GENERAL WATER QUALITY OF MUVATTUPUZHA RIVER IN ERANAKULAM DISTRICT

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Abstract : Rivers in Kerala play an important role in the lives of the people. Muvattupuzha River is one of the important rivers in Eranakulam District of Kerala,which is the second major river source used by Kerala Water Authority for supplying piped water in Eranakulam district. In the present study, identification of water quality was carried out so as to evolve better management of the available water in the river Muvattupuzha. Samples were collected during 2015-2016 from the selected points and following parameters were analyzed - pH, turbidity, chloride, iron, nitrate, fluoride, total organic carbon(TOC), total suspended solids(TSS), total dissolved solids(TDS), phosphate, ammoniacal nitrogen, surfactants, Chemical Oxygen Demand(COD), Dissolved Oxygen(DO), Biochemical Oxygen Demand (BOD) ,total coliform bacteria and metals Fe, Cu, Zn, Mn, Pb, Cr and Cd. Hydro chemical analysis of Muvattupuzha river from the selected points during the year 2015-2016 revealed that some of the water quality parameters like turbidity, iron and total coliform bacteria exceeded the permissible standard limit set by BIS 2012& WHO 2018. Factor analysis indicated that geochemical processes contribution was a major factor during the river course flow and municipal waste discharge might also be happening . During the flow of river from upper to lower reaches, organic matters were oxidized or reduced with abundance of oxygen in river. Therefore organic pollutants might not be a predominant factor in this river course.

IndexTerms **- Muvattupuzha river,KWA, correlation,iron, Total coliform, Eranakulam district, hydro chemical, factor analysis, loading.**

I. INTRODUCTION

A river is a natural flowing water course, usually fresh water, flowing towards an ocean, sea, lake or another river. They are very important part of the hydrological cycle. The rivers of India play an important role in the lives of people, they provide potable water, cheap inland transportation, irrigation, inland fishing and support the livelihood of many people nationwide. They are responsible for deposition of fertile soil in the plains as well as in the formation of deltas. Seven major rivers along with their tributaries make up the river system of India. Most of the rivers pour their waters into Bay of Bengal, however some of the rivers empty into the Arabian sea.

Rivers in Kerala play an important role in the lives of the people, not only do they irrigate the fields of this rice dominating region but they are also the source of livelihood for various fishermen and holds great value in the tourism industry. There are 44 rivers in Kerala, 41 of them flow westward and 3 eastward, all but 3 originate in the Western Ghats . Due to the hilly terrain and the relatively shorter distance between Western Ghats and the sea, the rivers flow faster. Many of the rivers dry up completely during summer as they are entirely monsoon fed. Compared to the rivers nationwide the rivers of Kerala are smaller in terms of length, breadth and water discharge. The quality and quantity of these rivers are changing over the years due to a number of reasons like deforestation, soil erosion, mining, release of industrial toxic effluents into the rivers and pressure from urbanisation.

Muvattupuzha is one of the important rivers in Eranakulam District of Kerala, length of which is 121 Km. This river is the union of three rivers - Thodupuzha, Kaliyar and Kothamangalam. The Kaliyar river, Thodupuzha river and Kothamangalam river joining together at Muvattupuzha and flowing down the south-west as a single river for about 115 km after confluence and traversing a total length of 121 km constitutes the Muvattupuzha river basin. The total drainage area of the river is 1554 km^2(Aparna et al ,.2015). These rivers join together at Muvattupuzha and then flow towards south-west as a single river to reach the Vaikkom Lake. Finally, it merges with the Arabian Sea. The river is selected for this study as it is the second major river source used by KWA for supplying piped water in Eranakulam district. Furthermore one of the major treatment plants of Kerala Water Authority is situated at Maradu which is drawing raw water from Muvattupuzha river for treatment. The study aims at identification of water quality so as to evolve better management of the available water in the Muvattupuzha River.

II. MATERIALS AND METHODS

Based on density of population consuming the water supplied by KWA, the present study locations lies between 9 ° 87 I 71.37 II &10° 05 I 66.48 II N latitudes and76 ° 48 I 56.56 II & 76° 68 I 26.15 II E longitudes were selected. Samples were collected from four sampling stations , from January 2015 to March 2016 ,of which 2 stations were from Muvattupuzha river , third from Kaliyar and the last from Thodupuzha river.Near Muvattupuzha bridge, Kacherithazham and Piravom bridge were sampling points from Muvattupuzha river, near Hanging bridge at Madakkathanam from Kaliyar river and near Kozhippilly bridge Kothamangalam from Thodupuzha river.

III. DETAILS OF SAMPLING POINTS

Water samples were collected from the selected stations and analysis were done periodically in pre monsoon (January2015, February2015, March2015 &April 2015-season1), monsoon (May2015, June2015, July2015,& August2015-season-2),post monsoon (September2015, October2015, November 2015&December 2015-season-3) and pre monsoon in 2016(season-4) as per the standard methods recommended by the American Public Health Association (2012) , ASTM (2006) Indian Standard methods(2015), Grasshoff (1999), Cochran (1950) .The suitability of the river water for various purposes were evaluated by comparing the water quality parameters with those of Indian Standard 10500 ;2012,World Health Organization (WHO 2018) and CPCB guidelines.The parameters pH, Turbidity, Chloride, Nitrate, Fluoride, Total Organic Carbon(TOC),Total Suspended Solids(TSS),Total Dissolved Solids(TDS), Phosphate, Ammoniacal Nitrogen,Surfactants, Chemical Oxygen Demand(COD), Dissolved Oxygen(DO), Biochemical Oxygen Demand (BOD),Temperature and Fecal Coliform Bacteria were analyzed. Zn,Cu,Mn,Cr,Pb &Cd metals were analysed using AAS with graphite furnace and Fe was checked with spectrophotometer. Results were statistically interpreted using principal component analysis and Correlation method (Hem, 1985 ;Hounslow, 1995;Taqveem Ali Khan , 2011; Park et al.,2010). (Table. 1, Figure 1 and 2)

IV. RESULTS AND DISCUSSION

Analysis of water for the general parameters such as Temperature,Chemical Oxygen Demand(COD), pH, Turbidity, Chloride, Nitrate, Fluoride, Dissolved Oxygen(DO),Biochemical Oxygen Demand(BOD),Total Organic Carbon(TOC), Phosphate, Ammonia Nitrogen, Total Dissolved Solids(TDS),Total Suspended Solids(TDS), Surfactants, Fecal Coliform Bacteria from the four stations were determined and compared with the standard values given in IS(2012),WHO(2018),CPCB guidelines. Here mean value of data from the four locations and their standard deviations were recorded were given in ***Table-2***

In the first sampling point , Muvattupuzha bridge, Kacherithazham, pH was with in the drinking water standard limit in all the three seasons and in the next year it showed a slight increase but with in the limit of the standard value. A high value of turbidity of 4.175NTU was noted during monsoon season and lowest value of 1.475NTU in pre monsoon was obtained. In all seasons turbidity value was above drinking water standard limit. High values for COD, BOD , TOC and Surfactants were obtained in the pre monsoon samples. Values for Ammonia Nitrogen, Phosphate and total Coliform number reached high during monsoon and post monsoon seasons and it might be due to municipal run off .Chloride, Nitrate&TSS were also high during monsoon which indicated agricultural run off and municipal discharge. Fluoride, Ammonia Nitrogen and coliform bacteria were high during post monsoon indicating the concentration of agricultural run off after slowing down of river flow.

In the second sampling location values of TOC, COD, Phosphate, Surfactants and total coliform were high during pre-monsoon season. Values of Turbidity, Chloride, Nitrate, TSS, TDS, BOD and Ammonia Nitrogen were high in monsoon season while in post monsoon season, pH, Fluoride and DO were high in the location.

In the third location, Nitrate, Phosphate, Ammonia Nitrogen, Surfactants, BOD and total coliform were comparatively high during pre-monsoon and the parameters Turbidity, Chloride, TOC, TSS, TDS were high in the monsoon season indicating almost same trend in all locations. Like other stations ,pH ,Fluoride, DO showed high value in post monsoon season

In the fourth location, values of pH, Chloride, Fluoride, TOC, TDS, BOD, COD and Surfactants were high during pre-monsoon showing accumulation of the ions due to weak discharge while Nitrate ,TSS, Phosphate and total coliform were found to be high during monsoon season. Highest values for Turbidity and DO obtained in post monsoon samples.

In general all sampling stations indicated presence of total coliform bacteria above drinking water standard limit .This might be due to municipal run off and improper waste disposal mechanism in rural as well as urban areas near natural waters. Presence of coliform bacteria in natural spring water indicated potential adverse health effects for individuals or populations exposed to this water(An and Breindenbach, 2005)

V. METALS

Samples were collected from all the four locations in the pre-monsoon, monsoon, post-monsoon in 2015 and again in pre-monsoon in 2016 and Zn, Cu, Mn, Cr, Pb, Cd and Fe were analyzed. The sampling and analysis were carried out as per standard methods given in APHA (2012) and IS 3025, and Grasshoff (1999).

Generally in all the sampling locations metallic concentration were high during pre-monsoon but with in the limit of IS specification 10500;2012.The flow of water discharged through the river was very low in pre-monsoon period, which cause the high concentration of metals in the river (Anju et al ., 2011; Nair et al.,2011) concentration of Fe and Mn were high in monsoon and post monsoon seasons while Cr and Cd reached peak value in post monsoon season. Here all the elements except Fe were found in acceptable limit as per IS standards. Previous studies showed that considerable enrichment of metals in the Muvattupuzha River environment from domestic and agricultural wastes (Josekutty, 2015). Concentration of Zn, Cu and Mn showed an increase towards downstream while Cd and Fe were high in the upstream region (Padmalal, 1992, Sundaray et al .2012). The high flow rate of the river water in the upstream avoided the free settling of the lighter elements like Zn in the upstream side. Hence, these lighter

metals were flushed to the downstream and deposited; whereas the denser metals like Fe were present in the upstream in higher concentration . (Table 3,Figures 3 to 26)

On studying correlation matrix (Table-4,5 &6)significant correlation was seen among the parameters. Correlation matrix was useful when there were large number of data set obtained in hydrochemical analysis which could point out association between variables and could explain the participation of individual chemical parameters among them (Helena et al. 2000).Here significant negative correlation between nitrate and pH (r^2 = - 0.530,$p<0.01$) was observed. Also there was strong positive correlation between turbidity and TSS (r^2 = 0.815,$p<0.01$) ,significant correlation among nitrate and chloride A(r^2 = 0.516,$p<0.01$),BOD and nitrate(r^2 = 0.505,$p<0.01$).Among correlation between general parameters and metals, significant values were obtained between Mn and nitrate (r^2 = 0.584,$p<0.01$) .Positive correlation between Cr and Pb were also noted (r^2 = 0.624,$p<0.01$) among metals(Singh et al.,2004;Shrestha and Kazama ,2007; Oslen et al., 2012; Razmkhah et al.,2010; Sundar and Saseetharan,2008).(Tables 4,5 &6)

Factor analysis of general parameters, among general parameters and metals and factor analysis among metals alone were carried out(Table-7,8 &9). Factor analysis of general parameters explained 62.99% of total variance. Each factor consisted of variable with eigen value more than 1. The factors were given in descending order depending upon the variance. The factor having highest variance was assigned number 1 position and with least variance was given the fifth place. Factor 1, accounted for about 20.03% of the total variance, provided information about turbidity TOC and TSS.Anaysis suggested that these parameters were inter related and gave an idea about agricultural run off during monsoon .However, these contents in these areas were within the acceptable limits of Indian Standard specification.During the flow of river from upper to lower reaches,organic matters were oxidized or reduced with abundance of oxygen in river.So there was a mechanism of self purification during the course of river flow. Factor 2 accounted for 16.94% of total variance and clusters fluoride and pH with negative loading and BOD and nitrate with positive loading. Factor 2 indicated that geochemical contribution was a key factor in this river course.Factor 3 accounted for 10.62 % of total variance and ammonia nitrogen,total coliform ,DO and temperature were having positive loading while surfactants having negative loading. Dissolved oxygen variations were due to a combination of biological activity and of the temperature dependence of the oxygen solubility(Bourg et al.,2000).Turbidity and total coliforms were present above the acceptable limit prescribed by IS standard in all the four stations and made impact in this factor suggesting the dominance of the variable in the area(Sreekala et al .,2018).This might be due to contamination from municipal waste and agricultural waste (Bojarczuk etal .,2018)Factor 4 contents variables Chloride,phosphate and TDS with positive loading and showed 8.832% of total variance.TDS was the major factor here and due to run off ,chloride and phosphates contributed to it.Heavy rain resulted in washing out of sediments and nutrients from agricultural land on steep hilltops (Park et al.,2010)

Factor analysis of general parameters and metal gave 68.57% of total variance.In factor 1,Mn,nitrate and BOD contributed up to 15.13%,in the 2nd,Fe ,turbidity and TSS gave positive loading (Hannouche et al.2011)and in the fourth factor ,chloride and Zn contributed up to 7.936% of the total variance.

Factor analysis of metals alone gave three contributing factors with cumulative variance of 60.78%.In factor 1,Pb and Cr had strong positive loading and 25.19% of total variance.In the second factor,positive loading of Zn and negative loading of iron were seen.In factor 3,positive loading of Cu and Cd and negative loading of Mn were found and the variance is 16.49% of the total(Khound et al. 2017; Sundaray et al.2012). (Tables 7,8 &9)

VI. CONCLUSION

In the study ,hydrochemical analysis of Muvattupuzha river from the selected points during the year 2015-2016 revealed that some of the water quality parameters like turbidity and total coliform bacteria exceeded the permissible standard limit set by BIS 2012,WHO 2017 . On studying correlation matrix significant correlation were seen among the general parameters and metals. Factor analysis of general parameters explained 62.99% of total variance, general parameters and metal gave 68.57% of total variance and factor analysis of metals alone gave three contributing factors with cumulative variance of 60.78%. Factor analysis gave more interpretations and indicated that municipal waste discharge might also be happening . During the flow of river from upper to lower reaches,organic matters were oxidized or reduced with abundance of oxygen in river.Therefore organic pollutants might not be a predominant factor in this river course.

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Table 1 Sampling Points.

Sampling points	Latitude	Longitude
Muvattupuzha bridge,Kacherithazham,SP1	9 °98 I50.25 II	76° 58 I 34.90 II
Piravom bridge,SP2	9 °87 I 71.37 II	76 °48 I 56.56 II
Hanging bridge at Madakkathanam,SP3	9° 91 I 73.69 II	76° 68 I 26.15 II
Kozhippilly bridge Kothamangalam,SP4	10° 05 I 66.48 II	76° 63 I 27.29 II

Table 2 General Parameters

SP	Parameters/ Unit		Seasons				Acceptable limit as per IS 10500,2012	Surface water quality criteria for different uses specified by CPCB		WHO guide line2018
			1	2	3	4		Drinking water source with out conventional treatment but after disinfection A class	Drinking water source with conventional treatment followed by disinfection C class	
	pH	Mean	7.0077	7.1895	7.356	7.402	6.5-8.5	6.5-8.5	6.9	No Health Based Value is proposed
		SD	0.03291	0.0439	0.1843	0.0859				
	Turbidity NTU	Mean	1.941	4.53	5.0151	1.556	Max 1	….	…..	None set
		SD	0.44606	1.3791	2.9299	0.19950.				
	Temperature ℃	Mean	27.9375	28.3475	27.937	29.75				None set
		SD	0.62186	0.1623	0.4098	0.53033				
	AmbientTemperature ℃	Mean	33.25	33.908	33.65	33.187				
		SD	1.6658	0.5814	0.7973	0.7979				
	Chloride mg/l	Mean	12.5	19.187	9.187	18.75	Max 250	Max 250	Max 600	200-300
		SD	0.6123	1.0364	0.7781	0.75				
	Fluoride mg/l	Mean	0.022	0.024	0.0392	0.036	Max 1.0	1.5	1.5	Max 1.5
		SD	0.000816	0.00106	0.0028	0.0043				
	TDS mg/l	Mean	31.143	32.756	31.76	32.483	Max 500	Max 500	Max 1500	No Health Based Value is proposed
		SD	0.6238	0.7886	0.545	0.88704				
	TSS mg/l	Mean	31.55	40.025	35.482	33.55				

		SD	2.4806	1.3591	3.4010	1.7088				
	TOC mg/l	**Mean**	5.0562	5.2625	4.7625	5.168				
		SD	0.3886	0.38507	0.61707	0.2996				
	Nitrate mg/l	**Mean**	1.6265	2.166	0.4602	0.374	Max 45	Max 20	Max 50	Max 50
		SD	0.7827	0.0903	0.0238	0.0433				
	Phosphate mg/l	**Mean**	0.00375	0.0075	0.00062	0.00125				
		SD	0.00216	0.00883	0.00108	0.00125				
	AmmoniaN mg/l	**Mean**	0.000625	0.001875	0.00125	0.00187	Max 0.5	…..	……	Max 1.5
		SD	0.00108	0.002072	0.00216	0.00207				
	Surfactants mg/l	**Mean**	0.3	0.1375	0.168	0.1812				
		SD	0.0176	0.06731	0.0541	0.0817				
	DO mg/l	**Mean**	5.7	6.4437	7.143	6.881	…..	Min 6.0	Min 4.0	No Health Based Value is proposed
		SD	0.4142	0.4674	0.2354	0.3139				
	BOD mg/l	**Mean**	0.8062	0.7437	0.2375	0.275	……	Biochemical Oxygen Demand 5 days 20 ℃, 2mg/l or less	Biochemical Oxygen Demand 5 days 20 ℃, 3mg/l or less	…….
		SD	0.2451	0.19555	0.0279	0.0918				
	COD mg/l	**Mean**	3.1875	1.5	1.25	4.125				
		SD	1.5749	0.3952	0.3952	0.5153				
	Total Coliform/100ml	**Mean**	274.875	752.68	507.93	568.7	0	Total Coliforms Organism MPN/100 ml shall be 50 or less	Total Coliforms Organism MPN/100ml shall be 5000or less	Must not be detectable in any 100ml sample
		SD	200.629	116.21	253.65	120.27				

Table 3 Metals

SP	**Parameters/ Unit**	**Seasons**				**Acceptable limit as per IS 10500,2012**	**Surface water quality criteria for different uses specified by CPCB**		**WHO guide line2018**
		1	**2**	**3**	**4**		**Drinking water source with out conventional treatment but after**	**Drinking water source with conventional treatment followed by disinfection C class**	

								disinfection A class		
	Zn mg/l	**Mean**	0.00415	0.00785	0.00143	0.0142	5	15	15	No Health Based Value is proposed
		SD	0.001119	0.0014	0.00108	0.00908				
	Cu mg/l	**Mean**	0.0108	0.00852	0.0038	0.0058	0.05	1.5	1.5	2.0
		SD	0.00119	0.00128	0.00123	0.00167				
	Pb mg/l	**Mean**	0.00043	0.000572	0.00041	0.00102	0.01	0.1	0.1	0.01
		SD	0.000449	0.000148	0.00023	0.00062				
	Mn mg/l	**Mean**	0.0038	0.0186	0.00402	0.0078	0.3	0.5	….	0.4
		SD	0.00097	0.00247	0.00084	0.0077				
	Cr mg/l	**Mean**	0.000088	0.0000325	0.000087	0.0004775	0.05	0.05	0.05	0.05
		SD	0.00009	0.000034	0.000086	0.000544				
	Cd mg/l	**Mean**	0.00019	0	0.000098	0.0001575	0.003	0.01	0.01	0.003
		SD	0.000202	0	0.000088	0.0001578				
	Fe mg/l	**Mean**	0.0752	0.0807	0.1608	0.0327	1.0	1.0	….	No Health Based Value is proposed
		SD	0.0106	0.0166	0.1037	0.0159				

Table 4 Correlation between General Parameters in Muvattupuzha River

Temperature (C)																0.309*
Total Coliform (No/100 ml)															0.254*	0.333**
Chemical Oxygen Demand (mg/l)														-0.023	0.286*	0.043
Biochemical Oxygen Demand (mg/l)													0.117	-0.229	-0.265*	-0.084

pH	Turbidity (NTU)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate (mg/l)	Total Organic Carbon (mg/l)	Total Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Phosphate (mg/l)	Ammoniacal Nitrogen (mg/l)	Surfactants (mg/l)	Dissolved Oxygen (mg/l)
-0.106											
-0.290*	-0.144										
0.353**	-0.246	-0.081									
-0.530**	-0.075	0.516**	-0.361**								
0.110	0.278*	0.170	-0.190	-0.033							
0.065	0.815**	0.054	-0.221	-0.078	0.499**						
-0.062	-0.119	0.409**	-0.051	0.375**	-0.169	-0.100					
-0.238	-0.046	0.254*	-0.155	0.425**	0.134	-0.096	0.265*				
0.095	-0.075	0.078	0.102	0.026	-0.097	-0.048	0.069	-0.058			
-0.176	-0.038	-0.029	-0.094	0.140	0.032	-0.198	-0.100	0.201	-0.173		
0.140	-0.158	0.081	0.441**	-0.209	-0.247*	-0.141	0.021	-0.226	0.182	-0.328**	
-0.358**	0.058	0.285*	-0.289*	0.505**	0.295*	0.106	0.046	0.149	0.137	0.064	-0.255*
0.082	-0.206	0.149	0.029	-0.070	0.045	-0.182	0.096	-0.087	0.069	0.028	0.086
0.010	-0.058	0.152	-0.032	0.021	-0.336**	0.038	0.100	-0.036	0.205	-0.170	0.255*
0.020	-0.336**	0.371**	0.282*	-0.128	-0.124	-0.259*	0.177	-0.113	0.244	-0.144	0.391**
-0.195	-0.250*	0.159	0.273*	0.198	-0.450**	-0.372**	0.145	0.027	0.170	-0.096	0.496**

Turbidity (NTU)
Chloride (mg/l)
Fluoride (mg/l)
Nitrate (mg/l)
Total Organic Carbon (mg/l)
Total Suspended Solids (mg/l)
Total Dissolved Solids (mg/l)
Phosphate (mg/l)
Ammoniacal Nitrogen (mg/l)
Surfactants (mg/l)
Dissolved Oxygen (mg/l)
Biochemical Oxygen Demand (mg/l)
Chemical Oxygen Demand (mg/l)
Total Coliform (No/100 ml)
Temperature (C)
Ambient temperature (C)

**** Correlation is significant at 0.01 level**

*** Correlation is significant at 0.05 level**

Table 5 Correlation between General Parameters and Metals in Muvattupuzha River

Chemical Oxygen Demand	Total Coliform (No/100	Temperature	Ambient Temperat	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Manganese	Cromium	Cadmium	Iron (mg/l)
1.000										
-0.023	1.000									
.286*	.254*	1.000								
0.043	.333**	.309*	1.000							
0.076	0.044	0.166	0.020	1.000						
.371**	-0.015	0.060	-0.084	0.100	1.000					
0.040	0.053	0.136	-0.060	-0.033	-0.194	1.000				
-0.149	0.140	0.166	0.171	0.167	-0.225	-0.014	1.000			
-0.028	-0.084	0.224	-0.053	0.131	-0.208	.624**	-0.011	1.000		
-0.124	-0.080	-0.047	-0.149	-0.058	0.043	-0.069	-0.127	-0.060	1.000	
-0.218	-0.125	-.252*	-0.159	-0.155	-0.095	-0.004	-0.161	-0.065	-0.032	1.000

pH	Turbidity (NTU)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate (mg/l)	Total Organic Carbon (mg/l)	Total Suspended	Total Dissolved	Phosph ate	Ammoniacal Nitrogen	Surfacta nts	Dissolved Oxygen	Biochemical Oxygen Demand
1.000												
-0.106	1.000											
-.290*	-0.144	1.000										
.353**	-0.246	-0.081	1.000									
-.530**	-0.075	.516**	-.361**	1.000								
0.110	.278*	0.170	-0.190	-0.033	1.000							
0.065	.815**	0.054	-0.221	-0.078	.499**	1.000						
-0.062	-0.119	.409**	-0.051	.375**	-0.169	-0.100	1.000					
-0.238	-0.046	.254*	-0.155	.425**	0.134	-0.096	.265*	1.000				
0.095	-0.075	0.078	0.102	0.026	-0.097	-0.048	0.069	-0.058	1.000			
-0.176	-0.038	-0.029	-0.094	0.140	0.032	-0.198	-0.100	0.201	-0.173	1.000		
0.140	-0.158	0.081	.441**	-0.209	-.247*	-0.141	0.021	-0.226	0.182	-.328**	1.000	
-.358**	0.058	.285*	-.289*	.505**	.295*	0.106	0.046	0.149	0.137	0.064	-.255*	1.000
0.082	-0.206	0.149	0.029	-0.070	0.045	-0.182	0.096	-0.087	0.069	0.028	0.086	0.117
0.010	-0.058	0.152	-0.032	0.021	-.336**	0.038	0.100	-0.036	0.205	-0.170	.255*	-0.229
0.020	-.336**	.371**	.282*	-0.128	-0.124	-.259*	0.177	-0.113	0.244	-0.144	.391**	-.265*
-0.195	-.250*	0.159	.273*	0.198	-.450**	-.372**	0.145	0.027	0.170	-0.096	.496**	-0.084
-0.056	-0.058	.288*	0.022	0.010	0.189	-0.072	-0.050	-0.028	0.033	-0.180	0.020	0.006
-0.025	-0.090	0.018	-.281*	0.069	0.215	0.043	-0.078	-0.025	0.148	0.053	-.252*	.298*
-0.106	0.086	0.063	0.009	-0.036	-0.074	0.014	0.164	-0.007	-0.098	0.166	-0.002	-0.088
-.443**	-0.032	.461**	-0.181	.584**	-0.150	-0.028	.367**	0.162	-0.084	-0.088	-0.054	0.061
-0.079	-0.045	0.023	0.015	-0.076	-0.037	-0.090	0.021	-0.038	0.010	-0.108	0.046	-0.039
-0.163	-0.080	0.017	-0.080	-0.045	0.140	0.041	-.247*	-0.055	-0.072	-0.067	-0.041	-0.026
0.047	.442**	-.349**	-0.090	-0.157	0.168	.348**	-0.121	-0.107	-0.065	-0.162	-0.076	0.046

	pH	Turbidity (NTU)	Chloride (mg/l)	Fluoride (mg/l)	Nitrate (mg/l)	Total Organic Carbon (mg/l)	Total Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Phosphate (mg/l)	Ammoniacal Nitrogen (mg/l)	Surfactants (mg/l)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Chemical Oxygen Demand (mg/l)	Total Coliform (No/100 ml)	Temperature (C)	Ambient temperature (C)	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Manganese (mg/l)	Cromium (mg/l)	Cadmium (mg/l)	Iron (mg/l)

** Correlation is significant at 0.01 level

* Correlation is significant at 0.05 level

Table-6 Correlation between Heavy Metals in Muvattupuzha River

	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Manganese (mg/l)	Cromium (mg/l)	Cadmium (mg/l)
Copper (mg/l)	0.100					
Lead (mg/l)	-0.033	-0.194				
Manganese (mg/l)	0.167	-0.225	-0.014			
Cromium (mg/l)	0.131	-0.208	0.624**	-0.011		
Cadmium (mg/l)	-0.058	0.043	-0.069	-0.127	-0.060	
Iron (mg/l)	-0.155	-0.095	-0.004	-0.161	-0.065	-0.032

** Correlation is significant at 0.01 level

Table-7 Factor Analysis of General Parameters in Muvattupuzha River

	Component				
	1	2	3	4	5
pH	0.115	**-0.753**	-0.005	-0.130	0.165
Turbidity (NTU)	**0.789**	0.126	0.002	-0.158	-0.295
Chloride (mg/l)	0.067	0.283	0.228	**0.724**	0.315
Fluoride (mg/l)	-0.316	**-0.534**	0.255	-0.087	0.113
Nitrate (mg/l)	-0.098	**0.752**	-0.048	0.474	-0.037
Total Organic Carbon (mg/l)	**0.629**	-0.012	-0.326	0.080	0.467
Total Suspended Solids (mg/l)	**0.946**	0.016	0.066	-0.024	-0.104
Total Dissolved Solids (mg/l)	-0.073	0.032	0.096	**0.749**	-0.021
Phosphate (mg/l)	-0.070	0.232	-0.349	**0.585**	-0.133
Ammoniacal Nitrogen (mg/l)	-0.022	0.161	**0.540**	-0.107	0.282
Surfactants (mg/l)	-0.292	0.175	**-0.566**	-0.013	-0.022
Dissolved Oxygen (mg/l)	-0.201	-0.282	**0.696**	-0.017	0.017
Biochemical Oxygen Demand (mg/l)	0.155	**0.749**	-0.084	-0.039	0.438

Chemical Oxygen Demand (mg/l)	-0.176	-0.068	0.075	0.061	**0.673**
Fecal Coli Form (No/100 ml)	-0.033	-0.028	**0.576**	0.211	-0.367
Temperature (C)	-0.268	-0.302	**0.487**	0.349	0.326
Ambient temperature (C)	-0.507	0.163	**0.581**	0.111	-0.188
Eigenvalues	**3.405**	**2.879**	**1.805**	**1.501**	**1.117**
% of Variance	**20.03**	**16.94**	**10.62**	**8.832**	**6.571**
Cumulative %	**20.03**	**36.96**	**47.58**	**56.41**	**62.99**

KMO = 0.599 and Bartletts's test is significant

Table-8 Factor Analysis of General Parameters and Metals in Muvattupuzha River

	Component							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
pH	-0.824	0.045	0.052	0.005	0.061	-0.167	0.198	-0.069
Turbidity (NTU)	0.038	0.860	-0.076	-0.135	-0.100	0.059	0.011	0.033
Chloride (mg/l)	0.452	-0.076	0.080	0.685	0.066	0.016	0.298	0.037
Fluoride (mg/l)	-0.501	-0.348	0.430	0.043	-0.278	0.000	0.106	-0.176
Nitrate (mg/l)	0.849	-0.086	-0.069	0.087	-0.011	-0.121	0.285	-0.060
Total Organic Carbon (mg/l)	-0.080	0.460	-0.247	0.431	0.196	-0.087	-0.078	-0.507
Total Suspended Solids (mg/l)	-0.039	0.917	-0.064	0.127	0.004	-0.053	-0.008	0.026
Total Dissolved Solids (mg/l)	0.228	-0.078	0.035	0.157	-0.046	0.055	0.731	0.115
Phosphate (mg/l)	0.360	-0.129	-0.302	0.068	-0.129	-0.122	0.380	-0.184
Ammoniacal Nitrogen (mg/l)	0.062	0.008	0.570	-0.059	0.386	-0.026	0.096	0.016
Surfactants (mg/l)	0.105	-0.293	-0.590	-0.284	0.101	0.077	0.074	-0.066
Dissolved Oxygen (mg/l)	-0.220	-0.182	0.711	0.100	-0.176	0.041	0.008	0.172
Biochemical Oxygen Demand (mg/l)	0.597	0.147	0.082	-0.043	0.390	-0.054	0.041	-0.516
Chemical Oxygen Demand (mg/l)	-0.162	-0.235	0.028	0.163	0.664	0.084	0.181	-0.009
Total Coliform (No/100 ml)	0.048	0.039	0.219	0.053	0.070	-0.051	0.079	0.815
Temperature (0C)	-0.141	-0.326	0.356	0.464	0.164	0.258	0.105	0.304
Ambient temperature (0C)	0.236	-0.401	0.571	-0.106	-0.097	-0.069	0.122	0.290
Zinc (mg/l)	0.008	-0.022	0.075	0.653	0.044	0.040	-0.122	-0.046
Copper (mg/l)	0.079	0.012	-0.120	0.050	0.820	-0.205	-0.138	0.009
Lead (mg/l)	0.007	0.034	-0.131	-0.033	-0.042	0.882	0.139	0.097

Manganese (mg/l)	0.566	-0.029	-0.014	0.353	-0.350	-0.051	0.265	0.254
Cromium (mg/l)	0.006	-0.036	0.082	0.110	-0.079	0.879	-0.042	-0.115
Cadmium (mg/l)	0.121	-0.052	-0.090	0.173	-0.092	-0.076	-0.728	-0.032
Iron (mg/l)	-0.066	0.578	0.150	-0.375	-0.149	-0.004	-0.053	-0.193
Eigenvalues	3.632	3.367	2.083	1.905	1.777	1.337	1.247	1.109
% of Variance	15.13	14.03	8.679	7.936	7.406	5.571	5.197	4.620
Cumulative %	15.13	29.16	37.84	45.78	53.18	58.75	63.95	68.57

KMO = 0.517 and Bartletts's test is significant

Table-9 Factor Analysis of Heavy Metals in Muvattupuzha River

	Component		
	1	**2**	**3**
Zinc (mg/l)	0.046	**0.730**	-0.095
Copper (mg/l)	-0.287	0.368	**0.656**
Lead (mg/l)	**0.885**	-0.042	-0.042
Manganese (mg/l)	-0.127	0.306	**-0.786**
Cromium (mg/l)	**0.895**	0.132	-0.048
Cadmium (mg/l)	-0.035	-0.027	**0.467**
Iron (mg/l)	-0.035	**-0.712**	0.000
Eigenvalues	**1.763**	**1.337**	**1.155**
% of Variance	**25.19**	**19.10**	**16.49**
Cumulative %	**25.19**	**44.29**	**60.78**

KMO = 0.491 and Bartletts's test is significant

figure-1

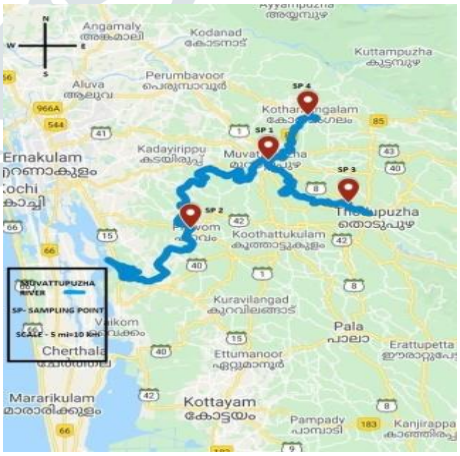
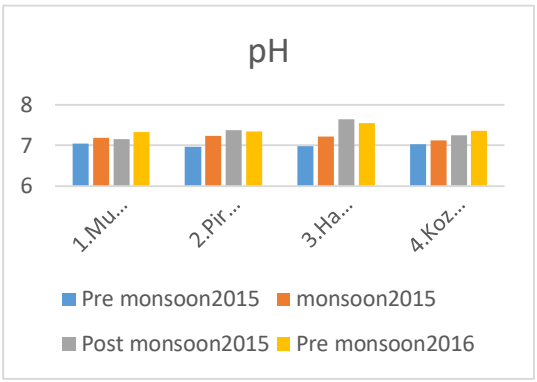


figure-2



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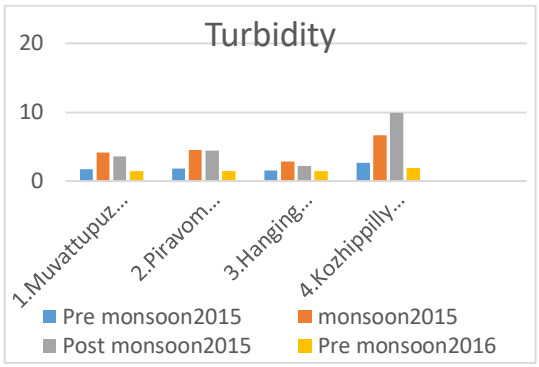

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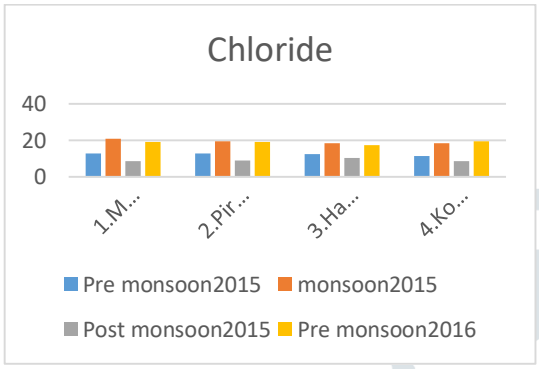

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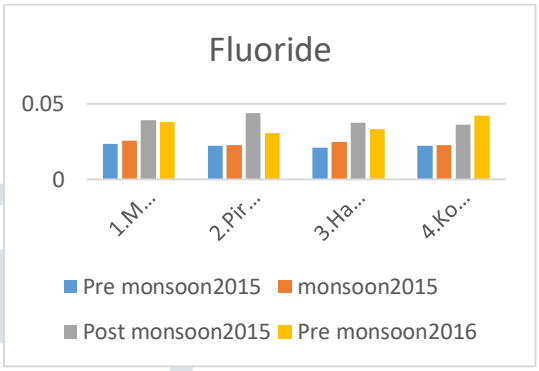

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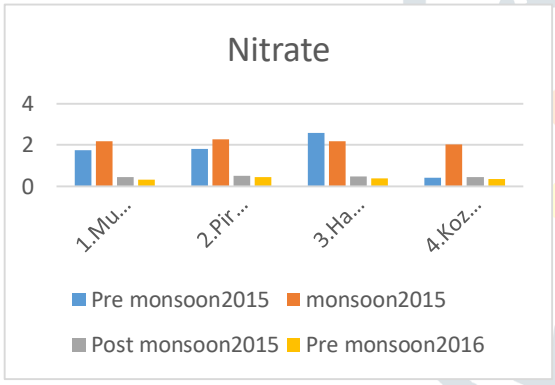

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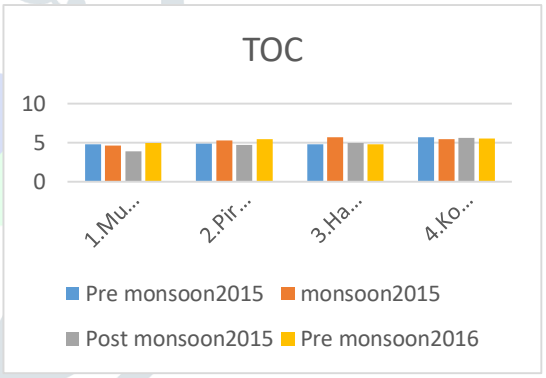
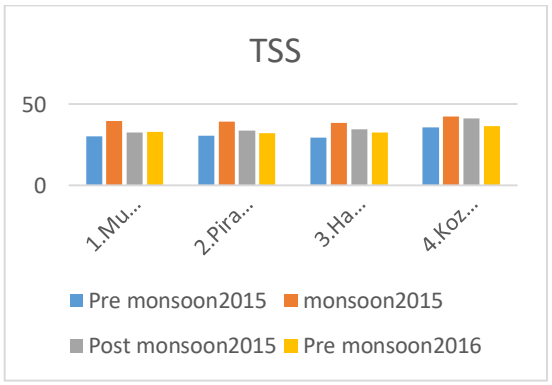


figure8



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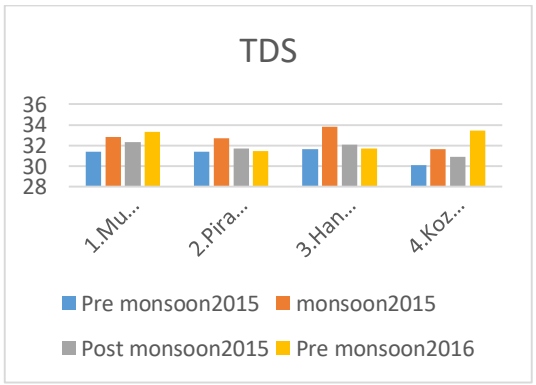

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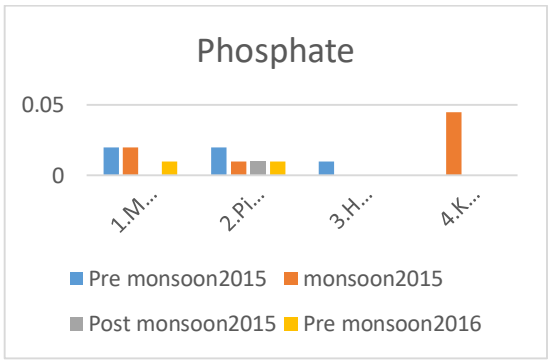

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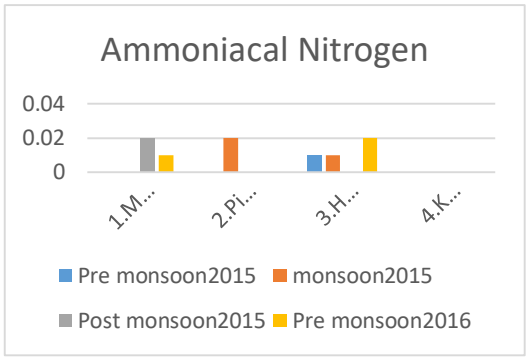

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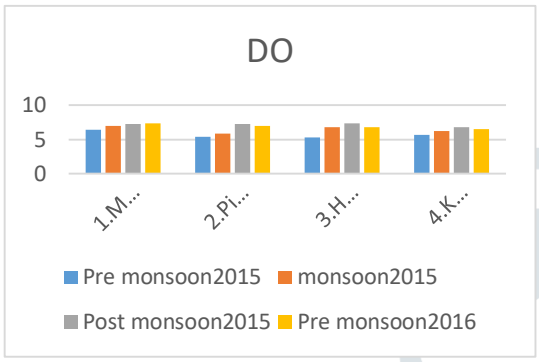

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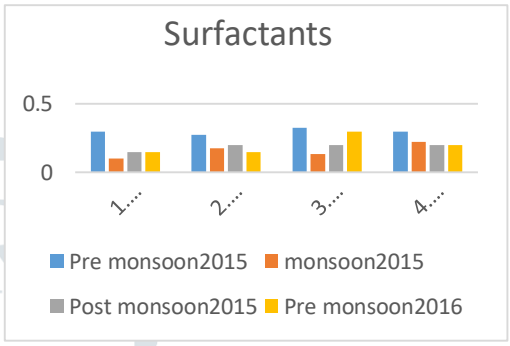

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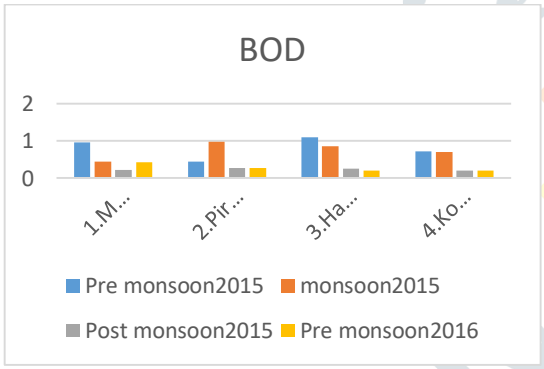

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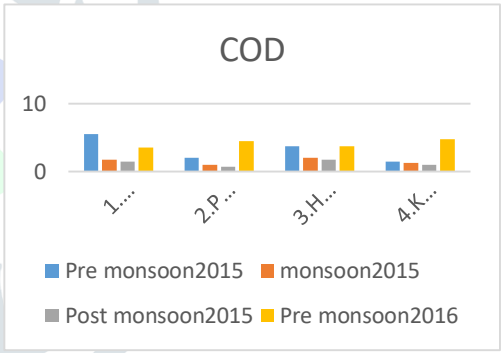

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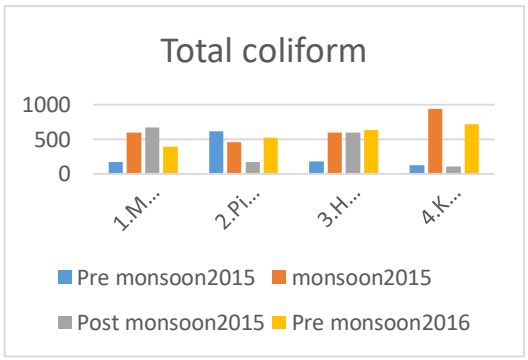

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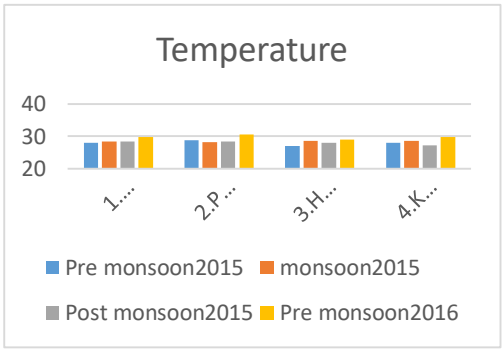

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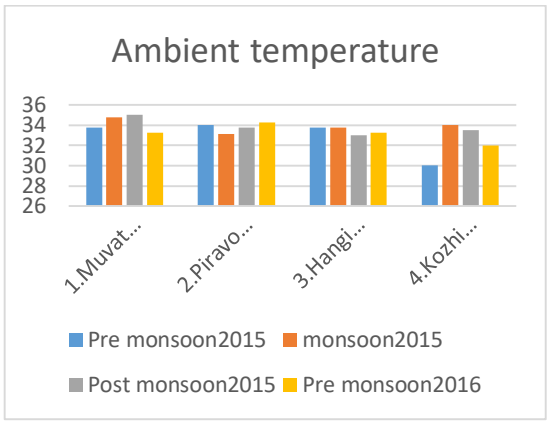

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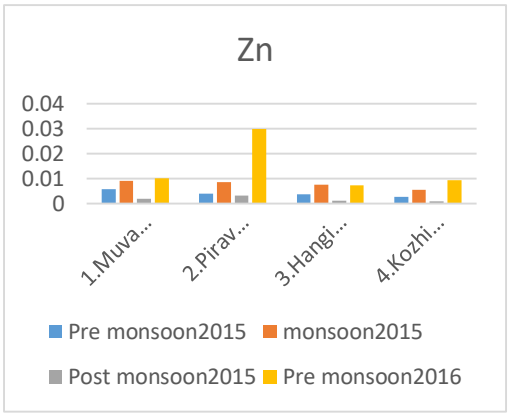

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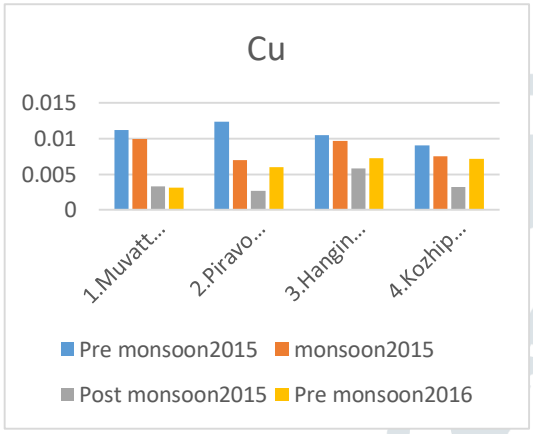

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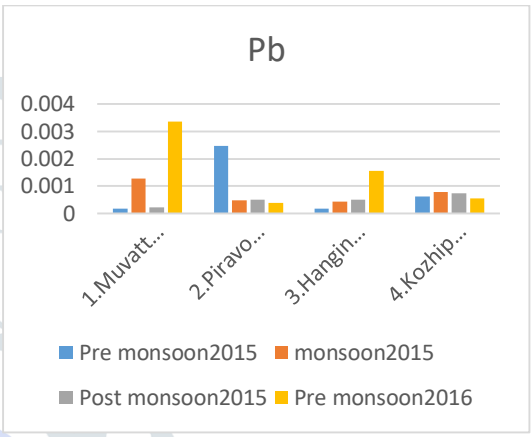

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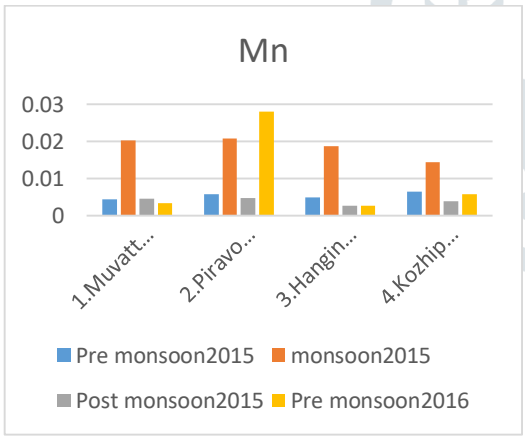

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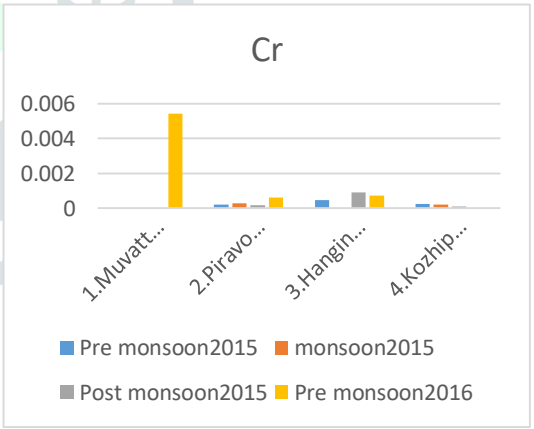

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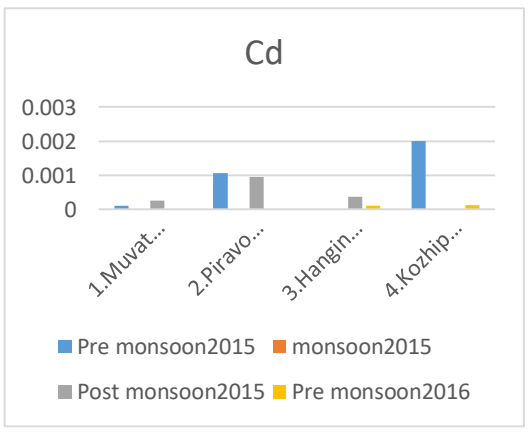

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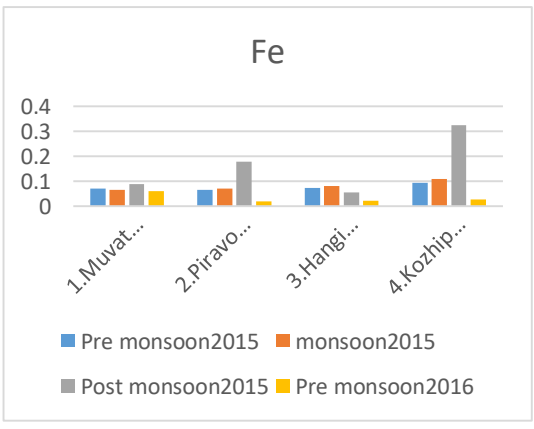

figure 26

IX. ACKNOWLEDGEMENT

Kerala Water Authority (KWA), Kerala, India

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