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Groundwater Quality Characteristics of Kattampally and Biyyam Wetlands of Kerala, India

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ABSTRACT

Groundwater is an essential component of our life-supporting system and its quality determination and management are of primary concern. The objective of the study is to assess the quality of groundwater samples collected from the Kattampally and Biyyam wetlands of Kerala. A total of 24 groundwater samples were collected from each wetland during the pre-monsoon season and physicochemical and bacteriological analysis were carried out. The percentage of samples having pH below 6.5 is 88% and 71% in Kattampally and Biyyam wetlands respectively. The bacteriological analysis revealed that 58% of samples from Biyyam wetland and 20% of the samples from Kattampally wetland were contaminated with *Escherichia coli*. No significant concentration of heavy metals was observed. Pearson Correlation coefficients were calculated to identify the relationships among various water quality parameters. Water Quality Index of the samples was calculated to determine their suitability for drinking purpose. The results indicated that 71% of samples collected from Biyyam and 96% of samples collected from Kattampally wetland are excellent for human consumption. Only 4% of the samples were poor in the two wetlands. The outcome of the analysis proved that most of the groundwater samples were found to be suitable for drinking purposes and the rest of them can be used only after appropriate treatment methods. Spatial distribution maps of certain water quality parameters were plotted using GIS to identify the vulnerable sites. Evaluation of groundwater chemistry revealed that Ca-Na-Cl-HCO_3 type (21%) in Biyyam wetland and Na-Ca-Cl (25%) and Na-Cl types (25%) in Kattampally wetland were predominant water types. Soluble Sodium Percent, Sodium Adsorption Ratio, Kelly's Ratio and Magnesium Hazard were calculated to determine Irrigation Water Quality Status of the wetlands and interpreted that majority of the samples were suitable for irrigation purpose.

Key Words: Water Quality Index; GIS; Pearson Correlation Coefficient; Groundwater Chemistry; Irrigation Water Quality

INTRODUCTION

Water is a prerequisite for the existence of life and is the most limiting factor for many aspects such as economic growth, environmental stability, conservation of biodiversity, food security and health care (Barman et al. 2015). Owing to inadequate availability of surface water, in order to meet the necessity of human activities, groundwater became one of the crucial options to supplement the ever-increasing demand for water. The rapid growth in population, industrialization, unplanned urbanization and excessive use of agrochemicals has led to groundwater quality issues (Joarder et al., 2008). The evaluation of drinking water quality is a powerful environmental determinant of health (WHO, 2010).

Once pollutants entered the subsurface environment, they may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other purposes (Jain, 2000). Pollutants are being added to the groundwater system through human activities as well as natural processes. Higher proportions of dissolved constituents are found in groundwater than in surface water because of greater interaction of groundwater with various materials in geological strata. Conservation of groundwater is a major environmental issue since the significance of water quality on human health has attracted a great deal of interest in recent years (Akinbile, 2011, Harikumar et al, 2017)

The ecologically sensitive Kattampally (Final code: IN238) and Biyyam (Final code: IN239) wetlands comes under the category of Important Bird Areas (IBAs), Key Biodiversity Areas (KBAs) and Important Coastal and Marine Biodiversity Areas (ICMBAs). Hence the monitoring of environmental status of these

wetlands are ecologically and economically significant. In this particular study, the objective is to assess the groundwater quality and its suitability for drinking and irrigation purposes. Groundwater quality is analyzed for its physical, chemical and biological parameters which are interlinked.

MATERIALS AND METHODS

Study Areas

Biyyam wetland:

Biyyam is a coastal wetland spreads through Malappuram and Thrissur districts of Kerala and spread over 59.58 sq km area. Geographically the wetland is located between the coordinates10°43'21.38"N to 10°40'26.13"N latitudes and 75°56'22.48"E to 76°04'15.23"E longitudes. The Malappuram District is bounded by the Nilgiri Hills in the east, the Arabian Sea in the west and Thrissur and Palakkad districts in the south. Biyyam wetland is distributed in Ponnani Municipality and among 6 Panchayaths namely; Marancheri, Edappal, Veliyankode, Nannamukku, Perumbadappu and Punnayoorkulam. Biyyam Kayal is one of the finest tourist destinations in Ponnani. The estuarine system of the wetland is exposed to tides from Arabian Sea and hence water is brackish almost throughout the year (Kutty *et al*., 2016). The Biyyam regulator-cum-Bridge built across the backwaters regulates the flow of water for irrigation, prevents salinity and enables transportation.

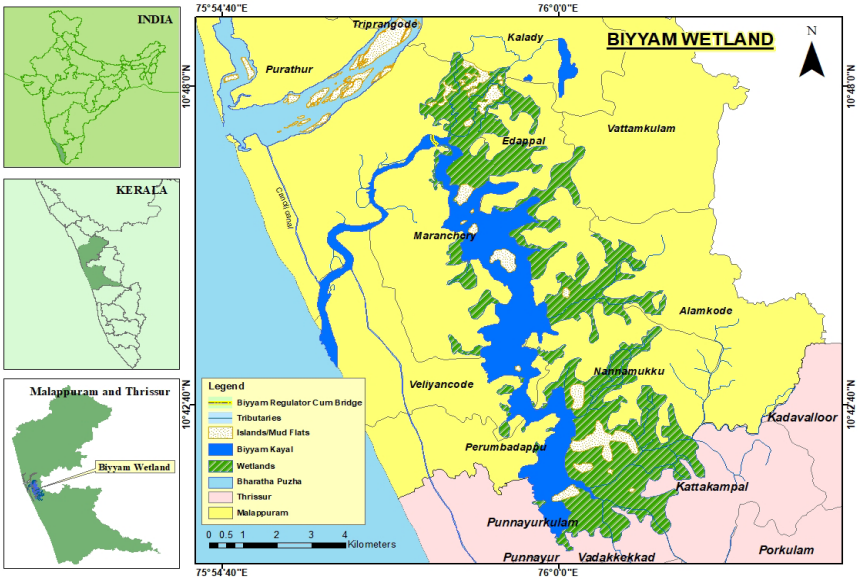

Figure 1. Location map of Biyyam Wetland

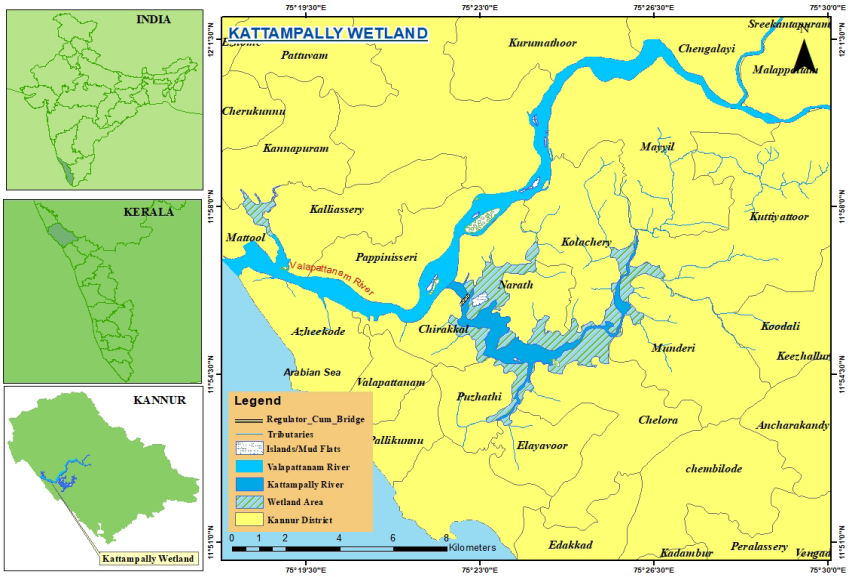

Figure 2. Location map of Kattampally wetland

***Kattampally wetland**:*

Kattampally is a coastal wetland in Kannur district with having an area of 15.32 Sq km Geographically it is located between the coordinates: 11°57'28.3"N to 11°55'51.6"N latitudes and 75°22'28.9"E to 75°23'46.8"E longitudes. Kattampally wetland is distributed in Kannur Corporation (Puzhathi, Chelora, Elayavoor) and among 6 Panchayaths of Kannur- Chirakkal, Narath, Munderi, Mayyil, Kuttiyattoor, Kulacheri. The wetland area is distributed over either side of the Kattampally River, a tributary of the Valapattanam River.

Collection, Preservation and Analysis of Groundwater Samples

Twenty-four wells, currently in use, were selected for the assessment of groundwater quality of Biyyam and Kattampally wetlands of Kerala state. The selected wells are being used for domestic and agricultural purposes. Groundwater sampling was performed during pre-monsoon season. The samples were collected in pre-cleaned, non-reactive plastic bottles (1L) and sterilized bottles (100ml) for physico-chemical and bacteriological analysis respectively. Electrical conductivity, pH and total dissolved solids were measured in-situ and the samples were carried to the laboratory for physico-chemical and bacteriological analysis as per the standard procedure (APHA, 2012).

RESULTS AND DISCUSSION

The results of the physico-chemical characteristics of the groundwater samples collected from the two wetlands are compared with results reported on groundwater quality characteristics of Kavvayi, a coastal wetland in Northern Kerala (Shiji, 2018). The comparative results are provided in Table 1.

Physico-chemical and Bacteriological Analysis

Biyyam wetland

The pH values of the groundwater samples collected from Biyyam wetland ranged from 4.59 to 7.47 with an average value of 6.0. The pH values are spatially represented in Fig. 3. It showed that 71% of the samples had pH below 6.5 and 17% of samples had pH below 5 which is acidic in nature. This may be attributed to natural phenomena like geochemical processes and anthropogenic activities like disposal of sewage and application of fertilizers (Prasanth *et al.,* 2012). Acceptable limit of pH as per IS 10500:2012 is 6.5-8.5. The EC values varied from 3.75 to 1711.0 µS/cm. Turbidity was found to be within the limit (1NTU) except 3 samples: BMG1, BMG2 and BMG3. The maximum value observed for turbidity was 3.0 NTU. The values of salinity varied from 0.05 to 1.75 mg/l. Only two samples were reported with total alkalinity above the acceptable limit (200.0 mg/l). The samples were BMG4 and BMG5. The highest value observed for total alkalinity was 616.0 mg/l.

The predominant anion trend was in the order of $Cl^{-}>SO_4^{2-}>NO_3^{-}>PO_4^{3-}$ with chloride being dominant anion. Concentration of chloride ranged from 24.0 to 400.0 mg/l with an average value of 151.40 mg/l. Five samples (BMG1, BMG3, BMG5, BMG10 and BMG17) had chloride concentration above the acceptable limit (250.0 mg/l). All the groundwater samples of Biyyam wetland were suitable for drinking purpose with respect

Table.1 Physico-chemical characteristics of the groundwater samples

Parameters	Biyyam wetland		Kattampally wetland		Kavvayi wetland	
	Range	Mean	Range	Mean	Range	Mean
pH	4.59-7.47	6.00	4.3-7.35	5.48	6.62-10.67	7.59
EC (µS/cm)	3.75-1711.0	440.45	2.41-365.0	132.74	79.30-5953.0	436.62
TDS (PPM)	60.0-2590.0	406.17	42.96-1710.0	165.03	50.75-5060.0	311.37
Turbidity (NTU)	BDL-3.0	0.57	0.68-1.80	0.82	BDL-28.0	1.33
Salinity (ppt)	0.05-1.75	0.28	0.03-1.04	0.10	0.02-4.67	2.43
Total alkalinity (mg/l)	3.76-616.0	78.33	3.9-111.90	20.73	3.29-270.60	85.59
Calcium (mg/l)	3.01-87.53	27.73	1.6-51.20	9.26	4.80-60.80	30.88
Magnesium (mg/l)	1.83-78.84	10.43	0.39-12.44	2.25	BDL-150.70	9.74
Chloride (mg/I)	24.0-400.0	151.40	15.9-719.90	58.73	11.74-2601.50	91.61
Sodium (mg/l)	4.09-92.70	35.63	2.46-338.50	25.06	0.25-1856.0	41.77
Potassium (mg/l)	0.26-53.20	6.28	0.15-56.0	4.82	BDL-102.0	6.33
Sulphate (mg/l)	12.8-215.0	60.71	0.04-27.16	4.48	0.28-145.92	11.98
Nitrate-N (mg/l)	0.15-5.13	2.31	0.10-5.34	1.86	BDL-1.90	0.19
Phosphate-P (mg/l)	BDL-0.32	0.03	0.01-0.02	0.003	BDL-3.11	0.30
Iron (mg/l)	BDL-0.76	0.15	0.10-0.40	0.26	0.10-0.58	0.16

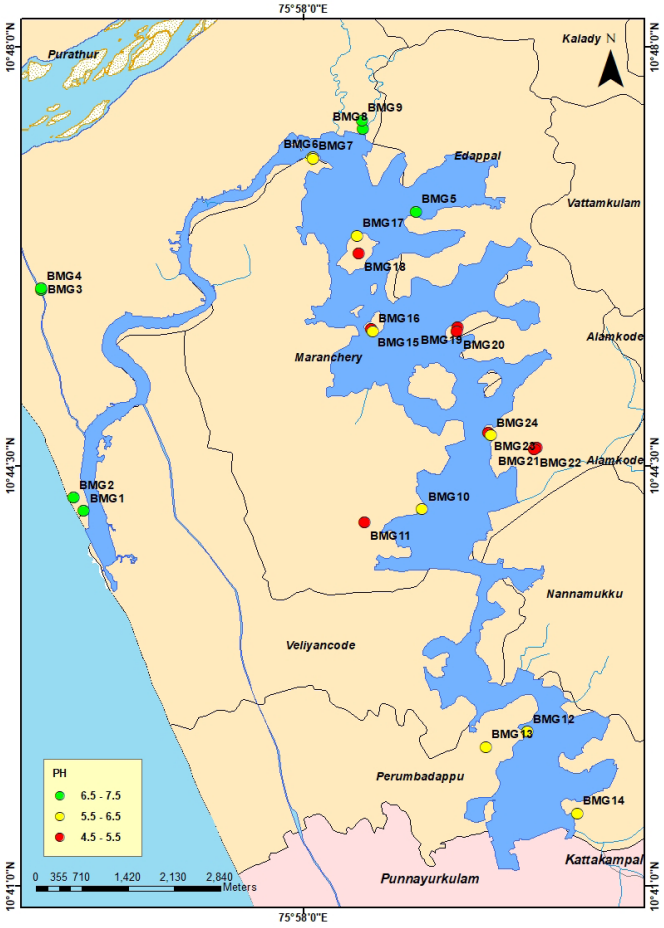

Figure 3. Spatial representation of pH values of Biyyam wetland

to sulphate concentration (200.0 mg/l) except one sample (BMG4). The concentration of nitrate varied from 0.15 to 5.13 mg/l with an average value of 2.31 mg/l. The highest concentration observed for phosphate was 0.32 mg/l.

The predominant cation trend was in the order of $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ with sodium being dominant cation. Concentration of calcium varied from 3.01 to 87.53 mg/l. Two samples (BMG4 and BMG5) were observed with concentrations above the acceptable limit (70.0 mg/l). The average concentration of calcium was 27.73 mg/l. The concentration of magnesium ranged from 1.83 to 78.84 mg/l. The average values observed for sodium and potassium were 35.63 mg/l and 6.28 mg/l respectively. Major anionic and cationic concentrations in Biyyam wetland are shown in Figure 4 (a) & (b).

Heavy metal analysis reported that the concentration of lead, cadmium, nickel, copper and manganese were below detection limit in the groundwater samples of Biyyam wetland, but zinc was present in trace amounts (0.007 mg/l to 0.30 mg/l). All of the samples had iron concentration within the acceptable limit (1.0 mg/l). All of the samples were tainted with total coliform bacteria. In Biyyam wetland 58% of the samples were contaminated with *E coli* and is shown in Fig. 5.

Kattampally wetland:

Analysis of groundwater samples of Kattampally wetland revealed that only three samples (KPG 1, 2 and 9) had pH within the acceptable limit (6.5-8.5). The values of pH ranged from 4.3 to 7.35 and 88% of groundwater samples were acidic in nature. The EC values varied from 2.41 to 365.0 µS/cm and TDS values ranged from 42.96 to 1710.0 mg/l. Samples KPG4 and KPG7 were reported with turbidity values 1.12 and 1.80 NTU respectively.

The predominant anion trend was in the order of $Cl^{-}>SO_4^{2-}>NO_3^{-}>PO_4^{3-}$ with chloride being dominant anion.

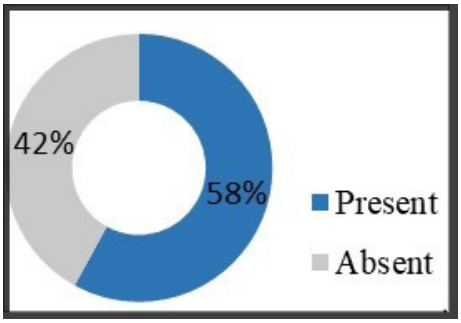

Figure 5. Samples of Biyyam wetland contaminated with *E coli*

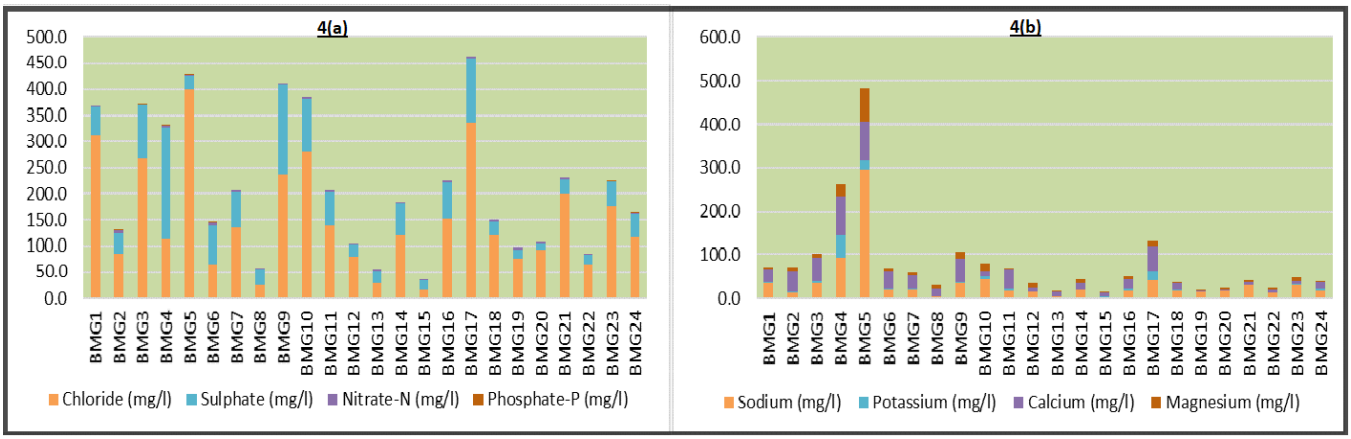

Figure 4. (a) Major anionic concentrations & (b) Major cationic concentrations in Biyyam

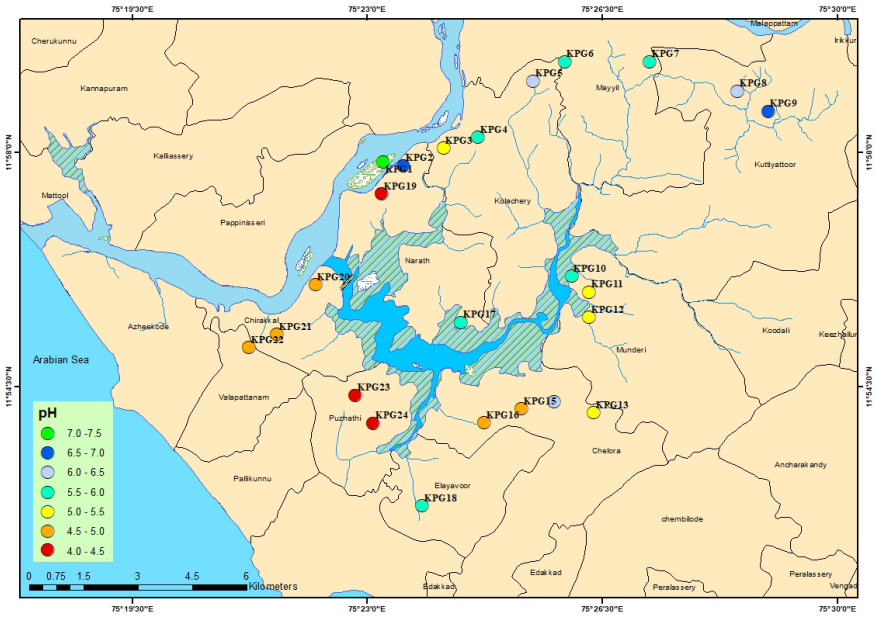

Figure 6. Spatial representation of pH values of Kattampally wetland

Chloride values ranged from 15.90 to 719.90 mg/l with an average value of 58.73 mg/l. All the groundwater samples of Kattampally wetland are suitable for drinking purpose with respect to sulphate concentration (200.0 mg/l). The concentration of nitrate varied from 0.10 to 5.34 mg/l. The highest value observed for phosphate was 0.003 mg/l.

The concentration of heavy metals was negligible. All the samples were befouled with total coliforms. Five samples (KPG5, KPG7, KPG14, KPG17 and KPG19) were found to have *E. coli* bacteria. The percentage of groundwater samples of Kattampally wetland contaminated with *E. coli* is represented in Fig. 8.

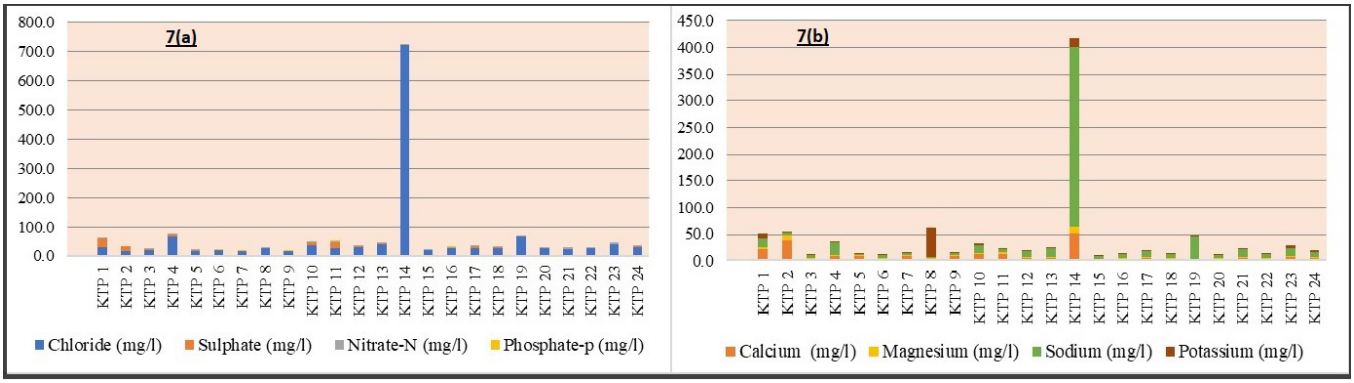

Figure 7. (a) Major anionic concentrations & (b) Major cationic concentrations in Kattampally

The predominant cation trend was in the order of $Na^{+}>Ca^{2+}>K^{+}>Mg^{2+}$ with sodium being dominant cation. Concentration of calcium varied from 1.6 to 51.02 mg/l. The average concentration of calcium in the groundwater samples was 9.26 mg/l. Concentration of magnesium is within the acceptable limit for all the groundwater samples analyzed. The values of magnesium ranged from 0.39 to 12.44 mg/l with an average value of 2.25 mg/l. The average values observed for sodium and potassium were 25.06 mg/l and 4.82 mg/l respectively. Major anionic and cationic concentrations in groundwater samples of Kattampally wetland are shown in Figure 7 (a) & (b).

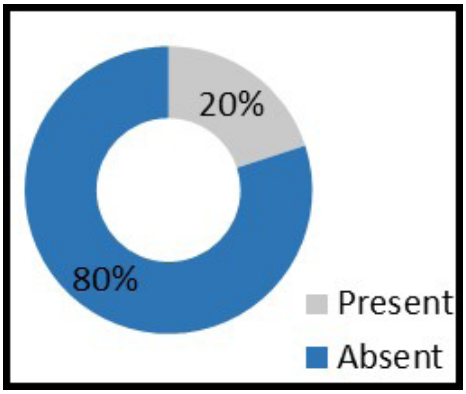

Figure 8. Samples of Kattampally contaminated with *E coli*

Comparison of the groundwater quality status of Biyyam and Kattampally wetlands with that of Kavvayi wetland revealed that Kavvayi groundwater samples are more alkaline in nature. The deposit of shells in the coastal areas of Kavvayi wetland might have contributed to the increased alkalinity in the groundwater samples. In Kavvayi wetland system, TDS values ranged from 50.75 to 5060.0 mg/l with an average value of 311.37 mg/l. The average concentration of nitrate in Kavvayi (0.19 mg/l) was found to be less than that of Biyyam (2.31 mg/l) and Kattampally (1.86 mg/l) wetlands. Average values of ionic concentrations figured out that the dominance of major cations was in the order of $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ in both the study areas, but the dominance of major anions was in the order of $Cl^{-}>SO_4^{2-}>PO_4^{3-}>NO_3^{-}$ and $Cl^{-}>SO_4^{2-}>NO_3^{-}>PO_4^{3-}$ in Kattampally and Biyyam wetlands respectively. The mean value of the major ions (cations and anions) in groundwater samples of Kavvayi wetland follows the order of $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ and $Cl^{-}>HCO_3^{-}>SO4^{2-}$. Dominance of Na^{+} and Cl^{-} indicates salinity intrusion. Groundwater samples of all the three wetlands were reported iron concentration within BIS acceptable limit (1.0 mg/l). In Kavvayi wetland, concentration of Mn and Zn ranged from BDL to 0.01 mg/l and BDL to respectively 5.0 mg/l. In the case of Kavvayi wetland system, extremely high count of total coliform (≥2400) contamination was reported in 83% of the total groundwater samples analyzed and *E. coli* was detected in 69% of the groundwater samples.

Water Quality Index

Water Quality Index is one of the effective tools to express water quality that offers simple, stable, and reproducible unit of measure and communicate information about water quality (Singh *et al*., 2013). In the present study WQI was calculated in terms of physico-chemical characteristics of the groundwater samples. Each of the parameters has been assigned a weight based on its relative importance in determining the quality of water for drinking purpose (Vasanthavigar *et al*., 2010). Developing WQI in an area is a fundamental process in the planning of land use and water resources management (Saeedi *et al*., 2010). Categories of water samples based on WQI are shown in Table 2. The calculated values of WQI are represented in Figure 9, 10 (a) and (b).

Table.2 Category of water based on WQI

WQI Range	Category of water
<50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very Poor water
>300	Unfit for drinking purpose

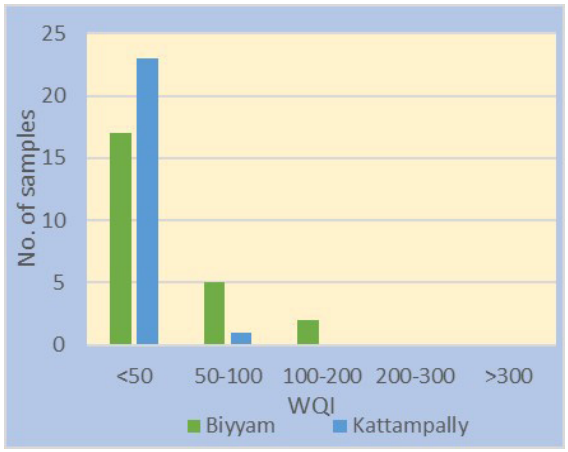

Figure 9. WQI value

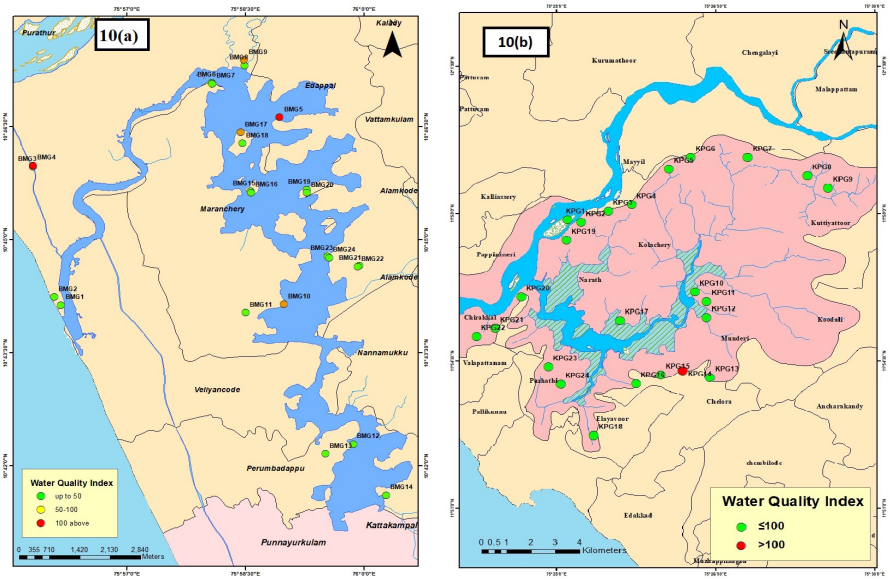

Figure 10. WQI (a) Biyyam wetland (b) Kattampally Wetland

It was found that 17 water samples of Biyyam and 23 samples of Kattampally were Excellent. The number of Poor water samples were 2 and 1 in Biyyam and Kattampally wetlands respectively. In Biyyam wetland, 5 samples were observed as Good water.

Statistical Analysis

Pearson's correlation coefficient (*r*) is a measure of the linear association between two variables. The correlation coefficient ranges from –1 to +1. Values of correlation coefficient close to zero indicate a low association between variables, and those close to –1 or +1 indicate a strong linear association between two variables.

The result of Pearson correlation analysis of Biyyam revealed that pH shows positive correlation with total hardness (r=0.618) and calcium (r=0.676). EC shows strong positive correlation with sulphate (r=0.909). Hardness contributed by calcium compounds and magnesium compounds is almost equal. Both TDS and salinity are significantly correlated with total hardness, total alkalinity, calcium, magnesium and sodium. Significant correlation of total alkalinity with calcium (r=0.725) and magnesium (r=0.724) indicates that calcium and magnesium compounds contribute to the alkaline nature of the water samples. In Kattampally pH has significant correlation with total alkalinity (r=0.738) and sulphate (r=0.610). TDS shows strong positive correlation with salinity, total hardness, chloride, calcium, manganese and sodium. Nitrate and potassium have no correlation with any of the physico-chemical parameter.

Chloride shows strong positive correlation with alkaline earth metal ion magnesium (r=0.737), alkali metal ions sodium (r=0.998) and calcium (r=0.736)

Table 3. Pearson Correlation Matrix of groundwater samples of Biyyam wetland

	PH	EC	Turbidity	TDS	Salinity	TH	TA	Cl^-	SO_4^{2-}	NO_3^{3-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
PH	1.000													
EC	0.325	1.000												
Turbidity	0.222	0.013	1.000											
TDS	0.474	0.173	-0.034	1.000										
Salinity	0.489	0.221	-0.063	0.974	1.000									
TH	0.618	0.359	-0.012	0.934	0.969	1.000								
TA	0.587	0.175	-0.047	0.956	0.974	0.967	1.000							
Cl^-	0.278	0.351	0.104	0.580	0.663	0.609	0.527	1.000						
SO_4^{2-}	0.463	0.909	-0.087	0.265	0.311	0.462	0.283	0.336	1.000					
NO_3^{3-}	-0.097	0.149	-0.263	-0.048	0.014	0.090	0.032	-0.134	0.188	1.000				
Ca^{2+}	0.676	0.568	0.068	0.744	0.796	0.913	0.799	0.514	0.664	0.230	1.000			
Mg^{2+}	0.458	0.097	-0.088	0.963	0.975	0.918	0.969	0.600	0.189	-0.062	0.677	1.000		
Na^+	0.382	0.045	-0.079	0.961	0.976	0.901	0.952	0.617	0.119	-0.056	0.660	0.985	1.000	
K^+	0.380	0.679	-0.160	0.586	0.650	0.726	0.660	0.294	0.661	0.241	0.760	0.574	0.561	1.000

Table 4. Pearson Correlation Matrix of groundwater samples of Kattampally wetland

	pH	EC	Turbidity	TDS	Salinity	TH	TA	Cl^-	SO_4^{2-}	NO_3^{3-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
pH	1.000													
EC	0.137	1.000												
Turbidity	0.141	0.014	1.000											
TDS	0.185	-0.143	0.052	1.000										
Salinity	0.154	-0.188	0.059	0.997	1.000									
TH	0.384	-0.148	0.030	0.947	0.932	1.000								
TA	0.738	0.377	-0.009	0.209	0.140	0.366	1.000							
Cl^-	0.125	-0.257	0.058	0.991	0.995	0.929	0.110	1.000						
SO_4^{2-}	0.610	0.561	-0.098	-0.015	-0.059	0.113	0.686	-0.118	1.000					
NO_3^{3-}	-0.305	-0.014	-0.179	0.483	0.497	0.419	-0.193	0.488	0.003	1.000				
Ca^{2+}	0.542	0.075	0.016	0.798	0.752	0.879	0.725	0.736	0.426	0.296	1.000			
Mg^{2+}	0.542	0.075	0.016	0.798	0.752	0.880	0.724	0.737	0.426	0.296	1.000	1.000		
Na^+	0.116	-0.221	0.054	0.993	0.997	0.923	0.117	0.998	-0.110	0.494	0.737	0.737	1.000	
K^+	0.241	-0.067	0.105	0.171	0.177	0.347	-0.032	0.183	-0.039	-0.018	0.100	0.100	0.160	1.000

indicate the presence of chloride salt of these cations in the groundwater samples of Kattampally wetland.

Groundwater Chemistry

Interpretation for the groundwater quality was done using AQUACHEM software. In Biyyam 12 types of water samples were recognized. Highest percentage (21%) was belonged to Ca-Na-Cl-HCO_3 type. Na-Cl and Na-Ca-Cl were interpreted as other major types (17%). In Kattampally, 11 types of waters samples were reported. Among which Na-Ca-Cl and Na-Cl types (25%) were predominant.

Piper diagrams are tri linear representations of the ions found in the water and are used in order to classify water types of chemical facies. The water types are designated according to the area in which they occur on the diagrams. Piper and Durov diagrams constructed for the study areas are displayed in Figures 12a-12d.

Among the samples collected from Biyyam 21% were Na^+/K^+ type and 25% were Ca^{2+} type. Majority of the samples collected from Ponnani municipality were

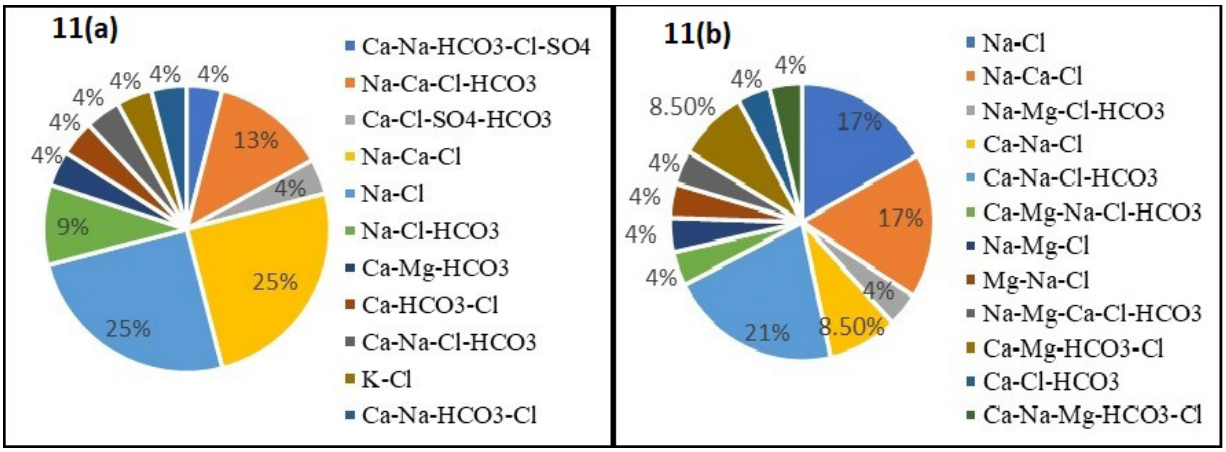

Figure 11. Water types (a) Kattampally & (b) Biyyam

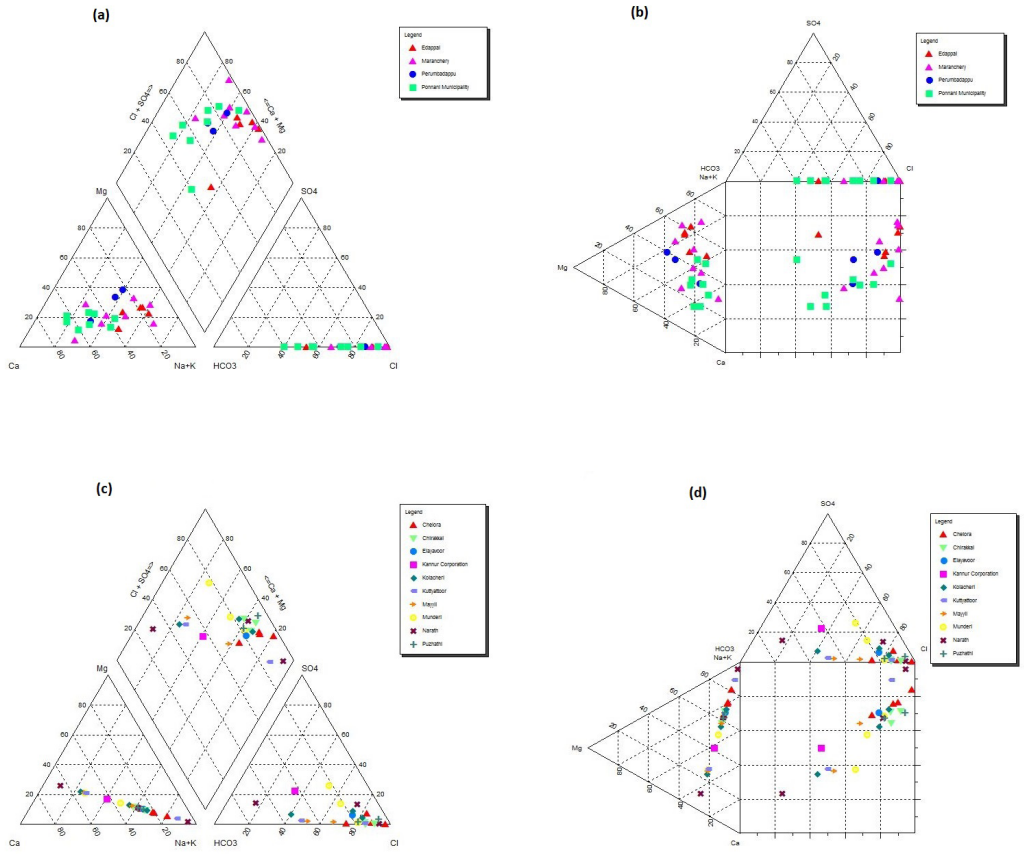

Figure 12. (a) & (b) Piper & Durov diagrams for Biyyam and (c) & (d) Piper & Durov diagrams for Kattampally

dominated by calcium cation. But in the case of Edappal panchayath 50% of the samples were rich in Na^+/K^+. Right lower triangle indicated that the major anion present in Biyyam groundwater samples was Cl-. In the case of Kattampally wetland, right lower triangle in the piper diagram indicated that chloride is the dominating anion. And HCO_3^- is the predominant anion in four groundwater samples. The samples were rich in Na^+/K^+.

The concentration of ions in the groundwater samples is also shown by Durov Diagram (1948), which is an alternative to the Piper diagram (Ali, 2018). According to the Durov diagram, it can be found that Ca^{2+} and Na^+/K^+ ions are high in each sample while as Cl is the dominant ion in the water samples of the study area. According to Durov diagram it was again confirmed that, the samples collected from Biyyam wetland were dominated by the ions like Ca^{2+} and Na^+/K^+. Durov diagram of Kattampally wetland confirmed that calcium and Na^+/K^+ ions are the dominant cations and chloride being the dominant anion.

Groundwater Quality Criteria based on Irrigation Standards

Groundwater is of good quality although its agricultural quality has been scarcely studied (Delgado, 2010). In order to study the suitability of groundwater for irrigation purpose, the concentration of water quality parameters was compared with the standard specifications. Soluble Sodium Percent (SSP), Sodium Adsorption Ratio (SAR), Kelly's Ratio (KR) and Magnesium Hazard (MH) are used to assess the quality of irrigation water. From the calculated values it was observed that 92% of groundwater samples in Biyyam wetland are suitable for irrigation purpose as per SSP whereas all the samples possess excellent Irrigational Water Quality as per SAR. KR shows that only 4% of samples were unsuitable for irrigation purpose. As per MH values it was found that 67% of the samples were suitable for irrigation purpose in Biyyam wetland area. Both the SAR and MH values revealed that all the groundwater samples are suitable for irrigation purpose. KR shows that only 16% of samples were unsuitable for irrigation purpose. The Irrigation Water Quality parameters like SSP, SAR, KR and MH indicated that majority of the groundwater samples from Biyyam and Kattampally wetland areas are suitable for irrigation purpose. Specification of groundwater samples from Biyyam and Kattampally wetlands is graphically represented in Fig. 13.

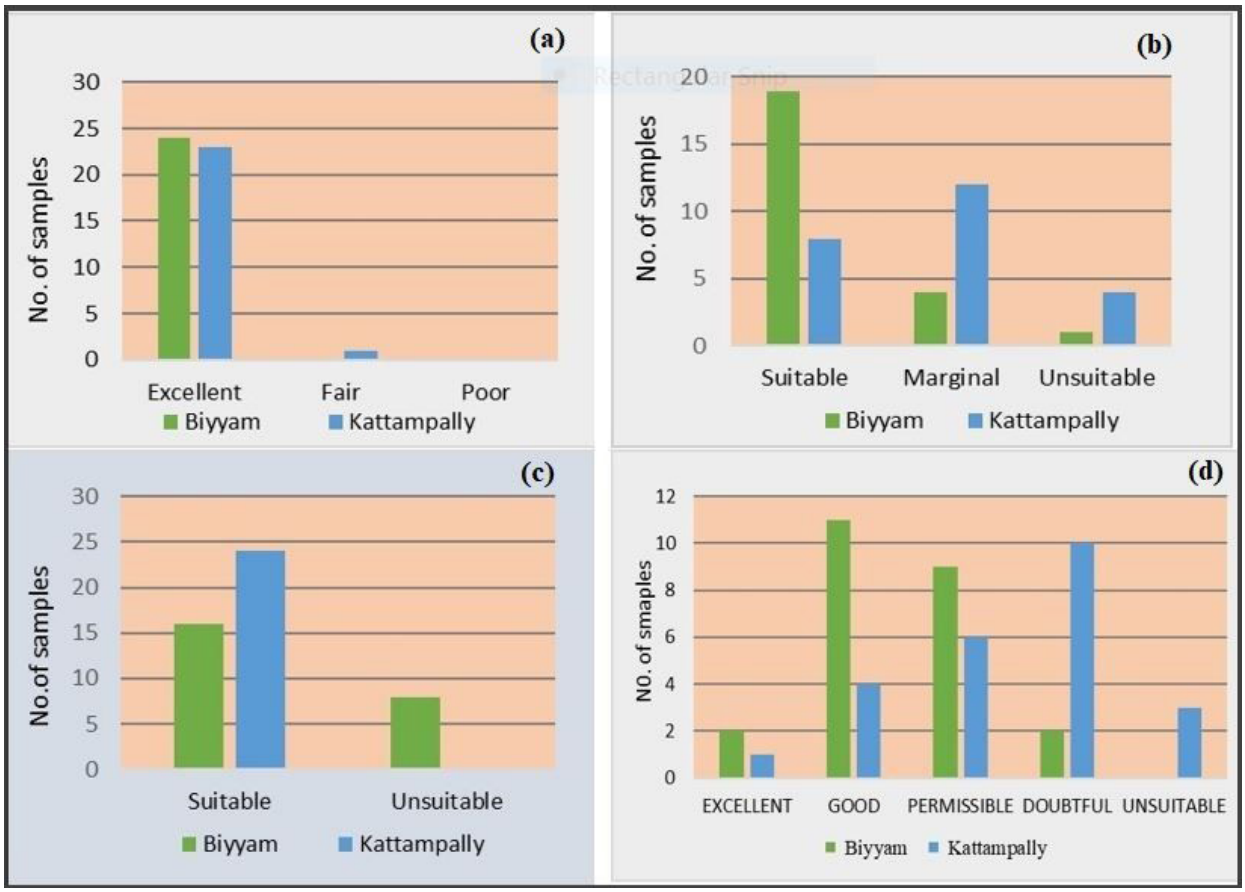

Figure 13. IWQ as per (a) SAR, (b) KR, (c) MH & (d) SSP

CONCLUSION

This study evaluated the groundwater quality characteristics of the two wetlands of Kerala, India and concluded that lower pH value of groundwater samples is one of the drinking water problems in both the wetlands during pre-monsoon. Presence of heavy metal concentrations was negligible but total coliform bacteria was detected in all of the water samples, indicating the recent fecal contamination and hence proper disinfection techniques are necessary to consume the groundwater. Pearson correlation analysis drawn the inference that calcium and magnesium compounds contributed to the alkaline nature of the water samples of Biyyam wetland. The number of water types identified from Biyyam wetland was 12 and that in Kattampally wetland was 11. Ca-Na-Cl-HCO_3 type (21%) in Biyyam and Na-Ca-Cl (25%) and Na-Cl types (25%) in Kattampally were predominant water types. Majority of the samples were suitable for irrigation purpose as per SSP, SAR, KR and MH. Groundwater samples of Biyyam wetland show more suitability for irrigation than that of Kattampally wetland.

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