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"Gheorghe Asachi" Technical University of Iasi, Romania

PREDICTION OF WATER QUALITY INDEX OF AN INDIAN RIVER USING ARITHMETIC INDEX AND REGRESSION MODELS

Divya Airattil Haridas[1], Soloman Pooppana Antony[2*]

[1]Environmental Engineering and Research Laboratory, Department of Chemical Engineering, Government Engineering College, Thrissur, PIN 680009, Kerala, India
[2]Department of Chemical Engineering, Government Engineering College, Thrissur, PIN 680009, Kerala, India

Abstract

This paper focuses on the effect of some water quality parameters of river water which helps in the calculation of water quality index (*WQI*) that culminates in the development of a regression model for prediction of *WQI* of the river system in India. The index was calculated by arithmetic index method using twelve various experimentally estimated water quality parameters such as potential hydrogen, chlorides, dissolved oxygen saturation, nitrates, sulphates, phosphates, total dissolved solids, biochemical oxygen demand, electrical conductivity, total hardness, turbidity and total coliform of the water at eight locations, for a 55 km stretch of Chalakkudy river November 2013 to December 2018. It was identified that total coliform is the major parameter contributing to the bad quality of water. Water quality regression model has been developed as a function of total coliform content. The performance of the model in predicting the *WQI* has been tested by comparing with the calculated *WQI* for the following year 2018. The regression model has been found to be good with an absolute average relative error and root mean square error values of 0.693 and 0.5 respectively. The results indicate that the basin is slowly getting into a serious drinking water crisis.

Key words: arithmetic index method, Chalakudy River, regression model, water quality index

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1. Introduction

Water pollution is a major environmental problem. Unless due attention is given and proper measures are undertaken, the situation would be worse in the future. In recent years, due to tremendous changes in the field of agriculture and industry, and increase in population, natural water systems has become perceptibly altered in several respects. Consequently, they are exposed to all local disturbances regardless of their source of occurrence (Amanatidou et al., 2018; Kido et al., 2009; Venkatesan, 2007). Significantly, improper water management leads to the inevitable water crisis in the entire world. The health of the rivers and their biological diversity will be directly related to the health of almost every component of the ecosystem (Ramesh et al., 2007). Surface water pollution with chemical, physical and biological contaminants due to anthropogenic activities is having both high risk and environmental attention (Hao et al., 2018; Nkedi et al., 2006).

Constant discharges of domestic and industrial wastewater and seasonal changes like climate and surface runoff also have an important role in the river water quality (Li et al., 2017; Shang, 2003). The increase in the supply of nutrients like phosphate, sulphates, and nitrates enhances the eutrophication process and is inversely proportional to the dissolved oxygen level of water. Algal bloom also releases some toxic chemicals which adversely affect fish and other aquatic life and makes the water body stink. The local fisherman who was in the habit of using dynamites for catching fish added to the gravity of this situation. As

* Author to whom all correspondence should be addressed: e-mail: pasolomon@gmail.com

a case study, Chalakudy river in India turned out to be a typical example of deteriorating water quality.

Water quality index (*WQI*) can be used as a good tool to convert the complex data into a simple and understandable tool making it feasible for the public to rely upon. *WQI* is a single measure of overall water quality in a specific location with a special emphasis on the time-based readings of water quality parameters (Singh et al., 2013; Taseli, 2017). Similar types of studies related to *WQI* have been conducted in India (Chowdhary et al., 2012; Pathak et al., 2015; Vineeta Kumari et al., 2015). Water quality river models such as artificial neural network model (ANN), extreme learning machine model (ELM) and support vector regression model (SVR) were reviewed (Alizadeh et al., 2015). Viewed from this perspective, water quality monitoring and analysis of water quality index are remarkable steps in the process of managing and conserving the entire ecosystem (Smerjit Kaur and Sindhu Singh, 2012).

Chalakudy river is one of the longest rivers in Kerala, India and the longest one in Thrissur district, having a length of 145.5 km with a total drainage area of 1704 sq km, out of which 1404 sq km is in Kerala and the rest 300 sq km happened to be in Coimbatore district of Tamil Nadu. It originates from the Anamalais and Nelliampathy ranges of the Western Ghats. In Kerala, it flows westward through Palakkad, Thrissur, and Ernakulam districts. A major portion lies in the Thrissur district (Maya and Seralathan, 2005).

The present study area covers 55 km i.e. 38% of the total river length, starting from Vazhachal, situated 400m above sea level and ending at palapuzhakadavu at Sea level. Refer to the map given in Fig. 1. Eight sampling sites are selected from the upstream to downstream of the river, as detailed in Table 1.

The study mainly focuses on the following objectives:

- develop the *WQI* model by arithmetic index method for the assessment of the pollution load of Chalakudy river based on actual experimental data.
- develop the regression model as a function of total coliform content for predicting *WQI* of Chalakudy river.
- validate the regression *WQI* model by comparing with the calculated *WQI* for the following year 2018.

2. Material and methods

2.1. Sample collection

Water samples were collected from eight selected stations (Table 1) of Chalakudy River from November 2013 to October 2018, once in a month, using the grab sampling method. Samples were collected in 1000 ml HDPE bottles for determination of all the parameters except biochemical oxygen demand (BOD), total coliform (TC) and dissolved oxygen (DO). The sample bottles were rinsed with 1M HCl and then with distilled water. The bottles were also rinsed thrice with water sample before collection. The collected samples were capped tightly and placed in a cooler box with ice for transportation to the laboratory.

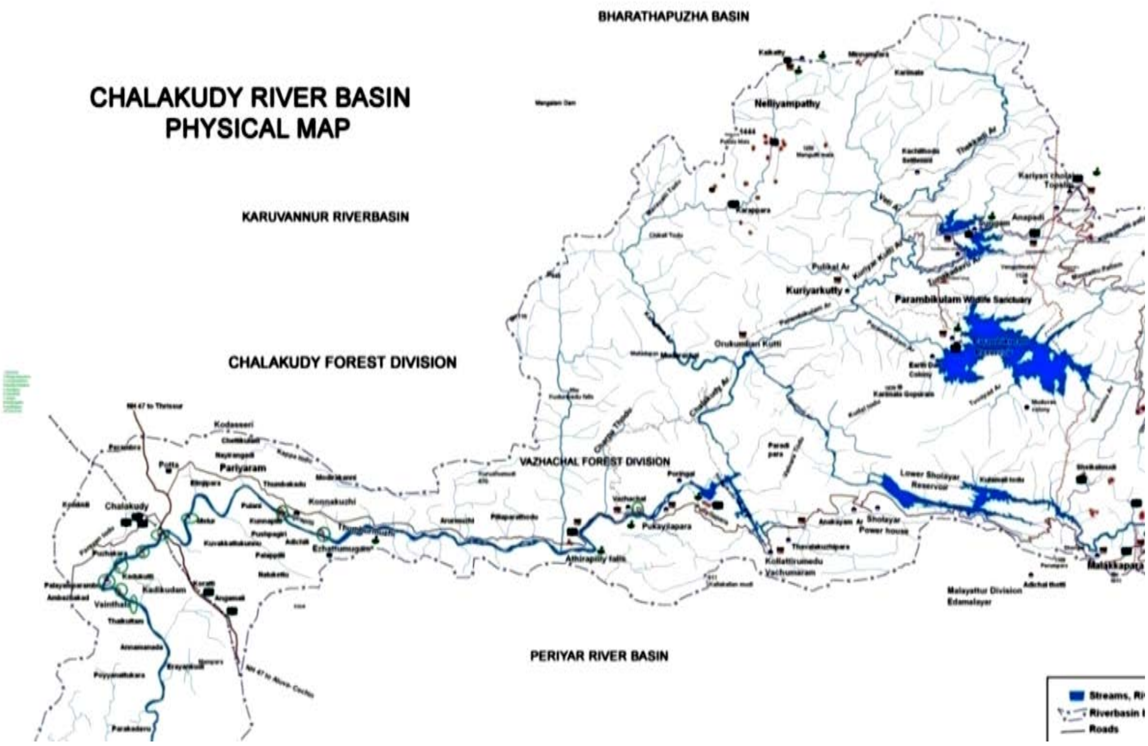

Fig. 1. Chalakudy River basin map

Table 1. Sampling stations

site	*Place*	*Activity*	*longitude and latitude*
I	Vazhachal	tourist spot, forest division	10°17’18.34N-76°31’42.18E
II	Vettilappara	the water theme park, agricultural area	10°17’33.86N-76°28’39.32E
III	Kanjirappilly	paper mill (Presently not working)	10°18’14.59N-76°23’48.29E
IV	Pariyaram	bathing, Skol breweries	10°17’31.65N-76°21’26.06E
V	Chalakudy	major town, KWA pumping station	10°17’41.04N-76°20’11.06E
VI	Vynthala	KWA drinking water pumping station with Treatment plant.	10°11’33.75N-76°20’07.24E
VII	Pulikkakadavu	downstream of DCP plant	10°14’01.75N-76°19’53.29E
VIII	Palapuzhakadavu	bathing, residential area, agriculture area	10°14’01.75N-76°20’10.96E

For TC, BOD and DO, sterilized sample bottles were filled along the sides of the bottle carefully up to the brim, without trapping the air inside (Haider and Waris, 2013). DO has been fixed using manganese sulphate and alkali iodide azide and capped. The samples were stored in a refrigerator at 4^{o}C immediately upon arrival at the laboratory.

2.2. Analytical methods

All the water quality parameters were analyzed by the standard procedures of the American Public Health Association (APHA, 2012).

2.3. Water Quality Index (WQI) calculation

WQI was calculated by arithmetic index method using twelve physicochemical parameters. There are various versions of the method reported by different researchers (Rao, 2011). In most of the *WQI* model development methods use of various subindex formulae for the range of constituent water quality variables are very essential (Gazzaz et al., 2012). DO is a very important parameter in WQI calculation (Zhang et al., 2017).

Eqs. (1-4) are used to calculate *WQI* by arithmetic index method.

$$WQI = \sum qnwn \tag{1}$$

Water quality rating (q_n) of each parameter is calculated using Eq. (2):

$$qn = \frac{100*(Vn - Vi)}{(Vs - Vi)} \tag{2}$$

Here *Vn* is the observed value of the nth parameter, *Vs* is the standard value of each parameter and *Vi* is the ideal value of the nth parameter. All the ideal values except pH and DO are taken as zero. Ideal value for *pH=7*, and for % *DO saturation=100*. If $qn = 0$, it indicates the complete absence of pollutants. While $0 < q_i < 100$ implies that the pollutants are within the prescribed standard. When $q_i > 100$, it means that the pollutants are above the standard (Mohanty, 2014).

The unit weight is given by Eq. (3):

$$Wn = \frac{K}{Vs} \tag{3}$$

where

$$K = \frac{1}{\frac{1}{Vs1} + \frac{1}{Vs2} + \frac{1}{Vs3} + \frac{1}{Vs4} ... + \frac{1}{Vsn}} \tag{4}$$

The method of calculation of *WQI* by considering the TC standard limit as 50 CFU/100 mL and 10 CFU/100 mL respectively as shown in Tables 2-3.

2.4. Classification of river water according to the WQI

Quality of river water is classified in to five groups as ‘Excellent’, ‘Good’, ‘Poor’, ‘Very poor’ and ‘Not suitable for drinking’ as per the classification is shown in Table 6 (Ramakrishnaiah et al., 2009).

2.5. Data Analysis

All the data were initially arranged and consolidated such as year, site, month, season, type, parameter, and value. Pivot table analysis of *Microsoft Excel* was used to process the necessary combinations of data from the entire data table. Calculation of water quality index by the arithmetic method and development of regression model was performed using *Microsoft Excel*. Two-way analysis of variance (ANOVA) and Tukey post-hoc analysis were performed with *Minitab 17* statistical software.

2.6. Regression Model

Two sets of data, $WQI_{(at\ TC\ limit\ as\ 10\ CFU/100mL)}$ and $WQI_{(at\ TC\ limit\ as50\ CFU/100mL)}$ calculated using the arithmetic index were used to develop the linear regression model of *WQI* in terms of *TC* (Eqs. 5-6). The ability of the regression models in predicting the WQI was tested using average absolute relative error and root mean square error.

Average absolute relative error is given by Eq. (5):

$$AARE\% = \sum_{i=0}^{n} \frac{(Ei - Pi)}{Ei} \times 100 \tag{5}$$

Table 2. WQI calculation by arithmetic method considering standard TC limit as 50 CFU/100mL

Parameters	***Range***		***1/Vs***	***Unit Weight(Wn)***	***Observed value***	***wn*Qn***
	limit	***best***				
BOD, mg/L	3	0	0.333	0.3714	1.88	23.274
Chlorides, mg/L	250	0	0.004	0.0045	22	0.039
DO saturation, %	50	100	0.020	0.0223	63	1.649
Electrical Conductivity, μmhos/cm	300	0	0.003	0.0037	69	0.085
Nitrates, mg/L	45	0	0.022	0.0248	0.56	0.031
pH	8.5	7	0.118	0.1311	6.4	5.243
Phosphates, mg/L	6	0	0.167	0.1857	6.7	20.736
Sulphates, mg/L	200	0	0.005	0.0056	1.05	0.003
Total Coliform CFU/100mL	50	0	0.020	0.0223	50	2.228
Total Dissolved Solids, mg/L	500	0	0.002	0.0022	56	0.025
Total hardness as $CaCO_3$, mg/L	200	0	0.003	0.0037	49	0.061
Turbidity NTU	5	0	0.200	0.2228	0.67	2.986
			0.898	**1.00**		**56.33**
		K=	1.114			

Table 3. WQI calculation by arithmetic method considering standard TC limit as 10 CFU/100ml

Parameters	***Range***		***1/Vs***	***Unit Weight(Wn)***	***Observed value***	***wn*Qn***
	limit	***best***				
BOD, mg/L	3	0	0.333	0.3410	1.88	21.369
Chlorides, mg/L	250	0	0.004	0.0041	22	0.036
DO saturation, %	50	100	0.020	0.0205	63	1.514
Electrical Conductivity, μmhos/cm	300	0	0.003	0.0034	69	0.078
Nitrates mg/L	45	0	0.022	0.0227	0.56	0.028
pH	8.5	7	0.118	0.1204	6.4	4.814
Phosphates, mg/L	6	0	0.167	0.1705	6.7	19.039
Sulphates, mg/L	200	0	0.005	0.0051	1.05	0.003
Total Coliform CFU/100mL	10	0	0.100	0.1023	50	51.149
Total Dissolved Solids, mg/L	500	0	0.002	0.0020	56	0.023
Total hardness as $CaCO_3$, mg/L	200	0	0.003	0.0034	49	0.056
Turbidity NTU	5	0	0.200	0.2046	0.67	2.742
			0.978	**1.00**		**100.85**
		K=	1.023			

Root mean square error is calculated by Eq. (6).

$$RMSE = \left[\frac{1}{n} \sum_{i=0}^{n} \frac{(Ei - Pi)}{Ei} \right] \quad (6)$$

where: E_i is experimental, P_i is the predicted value obtained from the regression model.

3. Results and discussion

The values of *WQI* calculated using arithmetic index method is shown in Table 4. The range of values with a mean and standard deviation of *WQI* at each site are shown in Table 5. *WQI* of Chalakudy River is found to be between 166 to 4745 and 47 to 996 considering *TC* standard value as 10 CFU/100mL and 50 CFU/100 respectively. As per the classification shown in Table 6, most of the samples lie within the class ‘not suitable for drinking purpose’. This is mostly due to the presence of high values of TC. Most of the parameters analyzed in the river water samples were found to be within the permissible limits according to the drinking water standards. Vazhachal, Vettilappra and Pariyaram sites were found to be having less *TC* contamination as compared with Chalakudy, Vynthala, Pulikkakadavu and Palapuzhakadavu sites with a lower mean values of *WQI*.

Two-way analysis of variance (ANOVA) of *WQI* is shown in Table 7. Prior to analysis, data were checked for normality. The P value for the site was obtained as 0.001 ($P < 0.05$) and season 0.212. It means the site is statistically significant with the *WQI* and season is insignificant.

The impact of urbanization-flats, hotels, waste from a cattle farm, poultry farms, thickly populated human stay situated very close to the river resulted in an adverse effect on the water quality. This leads to the inference of load of pollution in Chalakudy site, specifically due to the influence of untreated sewage discharge from the nearby area. The Tukey post hoc analysis revealed that Chalakudy and Palapuzhakadavu are the sites statistically different from others in terms of *WQI*. The behavior is visible in Fig. 2 also. The marked increase in the WQI values in these sites is due to the presence of high concentration of coliform bacteria.

Table 4. *WQI (at TC limit 10 CFU/100ml)* of the sites from November. 2013 to October. 2018 by arithmetic index method

Month& Year	***Vazhachal***	***Vettilappara***	***Pariyaram***	***Chalakudy***	***Vynthala***	***Pulikkakadavu***	***Palapuzakadavu***
2013							
Nov	276	925	1148	485	1121	412	852
Dec	836	898	710	1365	1123	516	930
2014							
Jan	651	925	490	1001	465	1048	1224
Feb	556	534	1127	881	294	750	1380
Mar	166	259	611	442	652	655	354
Apr	1182	803	955	234	1349	1116	489
May	983	620	855	1229	1305	408	709
Jun	926	650	1462	1131	1036	755	1170
Jul	1206	765	1078	697	1237	994	346
Aug	649	791	623	1282	1072	367	493
Sep	635	611	1376	1525	647	1231	863
Oct	1282	907	1205	479	1237	1017	612
Nov	827	1056	863	1441	1198	668	725
Dec	889	981	1804	1388	1145	1602	1030
2015							
Jan	1052	726	952	662	909	1135	1227
Feb	455	556	1393	1220	735	961	828
Mar	653	1225	224	1107	1391	611	458
Apr	613	669	552	1706	1228	1537	1811
May	172	195	785	1497	437	1379	1254
Jun	755	1098	756	1129	1180	527	1423
Jul	1275	1482	1253	1003	1533	1225	1191
Aug	534	292	470	426	254	244	312
Sep	1642	1211	415	565	1077	1020	832
Oct	1018	1282	833	1126	1196	423	945
Nov	702	1009	1048	1115	1296	1191	1036
Dec	637	708	279	1112	230	179	1207
2016							
Jan	618	1518	707	1300	975	500	742
Feb	1156	1178	840	2278	789	708	2008
Mar	1006	689	1176	1949	918	979	1134
Apr	547	491	394	464	741	650	965
May	512	1092	547	2031	1749	1836	1990
Jun	509	1007	882	681	271	551	792
Jul	438	388	1133	1295	395	580	987
Aug	740	769	507	957	557	598	649
Sep	878	848	658	534	581	984	681
Oct	978	888	691	938	759	770	426
Nov	484	725	360	1195	707	745	1004
Dec	992	646	636	846	714	1642	1143
2017							
Jan	756	907	927	1624	633	1570	1735
Feb	1494	751	1887	669	574	853	1833
Mar	1210	202	891	2217	2036	1869	2233
Apr	807	638	486	1570	583	1841	1767
May	887	436	822	1676	971	1810	2373
Jun	257	521	504	720	663	866	616
Jul	195	433	667	394	606	643	619
Aug	709	814	435	802	928	1011	568
Sep	612	516	712	895	872	552	975
Oct	506	1012	388	1506	1265	1571	1630
Nov	432	395	1127	484	403	572	998
Dec	754	787	516	956	549	602	660
2018							
Jan	880	804	736	1502	1988	2219	1929
Feb	883	580	1057	1380	768	792	1778
Mar	288	647	1002	2370	1227	2320	3693
Apr	771	549	608	1123	512	758	546
May	980	1153	475	1174	2306	526	1395
Sep	2245	2622	3498	4484	4365	4543	4745
Oct	2609	2613	2864	3604	2619	2868	2997

Table 5. The maximum, minimum and mean ±SD values of each site

	WQI, TC limit: 10 CFU/100mL				*Mainly contributing by*
Sites	*Mean*	*SD*	*Max*	*Mini*	
Vazhachal	819.39	445.5	2609	166	TC
Vettilappara	838.54	451.6	2622	195	TC
Kanjirappilly	931.68	545.9	3254	221	TC
Pariyaram	901.75	566.4	3498	224	TC, TH
Chalakudy	1225.72	738	4484	234	TC, BOD, TH
Vynthala	1024.05	671.5	4365	230	TC, BOD
Pulikkakadavu	1057.9	728.5	4543	179	TC, BOD
Palapuzhakadavu	1216	814.6	4745	312	TC, BOD

Table 6. Water quality classification based on *WQI* values

The range of WQI Value	*Water quality*	*Number of water samples*	
		TC limit 10 CFU/100mL	*TC limit 50 CFU/100mL*
WQI < 50	Excellent	0	1
50 < WQI <100	Good	0	40
100 < WQI <200	Poor	5	209
200<WQI <300	Very Poor	15	135
WQI >300	Not suitable for drinking	436	71

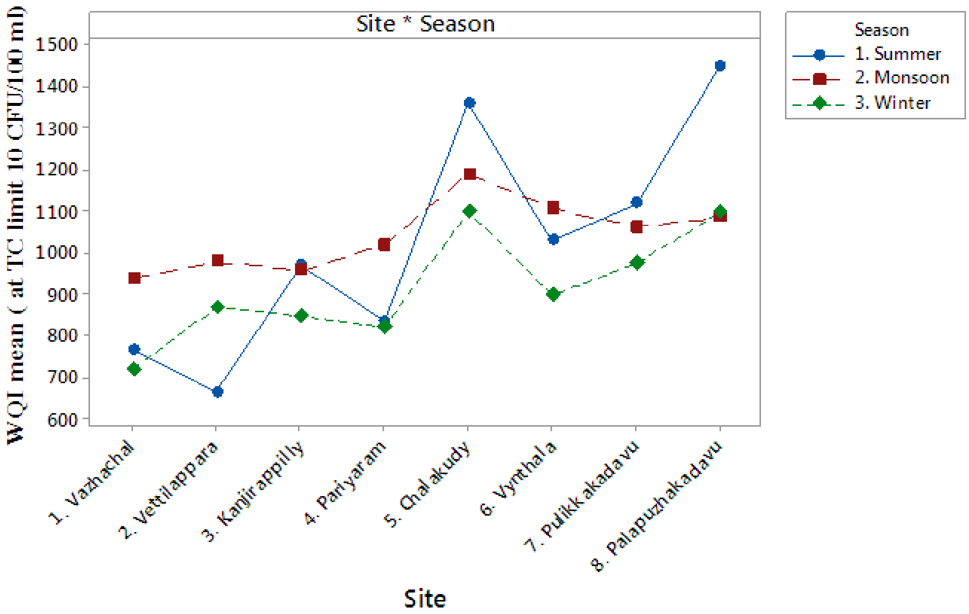

Fig. 2. Mean value plot of WQI by two way ANOVA

Table 7. Two way ANOVA result

Source	*DF*	*Adj SS*	*Adj MS*	*F- Value*	*P-Value*
Site	7	10209959	1458566	3.93	0.001
season	2	959882	479941	1.29	0.276
Site * season	14	3587578	256256	0.69	0.785
Error	432	160423302	371350		
Total	455	1755062433			

The spatial and temporal variations of *WQI* is shown in Fig. 3. The highest *WQI* values of 4454, 4543, 4745 and 4365 were noticed at Chalakudy, Pulikkakadavu, Palapuzhakadavu, and Vynthala sites respectively during September 2018. This may be the after effect of the flood in the river during August 2018. After the flood in Kerala, the water level in the river had drastically decreased. This resulted in a high level of deterioration of water quality. It was observed that the poor water quality of the river water surely due to the high concentration of total coliform. BOD, pH, and TH are also affecting the water quality but not to a greater extent as caused by the TC. Sometimes at Palapuzhakadavu and Pulikkakadavu sites, shows deviations from standard values. Also, the same sites were found to have high values of TC and BOD. The resultant changes in water quality might be attributed to the influence of anthropogenic sources like domestic sewage effluent and settling after the runoff. Specifically, this area is residential and agricultural. The least value for pH (4.2) and DO (5.1) were observed at Kanjirappilly site during 2016. It may be attributed to the leachate from the settled sludge from the pulp and paper industry. All the other parameter analysed except the above were found to be within Indian standard and WHO standard.

A flourishing Dicalcium Phosphate industry located near the river is directly discharging its treated effluent into the river. Contaminants may be also carried in through one small stream called Perumthodu, which meets Chalakudy River almost a fewmeters upstream of Pulikakadavu site. Though the industry has well-established ETP with online monitoring meters and ensures the quality of effluent discharge, still effluent discharge to the river at this area may have turned harmful to the quality of water. The maximum seasonal average of pH is 7.2. Most of the values of water pH are within the permissible limit. It is specified that pH range 6.7 to 8.4 is very essential for the growth of aquatic biota. pH values of most of the samples were within the pH range assigned by Indian standard for drinking water (IS, 2012) (6.5 - 8.5).

As shown in Table 6, according to the classification already given, the water quality of the Vazhachal and Vettilappara site had displayed comparatively less biological pollution because of the freshwater availability due to the high rainfall in the forest area and high level of DO during winter and monsoon. During some season it was also noticed that water samples collected from this site contained the presence of nitrates and phosphates. This may be from natural sources like rocky surface and land drainage (Johnes and Burt, 1993). Moreover, the study indicates that the most affected parameter on WQI is the presence of a high value of TC throughout the period of study. Chalakudy and Palapuzhakadavu sites were found to have the worst water quality due to the high contamination of coliform bacteria.

For all seasons Vynthala site was found to show a mean WQI above 1000. Pallithodu is a natural water source through which the excess rainwater reaches Parayanthodu which flows from Chalakudy town area. Therefore, there are all possibilities that a portion of the untreated sewage wastes reach the river through Pallithodu which reaches Parayanthodu, which ultimately joins the river about 1 km upstream of Njaralakadavu at the Vynthala site. This may in effect deteriorate the water quality and affects the bio-diversity of the Chalakkudy River (Chattopadhyay et al., 2005). Also, this might turn harmful to the two major drinking water pumping stations that are located near Vynthala site which caters the purpose of domestic supply for more than ten local bodies. At this site, KWA treatment plant having 26.1 Million Cubic Meter capacity is also functioning.

Moreover, during the period of study, *TC* values of the river water were not found to comply with the permissible standards (absent or less than 10 CFU/100mL, or 50CFU/100 mL in the absence of alternate source). Remarkably all other values used for computing *WQI* except *TC*, at all the sites, were found to be within the permitted standards meant for human consumption But *TC* is an essential and important parameter for the drinking water quality assessment of human concern because this parameter is an indication of disease-causing pathogens.

On moving downstream, the water quality of the Chalakudy River varied and became terribly poor based on the drinking water quality assessment. But at the same time, due to a comparatively good flow of fresh water in the river during monsoon, the rate of dilution of wastes will also was high.

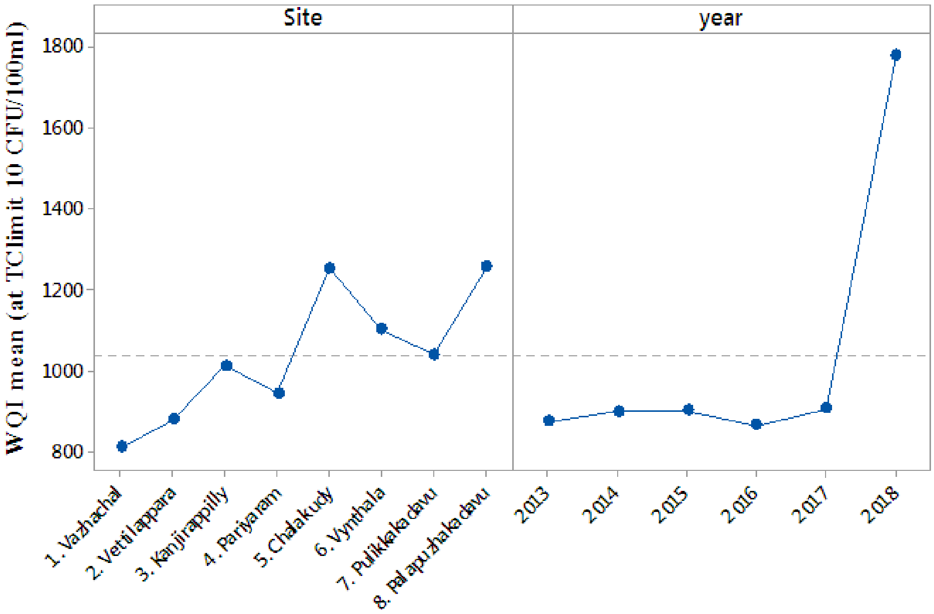

Fig. 3. Temporal and spatial variations of *WQI*

Evidently, the distillery industry located in Pariyaram and DCP plant at the Pulikkakadavu site did not contribute much pollution in to the river. But, the presence of some organochlorine pesticides residue was noticed in the bottom sediment of Paraiyaram site (Divya and Soloman, 2018). The linear regression model of the *WQI* of Chalakudy River is shown in Fig. 4 and Fig. 5. The regression analysis gives the following model equations Eqs. (7, 8) with the value coefficient of regression R^2. This gives the relationship between *WQI* and *TC* of the Chalakudy River.

$$WQI_{(at\ TC50\ CFU/100ml)}=0.253*TC+18.53, \text{ with } R^2=0.993 \quad (7)$$

$$WQI_{(at\ TC10\ CFU/100ml)}= 1.240*TC+18.45, \text{ with } R^2=0.999 \quad (8)$$

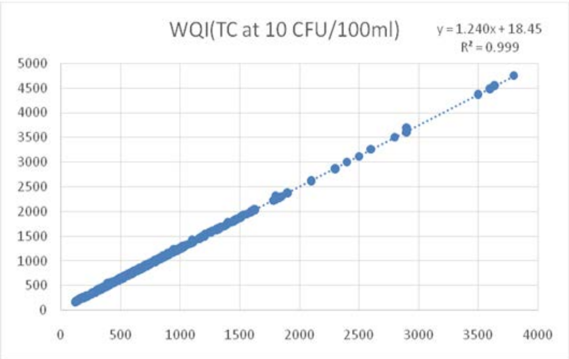

Fig. 4. The regression model of *WQI* by considering TC limit as 10 CFU/100mL

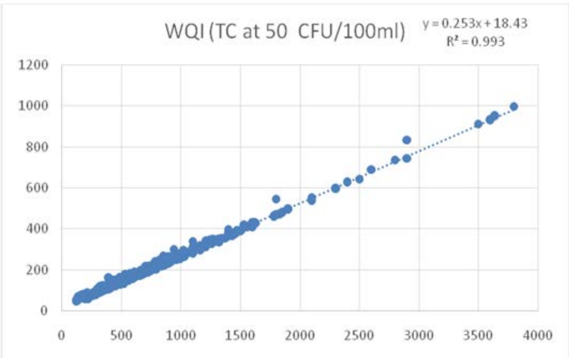

Fig. 5. The regression model of *WQI* by considering TC limit as 50 CFU/100mL

The closeness of the arithmetic index value of *WQI* $_{(at\ TC\ standard\ 10\ CFU/100mL)}$ and *WQI* $_{(at\ TC\ standard\ 50\ CFU/100mL)}$ with the predicted value of *WQI* using regression equations Eq. (7) and Eq. (8) is shown in Table 8. The performance of the two models in predicting the *WQI* has been tested by comparing with the data available for the year 2018 and found to be significantly good with an absolute average relative error (AARE) and root mean square error (RMSE) of 0.693 and 0.5 respectively for the first model. In the case of the second model also the AARE and RMSE values are fairly good, 1 and 0.028 respectively.

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4. Conclusions

Identification of *WQI* is an essential step to monitor, prevent and reduce water pollution. Water quality index using twelve important physicochemical factors at eight locations stretching 55 km from Vazhachal to Palapuzhakadavu of Chalakudy River has been estimated experimentally for a period from November 2014 to October 2018. WQI models have been developed in two approaches such as arithmetic index method and linear regression model using *Microsoft Excel*. *WQI* $_{(at\ TC\ limit\ 10\ CFU/100ml)}$ values and *WQI* $_{(at\ TC\ limit\ 50\ CFU/100\ ml)}$ ranges from 166 to 4745 and 47 to 996 respectively. The water of none of the sampling stations was found fit for direct human consumption because of the contamination due to *TC*. Two-way analysis of variance shows that spacial influences are statistically significant for the *WQI*. Most of the other parameters analyzed during the period of study complied with the drinking water quality specifications. The results indicate that water from this river is suitable for irrigation and not suitable for drinking and bathing. So highest priority should be given to conventional treatment along with disinfection before the distribution of water to the public. Direct consumption may lead to severe water born diseases in the basin.

The performance of the regression models was tested by comparing with calculated values of *WQI* during the following year 2018 and found that the models are performing very good with AARE 0.693 and RMSE 0.5. Thus, the regression model and the arithmetic index model are reliable and effective models which can be used as a yardstick for measuring the approximate value of *WQI* of this river. By knowing the *WQI*, proper remedial measures can be taken for healthy water management system.

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Table 8. The closeness of calculated value with the predicted value of *WQI*

TC CFU/100mL	*WQI (TC limit 10 CFU.100mL)*	*Predicted WQI*	*WQI (TC limit 50 CFU.100mL)*	*Predicted WQI*
700	880	886.45	190	195.55
630	804	799.65	183	177.84
560	717	712.85	164	160.13
1200	1502	1506.45	318	322.05
1780	2219	2225.65	463	468.79
1530	1929	1915.65	419	405.54
1590	1988	1990.05	419	420.72
700	883	886.45	192	195.55
450	580	576.45	136	132.3
1010	1258	1270.85	261	273.98
820	1057	1035.25	248	225.91
1100	1380	1382.45	294	296.75
610	792	774.85	190	172.78
1400	1778	1754.45	396	372.65
600	768	762.45	176	170.25
210	288	278.85	80	71.58
490	647	626.05	163	142.42
1200	1499	1506.45	315	322.05
790	1002	998.05	223	218.32
1900	2370	2374.45	496	499.15
1800	2320	2250.45	544	473.85
2900	3693	3614.45	832	752.15
940	1227	1184.05	299	256.27
610	771	774.85	169	172.78
420	549	539.25	134	124.71
510	654	650.85	151	147.48
470	608	601.25	144	137.36
890	1123	1122.05	245	243.62
590	758	750.05	176	167.72
390	546	502.05	161	117.12
400	512	514.45	118	119.65
780	980	985.65	211	215.79
900	1153	1134.45	265	246.15
530	701	675.65	178	152.54
370	475	477.25	110	112.06
930	1174	1171.65	256	253.74
400	526	514.45	131	119.65
1100	1395	1382.45	310	296.75
1850	2306	2312.45	481	486.5
1800	2245	2250.45	469	473.85
2100	2622	2622.45	550	549.75
2600	3254	3242.45	689	676.25
2800	3498	3490.45	735	726.85
3600	4484	4482.45	932	929.25
3640	4543	4532.05	952	939.37
3800	4745	4730.45	996	979.85
3500	4365	4358.45	912	903.95
2100	2609	2622.45	537	549.75
2100	2613	2622.45	542	549.75
2500	3108	3118.45	642	650.95
2300	2864	2870.45	595	600.35
2900	3604	3614.45	743	752.15
2300	2868	2870.45	599	600.35
2400	2997	2994.45	629	625.65
2100	2619	2622.45	547	549.75

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