Mapana – Journal of Sciences
2024, Vol. 23, No. 1, 169-188
ISSN 0975-3303|https://doi.org/10.12723/mjs.68.9

A Study on Land Use Change and Water Quality in the Wetland of Kuttanad Region, Southern India

Higgins Robert* and Dhanush D M†

Abstract

Land use changes in urbanization, industrialization, and agricultural processes will continue to have negative impacts on water quality at all scales. The impact of land use change on water quality is generally studied by analysing the relationship between land use and water quality indicators. Water samples were collected from the surface of Pampa River basin, and analysed for physical, chemical and micro biological parameters. Water quality parameters such as electrical conductivity, Total dissolved solids, Biochemical oxygen demand, Total Coliform, and Fecal Coliform etc., were found to be high in the urban environment. On the other hand water pH and 'DO' were high in the forest area and nitrate values and E.Coli were maximum in the SMT land use. The water pollution index (WPI) showed that the river water was very pure in the forest area, moderately polluted in the paddy fields, polluted in the urban environment and heavily polluted in the SMT land use. The findings demonstrated that significant effect of land use change on water quality.

Keywords: Water quality, Physicochemical, Biological, Land Degradation, Land Use, Total Hardness

---

* Department of Geography, University College, Thiruvananthapuram, Kerala, India (Corresponding Author)

† Department of Geography, Government College, Kariavattom, Thiruvananthapuram, Kerala, India.

1. Introduction

The environmental problems like climate change, global warming, surface and ground water quality issues are due to the land use changes of increasing population. The present study focusses on the surface water quality in Kuttanad. This region is a wetland situated 2.5 metres below the mean sea level. It is a vast flood plain jointly created by the depositional work of four rivers. They are river Pampa, Manimala, Achankovil, and Meenachil. Traditionally this region is a rice-growing tract and, thus, it is called 'the Rice Bowl of Kerala'[1]. This region comprises of backwaters, kayals, rivers and estuaries. Due to population increase the land use pattern of this region has changed significantly. The built up lands and settlements are increasing at the expense of water bodies. This type of land-use change, that is, from paddy fields to SMT, water body to built-up land may have serious environmental effects. These changes has its impact on the water quality of this region. Thus, it is essential to analyse the process and pattern of land-use change in the Kuttanad region. Land use change is one of the prime causes of several environmental problems like global warming and climate change, surface and groundwater quality issues, land and soil degradation [2]. The present study concentrates on surface water quality deterioration.

1.1 Land Use Change Effect on Water Quality

The USGS definition of Water quality is the measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. The water quality of rivers and lakes changes with the seasons and geographic areas, even when there is no pollution present[3]. The factors influencing water quality degradation ar climate changes, natural disasters, geological factors, soil-matrix, and hyporheicexchange. Water could also be contaminated by anthropogenic factors. The present study selected 11 physical and 4 biological parametres to analyse the effect of land use change on water quality.

1.2 Study Area

1.2.1 Location

Kuttanad region is situated between 9^{o} 14′ and 9^{o} 47′ N latitude and 76^{o} and 76^{o} 36′ E longitudes. There are 76 panchayats spread over

Alappuzha, Kottayam and Pathanamthitta districts (Fig.1). The total area of the region is 1136 sq. km. Kuttanad stretches for 75 km from Kollam in the south to Kochi in the north and is situated between the foothills of the Western Ghats in the east and the comparatively elevated plains of coastal Alappuzha in the west. The rivers draining through the region are Meenachil, Manimala, Achankovil and Pampa. The organic matter transported from high ranges makes Kuttanad a unique ecosystem in the world[4]. The entire region consists of rivers, backwaters, waterways and canals, paddy fields enclosed by dykes and coconut groves.

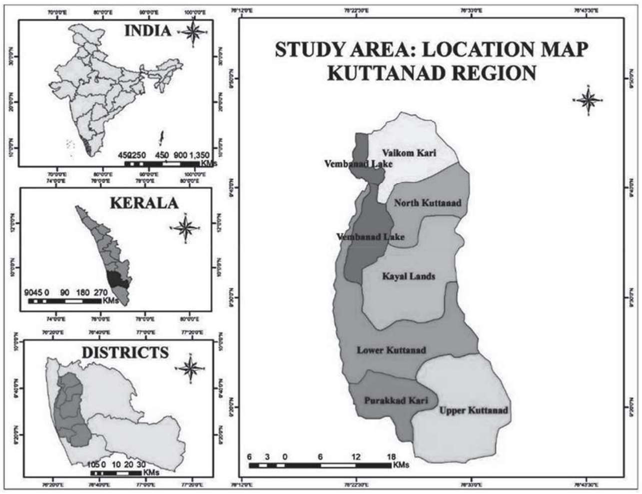

Fig. 1: Study Area: Location Map – Kuttanad Region

2. Materials and Methods

The water samples were collected from the surface of rivers during post-monsoon (January 2020), Pre-monsoon (May 2019) and monsoon (July 2019). A total number of 19 samples representing 4 land-uses namely forest (2 samples), paddy (3 samples), SMT (9 samples) and urban (5 samples) were collected. These water samples were tested in Central Chemical Laboratory (Hydrological process group) of National Centre for Earth Science and Studies (NCESS), Thiruvananthapuram for 15 physico-chemical and microbiological parameters including pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Nitrate values, Phosphate values, Total Viable count, Total Coliforms, Escherichia Coli (E. Coli) and Faecal Streptococci (F. Coli). Besides conducting a land-use-wise comparison of different water quality parameters, two statistical techniques namely Water Pollution Index (WPI) and Water Pollutants Index were derived to identify the water pollution status in various land-uses. The WPI can be calculated by using the following formula [5]

$\mathbf{WPI} = \frac{1}{n}\sum Ci/Si$ Where;

Ci = Average observed concentration of the i^{th} parameter in Mg/l

Si = Maximum permissible limit (standard value) for the i^{th} parameter

n = Number of water quality parameters

World Health Organization (WHO) Standard value was used as Si.

Based on WPI, the water quality can be classified into six categories (Table 1)

Table 1: Water Pollutants Index and the status of water Pollution

WPI Value	Water Quality Status
< 0.3	Very pure
0.3 – 1.0	Pure
1.0 – 2.0	Moderately Polluted
2.0 – 4.0	Polluted
4.0 – 6.0	Impure/Severely polluted
> 6.0	Heavily Impure

Source: Qin et al. 2014

To identify the share of each pollutant to the total water pollution, a water pollutants Index was also employed [5]. It can be given as;

$Ki = \frac{Mi/Ni}{\sum Mi/Ni}$ Where;

Ki = Share of each parameter/element to the total pollution index

Mi = Average observed concentration of the i^{th} parameter

Si = Maximum permissible limit (standard value) for the i^{th} parameter

3. Results and Discussion

3.1 Water Physico-Chemical Characteristics

3.1.1 Water pH

Water pH is a measure of how acidic or basic water is. A pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base [6]. pH is an important indicator of water quality. The analysis of surface water indicates that river water is mildly acidic in all the land uses except forest (Fig. 2). The three season average of pH value varied from 6.390 in the urban area to 7.260 in the forest (Table 2). Considering the seasons, the highest average pH (7.40) was recorded in the forest area in post-monsoon season, whereas the lowest (6.05) was found in the urban area in the pre-monsoon period (Table 3). Among the sample sites, the highest pH of 7.68 was seen in urban in one of the stations in post-monsoon seasons and the lowest of 5.06 in the same land use in pre-monsoon (Table 3). During the monsoon and post-monsoon seasons, all the stations recorded a pH of more than 6. During the pre-monsoon and monsoon seasons, the lowest pH was recorded in the urban land use, whereas, in the post-monsoon period the lowest pH was experienced in paddy.

Table 2: Pampa River – Three season average of different Water quality parameters in various land use

Parameter	Land Use			
	Forest	Paddy	SMT	Urban
pH	7.26	6.54	6.406	6.390
EC (In micro siemens/cm)	278.83	2077.51	3588.54	4737.6
TDS (ppm)	107.123	1351.26	2328.61	3085.02
DO (mg/l)	8.51	7.76	7.745	7.51
BOD (mg/l)	0.347	0.482	0.503	0.646
TH (mg/l)	144.35	294.67	468.5	398.13
Ca (mg/l)	16.49	12.47	16.12	27.13
Mg (mg/l)	9.93	27.47	40.97	71.55
Cl (mg/l)	27.66	569.48	1161.64	1532.53
Nitrate (mg/l)	199.25	594.51	645.43	551.52
P (mg/l)	4.29	11.91	6.99	6.027
Total Viable Count (CFU/ml)	3691.08	1303611.11	394729.64	489418.34
Total Coliforms (CFU/ml)	31.33	1231.02	4899.25	9765.197
E. Coli (CFU/ml)	0	6.66	124	2
Faecal Coli (CFU/ml)	0	0	0	2

Source: Compiled by the Researcher

Table 3: Pampa River – Land use wise mean values of different Water Quality parameters in different seasons

Parameter	Forest			Paddy			SMT			Urban		
	Pr. Mon	Mon	Po. Mon	Pr. Mon	Mon	Po. Mon	Pr. Mon	Mon	Po. Mon	Pr. Mon	Mon	Po. Mon
pH	7.2	7.18	7.4	6.62	6.28	6.73	6.11	6.31	6.8	6.05	6.18	6.93
EC (In micro siemens/cm)	548	130	158.5	5421.33	636.67	174.53	10424.8	195.4	145.43	13730.2	249.4	233.19
TDS (ppm)	195	84	42.37	3523.33	408.33	122.113	6753	126.6	106.24	8929.2	161.6	164.25
DO (mg/l)	8.6	8.36	8.57	8.12	7.51	7.65	8.098	7.63	7.51	7.568	7.45	7.51
BOD (mg/l)	0.15	0.35	0.54	0.33	0.397	0.72	0.587	0.218	0.704	0.746	0.4	0.796
TH (mg/l)	300	72	76	762.67	78.67	42.67	1312.7	49.2	43.6	1093.6	51.2	49.6
Ca (mg/l)	37.06	5.54	6.87	25.8	6.28	5.34	40.15	3.48	4.72	69.9	3.42	8.07
Mg (mg/l)	20.81	2.8	6.17	74.43	3.96	4.01	117.31	2.09	3.52	206.84	2.35	5.47
Cl (mg/l)	44.28	22.14	16.56	1533.26	131	44.16	3420.79	32.66	31.46	4494.63	52.03	50.93
Nitrate (mg/l)	38.97	65.58	493.2	113.85	436.15	1233.53	93.269	497.96	1345.06	113.59	441.69	1099.28
P (mg/l)	3.95	5.81	3.12	3.87	20.06	11.8	3.99	9.12	7.85	3	8.65	6.44
Total Viable Count (CFU/ml)	11000	30	43.244	93833.33	736666.7	3080333	28990	755400	399798.9	33232	1233000	202023
Total Coliforms (CFU/ml)	0	6400	30	1000	2610	83.06	3115	11469	113.75	26018	3052	225.59
E. Coli (CFU/ml)	0	0	0	20	0	0	12	360	0	6	0	0

Pr. Mon. - Pre-Monsoon, Mon. - Monsoon, Po. Mon. - Post Monsoon

Source: Compiled by the Researcher

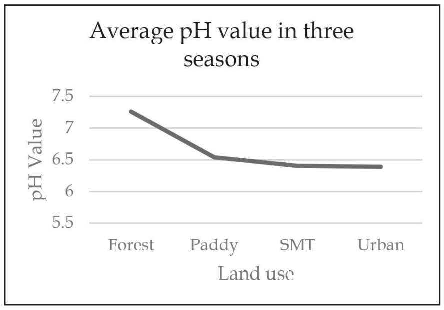

Fig. 2: Average pH value of three seasons

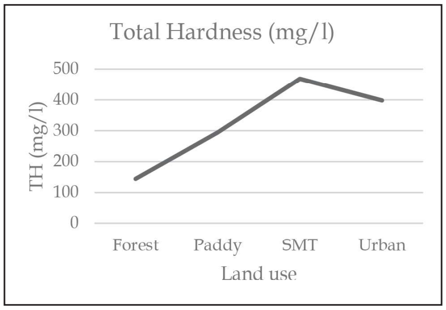

Fig. 3: Total Hardness

3.1.2 Total Hardness (TH)

Water hardness is a function of dissolved calcium and magnesium salts [7]. The TH was high in SMT and low in the forest area. The average TH of the three seasons ranged from 144.35 mg/l in forests to 468.5 mg/l in SMT. The urban area also had a higher mean TH of 398.13 mg/l (Fig. 3). Among the seasons, the highest average TH (1312.7 mg/l) was observed in pre-monsoon season in SMT and the lowest (42.67 mg/l) in paddy land use in the post-monsoon season. The higher values of TH in SMT and urban areas show that land use change has had a significant impact on water quality.

3.1.3 Electrical Conductivity (EC)

Electrical Conductivity depends on dissolved inorganic salts and solids in water. EC has significantly fluctuated in different land uses. The highest mean EC (4737.60 micro siemens/cm) was found in the urban land use, whereas, the lowest mean (278.83 Micro Siemens/cm) in the forest area (Fig. 4). Regarding all land uses the highest EC was recorded in the pre-monsoon season. EC in urban land use was higher due to its higher contents of chloride and Total Dissolved Solids (TDS). It shows that river water is more poolutted in the urban area. Significantly elevated electrical conductivity can indicate that pollution has entered the river.

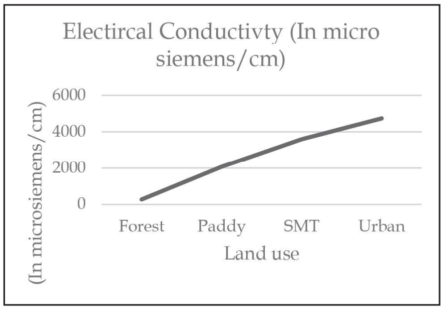

Fig. 4: Electrical Conductivity

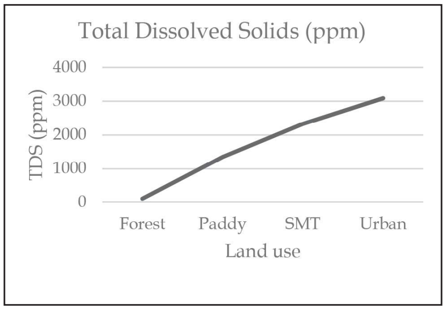

Fig. 5: Total Dissolved Solids

3.1.4 Total Dissolved Solids (TDS)

Total Dissolved Solids are the amount of organic and inorganic materials, such as metals, minerals and ions, dissolved in a particular volume of water[8]. The three seasons highest average TDS (3085.02 mg/l) was recorded in the urban area whereas the lowest average of 107.12 mg/l in the forest area (Fig 5). The highest average TDS in all the land uses were recorded in the pre-monsoon period due to the low volume of water in the river. Seasonally, the lowest average TDS was observed in the forest area (42.37) followed by SMT (106.235) and paddy fields (122.113) in the post-monsoon season. The higher concentrations of TDS in the urban area results in higher conductivity and density, lower dissolved oxygen and ultimately declining water quality.

3.1.5 Dissolved Oxygen (DO)

DO is a measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms [9]. The dissolved oxygen levels were notably high in the forest area and it reduced in the urban land use. The highest three season average of 8.51 mg/l (Fig. 6) was recorded in the forest area and the lowest in urban land use (7.51 mg/l). Among the seasons, the highest mean ‘DO’ was observed in pre-monsoon season in forests (8.60 mg/l) and the lowest in monsoon season in the urban environment (7.454 mg/l). ‘DO’ concentrations were significantly depleted in all the land uses except SMT in the monsoon period. In SMT, the reduced ‘DO’ was recorded in the post-monsoon season. A lower ‘DO’ average is a result of eutrophication and it represents declining water quality. In these conditions, the aquatic organisms cannot thrive in water. The depletion of DO levels in the waters of the urban area is due to the inorganic waste and the associated microbial activity.

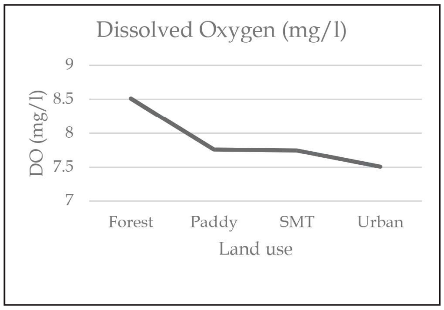

Fig. 6: Dissolved Oxygen

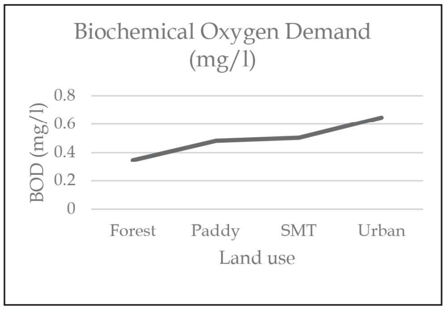

Fig. 7: Biochemical Oxygen Demand

3.1.6 Biochemical Oxygen Demand (BOD)

'BOD' is the amount of oxygen required to decompose organic matter in one litre of polluted water [10]. The BOD will be more if the water is polluted and more oxygen will be required to decompose it. The three season average BOD has greatly fluctuated in the study area. It varied from 0.347 mg/l in forest to 0.646 mg/l in urban environment (Fig.7). Seasonal variations indicated high values for all the land uses in the post-monsoon season. Both paddy (0.333 mg/l) and forest (0.15 mg/l) recorded their lowest averages in the pre-monsoon season whereas urban (0.396) and SMT (0.218 mg/l) in the monsoon season. The higher average BOD values in the urban and SMT land use indicate depleting water quality in such land uses.

3.1.7 Calcium

The distribution of Calcium has highly fluctuated. The highest concentration (27.13 %) of calcium is the urban area. The lowest concentration was recorded in the paddy (12.47%) and SMT (16.12%) areas (Fig. 8). Seasonally, all the land uses recorded the highest Ca concentration in the pre-monsoon period. The lowest concentration was observed in monsoon season for the forest, SMT and urban land uses whereas it was in post-monsoon season for paddy. In the urban areas, the increased Ca content was provided by construction materials and wastewater treatment plants. This increased amount of 'Ca' in the urban environment would increase water hardness thereby affecting severely the water quality.

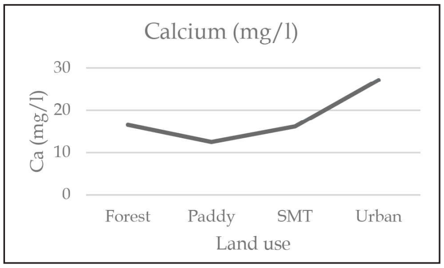

Fig. 8: Calcium

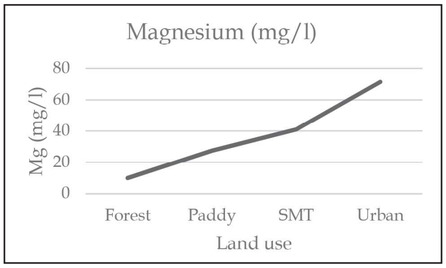

Fig. 9: Magnesium

3.1.8 Magnesium

Like all other parameters, the concentration of Mg was also significantly varied in different land uses. It was evident that the highest concentration of Mg had observed in the urban area (71.55 mg/l) and the lowest in the forests (9.93mg/l). Paddy and SMT areas had Mg concentrations of 27.468mg/l and 40.97mg/l respectively (Fig. 9). It is, thus, clear that Mg content has increased by 620.54%, 312.59% and 176.62% respectively in the urban area, SMT and paddy fields as compared to forest mean Mg stocks. In urban land use, this higher proportion of Mg was caused by fertilizers, industry and wastewater treatment plants. This higher concentration of Mg can increase water hardness thereby affect water quality [11].

3.1.9 Chloride Values

The high amount of chloride indicates a higher degree of organic pollution [12]. Thus, chloride is an essential element of water quality. High chloride concentrations in freshwater can harm aquatic organisms. It interferes with the biological process. There were great fluctuations in available chloride in the Pampa River. The three season average ranged from 1532.53mg/l in the urban environment to only 27.66mg/l in forests (Fig. 10). Seasonally, the highest average was recorded in the pre-monsoon season in the urban area (4494.627mg/l). The highest chloride averages in the pre-monsoon season in all the land uses and the lowest in post-monsoon. The analysis showed that chloride values had reportedly increased by 5440.60%, 4099.70% and 1958.86% in the urban, SMT and paddy land uses compared to forest average chloride value.

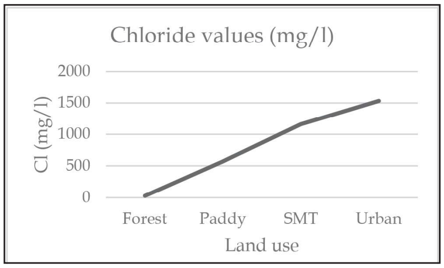

Fig. 10: Chloride

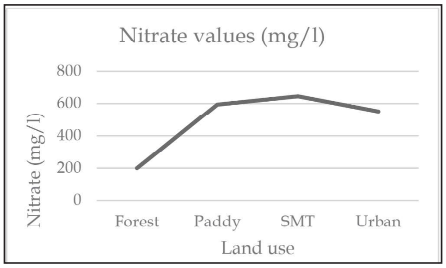

Fig. 11: Nitrate

3.1.10 Nitrate Values

Nitrates in excess can cause eutrophication in waters by stimulating excessive growth of algae and other aquatic plants and indirectly causing oxygen deficiency in the bottom waters and reduced biodiversity [13]. Nitrate values in the river water ranged from 199.25 mg/l in the forest area to 645.43 mg/l in the SMT (Fig. 11). Seasonally it fluctuated from 1345.06 mg/l in post-monsoon season in SMT to 38.97 mg/l in pre-monsoon season in the forest. The highest nitrate concentrations were noticed in the post-monsoon period in all the land uses and the lowest in the pre-monsoon season. The sources of these excess nitrates are agricultural activities (nitrogen fertilizers), human wastes or industrial pollution. In the forest area, it occurred naturally from the organic matter that contains nitrogen compounds.

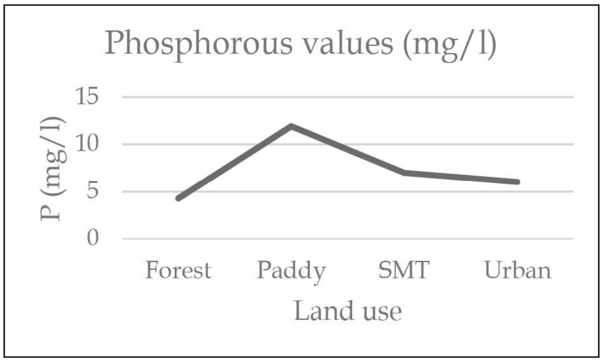

Fig. 12: Phosphorous

3.1.11 Phosphorous Values

In all the land uses the phosphorous content in the river water was high in the monsoon season. For all the land uses except forest, the phosphorous concentration was low in the pre-monsoon season whereas it was in post-monsoon season for the forest. The average 'P' content of the three seasons varied from 11.91 mg/l in paddy areas to 4.29 mg/l in the forest (Fig. 12). Forest and SMT also had comparatively high averages of 6.027 mg/l and 6.985 mg/l respectively. The major sources of phosphorous in the paddy and SMT areas were the chemical fertilizers. These fertilizers reach the stream along with the surface runoff. Its sources in the urban area include sewage treatment plants, toothpaste, detergents and food treating compounds [14]. These phosphorous when entered in streams cause eutrophication by depleting 'DO' levels.

3.2 Water Micro Biological Parameters

3.2.1 Total Viable Count

The term 'total viable count' is used to indicate the microbial community and refers to the different types and number of bacteria in a given sample [15]. The mean total viable count of the three seasons ranged from 3691.08 CFU/ml in forests to 489418.34 CFU/ml in paddy area (Fig. 13). The urban environment also had a higher average total bacteria count of 394729.64 CFU/ml. During the pre-monsoon and post-monsoon periods all the stations had a total bacterial count that exceeded the WHO limit of 1.0 x 10^2 CFU/ml. This is the standard acceptable limit of total bacterial counts for drinking water. In the post-monsoon period, forest area and three SMT stations had bacterial counts less than the WHO limit (Table 1). These total bacterial counts reflected the high organic matter content in the river water. The bacteria present in the water depend on various human, agricultural and industrial activities [16]. River water receives surface runoff from agricultural areas, animal wastes and effluent runoff discharges in populated areas which will ultimately cause bacterial contamination.

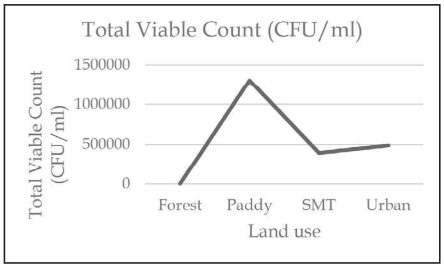

Fig. 13: Total Viable Count

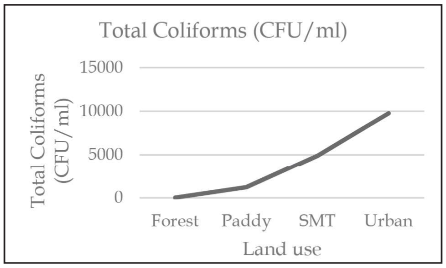

Fig. 14: Total Coliforms

3.2.2 Total Coliforms

Coliform bacteria find their way into rivers from human-animal waste, from leaching animal manure, improperly treated septic and sewage discharge, storm water runoff, and from domestic animals [17]. The three season average total coliforms showed the highest concentration in the urban environment is 9765 CFU/ml followed by SMT 4899 CFU/ml (Fig.14). The lowest concentration was found in the forest where the recorded value was 31 CFU/ml. All the land uses except forest reported the lowest concentrations of coliforms in the post-monsoon period. Forest areas recorded no coliforms in the pre-monsoon station. The WHO standard limit for the total coliform count is 3 coliforms/100 ml of water. 7 stations in the pre-monsoon season (two in paddy, four in SMT and one in the forest), five stations in the monsoon period (one in paddy, and four in SMT) and three stations in post-monsoon period (one in paddy and two in the urban environment) recorded no coliforms. In all other stations in the three seasons, the total coliforms exceeded the WHO limit.

3.2.3 Escherichia Coli (E Coli.)

E. Coli is a type of faecal coliform bacteria that is commonly found in the intestines of animals and humans [18, 19]. The average E.Coli. content of the three seasons ranged from ‘0’ in forests to 124 CFU/ml in SMT (Fig. 15). No stations in the four land use types recorded E. Coli. in the post-monsoon period. All the land uses except forest (where no E.Coli. was detected in the three seasons) was experienced their highest E. Coli. growth in the pre-monsoon period. These E. Coli. find their way into the river from faecal material from pets, livestock and wildlife as well as leaky septic tanks. These E. Coli. when reaching the human body can cause severe health problems.

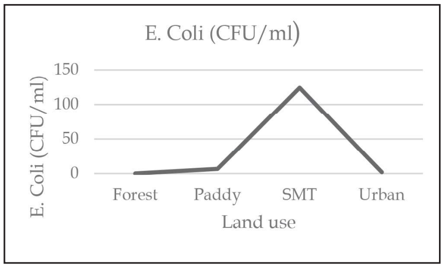

Fig. 15: Escherichia Coli

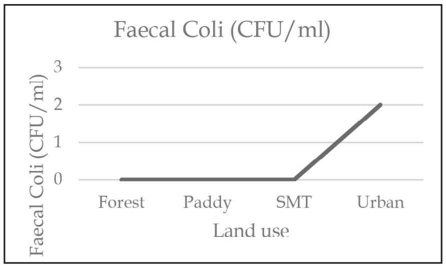

Fig. 16: Faecal Coli

3.2.4 Faecal Coli

Faecal coliform is a type of coliform bacteria. Faecal coliform reaches the river as a result of the overflow of domestic sewage or non-point sources of human and animal waste. [20]. The concentration of faecal coliform was very low in the river (Fig. 16). The three land uses, namely, forest, paddy, and SMT had no faecal coliform in all the three seasons. Only the urban area had recorded faecal coliform content in the pre-monsoon season [21]. In the post-monsoon and monsoon seasons, the urban area also had no faecal coliform. Even in urban land use, only one site had experienced faecal contamination (30 CFU/ml). The presence of faecal coliform in the urban land use indicates that the water has been contaminated with the faecal material of man or other animals [22].

3.3 Water Pollution Index (WPI)

Water pollution index (WPI) provides the overall quality of river water in different land uses. The WPI of the river varied from 0.270 in the forest to 12.440 in SMT areas (Table 4)

Table 4: Water Pollution Index for different parameters in different land uses in River Pampa

Parameter	Land use			
	Forest	Paddy	SMT	Urban
pH	0.071	0.064	0.063	0.063
EC	0.077	0.577	0.997	1.316
TDS	0.018	0.225	0.388	0.514
BOD	0.006	0.008	0.008	0.011
TH	0.041	0.082	0.130	0.111
Ca	0.018	0.014	0.018	0.030
Mg	0.028	0.076	0.114	0.199
Cl	0.009	0.190	0.387	0.511
Nitrate	0.001	0.001	0.001	0.001
P	0.001	0.001	0.001	0.001
E. Coli	0	0.556	10.333	0.167
Faecal Coli	0	0	0	0.167
WPI	0.270	1.795	12.440	3.091
Status	**Very pure**	**Moderately Polluted**	**Heavily impure**	**Polluted**

Source: Compiled by the Researcher

The water quality status of the river in the forest is very pure (0.270), moderately polluted in paddy lands (1.795), polluted in urban environments (3.091) and heavily impure in SMT area (12.440). This change in the status of water quality is related to land use change. In Kuttanad, the main type of land use change is from paddy fields to SMT and urban areas. When paddy fields were converted into urban and SMT, the water quality status also got transformed from moderately polluted to polluted and heavily impure [23].

By employing the water pollutants index the main pollutants causing water quality deterioration can be identified. There were differences in main water pollutants in different land uses [24]. The main contributory factors in water pollution were Electrical conductivity and E. Coli in paddy fields and SMT while it was Electrical conductivity and TDS in the urban environment (Table 5)

Table 5: Water Pollutants Index for different land uses in River Pampa in Kuttanad Region

Parameter	Land Use							
	Forest	%	Paddy	%	SMT	%	Urban	%
pH	0.263	26.3	0.036	3.6	0.005	0.5	0.020	2.0
EC	0.287	28.7	0.321	32.1	0.080	8.0	0.426	42.6
TDS	0.066	6.6	0.125	12.5	0.031	3.1	0.166	16.6
BOD	0.021	2.1	0.004	0.4	0.001	0.1	0.003	3.0
TH	0.154	15.4	0.046	4.6	0.010	1.0	0.036	3.6
Ca	0.068	6.8	0.008	0.8	0.001	0.1	0.010	1.0
Mg	0.102	10.2	0.042	4.2	0.009	0.9	0.064	6.4
Cl	0.034	3.4	0.106	10.6	0.031	3.1	0.165	16.5
Nitrate	0.002	0.2	0.002	0.2	0.001	0.1	0.001	0.1
P	0.003	0.3	0.001	0.1	0.001	0.1	0.001	0.1
E. Coli	0	0	0.309	30.9	0.830	83.0	0.054	5.4
F Coli	0	0	0	0	0	0	0.054	5.4
Total	1.0	100	1.0	100	1.0	100	1.0	100

Source: Compiled by the Researcher

Electrical conductivity itself is not a polluter [25, 26]. Since Electrical conductivity is a function of TDS and inorganic salts it can be considered as a type of water pollution. The higher EC in paddy and urban land uses were due to their higher concentrations of TDS and chloride values. Thus, EC is a major factor in water pollution in paddy and urban land uses. The second dominant polluting substance in paddy was E.Coli while it was TDS in the urban environment. In SMT, E.Coli is the most significant water-polluting element followed by EC. SMT areas also had a significant amount of TDS and chloride concentrations thus had higher EC value.

Conclusion

The land use change has deteriorated the water quality in the Kuttanad region. Land use change has also affected the surface water physico-chemical parameters. Water quality parameters such as EC, TDS, BOD, TH, Ca, Mg, Cl, Total Coliform, and Fecal Coliform were found to be high in the urban environment. On the other hand water pH and 'DO' were high in the forest area and nitrate values and E.Coli were maximum in the SMT land use. The water pollution index (WPI) showed that the river water was very pure in the forest area, moderately polluted in the paddy fields, polluted in the urban environment and heavily polluted in the SMT land use. The water pollutants index identified the chief factors in water pollution in different land uses which is as follows:

Paddy fields - EC and E. Coli

SMT - E. Coli and EC

Urban environment - EC and TDS

Conflict of interest

The authors would like to declare no competing financial interest for the present manuscript.

Funding information

No funds received from any institution or from the Government

Acknowledgements

The authors would like to thank and express their deep sense of gratitude and thankfulness to their supervisor Dr K. Mani, Principal (Retd), University College, Thiruvananthapuram for his guidance, encouragement, and constructive criticism. We further acknowledge our indebtedness to Dr Anoop Krishnan, Scientist, Central Chemical Laboratory, Hydrological Process Group, National Centre for Earth

Science Studies, Akkulam, Thiruvananthapuram for testing water samples at the institution.

Author Contribution Statement:

Dr. Higgins Robert has collected water samples from Pampa river basin and were tested in Central Chemical Laboratory (Hydrological process group) of National Centre for Earth Science and Studies (NCESS), Thiruvananthapuram during the present study. He has also written parts of the manuscript related to Impact of land use change on the water quality of Kuttanad region, Kerala. He has also made the final composition and acted as corresponding author.

Dr. Dhanush D M has collected water samples and has also written parts of the manuscript related to Impact of land use change on the water quality of Kuttanad region, Kerala.

References

[1] Jennerjahn T C, Soman K, Ittekkot V, Nordhaus I, Sooraj S, Priya R S, Lahajnar N, "Effect ofland use on the biogeochemistry of dissolved nutrients and suspended and sedimentary organic matter in the tropical Kallada river and Ashtamudi estuary, Kerala, India," *Biogeochemistry* vol. 90, pp. 29-47, 2008

[2] Ravikumar N, Ilavarasan N, "Assessment of water quality related to land use/land cover pattern change in Yercaud, Salem," International Journal of Chem Tech Research Vol. 10(14), pp. 17-21, 2017

[3] Kumar P, Dasgupta R, Johnson B A, Saraswat C, Basu M, Kefi M, Mishra B K, "Effect of land use changes on water quality in an Ephemeral coastal plain: Khambat city, Gujarat, India," Water, vol. 11(724), pp. 1-15, 2019

[4] Rowcroft P, "Frontiers of change: The Reasons behind Land use change in the Mekong Basin," *Ambio*, vol. 37(3), pp. 213-218, 2008

[5] Qin H, Su Q, Khu *S* T, Tang N V, "Water quality changes during rapid urbanization in the Shenzhen River Catchment: An integrated view ofsocio-economic and infrastructural development," *Sustainability* vol. 6, pp. 7433-7451, 2014

[6] Venkateswarlu, G,JayasankarG, Saradhi B V, “Impact assessment of land use change on ground water quality using Remote Sensing & GIS for Zone V under Municipal Corporation, Hyderabad,” *IOSR Journal of Mechanical and Civil Engineering*, vol. 11(1), pp. 36-42, 2014

[7] An S J, FuW C, TiXieD, “An insight on drivers of Land use change at Regional Scale,” *Chinese geographical science*, vol. 16(2), pp. 176-182, 2006

[8] Huang J, Zhan J, Yan H, Wu F, Deng X, 2013, “Evaluation of the impacts of land use on water quality: A case study in the Chaohu Lake basin,” Hindawi Publishing Corporation, The Scientific World Journal, Article ID 329187, 7 pages http://dx.doi.org/10.1155/2013/329187

[9] Likai Z,JijunM, Xiyan M, “Analysing land use change in farming pastoral transitional regionusing auto-logistic model and household survey approach,” *Chin. Geogra. Sci*. vol. 23(6), pp. 716-728, 2013

[10] Calijuri M L, Castro J de S, Costa L S, Assemany P P, Alves J E M, “Impact of land use land cover changes on water quality and hydrological behaviour of an agricultural subwatershed,” *Environ Earth Sci*, vol. 74, pp. 5373-5382, 2015

[11] Lambin E F, Turner II B L, Geist H J, Agbola S B, Angelsen A, Bruce J W, Coomes O T, Dirzo R, Fischer G,Folke C, George P S, Homewood K, Imbernon J, Leemans R, Li X, Moran E F, Mortimore M, Ramakrishnan P S, Richards J F, Skanes H, Steffen W, Stone G D, Svedin U, Veldkamb T A, Vogel C, Xu J, “The causes of land use and land cover change: moving beyond myths,” *Global Environmental Change*, vol. 11, pp. 261-269, 2001

[12] Soni S, Garg P K, Singh A, Maurya A K, “Assessment of land use land cover change in Chakrar watershed using geospatial technique,” *Tropical Plant Research*, vol. 2(2), pp. 101-107, 2015

[13] Ding J, Jiang Y, Fu L, Liu Q, Peng Q, Kang M, “Impacts of land use on surface water quality in a subtropical river basin: A case study of the Dongjiang river basin, Southeastern China,” *Water*, vol. 7, pp. 4427, 4445, 2015

[14] Baker A, “Land use and water quality,” *Encyclopaedia ofhydrological sciences*, Edited by Anderson M, John Wiley and Sons Ltd, 2005

[15] Joseph P V, Jacob C, "Physicochemical characteristics of Pennar river, A Freshwater wetland in Kerala, India. *Coden Ecjhao, E Journal of chemistry*, vol. 7(4), pp. 1266-1273, 2010

[16] Raju K, Anil K R, " Land use changes in Udumbancholataluk, Idukki district - Kerala: An analysis withthe application of remote sensing data," *Journal of the Indian Society of Remote Sensing,* vol. 34(161), page number not available, 2006

[17] Sinta K B, Sreekumar S, Diljo J T, Harilal C C, " Land degradation and water quality assessment of a part of Thrissur Kole wetland, Kerala, India – Ramsar site," *International Journal of Interdisciplinary Research and Innovations*, vol. 7(1), pp. 250-257, 2019

[18] Dipanwita De,Banerjee S, Ghosh S, "Asssessmentof land use and land cover changes in PanchrakhiVillage, Hugli district, West Bengal, India," *IOSR Journal of Humanities and Social Science (IOSR-JHSS),* vol. 19(7), pp. 120-126, 2014

[19] Kumar B M, "Land use in Kerala: Changing scenarios and shifting paradigms,"*Journal of Tropical Agriculture*, vol. 42 (1-2), pp. 1-12, 2005

[20] Rehman A, Mobeen M, Bashir S, Ranf M, Ullaha F, Aziz T, Abbas T, Riaz O, "Impact of land use change on water quality of Jhang district, Punjab, Pakistan. *Journal of Biodiversity and Environmental Sciences (JBES)*, vol. 13(6), pp. 174-182, 2018

[21] Kumar V, Dr Mohan K, "Land use-land cover change in Baddi Industrial town, Himachal Pradesh," *IJRAR InternationalJournal of Research and Analytical Reviews*, vol. 6(2), pp. 985-995, 2019

[22] Changhong S, Bojie F, Yihe L, Nan L, Yuan Z, Anna H, Lamparski H, "Land Use change and Anthropogenic driving forces: A case study in Yanhe river basin, " *Chin. Geogra. Sci.,* vol. 21 (5), pp. 587-599, 2011

[23] Duraisamy V, BendapudiR, Jadhav A, "Hotspots in land use land cover change and the drivers in a semi-arid region of India," *Cross mark, Environ Monit Assess*, vol. 19 (535), pp. 1-21, 2018

[24] Chauhan A,VermaS C, "Impact of land uses and seasons on Physico-chemical characteristics of surface water in Solan district of Himachal Pradesh," *Nature, Environment and Pollution Technology,* vol. 15(2), pp. 667-672, 2016

[25] Singh S K, Kumar V, Kanga S, "Land use Land cover change dynamics and river water quality assessment using geo-spatial technique: A case study of Harmu river, Ranchi, India," *International Journal of Scientific Research in Computer Science and Engineering,* vol. 5(3), pp. 17-24, 2017

[26] Roopa V and Vijayan N, "Detection of land use land cover changes in the wetlands of Kuttanad, Kerala," *International Journal of InnovativeResearch inScience, Engineering and Technology*, vol. 6(6), pp. 10488-10491, 2017