ANANLYSIS OF WATER QUALITY VARIATION IN KELANI RIVER, SRI LANKA USING PRINCIPAL COMPONET ANALYSIS

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ABSTRACT

This paper discusses the outcomes of a research project conducted to chracterise the water quality variation in Kelani River and the influential parameters such as land use types. The water quality data for nine parameters namely pH, Turbidity, Electrical Conductivity (EC), Chloride (Cl^-), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Bio Chemical Oxygen Demand (BOD), Total Coliforms, Escherichia Coli (E.Coli) collected from January 2010 to October 2012 from Kelani River was used for the analysis. In addition to the univariate data analysis, most importantly multivariate data analytical technique namely Principal Component Analysis (PCA) was used to understand the corelation between parameters. Data analysis revealed that a considerable variation of the water quality due to the different land use characteristics. However, the study identified importance of targetting the non point sources such as stormwater runoff when design the pollution mitigation strategies and BMPs irrespective of the type of land use. Furthermore, EC was identified as a surrogate indicator to represent the Cl^- concentration in water. In addition the use of PCA is recommended as a viable tool in water quality studies undertake in Sri Lanka.

***Key words*:** Kelani River, Different Land Uses, Pollutant Sources

1. INTRODUCTION

Water quality of receiving water bodies such as rivers and lakes is critically important because it is one of the most essential resources for human existence and settlement. However, rapid growth of population and increase of urban activities significantly influences the water quality of receiving water bodies [5,12]. This is mainly due to the deterioration of water quality due to the higher pollutant loads resulting from various point and non-point sources of pollution.

As noted by several researchers, point source of pollution primarily includes direct and uncontrolled discharges from different land use types such as residential, industrial and commercial land uses [5]. On the other hand urban storm water runoff has been recognized as the most important non-point source of pollution to receiving water bodies [3,5].

With the increasing attention on water quality of receiving water bodies, regulatory authorities strive to mitigate the adverse impacts of urbanization and population growth on water environments by implementing water quality mitigation strategies. This mainly includes implementation of water quality legislations and regulations on waste disposals and the Best Management Practices (BMPs) such as storm sewers wetlands and swales in the catchment areas. In this context, accurate knowledge on water quality variation and influential parameters is significant to develop appropriate mitigation strategies and BMPs.

On the other hand due to the increase demand on potable water the need of time and cost effective treatment facilities has become to a crucial importance. In this context, the identification of surrogate water quality indicators which can be used to represent the raw water quality is significant in order to reduce the cost and time associate with the water quality monitoring programs and hence the treatment processes.

However, in Sri Lanka even though the point source pollution is mostly controlled by legislation the attention on implementation of the BMPs to catchment areas is still limited. Furthermore, the treatment processes are highly cost and time consuming. These constraints are mainly due to the lack of understanding on the variability water quality of receiving water bodies with various influential parameters such as land use, pollutant sources and their pathways and the interrelationship between physical, chemical and biological water quality parameters.

This research project is conducted to understand the water quality variation of Kelani River in the Western Province of Sri Lanka with the type of land uses and other influential parameters and to identify the interrelationship between key indicators of the water quality. Kelani River, having the total length of 145 km and 2292 km^2 of river basin is the second largest catchment area in the country and it is the most polluted river in the Western Province due to rapid growth of industries located in the close vicinity of the river and passes through the Colombo City which is the most populated, industrialized and urbanized city in the country. At present around 470,000 m^3 water is produced from the Kelani river for the use of the people. People in the western Province depend on Kelani river for drinking water, industrial purpose and other water requirements [6].

The outcomes generated from this study are aimed to contribute to design and conduct the time and cost effective water quality monitoring programs, design of the BMPs and the effective and efficient water treatment processes.

2. METHODOLOGY

2.1. Study Area

The water quality data for this study was collected on a stretch of 7 km along the Kelani River. Three sites namely, Intake well, Welivita Bridge and Kaduwela Bridge were selected to collect water samples (Figure 1). These locations have been selected in order to represent the different land use characteristics in to understand the variability of water quality with the inherent characteristics of different land uses.

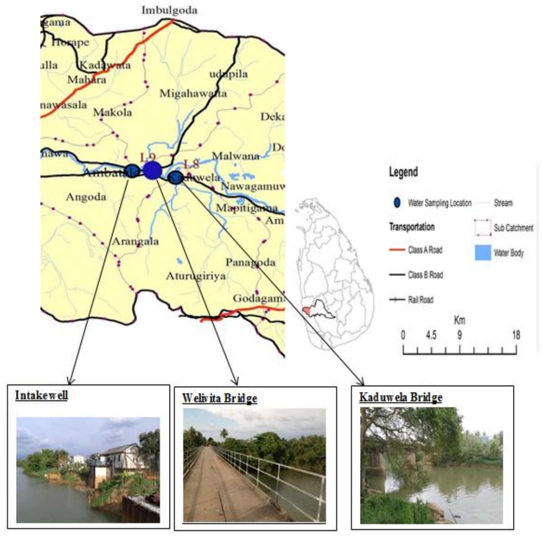

Figure 1: Location of study sites

Intake well is the place where the water is taken from the river to the water treatment plant. It is situated at a mix of industrial and residential land uses and it is near the main road of Mulleriyawa.

Kaduwela Bridge connects two busy town areas namely Kaduwela and Biyagama and located at the heart of the Kaduwela City. The traffic on the bridge is considerable higher compared to the other two locations. Welivita Bridge is located in a residential land use, well surrounded with trees and both bank of the river are heavily covered with the vegetation. During the site investigation researchers observed a quarry near the river bank

The water quality data for the selected sites were collected for the period of January 2010 to October 2012 from National Water Supply and Drainage Board, Sri Lanka. All the samples collected were then tested for range of physical, chemical and biological water quality parameters according to the specified by Standard Methods for Examination of Water and Wastewater (APHA, 2001).. This includes nine water quality parameters namely Turbidity (NTU), pH, Electrical Conductivity (EC) Chloride (Cl^-) Chemical Oxygen Demand (COD) Dissolved Oxygen (DO) Biochemical Oxygen Demand (BOD) Total Coliforms E. Coli at 440C/100ml

The data obtained from the laboratory testing was then analyzed using two sophisticated software packages available for the statistical data analysis namely Microsoft Excel 2010 and StatistiXL Version 1.9.

2.2. Data Analysis Techniques

Both univariant data analysis techniques and multivariate data analysis techniques were employed in this study to identify the variability of water quality with influential parameters and the correlation between water quality parameters.

2.2.1. Univariate Data Analysis

The univariate data analysis techniques considered in this study are mainly included analysis of mean, standard deviation and analysis of variability of each water quality parameter with land use and time. This analysis was conducted mainly in two stages.

Firstly, the average concentration of the each water quality parameter measured for all the three years at each location was analyzed using the methods of mean and standard deviation. This analysis was conducted primarily to understand the variability of the water quality data with type of land use. Secondly, yearly averages were obtained for each parameter measured at each location and analyzed for the variability of each parameter with time at each location.

2.2.2. Multivariate Data Analysis

Due to the constraints arise when handling the number of samples and number of variables simultaneously multivariate data analysis techniques were employed mainly to identify the correlation between water quality parameters. Multivariate data analysis in this study was performed using Principal Component Analysis (PCA) which is one of the extensively used pattern recognition techniques was employed [5,8].

PCA transforms multivariate data into orthogonal components called principal components (PCs) which are uncorrelated to each other and are linear combinations of the original variables. PCs retain the most variance within the original data so that transformation is achieved without loss of information in the data set. The first principal component describes most of the data variance while the second PC, the next largest amount and so on until as many PCs are generated depending on the number of variables.

In this study the PCA biplot was used to present the outcomes of the analysis. The bi-plot shows both the loadings and the score for two selected principal components in parallel. The relationships between the scores and the loadings are often best displayed on the bi-plot. Therefore patterns and relationships of data can be identified by using objects as scores and water quality parameters as the loadings [7,8,9]. The angle between the lines (loadings), or, to be more precise, the cosine of the angle between the lines, approximates the correlation between the variables they represent. The closer the angle is to 90, or 270 degrees, the smaller the correlation and the closer the angle to 0 degrees the stronger the correlation [7].

3. RESULTS AND DISCUSSION

The results obtained from the univariate data analysis is shown Table 1 for all the locations in terms of mean and standard deviation.

Table 1: The average concentration of each parameter at each location

Parameter	**Kelani River**		**Welivita Bridge**		**Intake well**	
	Average	**Standard deviation**	**Average**	**Standard deviation**	**Average**	**Standard deviation**
Turbidity (NTU)	14.56	21.19	11.03	14.46	11.16	14.18
pH	6.7	0.24	6.82	0.19	6.72	0.26
Electrical Conductivity at 25^0C - (µS/cm)	58.63	24.11	91.55	70.69	60.92	25.40
Chloride (as Cl^-) (mg/l)	13.40	7.43	17.18	13.72	10.88	4.33
Chemical Oxygen Demand (COD) – (mg/l)	19.39	21.75	17.78	27.93	11.79	10.18
Dissolved Oxygen (DO)- (mg/l)	7.41	0.38	7.36	0.43	6.90	1.05
Biochemical Oxygen Demand (BOD) (mg/l)	1.68	1.22	2.44	2.89	2.21	2.64
Total Coliforms at 35^0C/100ml	30,606	49928.08	31481.25	51047.37	28546.09	46468.32
E. Coli at 44^0C/100ml	16166.47	35818.41	16575.63	39289.64	12914.22	29727.66

As shown in Table 1 there is no considerable variation of pH between locations. However, Kaduwela bridge site show comparatively higher values for turbidity, COD compared to other locations. The higher Turbidity is mainly attributed to sand mining and the higher solids loads generated from nearby roads in the form of dust and wash-off with the runoff. Even though regulatory authorities in Sri Lanka have already implemented legislations to limit the sand mining no attention has yet been paid on the storm water runoff as a major source of pollutant sources to Kelani River. Therefore, with the increase of roads and vehicular traffic it is of significant to generate in-depth understanding on urban storm water runoff as a major pollutant source to rivers and hence to design and implement BMPs to minimize the impacts. Furthermore, in this context, regular street sweeping practices could also be recommended to minimize the solids build-up on roads and hence to minimize the solids wash-off with the storm water runoff to nearby water bodies such as rivers and lakes.

The relatively higher COD levels at Kaduwela Bridge site could be mainly attributed to the discharge of sewage as noted during the site visits conducted prior to the data collection. This is further confirmed by the findings of Mohan et al. [10] who noted that high values of COD due to accumulation of domestic sewage at Naya Talab lake, Jodhpur, India.

Moreover, as can be seen in Table 1 Cl-, EC, BOD, Total Coliforms and E.coli at Welivita Bridge is higher than that compared to the other locations. The higher value of EC can be mainly attributed to the comparatively higher Cl^- and the quarry situates near the river bank. In this regards also, storm water runoff could play a significant role in transporting pollutants such as rock minerals and explosives used in the quarry to the river. On the other hand the increment of BOD and E.Coli and Total Coli form level can be mainly attributed to the organic and micro biological pollution resulting from land use characteristics such as domestic waste water discharges, plant debris and animal waste [13].

Furthermore, higher Cl^- value at Welivita Bridge indicates the threat of eutrophication at this location compared to other locations studied in this research project.

Notably, the water quality data obtained for pH and Turbidity at all the sites whereas E-Coli for the Kaduawela and Welivita Bridge sites exceeds the permissible values for river water quality compared to the guidelines given by [4]. However, for other parameters are still within the permissible limits given by [4].

Figure 2 shows the PCA biplot obtained from the Principle Component Analysis (PCA) conducted. In PCA all the water quality data at all the locations were considered. This is due to the capability of this technique to analysis number of samples and number of variables simultaneously [8].

As can be seen in Figure 2 Turbidity shows a strong co-relation to E.coli and Total Coli forms. This suggests that, increase of turbidity directly affects to the increase of micro biological pollution. This could be attributed to the presence of solids which lead to increase of turbidity provides a sustainable surface for total coliforms to grow up. This highlights the significance of implementation on best management practices such as wetlands, filtration systems and pollutant traps in the catchment area to reduce the solids wash-off from the catchment generate from various anthropogenic activities. This further suggests the importance of identification of turbidity as a surrogate water quality parameter for Total Coliforms in water quality monitoring and treatments facilities associate with the Keleni Rriver.

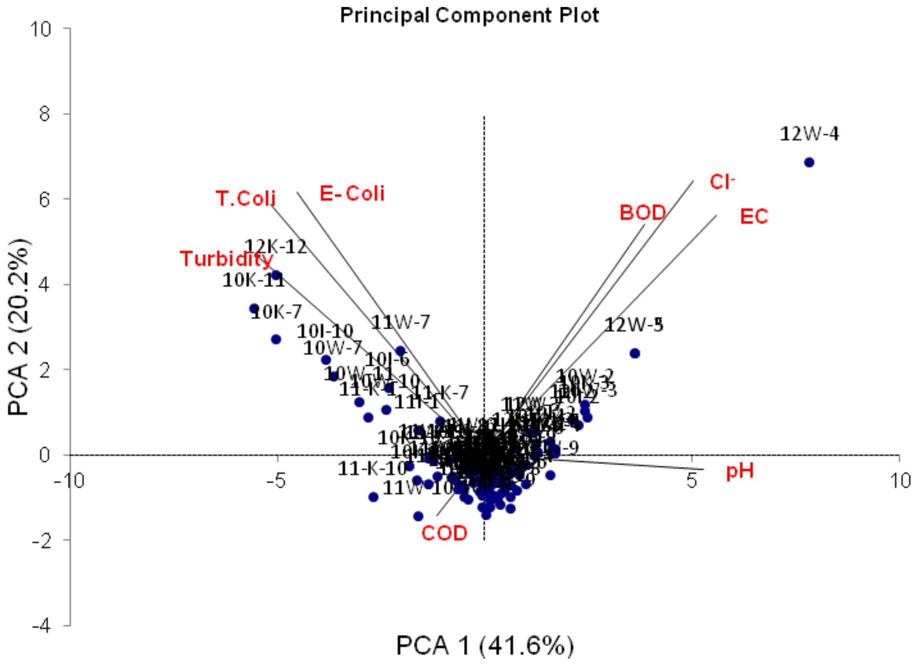

Figure 2: Principal Component biplot obtained for all the locations.

Furthermore, as can be seen in Figure 2 Cl^- shows a strong correlation to EC. This relationship is further confirmed by analysis of variation between EC and Chloride concentrations as shown in Figure 3.

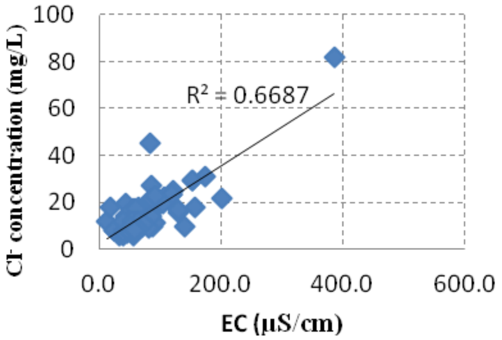

Figure 3: Variation of Cl^- concentration with EC

This suggests that the EC can be used as a good indicator of the Cl^- in the Kelani River. On the other hand the measurement of EC is considerably easier than the measurement of Cl^- Abyaneh et al. 2005testing procedure). Therefore, it is important to obtain in-depth understanding on the inter dependence between EC and Cl^- where EC can be then used as a surrogate to Cl- . This will eventually reduce the time and cost associated with the water quality monitoring programs and testing procedures.

Furthermore, another strong co-relation of this plot can be seen between the parameters of BOD and Cl^-..BOD is caused by aerobic biological organisms in water to break down organic material present in a given water sample at certain temperature. Increase in Cl^-concentration lead to increase the growth of in biological organisms. The strong correlation between Cl^- and BOD could be attributed to these reasons.

Additionally, the turbidity shows no correlation to EC. This confirms the importance of dissolved fraction of solids in the water which leads to EC.

This further suggests that the water treatment process and BMPs should also be targeted on minimizing the dissolved fraction of solids when designing water treatment facilities which mostly target the removal of only the suspended solids.

4. CONCLUSION

The water quality of Kelani River significantly depends on the different land use characteristics. However, study suggests that the importance of considering the storm water runoff as a major source of pollution to receiving water bodies when design the pollution mitigation strategies and BMPs irrespective of the type of land use. It is also recommended to adopt regular street sweeping practices to minimize the solids build-up on roads which minimizes the solids wash-off with the storm water runoff and hence to safeguard the receiving water quality. Furthermore, the study revealed that the use of EC as a surrogate indicator to Cl^- in water quality monitoring programs undertake based on the Kelani River. In addition the use of Principal Component analysis can also be recommended as a viable tool in water quality studies undertake in Sri Lanka.

5. ACKNOWLEDGMENT

We convey our gratitude to the National Water Supply and Drainage Board (NSW&DB) for providing us the relevant data to conduct this research project.

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