Impact of Land Use on Water Quality of Kelani River

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Abstract— *Kelani River water is consumed by a considerable portion of the population of the country. This study experimentally derives relationship between land use and surface water quality of Kelani River for effective water management. Water quality of river within selected study area is examined for duration of six months and they are correlated with the land use data of watershed of the river. Study area is divided into two catchments based on their land uses. Analysis of land use data in two catchments revealed that there is a significant increment of urbanization in Lower Kelani ganga catchment whereas agricultural and forest areas were higher in the Lower middle Kelani ganga catchment. Nitrate, Phosphate, Turbidity, TDS, Temperature, Fecal coliform have been increased in urban dominated catchment. Higher level of DO (sat) and pH have been observed with the increment of the cultivated areas. Although the water quality parameters show significant variations with the impact of land use patterns, overall water quality classified as Water Quality Index (WQI) was higher among the sample stations of catchment 2 and lower among the sample station of catchment 1.*

Keywords— **Kelani River, Land use, Water quality, Catchment**

I. INTRODUCTION

Kelani River flows through Colombo and Gampaha districts which have highest density of Industries in Sri Lanka. Since the water from Kelani river is consumed by a considerable portion of the population of the country, relationship between land use and surface water quality is essential for effective water management. Kelani river is the fourth longest river (144 km) in Sri Lanka which holds a vast economic importance to the Sri Lankan community as it contributes in many agricultural, industrial and domestic processes. Kelani river is considered as the second largest river basin that flows through two speedily industrializing and highly populated urban districts, Gampaha and Colombo in its lower middle area. Origins of the river is in the Peak Wilderness Sanctuary and Western face of the central uplands in the Horton Plains National Park. Kelani river drains approximately 2,292 km2 of land area

Kelani river mainly contributes in providing water resources which include drinking water requirements, generation of electricity, agriculture, industry, household consumption, refreshment and other environmental utilities. Also, the river contributes in maintaining a safe and sound eco system. There are several major intakes located directly on the Kelani River in Avissawella, Kosgama, Biyagama, Pugoda and Ambatale. Most of the urban populations in Colombo and Gampaha districts receive pipe born water pulled out from Kelani River by the National Water Supply and Drainage Board (NWSDB).

Furthermore, companies such as Ceylon Cold Stores PLC, Coca Cola beverages, Pepsi and American waters which use water as their major production material in large scales use Kelani river water in their vast productions. Due to disposing of industrial waste to Kelani river during their production processes pollution has increased. Moreover, due to poor local authorities' services and weak environment management and governance, the water quality of Kelani river has highly affected. According to the statistics published by Ceylon Electricity Board, one of the major hydraulic structures that produce about 1,800 GWh in 2010 which accounted for about 18% of total generation is in proximity to Kelani river. It is challenging to investigate whether there is an impact from land use patterns of watershed areas on the water quality, as the hydraulic retention time of major hydraulic structures could be 1-2 years. Furthermore, due to the huge variation of land use patterns after those hydraulics structures it is not convenient to specify the areas to a certain land use pattern. As a result, catchment area after hydraulic structure across the Keleni River is not considered in the research.

When the existing land use pattern is analysed it can be observed that the upper catchment of the basin is enclosed with tea plantations and forest areas. The middle and lower catchments are filled with rubber plantations and paddy fields. In the Kelani Basin there are large and medium scale private owned tea and rubber estates. Furthermore, a sizeable amount of medium scale tea, rubber, coconut and cloves plantations can be seen within the Kelani River Basin. According to above information there are many kinds of land use patterns such that agricultural, urbanization, forest and industrialization lies adjacent to the path of Keleni. As a result, to identify the

correlation between land use and the water quality of Kelani river, all these variations in land use should be taken into consideration during this study.

Aim of this research is was experimentally derive a relationship between land use and surface water quality of Kelani River for effective water management. The objectives of the research were to identify the land use patterns in selected area (Mattakkuliya to Pugoda Kalu palama), to check water quality in Kelani River from Mattakuliya to Pugoda Kalu Palama experimentally and to identify the effect of land use on water quality in Kelani River selected area.

II. Methodology

A. Study Area

Study area of the research was from Mattakuliya to Pugoda Kalu palama about 45 km along the Kelani River. Kelani River Basin has been divided into 20 sub-basins from the Survey Department which are different sizes. The 20 basins cover three provinces in the country. Western Province covers 34%, Central Province covers 47% and Sabaragamuwa Province covers 19%. Also, Kelani River cover the Nuwara Eliya, Kandy, Ratnapura, Kegalle, Kalutara, Colombo and Gampaha Districts that are included in 37 Divisional Secretariat areas. From the 20 sub basins 8 sub basins were selected as the study area.

B. Land Use Pattern

Quantitative land use data of relevant catchment areas were determined using Survey maps and Google maps with the help of photoshop software. Also, some data were collected from the Department of Census and Statistics.

C. Sampling Stations

9 Sampling stations were selected from study area; Thotalanga, Sedawatta, Ambathale near to the water treatment plant, Pattiwila near to the water treatment plant, Mabima, Kaduwela near to the bridge, Nawagamuwa, Hanwella, Pugoda near to the Kalu Palama.

D. Water Quality Parameters

Eight water quality parameters were checked, and they were Turbidity, Total Dissolved Solids (TDS), pH, Total phosphate, Nitrate- N, Dissolved Oxygen (DO), Fecal Coliforms.

E. Water Quality Index

Water samples were collected from May 2017 to August 2017 along the selected area and they were tested to calculate WQI. There were eight tests carried to determine physical, chemical and biological parameters of water and the water quality variation was observed from the tested values. Also, to collect the water samples, Polyethylene terephthalate (PET) bottles were used and they were transported within 24 hours to the laboratories using a cooler box with ice. All eight parameter test values totalled and averaged to calculate the final WQI. The overall WQI was ranged from 0 to 100 and quality of water was graded into five classes as below.

- 100-90 - Excellent
- 90-70 - Good
- 70-50 - Medium
- 50-25 - Bad
- 25-0 - Very bad

F. Data analysis

ArcGIS, Google maps and survey maps were used to analyse the quantitative land use data of selected two catchments. Also, to calculate and interpret the variation of WQI along the Kelani river, Microsoft excel 2016 software was used. Thotalanga Sample Station data set, which was calculated using Microsoft Excel 2016, is given below in Table 1.

Table 1. Thotalanga Sample Station Data Set

Parameter	Raw Data	Q value	Weighting factor	Total
DO (sat)	19.07	12.535	0.17	2.13
Temperature	29.7	10.24	0.10	1.024
Nitrate	1.01	94.04	0.10	9.4
Fecal coliform	1600	17	0.16	2.72
Turbidity	7.78	79.6	0.08	6.67
pH	5.71	46.01	0.11	5.06
Total phosphate	0.18	94.4	0.10	9.44
TDS	52.6	86	0.07	6.02
$\sum(Q\ value\ x\ Weighting\ factor)$ and $\sum\ weighning\ factors$			0.89	42.46
WQI				47.71
Water Quality category				Bad

Source: Developed by author

III. Result and Discussion

A. Land Use Pattern

Land use data obtained from Department of Census and Statistics and using Google and Survey maps of survey department, data was collected under categories of agricultural, built-up, coconut, forest, grassland, ground, home garden, hospital, marshy, mining, paddy, park, rubber. They were summarized under paddy, rubber, coconut cultivation and number of industries for the easiness of the study. Distribution of land use patterns in percentage of catchment is shown in Table 2. Number of industries and total area of the catchments is shown in Table 3.

Table 2. Distribution of land use patterns in f catchment

Land use pattern	Area	
	Catchment 1	Catchment 2
Home Garden	55.89	31.7
Paddy	9.67	5.93
Rubber	4.53	30.05
Coconut	10.88	16.24

Source: Developed by author

Table 3. Number of industries and area of the catchments

	Catchment 1	Catchment 2
Total Area	331 km^2	388 km^2
No. of Industries	1453	623

Source: Developed by author

B. Variation of water quality parameters

Maps obtained from the survey department and google maps were used to identify the various kinds of land use patterns present in the surrounding area of Kelani river within the selected study area. Depending on the variation of land use pattern determined, the water quality parameters of the selected sampling stations were experimentally determined. The results obtained from the 9 sampling stations are illustrated in Table 4.

Table 4. Laboratory Results

Parameter	Sample Locations								
	1	2	3	4	5	6	7	8	9
DO (%sat)	19.07	19.91	30.64	33.4	26.15	30.42	40.45	36.12	41.21
Temp. (°C)	29.7	29.2	29.5	28.7	27.4	28.2	27.2	27.4	27
Nitrate (mg/L)	1.01	0.9	0.5	0.5	0.3	0.4	0.3	0.4	0.2
Fecal coliform (Colonies/100ml)	400	300	900	1200	500	1100	1800	900	1700
Turbidity (NTU)	7.78	7.64	5.21	5.9	7.9	7.12	6.04	7.25	5.61
pH	5.71	5.86	6.12	6.23	5.96	6.08	6.21	6.01	6.89
Total phosphate (mg/L)	0.18	0.13	0.15	0.05	0.06	0.08	0.05	0.07	0.04
TDS (mg/L)	52.6	58.9	44.12	49.1	51.2	42.4	33.9	40.18	35.34

Source: Developed by author

C. Variation of Temperature (^0C)

According to the obtained results, it can be observed that the highest and lowest temperature values are near Thotalanga (29.7 0C) and Pugoda (27 0C) respectively. When analysing all the results, the most significant observation that can be identified is that all the temperature of the sampling stations is in the range of 0ºC to 30ºC. It can be observed that the first 20km which covers lower kelani ganga catchment had the highest temperature values relative to the lower middle kelani ganga catchment. The main reason for the increment of water temperature in the river is due to the addition of warm water bodies into the river. The highly probable cause for this scenario is the careless addition of residential and industrial wastewater into the river. From the results of land use pattern data, highest density of industries and home gardens were located in the catchment 1 area relative to the catchment 2 area and water near to the catchment 1 area had highest temperature values.

D. Variation of DO (sat%)

Highest and lowest values of DO (%sat) could be observed near Pugoda kalu palama and Sedawatta areas respectively. According to the results, highest recorded DO value was 41.21 whereas the lowest was 19.07. According to the standard, the adequate DO values should be more than 40. During the experiments only two sampling station were able to reach that mark. With the increment of temperature, solubility of oxygen starts to decrease. As a result, warmer the surface water, more capable to reach 100% air saturation. Thus, temperatures are higher near to the area of catchment 1 sample stations, it can be obtained that the solubility of oxygen is minimums at that sample locations. Similarly, temperatures are lower near to the catchment 2 sample locations relative to the catchment 1 sample locations and result of that solubility of oxygen are maximum at that sample locations.

E. Variation of pH

The most significant observation that can be made is that the highest pH value (6.89) can be found near Pugoda kalu palama and at the same time the lowest (5.71) was recorded near Thotalanga after Kollonwa ela. The area around the catchment 2, is not heavily populated relative to the catchment 1 area.

Most of the area is covered with cultivation and low density of home gardens and industries. The area around the catchment 1 is highly polluted and most of the area covered from the industries and home gardens. This can be identified as one of the main reasons for the increase of pollution of water which can affect the pH values. Due to the addition of more amounts of untreated chemicals to the river from surrounding industrial areas may result in development of acidity of river water.

F. Variation of Turbidity

The preferable range for surface water is in the range 1 to 50. Obtained results through the experiments from all the sampling station shows turbidity values within the above-mentioned range. The maximum turbidity value (7.9 NTU) was recorded near to the Mabima area and this area had high density of industries. The minimum turbidity value (5.21 NTU) was recorded near to the Ambathale water treatment plant. From the results it can be observed that high turbidity values are obtained from the highly polluted area of catchment one and catchment 2. In the catchment 2 Nawaagamuwa and Pugoda sample stations had low turbidity values relative to the other two locations since these two locations are in the semi urbanized area. Similarly, Paattiwila and Ambathale sample stations had low turbidity values relative to the other stations of the catchment 1. As a result, it can be identified that the wastewater discharged from the industries and residences can increase the turbidity value.

G. Variation of Total Phosphate

The maximum amount of phosphate (0.18 mg/L) was found near to the Thotalanga area while the lowest amount (0.04 mg/L) was found near Pugoda area. In this study, all the values obtained from the sampling stations were within the range of 0-0.5 mg/L. Therefore, it can be concluded that phosphate composition in the selected length of river is within the preferable range and there is a minimum variation in phosphate content due to land use patterns in the selected study area.

According to the land use pattern data, high discharge of wastewater can be occurred in the catchment 1 area due to the high density of industries and high urbanized area located around the river. Also, land use pattern data showed that the density of industries and urbanization of the catchment 2 is lesser than that of catchment 1. Hence land used pattern is affected to the Total Phosphate values in the Kelani River selected stretch.

H. Variation of Nitrate

The maximum amount of nitrate (1.01 mg/L) was obtained near to the Thotalanga area. Furthermore, the lowest amount (0.2 mg/L) was obtained near to the Pugoda Kalu palama.

According to the land use pattern data, the area around the catchment 2, is not heavily populated relative to catchment 1. Most of the area of catchment 2 is covered with cultivation and low density of home gardens and industries. Therefore, it has minimal effected to the nitrate concentration of the Kelani river surface water. But the seasonal variation such as rainy season is significant to the nitrate concentration of cultivation areas. The area around the catchment 1 is highly polluted and most of the area covered from the industries and home gardens. this will affect the water to be more polluted and most importantly it can affect the Nitrate value as well.

I. Variation of TDS

The maximum amount of TDS (58.9 mg/L) was obtained near to the Sedawatte area and the lowest amount (33.9 mg/L) was obtain near to Nawagamuwa area. TDS in water bodies originate from sewage, and industrial wastewater. Dissolved solids can be obtained through inorganic materials such as rocks and air that may have traces of nitrogen, Sulphur Calcium Bicarbonate, Iron Phosphorous and other minerals. When water temperature increases, the conductivity of water also increases; where TDS in water is directly related to conductivity. For each 1°C increment, conductivity rise by 2–4%. Temperature effects conductivity by growing ions mobility and additionally the dissolvability of many salts and minerals. Therefore, from the results of laboratory tests it can be observed that the maximum TDS levels are obtained from catchment 1 sample stations relative to catchment 2 sample stations. Hence, highly urbanized areas and lager amount of industries are located around catchment 1 area. Catchment 2 area had semi urbanized pattern and less amount of industries relative to the catchment 1.

J. Variation of Fecal Coliform

Fecal coliform illustrates the highest value (1700 colonies/100ml), at Sedawatte sampling station, which is a high urbanized area. The lowest amount of Fecal coliform (300 colonies/100ml) was found near to Nawagamuwa area. This area is semi urbanized. Highly urbanized areas and lager amount of industries are located around the catchment 1. Catchment 2 had semi urbanized areas. Laboratory test values are proved land used pattern affected to the Fecal coliform parameter.

K. Water quality index

Calculated Water Quality Index values using Weight Arithmetic WQI method developed by the National Sanitation Foundation National (NSF) using average laboratory values of DO (sat), Fecal coliform, pH, Temperature, Total phosphate, Nitrate nitrogen, Turbidity, TDS are shown in Table 5.

Table 5. WQI for Selected Sample Locations

Sample Stations	WQI
Thotalanga	47.71
Sedawatta	48.72
Ambathale near water treatment plant	52.17
Pattiwila near water treatment plant	51.8
Mabima	51.1
Kaduwela near to the bridge	52.7
Nawagamuwa	56.13
Hanwella near to the bridge	52.9
Pugoda near to the Kalu Palama	58.89

Source: Developed by author

According to obtained water quality index values, seven sampling stations except Thotalanga (sampling station 1) and Sedawatta (sampling station 2) has showed a “Medium” (WQI 70-50) water quality. Thotalanga sampling station is located after the Kolonnawa ela which is a highly polluted channel. Thotalanga sampling station showed a “Bad” (WQI 50-25) water quality. Similarly, Sedawatta sampling station also showed “Bad” water quality which is located at a high urbanized area.

From the land use pattern data, it can be recognized high amount of wastewater is discharged to the river from the catchment 1 due to the high density of industries and high urbanized area located around the river. According to the experimental results, it can be observed that the water quality index is higher in catchment 2 than catchment 1. Furthermore, the collected land use pattern data implies that the high density of industries and high urbanized area are located around the catchment 1. Catchment 2 consist with higher area of cultivations and lesser amount of industries and semi urbanized areas. Similarly, the highest WQI values are found in Pugoda area and Nawagamuwa area. Pugoda region is surrounded by cultivated lands where as Nawagamuwa semi urbanized area where disposal of waste to the river is minimal. As a result, around these two locations higher WQI can be observed due to lack of industries and urbanization. An extreme reduction in water quality near cities such as Hanwella, Kaduwela, Sedawatta can be identified due to the urbanization and high density of residential areas. These observations can be used to identify the relationship between land use pattern and water quality of Kelani river in the selected area.

When the land use is centralized under more urbanized and residential environment, the reduction of water quality in the river is higher. Whereas when the land use is effectively managed, the reduction of water quality is less.

IV. Conclusion

There is a significant difference between land use patterns of two catchments. According to data obtained from Survey Department land use pattern maps and Department of Census and Statistics, there is a noticeable reduction of cultivated area from catchment 2 to catchment 1, while urbanized areas and density of industries had been raised rapidly.

High variation in parameters such as DO (sat), Nitrate, Total phosphate, Temperature, Fecal coliform, TDS could be identified between two catchments and a minimum variance could be seen in Turbidity and pH. According to the laboratory test values, it can be identified that Nitrate, Total phosphate, Temperature, Fecal coliform, TDS have increased with the increment of urbanization area. Similarly, pH and DO (sat) values have decreased with the increment of urbanization area.

Although individual parameters show a significant variance with land use patterns, overall water quality within study area does not show a significant variance according to WQI. But, a slide decrease in water quality can be identified when moving into catchment 2 from catchment one. Furthermore, in the final stage of the downstream higher variation can be identified on the WQI with the increment of urbanization and industries.

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