GEO-EYE

RESEARCH ARTICLE

Land use effect on water quality in a tropical river basin of Kerala, India

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OPEN ACCESS

Received: 11.03.2019

Accepted: 27.04.2019

Published: 15.05.2019

Citation: Aneesh MR, Mani K, Prasad TK, Robert H. (2019). Land use effect on water quality in a tropical river basin of Kerala, India. Geo-Eye. 8(1): 28-36. https://doi.org/10.53989/bu.ge.v8i1.8

Funding: Department of Science and Technology (DST), Government of India for its financial support

Competing Interests: None

Published By Bangalore University, Bengaluru, Karnataka

ISSN
Print: 2347-4246
Electronic: XXXX-XXXX

Abstract

Water quality deterioration caused by land use changes has become a primary factor limiting the sustainable utilization of water resources. Rapid urbanization led to extensive land use changes which have a profound impact on surface water quality. This study is aimed to investigate the effect of land use on the water quality on a tropical river in Kerala, India. Water quality data for 20 stations were collected from Centre for Water Resources Development and Management (CWRDM), Kozhikode for 12 physicochemical parameters pertaining to three seasons namely pre-monsoon, monsoon and post-monsoon. All the stations were then field verified to identify the land use units to which it belongs to. The grouped data was then incorporated into three indices namely Water Quality Index (WQI), Water Pollution Index (WPI), and Water Pollutants Index to identify the effect of land uses on water quality and water pollution. Results indicated that urbanization has caused severe water quality deterioration compared to forests and settlement with mixed trees (SMT).

Keywords: Urbanization; Kerala; WQI; WPI 1

Introduction

Human actions are modifying the environment at an unprecedented rates, magnitudes and spatial scales. Among them land use is the most powerful force affecting the processes and functions of ecosystems. The changes in land use provide many social and economic benefits, but they also affect the natural environment adversely. Different land uses have strong impacts on surface water quality (Chattopadhyay et al., 2005; Zamani et al., 2013; Schreiber et al., 2015). It has been well documented that there is a positive relationship between watershed land use practices and soil erosion (Haidary et al., 2013), that is, the loss of forest cover is associated with increased soil erosion and decreased water quality. Anthropogenic disturbances in the form of land use change can pollute surface water since different water physico-chemical parameters react differently to different land uses (Wang et al., 2013). In the earlier days the effect of agriculture on river water quality was more stressed as it had a strong impact on total nitrogen, electrical conductivity (EC), pH, and turbidity (Ribeiro et al., 2014). At present most of the studies are concerned with analyzing the effect of urbanization on the hydrological system (Chattopadhyay et al., 2005; Ding et al., 2015; Schreiber et al., 2015; Revitt et al., 2016) as it has a profound impact on the water quality (Ding et al., 2015). Urbanization also resulted in serious microbial surface water pollution due to effluent from sewage plants or combined sewer overflows (Schreiber et al., 2015). Recently studies were also conducted to evaluate the pollution problems in urban areas arising from misconnections from toilets, kitchen sinks, washing machines and dish washers (Revitt et al., 2016). A number of studies incorporated water quality indices for evaluating the general water quality of a river (Yogendra et al., 2007; Yisa et al., 2010; Khwakakaram et al., 2012; Behmanesh et al., 2013; Al Saleh, 2014). Most of these studies did not attempted to apply water quality indices among land uses to identify the condition of stream water in a particular land use. Besides water quality index, water pollution indices were also widely applied to formulate sustainable development plans for restoring water quality (Miljasevic et al., 2011; Qin et al., 2014).

Karamana River is a river flowing through the Thiruvananthapuram district in the southern part of the state of Kerala. This river is one of the severely polluted rivers of the state. The present study is an attempt to evaluate the impact of land use, particularly urbanization, on the water quality of Karamana River by incorporating water quality and water pollution indices in three different land uses. The study identified that the worst water quality is associated with urban areas whereas the forest and settlement with mixed trees (SMT) have more or less good water qualities. Both water quality and water pollution indices show unfavourable water condition in the urban environment.

Methods and Methodology

Study Area

The area selected for the present study is the Karamana River. The Karamana drainage basin is located between latitudes $8^0 21'$ N to $8^0 42'$ N and in longitudes $76^0 52'$ E to $77^0 15'$ E. The river is originated from Chemmunji Mottai in Western Ghats at an attitude of 1717 m above mean sea level in the Nedumangad Taluk of Thiruvananthapuram district and flows into the Lakshadweep Sea near Pachalloor to complete a journey of 68 kilometers. This river is formed by the confluence of several small streams like Kavi Ar, Attai Ar, Vaiyapadi Ar and Todai Ar. Karamana River is the second largest river of the district and has a catchment area of 702 square kilometers. It is a 6^{th} order stream which ranks 20^{th} in length among the rivers of the state. The basinal boundary of the river coincides with the revenue boundary between Thiruvananthapuram district of Kerala and the Tirunelveli district of Tamil Nadu. The catchment area of the river experiences a tropical monsoon climate with high temperature and heavy rainfall during the months of June, July, August and September. The river passes through the outskirts of Thiruvananthapuram city, the capital of Kerala.

Methodology

Water quality data was obtained from the Centre for Water Resources Development and Management (CWRDM), Kozhikode for 20 stations pertaining to three seasons namely pre-monsoon, monsoon and post-monsoon. All the 20 stations were then field verified to identify the land use units to which it belongs to. Water physico-chemical parameters like temperature, electrical conductivity (EC), total hardness (TH), pH, dissolved oxygen (DO), nitrate values, phosphorous values, chloride values, Total Dissolved Sediments (TDS), calcium, magnesium, and sulphate values were examined to identify the effect of land use on water quality. The grouped data was then incorporated into a water quality index. Water quality index (WQI) was calculated by using the Weighted Arithmetic Index Method of Brown (Yogendra et al, 2007). For assessing the quality of water, the quality rating scale (QI) for each parameter was calculated by using the following equation;

QI = 100 [(Vactual-Videal) / (Vstandard-Videal)]

That is = 100[(Va-Vi) / (Vs-Vi)]

Where,

QI = Quality rating of the i^{th} parameter

Vactual (Va) = Actual value of the water quality parameter obtained

from laboratory analysis for a site

Videal (Vi) = Ideal value of the water quality parameter

(All the ideal values are taken as zero (0); except for pH=7, and DO=14.6 mg/l)

Vstandard (Vs) = Recommended ICMR/BIS standard for the parameter.

Secondly the Relative unit Weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter and can be expressed as

Wi = 1/Si

Where,

Wi = Relative (unit) weight for i^{th} parameter.

Si = Standard permissible value for each parameter

1 = Proportionality constant.

Finally, the overall WQI was calculated by aggregating the quality rating (Qi) with the Relative Unit Weight (Wi) linearly by using;

WQI = $\sum$QiWi/ $\sum$Wi

Where;

Qi = Quality rating

Wi = Relative Weight

Then the water quality can be achieved by comparing the obtained value with the theoretical value as given in table 1 (Chaterjee et al.„ 2002)

In order to assess the comprehensive character of the quality of river water a Water Pollution Index (WPI) is also

Table 1. Water Quality Index (WQI) and status of water quality

Water Quality Index Level	Water Quality Status
0-25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Unsuitable for drinking

Source : Chaterjee et al., 2002

incorporated in the present study. The WPI can be calculated by the following equation (Miljasevic et al., 2011; Qin et al., 2014):

$$WPI = 1/n \sum C_i/S_i$$

Where;

n = Number of water quality parameters

C_i = Average measured concentration of the i^{th} parameter in mg/l

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

Accordingly the water quality can be classified into six categories as provided in table 2

Table 2. Water Pollution 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

Finally the contribution of each polluting substance to the WPI was calculated by employing a water pollutants index as follows (Qin et al., 2014);

$$Ki = \frac{Ci/Si}{\sum Ci/Si}$$

Where;

Ki = Contribution of each substance to the summed pollution index

Ci = Average measured concentration of the ith parameter

Si = Maximum permissible limit (standard value) for the ith parameter

Results and Discussion

A. Land use effect on Surface water physicochemical properties

Analysis of surface water samples indicated that river water was mildly acidic with pH value varied from 6.2 in SMT to 6.5 in urban land uses (table 3). During monsoon season, the pH value ranged from 4.39 to 7.11 respectively in SMT and urban areas. It is during this season the pH value of a number of stations went down to 6 and all of them were under forest and SMT land uses. Post monsoon averages ranged from 6.05 in urban to 6.88 in SMT. Urban area recorded the highest average pH in all the seasons except in post monsoon. The highest average pH during the pre-monsoon months was due to decreased volume of water by evaporation. The higher pH of urban and downstream areas can be attributed to the overflow from septic tanks, sewage and domestic waste discharges.

Total Hardness (TH) of water depends on dissolved calcium and magnesium salts. Mean values of all the three seasons showed that TH was high in urban land uses and low in forest. The average TH ranged from 12mg/l in forest to 254.27 mg/l in urban (table 3). Seasonally it varied from 8 mg/l during post monsoon season in forests to 588.8 mg/l during monsoon in urban environment. The higher values in urban land uses show that urbanization has a significant effect on water quality.

The concentration of Dissolved Oxygen (DO) regulates the distribution of flora and fauna (Yogendra, et al., 2008). DO values were significantly higher in forest and SMT and it reduced considerably in urban area. The average DO values for forest, SMT and urban areas were 8.13 mg/l, 7.84 mg/l, and 4.69 mg/l respectively. However there were significant seasonal variations. 'DO' concentrations were depleted significantly in the monsoon season in all the land uses compared to other seasons. These differences are due to temperature and biological activities. The urban and SMT land uses recorded their higher DO averages (5.98 mg/l and 8.14 mg/l respectively) during the post monsoon season whereas forest (8.67 mg/l) in the pre-monsoon period. The main reason for the depletion of DO levels in the urban environment were due to the presence of organic wastes and associated microbial activity.

The nitrate values in the river water fluctuated from <0.2 to 6.50. The mean maximum value of 2.05 mg/l was recorded in the urban environment whereas the lowest (1.17 mg/1) in SMT. Seasonal variations indicated high values for urban and SMT in pre-monsoon season and for forest in monsoon season. The low averages during monsoon seasons were due to the dilution by rain water. The higher nitrate concentration in the urban areas were caused by inadequate sanitation, leaking septic tanks, manure from farm livestock, animal wastes, urban waste water, and discharges from car exhausts. Thus the low dissolved oxygen and high nitrate concentrations indicate the eutrophic status of river.

Phosphorous values were high in all the land uses during the post monsoon season. The highest average phosphorous was recorded in urban environment (9.416 mg/l) followed by SMT (3.835 mg/l) and forests (3.387 mg/l). No phosphorous content was detected during the pre-monsoon period in forest

Table 3. Land use wise mean water quality parameters in three different seasons

Parameter	Forest			SMT			Urban		
	Po-Mon	Pr-Mon	Mon	Po-Mon	Pr-Mon	Mon	Po-Mon	Pr-Mon	Mon
pH	6.78	6.64	5.97	6.41	6.40	5.80	6.30	6.69	6.51
TH	8.0	16.0	12.0	8.88	18.66	19.11	38.80	135.20	588.80
DO	8.53	8.67	7.20	8.14	7.89	7.49	5.99	4.57	3.51
NO3-N	<0.2	1.43	2.08	0.937	1.445	1.138	0.549	3.016	2.581
PO4-P	10.0	ND	0.16	11.33	ND	0.175	28.0	0.008	0.241
Temperature	28.60	32.10	26.60	27.17	30.73	27.43	28.13	31.93	27.07
Chloride	8.0	8.0	16.0	12.44	18.66	15.55	56.40	336.80	1879.60
TDS	14.34	15.37	17.75	21.18	41.40	35.12	160.81	1061.32	2769.48
EC	22.40	23.90	27.60	33.10	64.39	54.62	251.26	1650.57	4307.12
Calcium	1.60	3.20	1.60	1.95	4.27	4.27	7.84	17.76	64.64
Magnesium	0.97	1.94	1.94	0.97	1.94	2.05	4.66	22.06	103.71
Sulphate	2.96	2.24	1.20	3.071	4.448	3.453	7.044	48.256	177.712

Po - Mon – Post Monsoon, Pr - Mon – Pre Monsoon, Mon - Monsoon, ND - Not Detected

and SMT and it was very low for the urban area at the same season. Also important was the notably minor concentration of phosphorous during the monsoon months in all the three land uses. The major sources of phosphorous in the waters of urban environment are sewage treatment plants, industrial products such as toothpastes, detergents, pharmaceuticals, and food treating compounds. A higher level of phosphate in water is considered as pollution as it initiates eutrophication and thereby decreases DO levels.

Temperature is one of the most important water quality parameters affecting flora and fauna. It affects water chemistry and functioning of aquatic organisms. There were very slight differences in water temperature among different land uses. But seasonally, there were variations within land uses. The highest average temperature was recorded in the forest environment (29.1^0C) followed by urban (29.04^0C) and SMT (28.44^0C) areas. All the three land uses recorded their mean maximums during the pre-monsoons summer months.

Chloride is one of the most important parameters in assessing water quality as higher concentrations of chloride indicate higher degree of organic pollution (Yogendra et al., 2008). Chloride values were typically higher in urban land uses in all the three seasons and lower in forest areas. The average chloride concentrations in urban, SMT and forest areas were 757.6 mg/l, 15.55 mg/l and 10.67 mg/l respectively. This means that chloride values have reportedly increased by 7000.28%, and 45.74% in urban and SMT respectively compared to forests. Urban areas which recorded high chloride values during the monsoon period are due to heavy surface run off and its associated erosion and carrying of domestic and industrial sewage and effluents along with the run-off from adjoining agricultural fields.

TDS concentrations were high in urban sites in all the three seasons. The average TDS concentration of the urban land use was 1330.54 mg/l followed by SMT (32.57 mg/l) and forest (15.82 mg/l). In the urban environment TDS concentrations were low during the post monsoon period (160.81 mg/l) and high in the monsoon (2769.49 mg/l). Higher surface run off associated with the heavy monsoon rains carry more solids from the adjoining areas which resulted in more TDS concentrations during monsoon season in the urban environments. The higher TDS in the urban areas could also be due to the addition of ions into water bodies from industries, workshops and households. These concentrations of TDS result in higher conductivity and density, lower DO and ultimately declining water quality.

Electrical conductivity (EC) of water is directly related to dissolved inorganic salts and solids. There were significant fluctuations in EC among land uses in different seasons. The average EC was high in urban area (2069.65 micro Siemens/cm) followed by SMT (50.70 micro Siemens/cm) and forest 24.63 (micro Siemens/cm) environments. Urban and forest areas recorded highest EC averages during the monsoon season while SMT areas during the pre-monsoon. Urban areas had very high average Chloride and TDS values during the monsoon period that is why it had higher EC value during the same season. This means that the river water is severely polluted in the urban environment since the higher EC value refers to higher chloride and TDS values and both of which are important parameters of water quality.

There were notable fluctuations in the concentration of calcium both among land uses and in seasons. Among land uses, urban environment had the highest concentration of calcium followed by SMT and forests. Seasonally, monsoon season recorded highest amounts of calcium in urban and SMT whereas it was in pre-monsoon for forests. The calcium content was increased by 1312.2% and 64.3% respectively in urban and SMT compared to forests. Construction materials such as cement, brick lined and concrete, industries and waste water treatment plants provide most of the calcium contents in urban areas. This increased calcium concentration tend to increase the hardness of water thereby affecting severely the water quality.

Higher Magnesium (Mg) contents are recorded in urban area in all the three seasons. All the three land uses had their highest Mg concentrations during the Monsoon season and the lowest during the post monsoon. Limestone rocks, fertilizers, industry, and waste water treatment plants are the major sources of Mg in urban area. It is an important element of water quality as higher concentrations of Mg can negatively influence water hardness.

Sulphate concentrations were very higher in the urban environment in all the three seasons as compared to other land uses. The mean sulphate values were 77.670 mg/l, 3.657 mg/l and 2.130 mg/l respectively in urban, SMT and forest areas. This means that sulphate values were increased by 3546.478% and 71.69% respectively in urban and SMT areas compared to forest averages. Seasonally, higher sulphate concentrations in the urban environment were recorded in the monsoon period which is related to the higher surface runoff from the adjacent urban and industrial areas. These higher concentrations of sulphate along with chlorides indicate the unsuitability of water for domestic use.

B. Water Quality Index

A general Water Quality Index as well as for the three land uses were calculated to identify the influence of particular land uses on the quality of surface water. The results of WQI are provided in the tables 4 to 7.

$$WQI = \sum WiQi/\sum Qi$$
$$= 24.463/0.4046$$
$$= 60.462$$

Land use wise WQI for Karamana River

An analysis of WQI for different land uses yielded an entirely different result.

$$WQI = \sum QiWi/\sum Wi$$
$$= 18.074/0.4046$$
$$= 44.671$$
$$WQI = \sum WiQi/\sum Wi$$
$$= 20.891/0.4046$$
$$= 51.6337$$
$$WQI = \sum QiWi/\sum Wi$$
$$= 34.589/0.4046$$
$$= 85.489$$

Water quality index for the study was established from different physiochemical parameters as an average of three seasons in different land uses. The water quality index obtained for the river in different land uses ie; Forest, SMT and Urban were 44.67, 51.63, and 85.49 respectively. On the other hand the general water quality index was 60.46. Among these forest and SMT indicate good and poor water quality respectively whereas the urban environment displays very poor water quality. But the general water quality of the river falls in between the values of forest and urban as it was 60.5; that is the water quality of the forest and SMT areas were better than the general water quality of the river. It means that the water quality of the urban environment was very bad which caused the general water quality to have an unfavourable value compared to forests and SMTs.

C. Water Pollution Index (WPI)

Water Pollution Index (WPI) was used to assess the comprehensive status of the water quality of Karamana River. The annual average water pollution index (WPI) of the river fluctuated from 0.955 in forests to 4.481 in the urban environment (table 8).

Among the land uses the water quality was highly deteriorated in the urban area which represents impure/severely polluted water. The river water was moderately polluted in the SMT whereas the water quality status was much better in the forest. On the other hand the general WPI of the river was different from those determined in different land uses (table9).

Although the general WPI of 2.1724 means that the water was polluted but still it was a better status than that of the urban. But when compared to forest and SMT average water pollution indices, the river water quality was much deteriorated. It is thus clear that urbanization and its associated waste production and disposal is the chief reason behind the severe pollution of water in the urban areas.

D. Water Pollutants Index

The contribution of each polluting substance to the WPI was identified by incorporating a water pollutants index. The results indicated that the main pollutants vary significantly among land uses both in type and percentage share to the total pollutants index. While phosphate occupied the first position in the water pollutants index in all the three land uses, there were variations in the positions of the second and third ranking polluting substances (table 10).

It clearly shows that EC and chlorides were the chief pollutants in the urban area besides phosphorous. On the other hand phosphates, pH and EC were the chief factors in water pollution in the low human intervention zones like forest and SMT. It also shows that the percentage share of the chief water pollutant, phosphate, was differing significantly between forest and SMT on the one hand and the urban on the other. Electrical Conductivity and chloride concentrations which were not at all significant in other land uses had played a major role in polluting the river water in the urban environment. This proves that urbanization and urban processes have a major role in water pollution and the type of pollutants that causes the same.

Table 4. General WQI for different parameters in Karamana River

Parameters	Average Measured Value	WQ standard value	Wi	Qi	Weighted Value [Wi Qi]
EC	74.99	300	0.0033	238.33	0.786
TH	93.92	300	0.0033	31.307	0.103
DO	6.887	5	0.2	80.344	16.069
pH	6.39	8.5	0.118	40.667	4.799
Chloride	281.27	250	0.004	104.508	0.418
Nitrate	1.480	45	0.022	3.302	0.073
TDS	459.643	500	0.002	91.929	0.184
Calcium	11.903	75	0.013	15.871	0.206
Mg	15.583	30	0.033	51.943	1.714
Sulphate	27.819	150	0.006	18.546	0.111
			∑Wi= 0.4046		∑WiQi=24.463

Table 5. WQ1 for different parameters in forest

Parameters	Average Measured vale	WQ standard value	Wi	Qi	Weighted value (Wi Qi)
EC	24.63	300	0.0033	8.21	0.027
TH	12	300	0.0033	4	0.013
Do	8.13	5	0.2	67.4	13.480
Ph	6.46	8.5	0.118	36	4.248
Chloride	10.67	250	0.004	4.268	0.017
Nitrate	1.236	45	0.022	2.7	0.059
TDS	15.82	500	0.002	3.16	0.0063
Calcium	2.13	75	0.013	2.84	0.037
Mg	1.62	30	0.033	5.4	0.0178
Sulphate	2.13	150	0.006	1.42	0.0085
			∑Wi=0.4046		∑WiQi=18.074

Table 6. WQI for different parameters in SMT

Parameters	Average Measured Value	WQ standard value	Wi	Qi	Weighted Value [WiQi]
EC	50.70	300	0.0033	16.9	0.056
TH	15.50	300	0.0033	5.17	0.017
DO	7.84	5	0.2	70.4	14.08
pH	6.21	8.5	0.118	53	6.254
Chloride	15.55	250	0.004	6.2	0.025
Nitrate	1.173	45	0.022	2.606	0.057
TDS	32.57	500	0.002	6.514	0.013
Calcium	3.50	75	0.013	4.667	0.061
Mg	1.65	30	0.033	5.5	0.182
Sulphate	3.657	150	0.006	2.438	0.146
			∑Wi=0.4046		∑WiQi=20.891

Table 7. WQI for different parameters in urban Environment

Parameters	Average Measured Value	WQ standard Value	Wi	Qi	Weighted Value (Wi Qi)
EC	2069.65	300	0.0033	689.88	2.277
TH	254.27	300	0.0033	84.8	0.280
DO	4.69	5	0.2	103.2	20.64
pH	6.50	8.5	0.118	33.33	3.933
Chloride	757.60	250	0.004	303	1.212
Nitrate	2.048	45	0.022	4.55	0.100
TDS	1330.54	500	0.002	266.11	0.532
Calcium	30.08	75	0.013	40.11	0.521
Mg	43.48	30	0.033	144.93	4.783
Sulphate	77.670	150	0.006	51.78	0.311
			∑Wi=0.4046		∑WiQi= 34.589

Table 8. Table Land use wise Water Pollution Index (WPI) for different parameters in Karamana River

Parameter	Land use		
	Forest	SMT	Urban
pH	0.0760	0.0730	0.07647
EC	0.00821	0.01690	0.6898
TDS	0.00316	0.00651	0.2661
TH	0.0040	0.00516	0.0847
Mg	0.0054	0.0055	0.1449
Calcium	0.00284	0.00466	0.0401
Chloride	0.0043	0.0062	0.3030
Nitrate	0.0027	0.0026	0.00450
Phosphate	0.84675	0.9587	2.354
Sulphate	0.00142	0.00243	0.5178
WPI	0.95478	1.08166	4.48137
Status	Pure	Moderately Polluted	Impure / Severely polluted

Table 9. Water Pollution Index of Karamana River

Parameter	WPI
pH	0.0751
EC	0.2383
TDS	0.0919
TH	0.03129
Mg	0.0519
Calcium	0.0158
Chloride	0.1045
Nitrate	0.0033
Phosphate	1.3865
Sulphate	0.1738
∑WPI	2.1724
Status	Polluted

Table 10. Land use wise Water Pollutants Index for different parameters in Karamana River

Parameter	Land Use					
	Forest	%	SMT	%	Urban	%
pH	0.07959	7.959	0.06750	6.75	0.0190	1.90
EC	0.00860	0.860	0.01562	1.562	0.17180	17.180
TDS	0.00331	0.331	0.0060	0.60	0.06627	6.627
TH	0.00419	0.419	0.00477	0.477	0.02111	2.111
Mg	0.00566	0.566	0.00508	0.508	0.03609	3.609
Calcium	0.00297	0.297	0.00431	0.431	0.00999	0.999
Chloride	0.00447	0.447	0.00575	0.575	0.07550	7.550
Nitrate	0.00288	0.288	0.00241	0.241	0.00113	0.113
Phosphate	0.88678	88.678	0.88630	88.630	0.58620	58.620
Sulphate	0.00149	0.149	0.00225	0.225	0.01290	1.290
Total	1.0	100	1.0	100	1.0	100

Conclusion

Results showed that land use change has led to considerable deterioration in water quality in the Karamana river of Kerala. Different land uses have different effects on water pollution. Both water quality and water polluting substances had varied among various land uses. Water quality was highly deteriorated in the urban areas compared to other land uses. The prevailing governmental intervention to mitigate the impacts of urbanization on surface water quality is not sufficient. So the study demands the following intervention from the part of both the government and society to reduce the severity of impacts and to manage the environment. The most important and effective solution for most of the environmental problems is to make the people aware of environmental protection. Government can take measures in this regard. Seminars, campaigns, camps, workshops, advertisements, and house visits can be conducted. Necessary steps should be taken towards the reclamation of paddy lands, arable lands and to the establishment of farmland protection areas within the city and peripheral areas for developing 'urban villages'. Considerable amount of spaces within the city should be legally reserved for raising crops which will help in reducing urban pollution and improving the urban environment. Soil erosion is the result of land misuses and soil mismanagement. Hence, soil erosion management measures must be adopted by preserving vegetation and conserving agricultural areas. In urban areas green belts should be constructed at adequate intervals from the core to the periphery by pre-establishing buffer zones. Strict administration along with economic incentives should be adopted for shops, industries and households for treating the pollutants at the source in the urban areas rather than discharging into the river. Finally, infrastructural facilities should be constructed along with the rate of urbanization. Thus, it is concluded that unscientific and uncontrolled urbanization needs the attention of planners and land managers.

Acknowledgement

The authors would like to thank the Department of Science and Technology (DST), Government of India for its financial support. We also thank the Kerala State Council for Science, Technology, and Environment (KSCSTE) and Centre for Water Resources Development and Management (CWRDM) for providing us with the surface water quality data of Karamana River.[(1–10,12–17)]

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