COMPARISON OF WATER QUALITY STATUS OF MAJOR RIVERS IN SRI LANKA

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ABSTRACT

This paper discusses the outcomes of a research project conducted to characterize the variation of water quality parameters in major rivers in Sri Lanka. Consequently, six major rivers namely Mahaweli, Kalu, Kelani, Walawe, Menik and Gin were selected for this research study. The water quality data for Color, pH, Turbidity, Electrical Conductivity (EC), Chloride (Cl^-), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Bio Chemical Oxygen Demand (BOD), Total Alkalinity for past ten years from these rivers were collected for the analysis. In addition to the univariate data analysis techniques, most importantly multivariate data analytical technique namely Principal Component Analysis (PCA) was used to understand the correlation between parameters. Cl^- was identified as a surrogate indicator to represent the EC and total alkalinity concentration in water. In addition the use of PCA is recommended as a viable statistical data analysis tool in water quality studies.
Keywords: water quality, major rivers, surrogate indicators

1. INTRODUCTION

The water quality of the rivers is of vital importance since rivers are the major source of the portable water supply in the country. The deterioration of water quality of rivers creates adverse impacts on human health and hence the socio economic development of the entire country.

Due to the rapid development and rapid growth of the population in the country, most of these water bodies are being continuously polluted by different sources at an alarmingly increasing rate. These sources mainly include point sources such as industrial discharges, and uncontrolled sewerage discharges and non-point sources of pollution which primarily include the storm water runoff from residential, industrial, commercial and agricultural land uses [2, 4]. Regulatory authorities have already paid increasing attention to safeguard the water quality in rivers in Sri Lanka mainly by implementing the various mitigation actions such as structural and non structural best management practices and water quality monitoring programs. However, the effectiveness of these mitigation actions is still limited due to the time and cost associated with these measures and the lack of understanding on variability of pollution status with various influential parameters.

In this context, the in-depth understanding on the trends of pollution, spatial and temporal variability of river water quality, interrelationship between key water quality indicators are of crucial importance to increase the effectiveness of mitigation actions and water quality monitoring programs. Furthermore, detailed understanding on the water quality status of different rivers will also facilitate the unique design of cost and time effective treatment processes without adhering into one for all strategies. Consequently, this research study was conducted to understand the water quality statues of major rivers in Sri Lanka, trends of pollution and to identify the interrelationships between key water quality indicators.

2 METHODOLOGY

2.1. Study area

Six major rivers namely Mahaweli, Kalu, Kelani, Walawe, Menik and Gin were selected for this research study (Figure 1). These are considered as the major rivers which fulfill the demand for portable water supply in Sri Lanka and the drainage areas of these rivers represent the different geographical, climatic and land use characteristics in the country.

Mahaweli River is the largest of the 103 river basins found in Sri Lanka. It covers about 16% of the island's total area. The river itself has a winding course, rising about 50 km south of Kandy and flowing north then north-east to the sea near Trincomalee covering a distance of 320 km. It is the only perennial river to cross the dry zone. Due to the number of large scale hydropower and irrigation projects based on this river the encouragement to the economic profile of the country is significantly high in Mahaweli River [5].

Kalu River basin is the second largest river basin in Sri Lanka covering 2766 km^2 and much of the catchment is located in the highest rainfall area of the country, which reflects the high annual rainfall. The annual rainfall in the basin is averaged to 4000 mm and leads to 4000 million m^3 of annual flow. The Kalu River originates from the central hills of the wet zone at an altitude of 2250 m and receives rainfall on the western slopes and falls out to the sea at Kalutara after traversing about 129 km. The basin has steep gradients in upper part and lightly gradients in the lower part [7]. Due to these hydrological and topographical characteristics of the river basin, its lower flood plain suffers from frequent floods during the Southwest monsoon season. Although the KaluRiver has the second largest catchment in the country, it discharges the largest amount of water to the sea and it is in the order of 4000 million m^3. Another interesting characteristic of the Kalu River basin is that it accounts for largest amount of annual per capital water availability. It is about 7750 m^3 which is far more than the annual water availability at national level of 2300 m^3 [8].

Kelani River, having the total length of 145 km and 2292 $km^2$of river basin is the second largest catchment area and the fourth longest river in the country. This river is considered as 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. In the present around 470,000 m^3water 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.

Walawe is the largest river basin with 2442 km^2 in Southern Province Sri Lanka and it is one of the three main rivers flowing south in the area (Walawe, Kirindi and Menik) which, together with a few smaller catchments form a group of basins known as the Ruhuna drainage area. The total drainage area of Ruhuna is over 5500 km^2. A characteristic feature of the basin is two wet seasons in which Northeast and Southwest monsoons generate precipitation peaks in April and November. The mean annual precipitation (MAP) is 2050 mm with uneven spatial distribution. Despite the high precipitation, parts of the basin experience water scarcity problems during February-March and July-October almost every year. The Walawe basin features a variety of water related issues from massive irrigation development and increasing stress on the water environment due to prevailing water quality issues.

The Menik River basin with a total area of 1272 km^2 and is located in the Southern semi-arid part of Sri Lanka. The mean annual precipitation in the basin is 1496 mm and the estimated natural annual flow is 347 million m^3. The basins receive most of its annual rainfall during the Northeast monsoon period from November to January and the dry season lasts from June to September. More than half of the catchment area is covered by forests, which extends into one of the main attractions of the area, the “Yala National Park”. The Yala park covers 1512 $km^2$of about 594 $km^2$are within the Menik River basin. The area is rich in biodynamic and has the largest concentration of wild animals in the world.

The Gin River has a catchment area of about 932 km^2. Catchment of the Gin River includes Galle, Matara, Rathnapura, and Kalutara administrative districts. The Gin river originates from the Gongala mountains in Deniyaya and flows to the Indian Ocean at Ginthota in Galle District. Rainfall pattern in the catchment is bi-modal, falling between May and September and again between November and February [5]. The Gin River annually discharges about 1268 million m^3 of water to the sea [8] .

Figure 1: Locations of the selected river

2.2. Data Analysis Techniques

Both univariate 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. For this purpose two sophisticated software packages namely Microsoft Excel 2010 and StatistiXL were used.

2.2.1. Univariate Data Analysis

The univariate data analysis techniques mainly used in this research are analysis of mean and standard deviation. Consequently, the mean of each parameter for the entire recorded period was calculated so that the six rivers could be compared to see which had overall more pollution during the time period.

2.3.2. Multivariate Data Analysis

Multivariate data analysis techniques were employed mainly to identify the correlation between water quality parameters. Multivariate data analysis in this study was performed using Principle Component Analysis (PCA) which is one of the extensively used pattern recognition techniques in the modern era [2, 3].

Principle Component Analysis (PCA) is a statistical procedure that uses orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principle components. The number of principle components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principle component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to (i.e., uncorrelated with) the preceding components. Principle components are guaranteed to be independent if the data set is jointly normally distributed. PCA is sensitive to the relative scaling of the original variables [1].

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.

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.

3. RESULTS AND DISCUSSION

Figure 2 shows the variation of mean value of each parameter between the rivers for entire time period obtained from the univariate data analysis.

The results obtained from the univariate data analysis are shown Table 1 for all the six rivers in terms of mean and standard deviation. According to Table 1 the considerably higher standard deviation values of all the parameters indicate that the highly variable nature of these parameters irrespective of the river.

As shown in Table 1 there is no statistically significant variation of pH between rivers. However, Menik River shows comparatively higher values for all most all the parameters indicating that the highest polluted nature of the Menik River compared to the other rivers. This can be mainly attributed to the sand mining and the wash-off of higher solids loads generated from nearby roads in the form of dust with the runoff. Specially, the solids build-up on roads and other paved surfaces such as parking lots and pavements is higher in this region because of the long antecedent dry periods and frequent vehicular traffic and other anthropogenic activities in the region due to the large number of pilgrims visiting the area. . In this context, the design of proper storm water drainage systems and implementation of BMPs such as silt barriers and street sweeping are of crucial importance to safe guard the quality of water in Menik River.

Walawe River shows relatively higher EC level compared to that of Mahaweli, Kelani, Kalu and Gin Ganga. This can be mainly attributed to the higher level of Cl^- concentration and the rock salts and minerals generated from the quarries situate near the river bank. This further strengthens the need of detailed understanding on variability of river water quality with influential parameters such as land uses characteristics in the implementation of BMPs and water quality monitoring programs and the design of treatment processes.

Moreover, as seen in the Table 1 BOD values of Kelani river is considerably higher than that of other rivers. BOD 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.

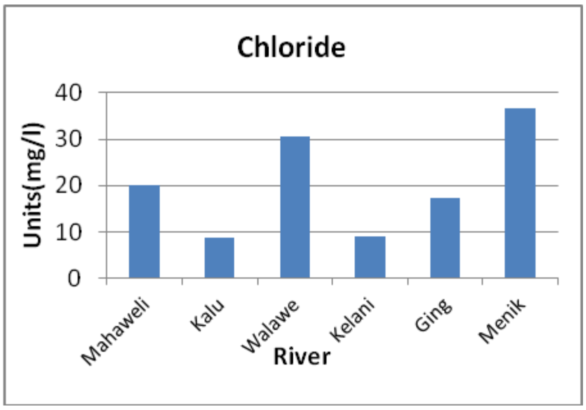
According to the Table 1 and Figure 2, further confirms that the Menik river is the most polluted river out of the selected rivers and Walawe is the second most polluted.

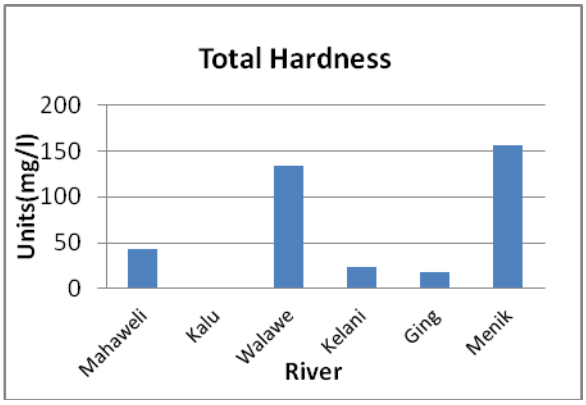
Figure 3 shows the PCA bi-plot obtained from the Principle Component Analysis (PCA) conducted. In PCA all the water quality data of all rivers were considered. This is due to the capability of this technique to analysis number of samples and number of variables simultaneously. As can be seen in Figure 4 around 80% of the data variance has included in the analysis.

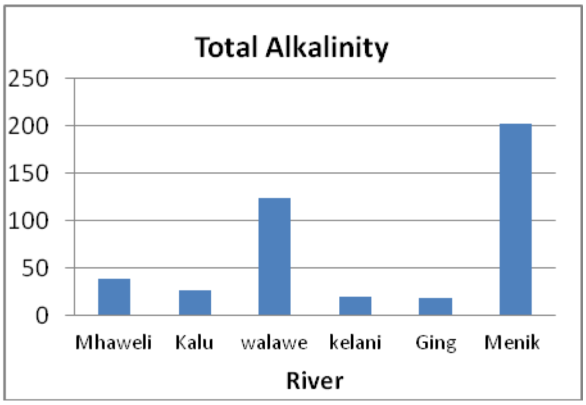
As can be seen in Figure 3, Turbidity shows a strong co-relation to Color. This suggests that, increase of turbidity directly affects to the increase of color. This further suggests the importance of identification of turbidity as a surrogate water quality parameter for Color in water quality monitoring and treatment facilities associate with these rivers. Furthermore, as can be seen in Figure 3, EC shows a strong correlation to Cl^- and Total Alkalinity.

This relationship further confirmed by analysis of variation of EC with Chloride and variation of EC

with Alkalinity shown in Figure 4 and Figure 5. Since the measurement of EC is considerably easier than the measurement of Cl^- and alkalinity it can be suggested that EC is a good surrogate indicator for the Cl^- and total alkalinity irrespective of the difference between the rivers based on the land use characteristics, geographical location and climatic characteristics in the region. Additionally, as shown in Figure 3 turbidity shows no correlation to EC further confirming the correlation between the solids and turbidity.







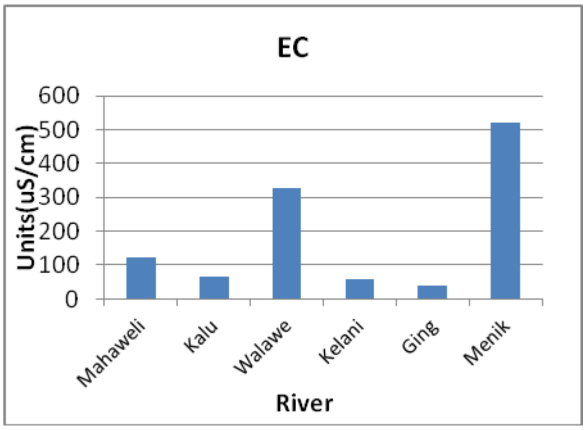


Figure 2: Variability of each parameter of rivers

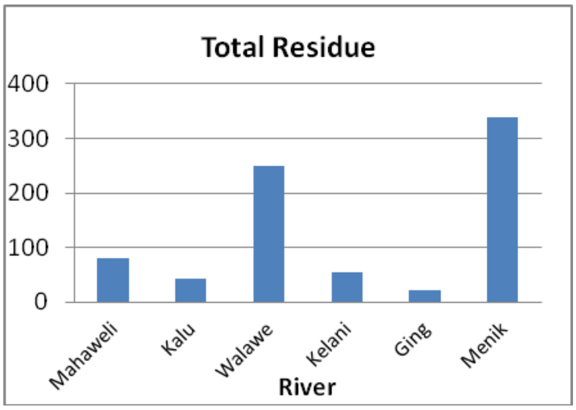


Table 1: The mean concentration of each parameter at each river

Parameter	Mahaweli		Kalu		Walawe		Kelani		Ging		Menik	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Color	83.7	56	28.8	5.6	82.85	32	9.5	2.87	69	15.2	153.57	56.8
Turbidity(NTU)	23.9	22	19	5.9	34	16	15	7.6	33.2	26	54	30
Electrical Conductivity at 25°C - (uS/cm)	121.6	22	65	12	326	106	56.5	8.4	37.5	3.2	536	61.2
pH	6.9	0.3	6.2	0.2	7.1	0.1	6.1	0.09	6.3	0.2	7.0	3.2
Chloride	20.1	25	8	0.7	30.7	6.8	8.9	1.9	16.9	4.8	37	7.5
Nitrates (NO_3^-) - (mg/l)	0.6	0.65	0.002	0.001	0.16	0.3	0.4	0.6	0.01	0.8	0.2	0.4
Total Alkalinity	40.8	18	27.9	6.2	129	19	18	2.6	18.5	2.9	203	11.7
Total Residue	No data	No data	50.3	16	267	70	59.2	23	21	0.19	347	39
Chemical Oxygen Demand(COD)-(mg/l)	No data	No data	26.8	10.7	14	3.2	13.3	5.8	No data	No data	17.3	7.6
Biochemical Oxygen Demand(BOD)-(mg/l)	No data	No data	No data	No data	1.19	0.5	252	832	0.11	0.3	0.8	0.76
Total Hardness	52.7	13.1	No data	No data	136.2	21.7	24.1	7.3	18.2	4.2	156.8	53.8
TDS	62.5	20.6	No data	No data	187.4	89.2	No data	No data	28.7	12.7	No data	No data

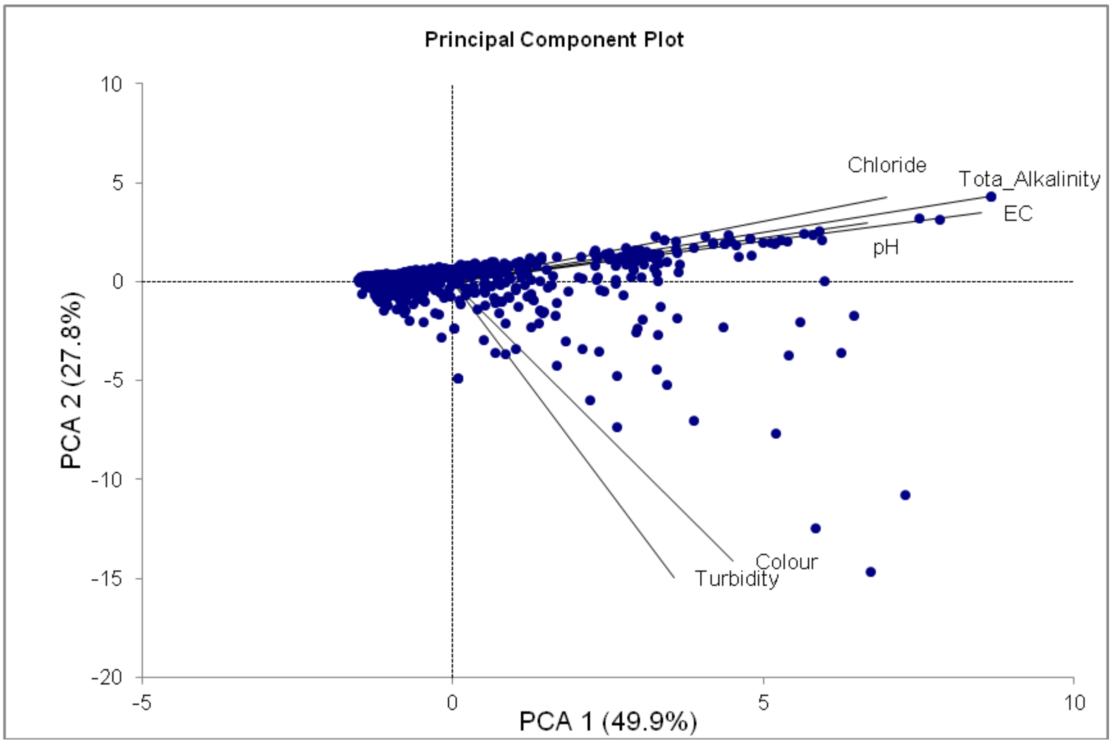
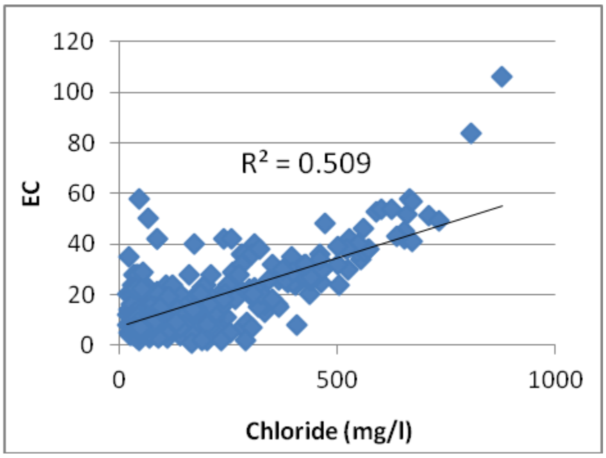


Figure 3: Principal Component bipod obtained for all the locations



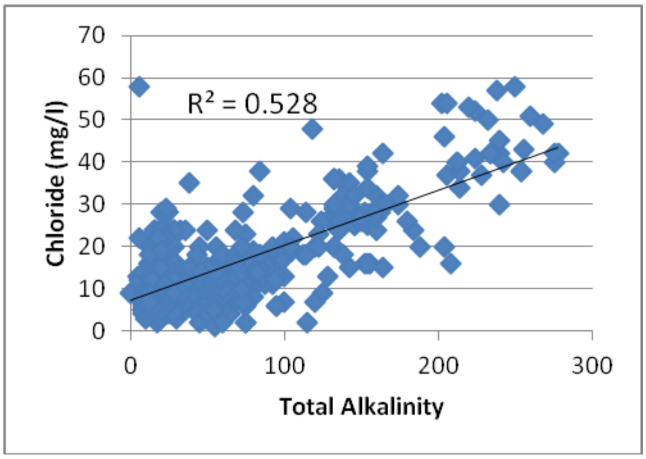


Figure 4 : Variation of Cl^- concentration with EC and Total Alkalinity

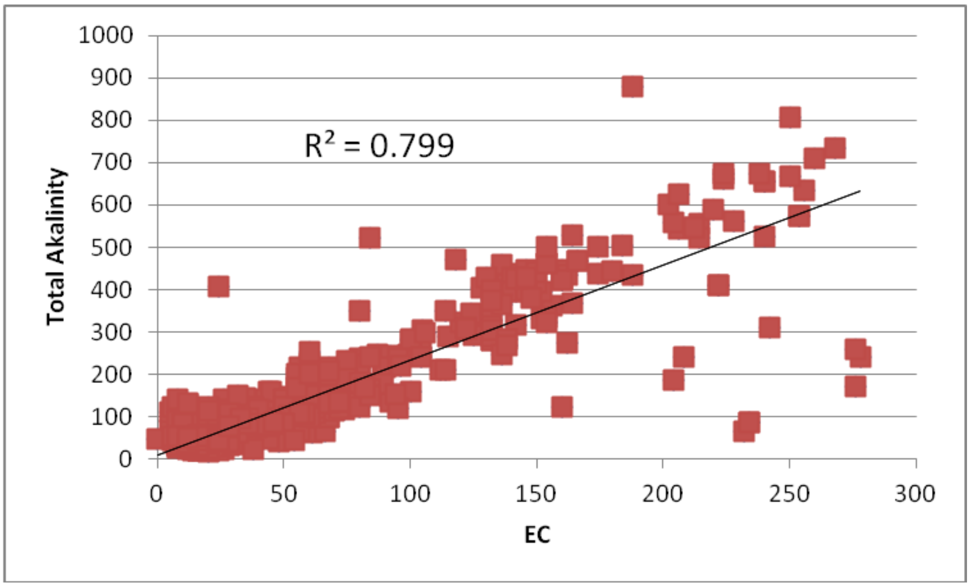


Figure 5: Variation of Total Alkalinity concentration with EC

4. CONCLUSION

Among these six rivers Menik River is the most polluted river where as the Walawe River shows the second largest trend of pollution. The level of pollution in rivers is strongly influenced by the difference in the land uses characteristics and the climatic characteristics in the basins. This strengthens the need of uniquely designed water quality monitoring programs for each river basin. Furthermore, these differences should also be critically taken into consideration in order to design the cost and time effective pollution mitigation measures, treatment processes and water quality monitoring programs. It should also be important to note the surrogate indicators of key water quality parameters in the measurement of water quality parameters in water quality monitoring programs. In addition, the regulatory authorities should also pay the attention on controlled discharge and treatment of storm water runoff in the attempts of safeguarding the water quality of rivers which now is being given a very low or no attention in Sri Lanka.

5. AKNOWLEDGEMENT

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