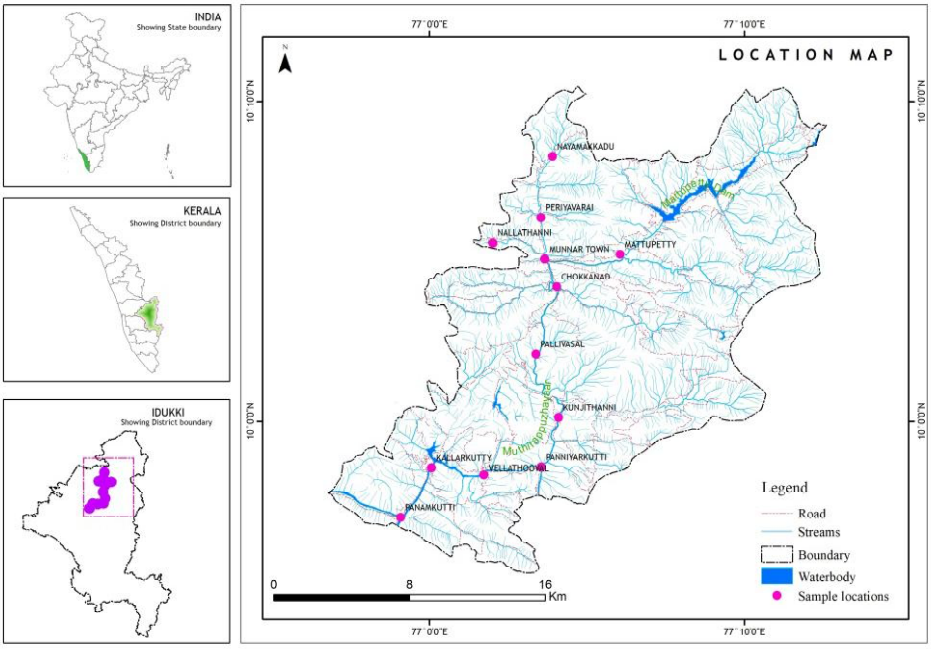

Fig. 1. Sampling stations of River Muthirapuzha, Kerala

calculate the Water Quality Index, all the ten physicochemical parameters have been utilized.

Weighting: The word weighting indicates the relative significance of the factor in the overall water quality, and it depends on the permissible level in drinking water, as suggested by CPCB (Central Pollution Control Board) and Bureau of Indian Standards (BIS:10500).

Factors that have higher permissible limits are less harmful and have low weightings.

Therefore

$Wi = K/S_n$

Where

Wi- The unit weight of chemical factors, K-constant of proportionality and given as:

$$K = \frac{1}{\frac{1}{Vs1} + \frac{1}{Vs2} \pm \text{-------------} + \frac{1}{Vsn}}$$

S_n- Standard value of the i^{th} parameter

Rating scale: Each chemical factor has been assigned a water quality rating to calculate WQI.

$Q_i = 100[(V_a-V_i)/(V_s-V_i)]$

Where,

V_a- an average of measured values in water samples at one place

V_s – the standard value of the i^{th} parameter

V_i – ideal value for pure water (0 for all parameters except p^H and DO)

The above equation becomes: $Qi = 100(V_a/V_s)$

For dissolved oxygen (DO): The ideal value = 14.6 mg/l and permissible value = 6 mg/l,

$Q\ DO = 100[(V_a-14.6)/(6-14.6)]$.

For p^H: The ideal value = 7.0,

maximum permissible value = 8.5,

$Q\ p^H = 100[(V_a-7.0)/(8.5-7.0)]$

Water Quality Index (WQI) = $[\Sigma(Q_iW_i)/\Sigma W_i]$

Using the Water Quality Index, all the samples were categorized into the five classes: Excellent (0-25), Good (26-50), moderately polluted (51-75), severely polluted (76-100), and unfit for human consumption (above 100). Correlation coefficient analysis was used for identifying the degree of correlation between the physico-chemical parameters. One way ANOVA and Dendrogram derived from the Bray-Curtis similarity index was used for the analysis of water quality index (WQI) data in this study.

3. Results and Discussion

Water qualities of the Muthirapuzha river from February 2014 to January 2016 over twelve stations were obtained in the current study. The physicochemical characteristics of the water samples from different stations were within the prescribed limit of the CPCB and BIS standards (Table 1). Table 2 shows the mean values of selected physico-chemical parameters for the three seasons of the two sampling years.

The pH values were neutral in the monsoon season of two sampling years and slightly alkaline in all stations during pre-monsoon and post-monsoon seasons and are close to the permissible limits. The range of total dissolved solids (TDS) in 2014-15 was 3.91–52.47 mg/l in pre-monsoon, 1.89- 28.14 mg/l in monsoon, and 3.47 – 39.46 mg/l in a post-monsoon while during 2015-16 it was 2.92- 44.83 in pre-monsoon, 2.28-22.33 in monsoon and 3.53 -39.19 in post-monsoon during the study period. In pre-monsoon, the values of TDS were slightly higher compared to other seasons that could be observed for both years of the study. According to Martin and Haniffa (2003), the increase in total dissolved solids is due to urban anthropogenic impact which can be often complicated by intense local agricultural activity leading to local, spatial and temporal variability in the run-off.

Table 1. The permissible values of various pollutants for drinking water (expressed in mg/l except for p^H) recommended by the Central Pollution Control Board (CPCB) and Indian Standards (IS)

SL.NO	PARAMETERS	CPCB	IS(10500)
1	p^H	6.5-8.5	6.5-8.5
2	TDS	500	500
3	Total Hardness	300	300
4	Total Alkalinity	200	200
5	DO	6	-
6	BOD	2	-
7	Chloride	250	250
8	Sulphate	200	200
9	Nitrate	20	45
10	Calcium	75	75

The total hardness of River Muthirapuzha was highest (61.8 mg/l) in pre-monsoon, 39.1 mg/l in monsoon, and 56.6 mg/l in post-monsoon during 2014-15. A similar trend of the total hardness was also found in the 2015-16 sampling year; the highest total hardness was reported in pre-monsoon (59.2 mg/l), 33.7 mg/l in monsoon, 41.6 mg/l in post-monsoon. The hardness was well within permissible limits in all stations and all seasons. The variations of total hardness between every season in all stations may be due to the fluctuations in the water discharge as well as the waste disposal from Munnar Town into the river. Similar observation was done by Seth *et al* (2016) in the water quality evaluation of Himalayan rivers of Kumaun region. The higher level of hardness during pre-monsoon could be due to the lower water flow and concentration of pollutants like detergents from domestic effluents. Detergents and soaps contamination influenced the hardiness of river water (Ahluwalia, 2008). The total alkalinity in all the sampling stations was in the range of 20.17 – 85.27 mg/l during the 2014-15 and 20.04-69.91 mg/l in the second sampling year for three seasons. These values were falling within the permissible limit (200 mg/l). The hydroxides, carbonates and bicarbonates, carbonate-rich soils, cleaning agents, food residue, discharge of city sewage, and domestic solid wastes are contributing to alkalinity (Rajurkar, *et al*., 2003).

In 2014-15 the values of DO in the sampling stations were 6.1 to 9.19 mg/l during the pre-monsoon season; it varied from 7.8 to 9.85 mg/l and 7.9 to 9.65 mg/ l during the monsoon and post-monsoon respectively. The DO level in the next sampling year was 5.01 -8.23 mg/l in pre-monsoon, 7.04 to 9.88 in post-monsoon, and 5.01 to 8.33 in monsoon seasons. The lowest level of DO (6.1 mg/l, 6.3 mg/l, and 6.5mg/l) was found in the pre-monsoon season between the sampling stations 4, 5, and 6, which are situated along with the Munnar Town during 2014-15. A similar trend was also observed as lowest values (5.09 mg/l, 5.01mg/l, and 5.06mg/l) along the same sampling stations (4, 5 & 6) during pre-monsoon of next sampling year (2015-16). This lowered value of DO in these stations along Munnar town could be due to the organic pollutant discharge from the township establishments (Kibria, 2004). Comparatively higher biological oxygen demand (BOD) recorded at stations 4, 5, and 6 in both sampling years substantiate this observation. Higher values of BOD were not reported at any other station of River Muthirapuzha during the three seasons between two sampling years. Though a status report of river Periyar was made by Joseph (2004), previous studies on pollution load of Muthirapuzha are not available except the matter is often discussed by local news daily and the Green Tribunal judgment directed mitigation measures to reduce domestic pollution in Muthirapuzha river (National Green Tribunal Southern Zone, 2017). Hence this study establishes the organic pollution load from Munnar Township into Muthirapuzha river. Wen *et al.* (2017) identified anthropogenic origin of organic pollution in rivers.

There was an increasing trend of BOD along the middle and lower streams of the river in pre-monsoon and post-monsoon seasons. This could be due to the concentration of sewage into the river in the middle and lower part due to reduced water flow during pre and post-monsoon. Apart from sewage, the presence of agriculture run-off scattered over the entire study area could be causing organic pollution along this stream. Agricultural runoff is the main source of organic pollution in rivers (Shaw *et al.*, 1975; Wen *et al.*, 2017) The range of chloride value was 0.49 – 14.79 mg/l in pre-monsoon, 0.19- 5.16 mg/l in monsoon, and 0.44 – 9.96 mg/l in post-monsoon of all stations during the first year of sampling and it was between 0.23 -5.6 mg/l in monsoon, 0.54 to 9.89 in post-monsoon and 0.37 to 10.24 in pre-monsoon of the year 2015-16. The chloride

Table 2. Physico-chemical parameters of river Muthirapuzha, Kerala (2015-16)

Stations	p^H	TDS	Hardness	Alkalinity	DO	BOD	Chloride	Sulphate	Nitrate	Calcium
1	7.12	3.145	3.01	21.83	9.24	0.26	0.417	0.14	0.22	0.91
2	7.1	3.2	3.253	21.55	9.19	0.4	0.407	0.17	0.25	0.95
3	7.23	4.005	4.118	22.04	9.25	0.5	0.503	0.21	0.34	1.12
4	7.43	33.55	40.92	53.41	7.05	2.1	8.467	1.92	2.14	10.9
5	7.58	33.71	40.7	54.81	7	2.17	8.673	1.84	2.23	11
6	7.53	32.57	42.16	53.09	7.38	2.34	8.962	1.9	2.23	10.9
7	7.63	32.41	42.71	56.11	8.07	1.77	8.497	1.73	2.04	10.8
8	7.75	33.25	43.98	56.37	7.62	1.73	8.268	1.42	1.97	11
9	7.75	33.75	44.6	57.96	7.78	1.55	7.665	1.5	1.68	10.3
10	7.78	31.59	44.86	50.08	7.7	1.79	7.677	1.4	1.95	10.3
11	7.87	32.71	45.94	49.83	7.85	1.74	7.82	1.55	1.77	10.8
12	7.82	33.47	46.47	51.66	8.03	1.85	7.688	1.61	1.81	10.7

reaches the river from different anthropogenic activities like septic tank effluents, animal feeds, use of bleaching agents by launderer and washing of clothes. In the present study, the estimated sulphate values in all sampling stations were in the ranges of 0.03 to 2.56 mg/l 2014-15 and 0.11 to 3.47 mg/l in 2015-16. It was highest during pre-monsoons of both sampling years. The domestic waste and untreated sewage were responsible for the higher level of sulphate in the Umian lake water (Rajurkar, *et al.*, 2003).

The values of nitrate in the study stations were quite below the permissible limits, 0.29 to 3.72 mg/l in pre-monsoon, 0.14 to 0.97 mg/l, and 0.21 to 1.92 mg/l in monsoon and post-monsoon seasons respectively. In the next sampling year, the values range from 0.12 to 1.45 mg/l on monsoon, 0.22 to 2.93 in post-monsoon, and 0.15 to 3.87 mg/l in pre-monsoon; comparatively a higher value during pre-monsoon season. The most important source of nitrate is the biological oxidation of organic nitrogenous substances. Nitrate in river Muthirapuzha may also result from the point and non-point sources such as sewage disposal systems, livestock wading, and tourism activities, bathing, and washing of clothes. The calcium content in all sampling stations was within the suggested standard values. In 2014 -15 it ranged from 0.8 to 9.62 mg/l in monsoon, 1.07 to 15.19 mg/l in post-monsoon and 1.78 to 15.33 mg/l in pre-monsoon. During the next sampling year, it was within the range of 0.4 to 7.46 mg/l, 0.54to 10.56 mg/l and 0.61 to 13.98mg/l during monsoon, pre-monsoon, and post-monsoon seasons respectively

Correlation coefficient analysis of the chemical parameters of twelve stations in three seasons of river Muthirapuzha revealed significant relationships in both sampling years. There is a negative correlation between DO and BOD in three seasons of the study period. There were significant positive relationships for total hardness with total chloride, nitrate, sulphate, and total dissolved solids. These parameters showed a significant negative relationship with dissolved oxygen also. This type of relationship was established in both pre-monsoon and post-monsoon seasons in two sampling years. A similar correlation between DO and BOD was reported by Dwivedi and Pathak (2007) in river Mandakini. Total hardness is positively correlated with total conductivity and TDS. In monsoon seasons total dissolved solid is positively correlated with total hardness, conductivity, and chloride (Tandon, *et al.*, 2015). One way ANOVA between three sampling seasons for physico-chemical parameters of river Muthirapuzha showed that p^H. TDS, DO, COD, chloride, sulphate, and nitrate were significant at 0.01 level in both sampling years. A similar seasonal behaviour of river Achenkovil was reported (Rajan and Samuel, 2016). Seasonal fluctuations of water quality parameters is characteristics to riverine ecosystem (Kumar *et al.*,2015; Sharma and Walia, 2016; Ling *et al*., 2017; Kumar and Mukerjee, 2019).

Based on the analysis of physicochemical parameters during sampling years 2014-16, the water quality index (WQI) of river Muthirapuzha was computed. WQI based quality assessment of riverine system is recognized recently (Kumar and Dua, 2009; Kalavathy *et al.*, 2011; Divya and Murthy, 2013; Sharada and Sharma, 2013; Donald and Blessing, 2019; Kamboji and Kamboji, 2019). The station wise (Table 3) analysis WQI of the Muthirapuzha river established a clear status of water quality in each station.

Table 3. Water Quality Index (WQI) of River Muthirapuzha computed for 2014-16 (Two years)

STATIONS	PRM	MON	POM
1	26.86**	15.01***	19.99***
2	35.15**	17.47***	21.34***
3	40.37**	19.43***	30.59**
4	100.76+	54.01*	91.26*
5	107.82+	55.17*	93.96*
6	111.36+	60.47*	95.7*
7	91.6*	45.43**	79.5*
8	90.45*	45.73**	82.98*
9	86.01*	51.16*	62.29*
10	89.34*	55.58*	80.31*
11	90	55.57	76.56
12	92.41	55.12	80.56

*PRM - –Pre-monsoon, **MON- Monsoon, ***POM - Post-monsoon; ***excellent (0-25), **good (26-50), * moderately polluted (51-75), *severely polluted (76-100), + unfit (above 100).

Stations 1, 2, and 3 were 'excellent' in water quality during monsoon and post-monsoon seasons of both sampling years as well as 'good' according to water quality index in the pre-monsoon season (Table 3). The remaining stations were severely polluted during pre and post-monsoon seasons according to the WQI index. The WQI values exceeded the prescribed upper limit 100 along the stretches of the Munnar township region (sampling stations 4, 5, and 6) during the pre-monsoon season indicating the water quality is unfit for human consumption. The exact status was observed for these stations during post-monsoon, though it did not exceeding the upper limit of WQI. The anthropogenic and tourism pressure on Munnar township makes the water unfit for human consumption. Downstream stretches showed severe pollution status during pre-and post-monsoon seasons. However, the monsoon season identified less polluted downstream since the WQI values falling below 60, indicating moderate pollution level. The township region representing stations 4, 5, and 6 were moderately polluted during monsoon in both sampling years since WQI was lower than 60. This was due to the impact of heavy runoff during monsoon rain. Though the lower stretches of river Muthirapuzha were comparatively un-polluted based on the standards of CPCB a progressive increase in the WQI was reported along downstream that indicated the river is under the cumulative effect of the pollutants. Compared to post-monsoon, the water quality was severely polluted during the pre-monsoon season. However, the water quality was 'good' during monsoon season according to the water quality index due to the influence of heavy rainfall.

Table 4. Water Quality Index (WQI) of River Muthirapuzha in Pre-Monsoon (2015-16)

SL. NO	PARAMETERS	Vi	Si	Qi	Wi	QiWi
1	PH	7.77	8.5	51.33333	0.136	6.981333
2	TDS	32.82	500	6.564	0.002	0.013128
3	TOTAL HARDNESS	41.46	300	13.82	0.004	0.05528
4	TOTAL ALKALINITY	50.73	200	25.365	0.005	0.126825
5	DO	7.2	6	86.04651	0.186	16.00465
6	BOD	1.94	2	97	0.555	53.835
7	CHLORIDE	8.71	250	3.484	0.004	0.013936
8	SULPHATE	2.01	200	1.005	0.005	0.005025
9	NITRATE	2.4	20	12	0.056	0.672
10	CALCIUM	10.25	75	13.66667	0.015	0.205

ΣWi = 0.968 ;ΣQiWi = 77.91; WQI = **80.48**

Table 5. Water Quality Index (WQI) of River Muthirapuzha in Monsoon (2015-16)

SL. NO	PARAMETERS	Vi	Si	Qi	Wi	QiWi
1	PH	7.16	8.5	10.66667	0.136	1.450667
2	TDS	16.86	500	3.372	0.002	0.006744
3	TOTAL HARDNESS	24.63	300	8.21	0.004	0.03284
4	TOTAL ALKALINITY	41.24	200	20.62	0.005	0.1031
5	DO	8.54	6	70.46512	0.186	13.10651
6	BOD	0.99	2	49.5	0.555	27.4725
7	CHLORIDE	3.66	250	1.464	0.004	0.005856
8	SULPHATE	0.34	200	0.17	0.005	0.00085
9	NITRATE	0.76	20	3.8	0.056	0.2128
10	CALCIUM	5.75	75	7.666667	0.015	0.115

ΣWi = 0.968 ;ΣQiWi = 42.5; WQI = **43.91**

Table 6. Water Quality Index (WQI) of River Muthirapuzha in Post-Monsoon (2015-16)

SL.NO	PARAMETERS	Vi	Si	Qi	Wi	QiWi
1	PH	7.7	8.5	46.66667	0.136	6.346667
2	TDS	27.14	500	5.428	0.002	0.010856
3	TOTAL HARDNESS	34.58	300	11.52667	0.004	0.046107
4	TOTAL ALKALINITY	45.19	200	22.595	0.005	0.112975
5	DO	8.27	6	73.60465	0.186	13.69047
6	BOD	1.6	2	80	0.555	44.4
7	CHLORIDE	6.38	250	2.552	0.004	0.010208
8	SULPHATE	1.48	200	0.74	0.005	0.0037
9	NITRATE	1.49	20	7.45	0.056	0.4172
10	CALCIUM	8.94	75	11.92	0.015	0.1788

ΣWi = 0.968 ;ΣQiWi = 65.21; WQI = **67.37**

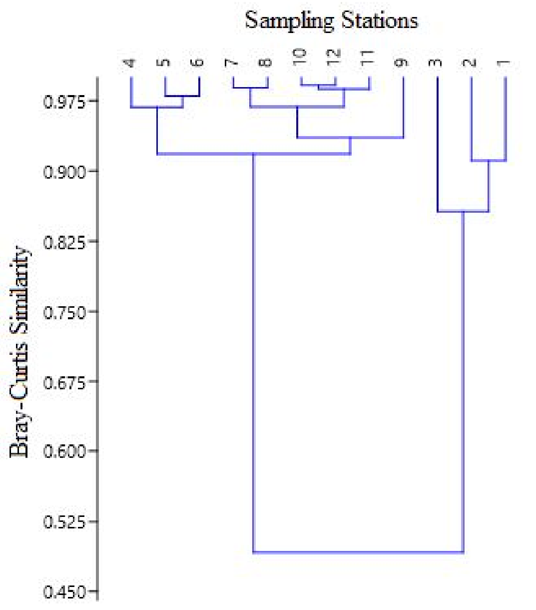

Fig. 2. Dendrogram showing Bray-Curtis Similarity Index of station wise WQI of river Muthirapuzha in 2014-16

Based on the categories of WQI, the quality of water was ‘excellent’ and ‘good’ in the upper stream of river Muthirapuzha in all three seasons during the study. The middle and lower stream stations were categorized into severely and moderately polluted in pre and post-monsoon. The water quality remains ‘good’ in the monsoon season. Dendrogram derived from Bray-Curtis similarity index analysis identified two clusters regarding the water quality of river Muthirapuzha. The index expresses similarities among stations 1, 2, and 3, these stations being the unpolluted upstream segment. The remaining stations come under another cluster which showed significant similarities in the pollution load of the river (Fig. 2).

The overall value of WQI for river Muthirapuzha was calculated with the help of mean values of specific physicochemical parameters, at pre-monsoon, it was 80.48 (Table 4). This indicated that the pollution load of the river Muthirapuzha was high at the pre-monsoon season. In post-monsoon, the WQI was 67.37 (Table 6) and in monsoon, it was 43.91 (Table 5). These values established the water quality of river Muthirapuzha, as it was

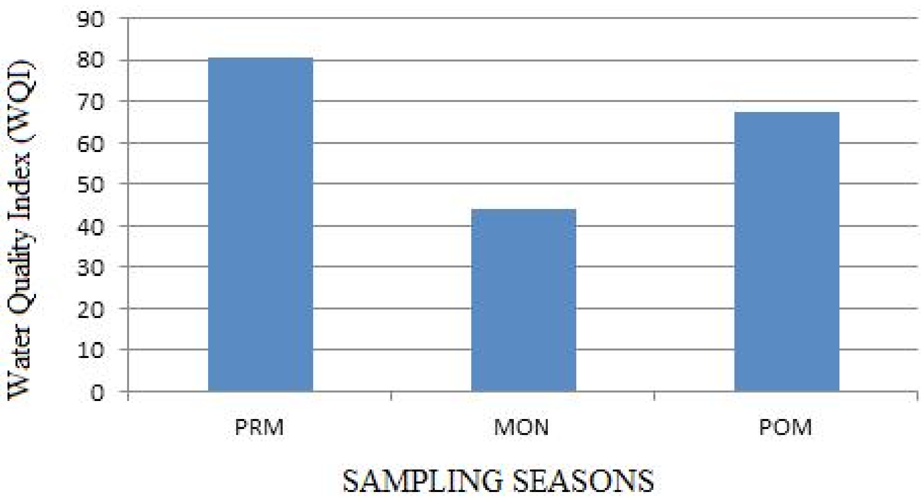

Fig. 3. Seasonal variation of water quality index (WQI) in river Muthirapuzha, Kerala (2014-16) PRM –Pre-monsoon, MON- Monsoon, POM-Post-monsoon

'moderately polluted' in post-monsoon and 'good' in monsoon seasons. (Figure 3). Yadhav and Sharma (2014) conducted ecological health assessment of Chambal river using water quality index. A similar observation was also reported by Singh and Kamal (2014) in Surface Water Quality Status of Goa. Hence WQI for river Muthirapuzha is appropriate for assessing the ecological status of the river especially Munnar having highest tourism potential (Murugadoss *et al*., 2016) constituting the major portion of this river basin.

5. Conclusion

River Muthirapuzha being the high altitudinal Western Ghats River basin of Periyar River; the water quality showed spatio-temporal variation. Applying the water quality index (WQI) River Muthirapuzha showed a polluted status during pre-monsoon and post-monsoon seasons except during monsoon. The upstream of river represented excellent water quality throughout the seasons while the middle stream flowing through the Munnar Township was badly affected in its water quality. The lower stream recorded a mixed range of water quality. WQI could differentiate the pollution load along this stream and turns to be ideal for monitoring the status of the river like Muthirapuzha.

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