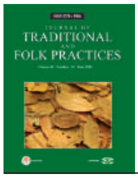

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Hydro-geochemical properties with respect to landuse in the southernmost river of Kerala

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Abstract

The hydro geochemical features of Neyyar River for a period of one year from May 2015 to April 2016 were analyzed. Six sampling sites were fixed considering physiography and present landuse pattern of the river basin. The residents in the drainage basin are primarily responsible for framing a better landuse and thereby maintain a good water and sediment regime. Geospatial pattern of the present landuse of the study area indicated that the sustainability of this river ecosystem is in danger due to unscientific landuse practices, which is reflected in the river quality as well. The parameters such as hydrogen ion concentration, electrical conductivity, chloride, Biological Oxygen Demand, total hardness and sulphate of river water and Organic Carbon of river bed sediments were analyzed in this study. The overall analysis shows that the highland areas are characterized by better quality of water together with low organic carbon, which is mainly due to better landuse and minimal reclamation. The midland and lowland areas are characterized by poor quality of water with high organic carbon, which is due to high anthropogenic activities and maximum pollutants associated with the region together with the alteration in landuse from a traditional eco-friendly pattern to a severely polluted current pattern.

Keywords: Neyyar, Chemical parameters, Landuse, Correlation

1. Introduction

Rivers are the lifelines of nature and have a great deal of environmental value. Rivers have very low percentage of water present in the earth but have an inevitable role in the mere existence of human by providing fresh water. But the rivers have been subjected to severe degradation due to several pollution activities. They can create severe negative effects on the structure and balance of these ecosystems. River bed sediments are the potential sources of natural geochemical constituents derived principally from rock weathering. The organic carbon plays a crucial role in assessing riverine environment because of its strong interaction with all processes operating there. Accumulation of pollutants in the sediment affects the quality of water due to sediment-water interaction (Birdwell *et al.,* 2007; Cheng *et al.,* 1995). The ecological decline of Indian rivers is mainly due to contaminated sediments (Virendra *et al.,* 2003). The landuse practices prevalent in a particular region are the prime reason for quality fallout in river. The landuse practices such as paddy reclamation, sand and clay mining, quarrying, deforestation, industrialization and unscientific construction activities in reclaimed areas can adversely affect the river. Land use information is the basic pre-requisite for planning proper utilization of the land, water and vegetation resources and the inventory of these resources therefore, assume increasing importance in sustainable management and effective development in various sectors like agriculture, water resources, and environment (Sheeja *et al.,* 2011).

Neyyar is the southern-most and small catchment river of Kerala, originates from Agasthya malai in the Western Ghat mountain ranges and flows through extremely mottled geologic and physiographic provinces of the area for a length of about 56km. Neyyar plays a crucial role in providing drinking water to the people of Thiruvananthapuram city along with Karamana river. The right bank canal from the Neyyar reservoir flows through Kattakada Panchayath has been enriched different local bodies with freshwater. But the river is under the verge of total destruction due to immense pollution activities and indiscriminate landuse practices by the people. The water related issues are very critical in the small catchment rivers of developing economies with high incidence of human stress (Padmalal *et al.,* 2011). The industrial and chemical pollution sources are established recently in this area and the waste water is directly debouching into the river. The electroplating and vehicle service stations near Neyyattinkara and boat painting stations near Poovar are operating in the study area. Research primarily on the water and sediment characteristics will give an in depth picture about life and stability of any ecosystem. So the purpose of the present study is to assess the water and sediment quality status by analyzing certain critical parameters and also document the current landuse pattern of the selected sites of Neyyar River, thereby we can lead the people towards a better river rescue program.

2. Materials and Methods

Neyyar is the southern-most river of Kerala State having a total basin area of 483sq. km, lies between 8°15′ to 8°40′-N latitudes and 77°00′ to 77°20′-E longitudes. For the present studies we have selected six sampling stations such as Neyyar reservoir (S1), Kallikkadu (S2), Mandapathinkadavu (S3), Aruvippuram (S4), Neyyattinkara (S5) and Poovar (S6) (Fig 1). These sites were selected on the basis of physiographic condition as well as the ecological condition of the zone. The S1 and S2 are situated at the highland physiographic area with less anthropogenic activities, whereas Station 3 (transection area of highland and midland) and Station 4 (midland) are located in a polluted environment. The S5 and S6, physiographically lowland in position are with severe pollution activities. Water samples were collected from six sampling stations of the river monthly for one year (May-2015 to April-2016). Water sample is analyzed for chemical parameters such as Hydrogen ion concentration (PH), Electrical conductivity (EC), Chloride, Biological oxygen demand (BOD), Total hardness (TH) and Sulphate (SO_4). In-situ determination is done for hydrogen ion concentration and samples of BOD are collected in BOD bottles in the field itself. All the analyses are carried out following standard methods (APHA, 2012). Monthly samples of sediments were collected from the six stations simultaneously during water collection using Van-Veen grab sampler. A portion of the sample was dried and powdered using agate and mortar. The sediment organic carbon (Org-C) was determined by using wet oxidation and titration method of El Wakeel and Riley (1957). All the instruments and methods used are summarized in the Table 1. In this study, Google satellite images and survey of India (SOI) toposheets (Nos. 58H/2 and 58 H/3) of 1966-68 (1:50,000 scale) have been utilized to map the landuse pattern of Neyyar River basin for a period of 2015-2016. The study of landuse patterns were carried out using GIS software version Arc GIS 10.1. The ground truth verification was done for better accuracy of the landuse and necessary changes were made in the map during post-interpretation.

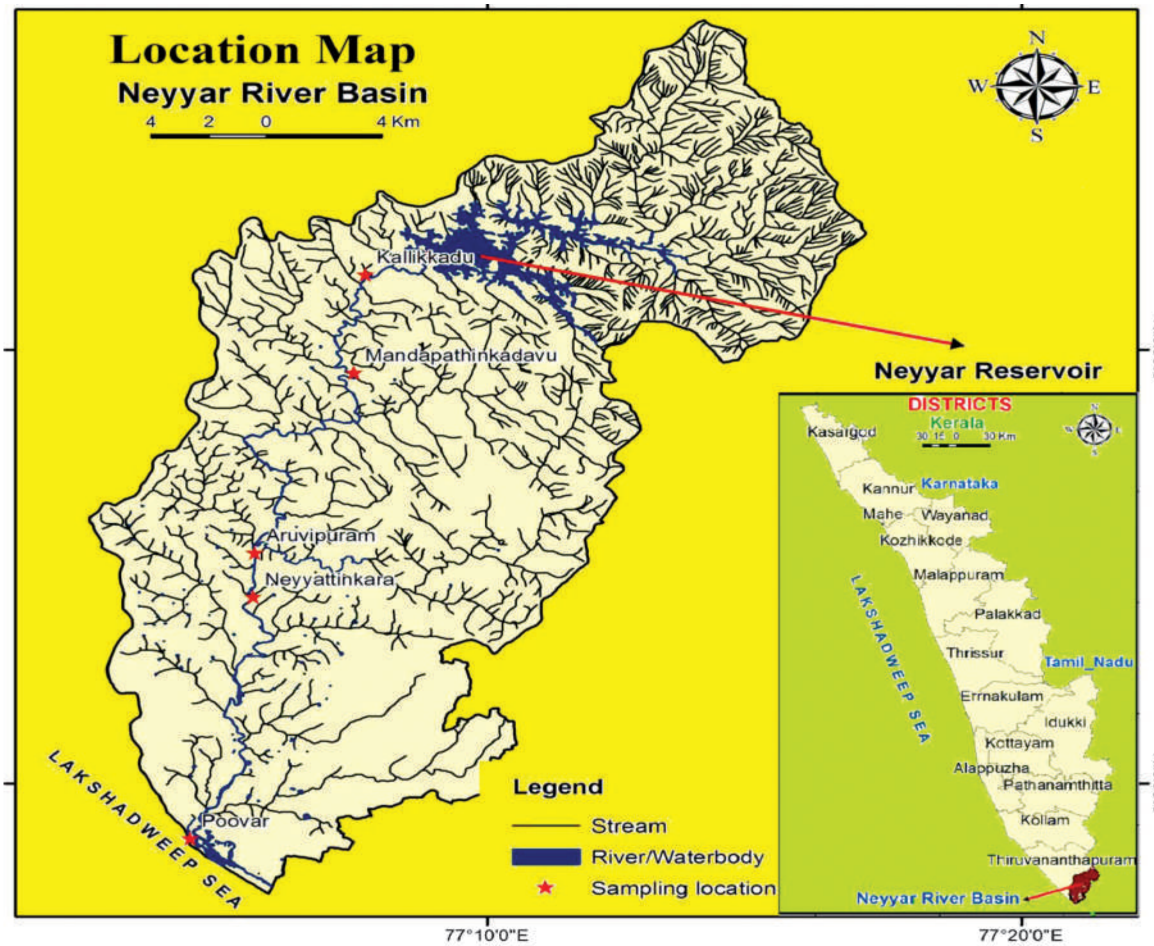

Fig 1. Sampling locations and drainage of Neyyar River basin

Table 1. Instruments and methods used for estimation of parameters

Parameters	Method	**Instrument**	**Reference**
pH	Electrometric Method	Digital Water Analysis Kit-Model-161	-
EC	Electrometric Method	Digital Water Analysis Kit-Model-161	-
Chloride	Argentometric Method	-	APHA (2012)
BOD	Winkler Method (5 day incubation)	-	APHA (2012)
TH	EDTA Titrimetric Method	-	APHA (2012)
SO4	Colorimetric Method	Systronics Spectrophotometer-106	APHA (2012)
Org-C	Wet Oxidation and Titration	-	El Wakeel and Riley (1957)

3. Results and Discussion

The chemical environment of river water and sediment functions in many ways and influences the biotic components. In the present study quantitative estimation of various chemical parameters were carried out. Results of the monthly variations in the chemical characteristics of water samples and Org-C of sediments from Neyyar River have illustrated in Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7 and Fig. 8. The mean, SD, minimum and maximum of various chemical parameters are summarized in Table 2. The correlation between the parameters is shown in Table 3.

Table 2. Mean, SD, Minimum, Maximum values of various hydro geochemical parameters

Stations	PH				EC			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
S1	6.8	0.15	6.6	7.0	32.8	6.11	25.4	44.4
S2	6.9	0.17	6.7	7.1	45.3	6.61	35.3	56.3
S3	7.0	0.17	6.7	7.2	52.2	5.41	44.4	60.3
S4	7.0	0.18	6.7	7.3	54.3	6.28	42.5	60.8
S5	7.0	0.23	6.8	7.4	65.3	8.94	49.2	75.8
S6	7.6	0.16	7.4	7.9	6344.5	1817.66	3134.3	8530.2
Stations	**Chloride**				**BOD**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
S1	5.7	1.2	4.0	7.4	0.7	0.37	0.3	1.5
S2	9.2	1.4	6.9	11.3	2.2	0.86	1.0	3.2
S3	13.8	3.9	7.4	19.4	2.8	0.72	1.7	3.9
S4	14.6	3.5	10.3	21.3	2.1	0.70	0.8	3.0
S5	19.6	5.6	11.7	28.4	4.6	0.61	3.9	5.7
S6	3092.4	2233.9	369.0	6818.2	5.0	0.47	4.4	5.9
Stations	**TH**				**Sulphate**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
S1	9.7	1.68	6.6	11.9	0.9	0.30	0.5	1.3
S2	12.1	2.06	9.5	15.1	2.5	0.83	1.3	3.8
S3	12.3	1.88	10.1	15.8	2.9	0.80	1.8	4.1
S4	13.0	2.02	9.8	15.8	2.5	0.42	1.9	3.2
S5	16.0	1.53	13.8	18.5	4.2	0.97	2.7	5.4
S6	241.8	42.08	176.6	318.4	110.8	33.41	60.8	162.7

National and International Drinking Water Quality Standards		
Parameters	**BIS Desirable Limit**	**WHO Guidelines**
pH	6.5-8.5	6.5-8.5
EC	1500µs	800 µs
Chloride	250mg/l	250mg/l
BOD	3mg/l	2-5mg/l
TH	200mg/l	200 mg/l
SO4	200mg/l	250mg/l
Org-C		

Stations	Mean	SD	Min	Max
S1	0.4	0.06	0.3	0.5
S2	1.3	0.11	1.2	1.5
S3	2.1	0.15	1.8	2.3
S4	1.9	0.14	1.7	2.1
S5	2.6	0.13	2.4	2.8
S6	3.0	0.12	2.8	3.2

3.1. Hydrogen Ion Concentration

The hydrogen ion concentration is the noteworthy chemical property of any water resource, which mainly indicates the acid or alkaline status of a solution. In a freshwater ecosystem the balance of pH is considered inside the range of 5.5 to 8.5 (Chandrasekhar *et al.,* 2003). The pH in the present study varied between 6.6 and 7.9, the minimum value at the reservoir and the maximum at Poovar (Fig. 1). The influence of physiography as well as landuse is clearly visible in the distribution of pH at Station-6 (Poovar), which is a near estuarine region. Monthly influence is considerable and during June, July, October and November, a lowering in pH was generally visible. Maximum pH in the months of March may be due to low precipitation and relatively low pH value in monsoon months may be due to heavy rainfall and consequent land run-off experienced in that environment.

3.2. Electrical Conductivity

EC is a basic index to select the suitability of water for agricultural purposes (Kataria *et al.,* 1995). The ability of water sample to conduct an electric current is considered as conductivity, which depends mainly up on the dissolved substances carrying ions. The water samples of Neyyar River showed conductivity values between 25.4 µS and 8530.2µS, the minimum value at the reservoir and the maximum at Poovar (Fig. 2). Monthly influence is considerable, the lowest value was observed during November 2015 and the highest value was visible in March 2016. The lower water volume has an influential role in diminished conductivity (Behera *et al.,* 2004). In the station near estuary, impact of saline intrusion was obvious in the distribution of EC. The various ions added to the water from catchment areas regulate the conductivity of the water. The increase in conductivity towards downstream could be due to the increased urban and agriculture land use drainage into the river.

3.3. Chloride

In all types of water chloride is naturally occurs in lower quantities especially in unpolluted water. But high concentration of chlorides in fresh water is considered to be an indicator of organic pollution. The chloride in the present study varied between 4mg/l (in November 2015) and 6818.2mg/l (in March 2016), the minimum value at the reservoir and the maximum at Poovar (Fig. 3). The concentration of chlorides increases with the degree of eutrophication and such a scenario is visible from the study area. The gradual increase in chloride concentration down the river could be due to the increase in urban land use and due to the addition of some industrial or factory discharge (Allan, 1996). The river water at Poovar in the present study is always above the desirable limit (250mg/l) prescribed by BIS (2004). The estuarine influence was also visible at Poovar, where the water is unsuitable for public water supplies. The chloride level in natural water is an important consideration for the selection in public water supplies (Subramanian, 2000).

3.4. Biological Oxygen Demand

The experimental analysis used to estimate the relative oxygen constraint of polluted water is the Biochemical Oxygen Demand (BOD), which is also used to compute the quantity of biochemically degradable organic matter in fairly accurate manner. The BOD in the present study varied between 0.3mg/l and 5.9mg/l, the minimum value at the reservoir and the maximum at Poovar (Fig. 4). The biological oxygen demand seems to be high during March 2016 probably due to stagnation of contaminants and low rainfall. Similar observations were confirmed by many other workers such as Pathak and Mudgal (2004), Babu *et al.,* (2003) and Aji (2005). The minimum BOD values obtained during October 2015 may be due to sufficient amount of water in the river and self purification due to increased flow. BOD is an essential parameter in water pollution control management and evaluation of self-purification capacity of streams (Trivedy and Goel, 1984). The lowland physiographic area shows highest BOD values especially at Neyyattinkara and Poovar, which indicates the higher demand of oxygen for microorganisms in consuming the organic matter. BOD is an excellent indicator of the strength of domestic and industrial contaminants in aquatic environments (APHA, 1998).

3.5. Total Hardness

The sum of concentrations of alkaline earth metals present in water is considered as total hardness. Hardness can be classified into two, permanent hardness and temporary hardness. The sulphates and chlorides of metals are responsible for permanent hardness, where as temporary hardness is caused mainly by bicarbonates and carbonates of Calcium and Magnesium (APHA, 1998). The total hardness in the present study varied between 6.6mg/l and 318.4mg/l, the minimum value at the reservoir and the maximum at Poovar (Fig. 5). The hardness values in the present study are beyond the limits for drinking water for downstream stations. The data on hardness of water suggest that the river water of the basin are generally soft except at Station 6 (Poovar) of lower stretches which exhibit higher values up to 318.37mg/1. Minimal values are noted during November 2015 (6.55mg/1). The monsoon rains are the reason behind the lower hardness prevailing at that period. Towards March 2016, the high concentration of hardness of water may be attributed to evaporation of surface water and addition of detergents and soaps due to washing and bathing in the study area.

3.6. Sulphate

The sulphates are present in most natural waters in lower concentrations. Because of atmospheric precipitation a considerable amount of sulphate can be added to the hydrologic cycle. The sulphate in the present study varied between 0.5mg/l and 162.7mg/l, the minimum value at the reservoir and the maximum at Poovar (Fig. 6). An increase in value is noticed during March 2016 at all stations, which might be due to the prevalent influence of evaporation, where as a decrease in concentration of sulphates during November 2015 clearly indicate the influence of sufficient amount of water in the river due to heavy rain fall. The sulphate values are generally low in the river water except at Poovar, where high values are possibly due to the prevalent influence saline water. Sulphate salts are mostly soluble and impart hardness to water. So the water at Poovar is more or less unsuitable for public use. The ground water may also exhibit increase in hardness in this region. Water with sulphate concentration 500 mg/1 and above will have a bitter taste (ICMR, 1975).

3.7. Organic Carbon

Sediments have an intricate and vibrant milieu, derived mainly from crustal weathering. Sediments act as a store house of chemical constituents like nutrients and other major, minor and trace elements. Organic carbon is critical in sediment quality analysis because it has a significant role in all the biogeochemical processes operating in river environments (Degens and Ittekkot, 1983). Organic carbon in the form of organic matter is a major energy source of all aquatic environments, it act as a sink and source of various metals under different geochemical set ups (Laanne and Ruardij, 1988). Hence the study of Org-C will showcase the intensity of pollutants in an aquatic system. The Org-C in the present study varied between 0.3% and 3.2%, the minimum value at the reservoir and the maximum at Poovar (Fig. 7). Higher organic carbon values were observed during October-2015 at S-6 and November 2015 at S5 (North east monsoon) than south west monsoon, which clearly indicate the influence of rain and consequent discharge of waste materials into the river site. The higher values of organic carbon during monsoon may be due to heavy sewage discharge (Lakshmi *et al.,* 2000). The slightly higher values of Org-C in March 2016 at S1, S2, S3, S4, S5 and S6 may be due to high rate of decomposition consequent to increase in temperature. The upstream regions of the Neyyar especially at reservoir station are distinguishable for very low organic carbon, which may be due to sand dominated sediments. The organic carbon content in sediments exhibit markedly high values towards downstream stations may be due to finer sediments in the river bed.

Correlation coefficient analysis of the water quality parameters demonstrates clearly the type and degree of relationship among them. pH showed significant positive correlation at 5% level with EC (r=0.754), Chloride (r=0.705), BOD (r=0.690), TH (r=0.785) and SO4 (r=0.787). EC, Chloride, BOD, TH and SO4 were showed positive correlation at 5% level with all parameters. Org-C also showed significant positive correlation at 5% level with all parameters. The highest significant correlation was observed in between EC and TH (r=0.990) followed by EC and SO4 (r=989) (Table 3).

Table 3. Pearson correlation co-efficient between various hydro geochemical parameters

	pH	EC	Chloride	BOD	TH	SO4	Org-C
pH	1						
EC	0.754	1					
Chloride	0.705	0.915	1				
BOD	0.690	0.536	0.483	1			
TH	0.785	0.990	0.886	0.560	1		
SO4	0.787	0.989	0.937	0.556	0.990	1	
Org-C	0.629	0.536	0.420	0.893	0.573	0.547	1

Fig. 1. Highland area (Neyyar Reservoir)

Fig. 2. Highland area (Kallikkadu)

Fig. 3. Intersection area of highland and midland (Mandapathinkadavu)

Fig. 4. Midland area (Aruvippuram)

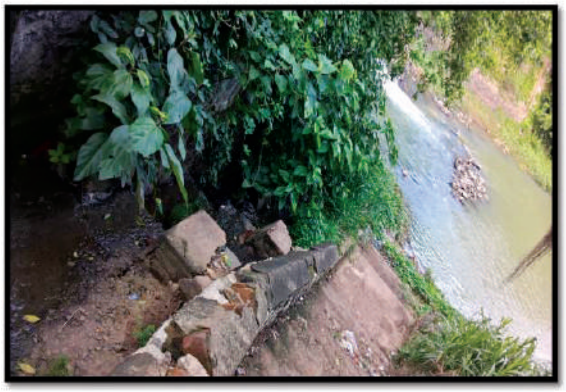

Fig. 5. Lowland area (Neyyattinkara)

Fig. 6. Lowland area (Poovar)

From these water and sediment quality properties of Neyyar River, it is evident that all the analyzed parameters are very high in downstream stretches of the river. The reasons are not only due to the high pollution activities associated with these regions but also the landuse has a decisive influence. The present landuse pattern of Neyyar river basin is illustrated in Fig. 9. There are fourteen categories of landuse are visible in the entire river basin. In the first station of highland physiographic area, the Neyyar reservoir (S1) (Plate 1) mainly constitutes forest area, rubber plantations, mixed crop and settlement with mixed crops. In this region the density of population is comparatively less. The struggle for existence of life is fewer in this area. The agglomerated settlement area on the reclaimed wetlands is less in this area. The less polluted surface water here is mainly due to less population density and consequent decrease in pollution, compared to midland and lowland. It is reflected in the water and sediment quality as well. The high land area is associated with minimal pollution threats especially in forest related landuse (Tong and Chen, 2002). The second sampling site, Kallikadu (Plate 2) is also located at the highland region with extensive rubber plantation. The chances of heavy contamination are comparatively less in this region because of fairly low population density. Even though, increase in concentration of BOD in water and Org-C in bed sediments than in Neyyar reservoir indicates the presence of organic waste dump and also water in this region is almost stagnant due to the extensive sand mining activities.

The sampling station at Mandapathinkadavu (S3) (Plate 3) is physiographically located in between highland and midland. Here reclamation of paddy fields is mainly concentrated in valley heads and near to the roads. Banana and tapioca are the major crops in the reclaimed land. The major pollution source is drainage carrying waste water from the settlement of a micro watershed is directly debouching into the river site, which is reflected in the overall water quality and sediment Org-C. All the parameters showed higher values than the Neyyar reservoir and Kallikkadu. Deforestation and extensive cultivation of rubber plantation is observed at Aruvipuram area (S4) (Plate 4). The paddy reclamation is so intense and is mainly occupied by rubber. They are also occupied by crops such as banana, tapioca and the disperse presents of settlements. The unscientific and extensive construction of bunds across the river is very common. All these factors will arrest the natural flow and self purification capacity of the river. Due to reclamation of wetlands, the extensive lateritic hillocks which are the major water holding formations are being derelicted in this region. The overall water and sediment quality is lower than S1 and S2 but slightly higher than the S3. This is because during our field visits we never observed any pollution source is directly debouching into the river site like that in S3.

The sampling site at Neyyattinkara (S5) (Plate 5), physiographically a lowland area is locates in a municipal province. The site is heavily polluted due to the presence of the agglomerated settlement and industrial effluence. The major landuse category in this region is settlement with mixed tree crops. Reclamations of paddy and wetland are most common in this region. The banana, tapioca and mixed crops are mainly occupied in the reclaimed areas. There is a very intense residential and other build up areas on reclaimed paddy fields in this region compared to that of Aruvipuram. The quality of water and sediment is degraded more in S-5 than S-1, S-2, S-3 and S-4. The water is highly polluted at Poovar, which is located in the lowland physiographic area. The cumulative effect of all the pollutants from the upstream is visible in this region. The coconut plantation with mixed tree crops is the major landuse around this area. Waste water drainages are very common in this region. All the water quality parameters and sediment Org-C are very high in this region. The reason behind are the severe pollution load as well as the influence of sea water because this site is located just above the Poovar estuary. The chances of polluting underground water in this region are very huge because of the interrelationships between ground water and surface water. Similar observations were made by Santhosh *et al.,* (2017) from Neyyar River basin.

The majority of built-up areas and pollution due to human intervention are dispersed mainly at lowland area of Neyyar River basin, it will be very much high in the region at Neyyattinkara and Poovar. The people used to purchase the paddy fields and wetlands because which are low cost and easily available and converting them into built-up areas. The main driving force for environmental degradation is the dramatic change of traditional agricultural practices (George Zalidis *et al.,* 2002). The majority of paddy fields and wetland are reclaimed in Neyyar river basin and they are totally reclaimed in lowland physiographic areas especially at Neyyattinkara and Poovar. Most of the lowland areas are being converted in to waste water logged which is the main ill effect of complete reclamation of paddy fields and extensive sand mining. The severe loss of water and sediment quality in lowland indicated that the intensity of pollution is very high in this region compared to midland and highland. During the entire period of our filed visits we felt that the threshold of destruction of Neyyar river basin is alarming due to all the above mentioned factors. If the situation will continue for the coming years, the existence of a sustainable ecosystem will be in danger.

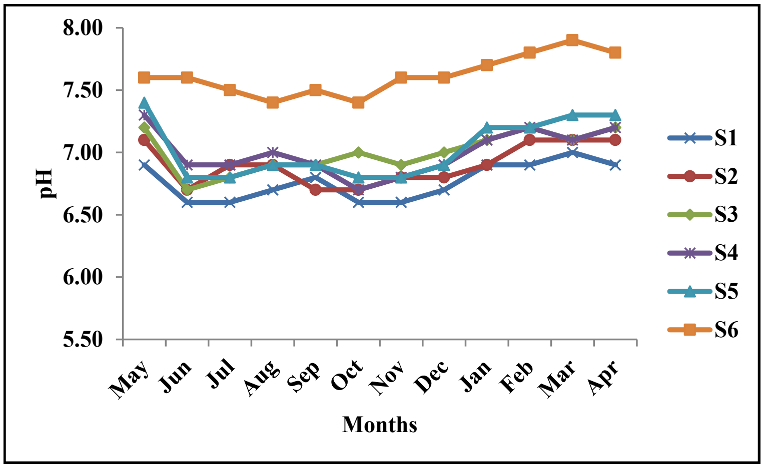

Fig. 2. Distribution of PH in the waters of Neyyar River

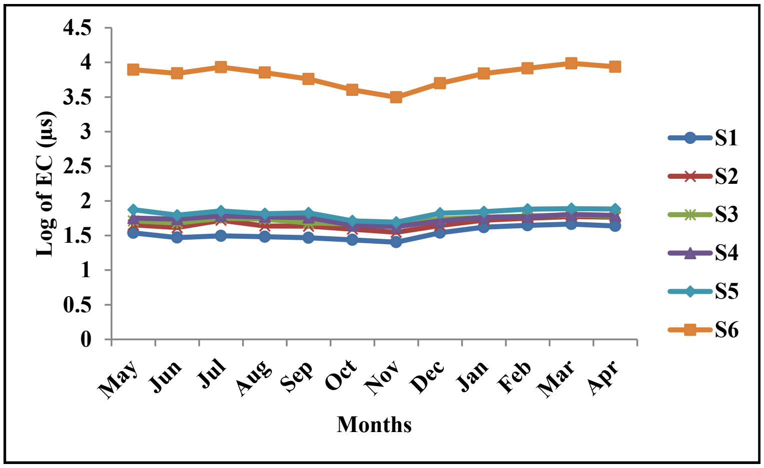

Fig. 3. Distribution of logarithmic values of Electrical conductivity in the waters of Neyyar River

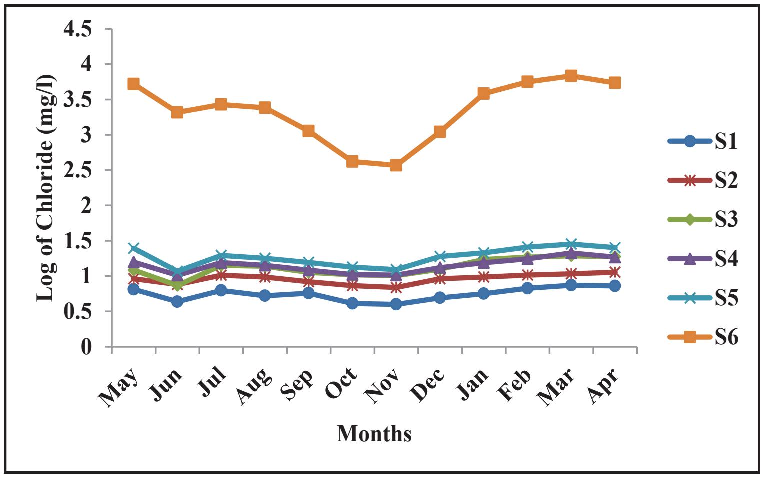

Fig. 4. Distribution of logarithmic values of Chloride in the waters of Neyyar River

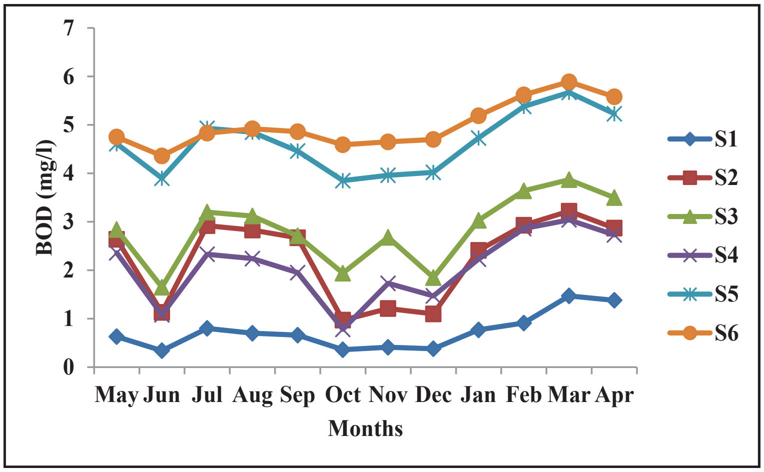

Fig. 5. Distribution of BOD in the waters of Neyyar River

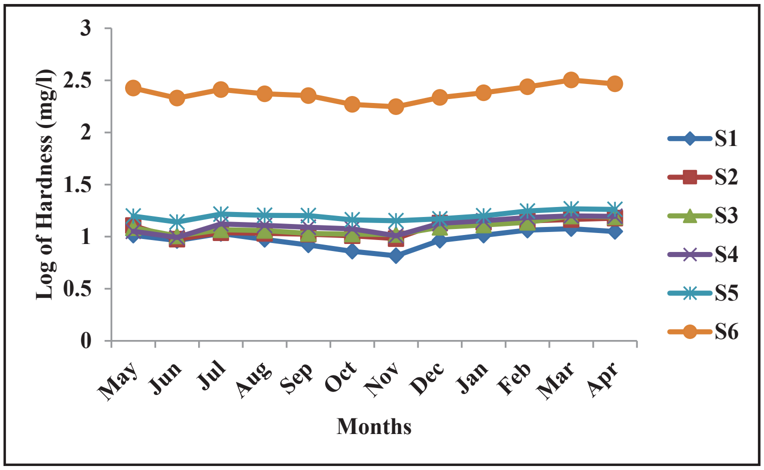

Fig. 6. Distribution of logarithmic values of Total hardness in the waters of Neyyar River

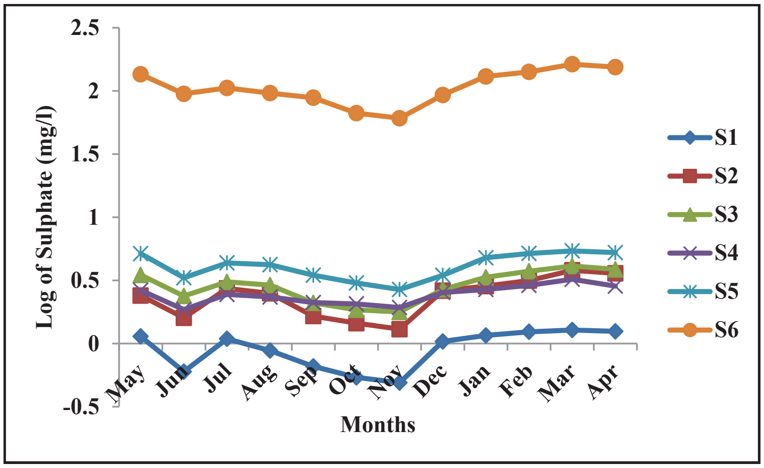

Fig. 7. Distribution of logarithmic values of Sulphate in the waters of Neyyar River

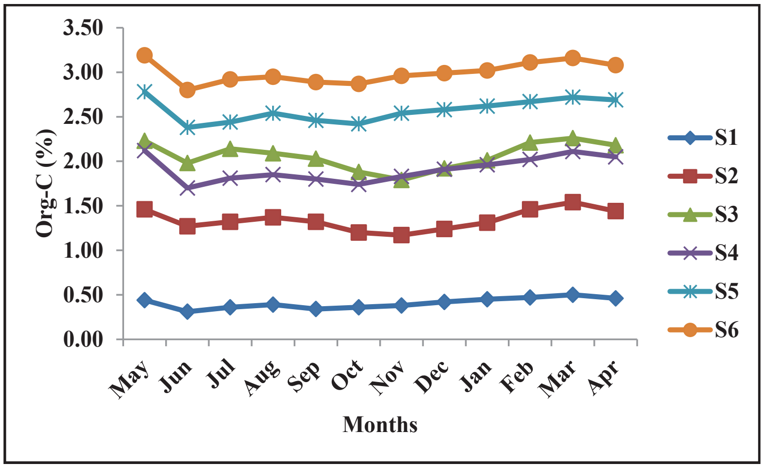

Fig. 8. Distribution of Organic carbon in the sediments of Neyyar River

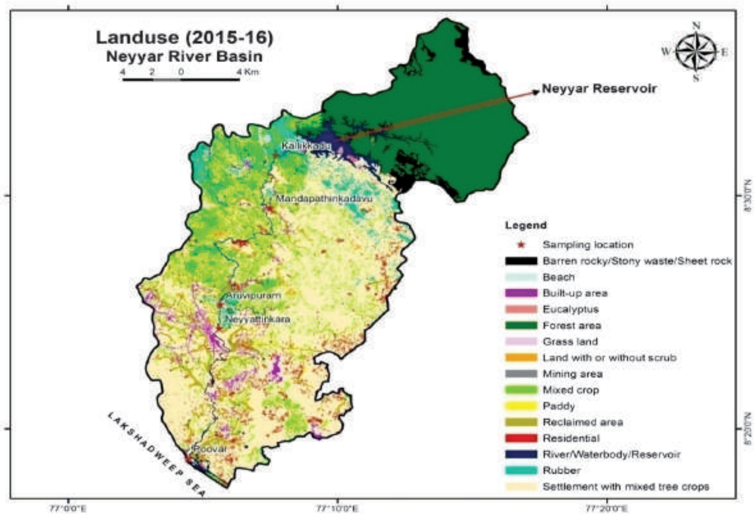

Fig. 9. Landuse pattern of Neyyar River basin

4. Conclusion

The quality of river is depleting rapidly with the change in landuse also. The present landuse pattern of the entire river basin is the clear indication of such degradation in downstream. Some of them are reclamation of paddy fields, construction activities, utilization of agricultural land and forest land for other developmental purposes and poor waste management. These problems may enhance the water borne diseases in the region. In conclusion, the water of Neyyar is highly contaminated at downstream stretches of the river during dry months. The increased distribution of water quality parameters and Org-C content of the river bed sediments towards downstream is mainly due to organic waste, poor sanitary facilities and high anthropogenic disturbances associated with the region. Wild use of chemical fertilizers and pesticides, devious dumping of domestic wastes are also the major causes of deterioration of water especially in Neyyattinkara and Poovar sampling station. Apart from the lowering of quality of water and sediment, the accumulation of sewage, municipal and agricultural wastes may adversely affect the biodiversity as well. Therefore appropriate programmes must be devised to educate the general public on the proper disposal of refuse, treatment of sewage for a broader perspective for maintaining the quality of fresh water.

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