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Multivariate analysis of physico-chemical and microbial parameters of surface water in Kelani river basin

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ABSTRACT

Water is essential for the survival of all known forms of life, and there is no substitute for water. Surface water pollution may occur in various types such as catchment characteristics, anthropological activities, land use practices and industrial discharges. Such polluting agents may affect physical, chemical and biological parameters of water. The kelani river is 144 km long and drains an area of 2,230 km2 covers six districts from nallathanniya (nuwara-eliya) to mattakkuliya (colombo). The present study was focused to analyze the present status of surface water quality in the kelani river basin by means of physico-chemical and microbiological parameters using the standard analytical and microbial methods. Heavy metals were detected using aas. Twenty seven surface water samples were collected from head, transitional and meandering zones for a period of six months from october 2012 to march 2013. Ph values of most of the samples of the transitional zone were deviated from the sls drinking water standards and ph of the head and meandering zones were remained within the sls standards (5.41-8.85). 90% of the samples showed high cod values (10.33-322.58 ppm) which were exeeded the sls drinking water standards. Bod values in kelani river basin ranged between 0.27-10.67 ppm while the conductivity, tds and hardness were within the ranged between 9.23-25200.00 µs/cm, 5.91-16381.00 ppm, 2.00-401.33 ppm. Acceptable concentrations of phosphate and nitrate were detected range between 0.006-0.303 ppm and 0.09-10.42 ppm respectively. Among the sampling locations 80% sampling points in the head and transitional zones and 90% locations in the meandering zone of the river basin was contaminated with total coliform and feacal coliform bacteria. The cd, al, zn, pb, cr, cu concentrations in surface water was ranged between 0.1183-0.775 ppb, 13.94-255.86 ppb, 1.059-31.44 ppb, 0.078-5.34 ppb, 0.00156-3.50 ppb and 3.11-14.44 ppb respectively. Pca analysis showed differentiations between three regions as the pc1 score into one-way anova test did not show significant difference between head and transitional regions while the meandering zone showed significant difference. Factor analysis showed six factors were according to their correlation.

KEYWORDS: *Kelani river basin, Surface water, Physico-chemical and microbiological parameters, Heavy metals, PCA and Factor analysis*

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1. INTRODUCTION

Water is essential for the survival of all known forms of life, and there is no substitute for water (Stikker, 1998). Surface water pollution may occur in various types such as catchment characteristics, anthropological activities, land use practices and industrial discharges. Such polluting agents may affect physical, chemical and biological parameters of water. The quality of surface water is a major factor affecting human health and ecological systems, especially around urban areas, since rivers and their tributaries passing through cities receive a multitude of contaminants released from industrial, domestic/sewage, and agricultural effluents (Qadir et al., 2008). Sri Lanka's river system comprising 103 rivers flowing from the central highlands makes up a total collective length of about 4560 km (MOFE, 2001). The Kelani river is 144 km long and drains an area of 2,230 km^2 originating at levels above 1,500 m on the steep slopes of the western rim of the central highlands. In their descent the main river and its numerous tributaries travel through deep, structurally controlled valleys, generally oriented in many directions at higher and lower elevations. The main river eventually empties into the Indian Ocean on the west coast of Sri Lanka just few kilometers north of Colombo (IGES, 2007). The Kelani river is the major source for supplying water to Colombo but it is contaminated with organic pollutants mainly from domestic and industrial wastewater (Lagerblad , 2010). The Kelani river could be ranked as the largest recipient of diverse ranging of industrial effluents of the country. The major wastewater generating industries upstream of the river intake include raw rubber factories, textile industries, beverage factories, rubber latex factories, milk food industries, steel manufacturing factories, plywood factories, fertilizer manufacturing factories and industries within the Biyagama Export Promotion Zone (Danish Hydraulic Institute, 1999). These industries are estimated to discharge about 1,000 kg/day of BOD into the Kelani river (Danish Hydraulic Institute, 1999). The petroleum refinery, chemical industries (soap, detergents, and pharmaceuticals) and Lindel industrial estate downstream of the Ambatale intake discharge about 2,000 kg/day of BOD (Danish Hydraulic Institute, 1999). Urbanization and industrialisation cause water pollution due to discharge of wastewater, sewage, solid waste, chemicals and heavy metals into different recipients. Kelani river indicates these sorts of pollution and the river discharges 36,000 kg/day of COD (Lagerblad 2010). The quality of water is typically determined by monitoring microbial presence, especially faecal coliform bacteria (FC) and physico-chemical parameters. These parameters could be affected by external and internal factors. There is an intricate relationship between the external and internal factors in aquatic environments. Meteorological events and pollution are a few of the external factors which affect physico-chemical parameters such as temperature, pH and dissolved oxygen (DO) of the water. These parameters have major influences on biochemical reactions that occur within the water. Sudden changes of these parameters may be indicative of changing conditions in the water. (Hacioglu and Dulger, 2009). The present study was focused multivariate analysis of physico-chemical and microbiological parameter to determine present status of surface water quality in the Kelani river basin as the detail information regarding the pollution status of the river basin is limited.

2. MATERIALS AND METHODS

Study area

Kelani river basin is (Northern latitudes 6° 47' to 7° 05' and Eastern longitudes 79° 52' to 80° 13') with in the area of 2230 km^2. Samples were collected from Head region; Nallathanniya to Thaligama, Transitional region; Thaligama to Hanwella and Meandering region ; Hanwella to Mattakkuliya to cover the whole Kelani river basin.

Sampling and analysis

Twenty seven sampling points were selected based on catchment characteristics, anthropological activities, land use practices and industrial discharges. Samples were collected from head, trasitional and meandering region at monthly intervals from October 2012 to March 2013 (Table 01, Fig 01). Poly ethylene terephthalate (PET) bottles were used to collect water samples. Sample bottles were transported to laboratory within 10 hours in ice after collection. Water temperature, pH and dissolved oxygen (DO) were measured by the HQD portable multi meter (HACH - HQ 40D), electrical conductivity (EC), Total dissolved solids and Salinity were measured by the Portable conductivity meter (HACH – Sension EC5) at the site itself. Winkler method was used to analyze Biological oxygen demand (BOD_5). Spectrophotometric (Spectro UV-VIS Double UVD 2960) methods were used to determine nitrates and total phosphate concentrations (APHA, 1995). Closed reflux digestion method was used to quantify Chemical Oxygen Demand (COD) (APHA, 1995) and titrimetric method with EDTA was used to determination of total hardness. Microbiological quality was analyzed by the standard most probable number (MPN) method (Geldreich, 1990). Atomic absorption spectrophotometric methods (Thermo scientific iCE 3000 series, graphite furnace) were used to analyzed Heavy metals (Pd, Cd, Cr, Cu, Zn, Al) (Yahaya et al.,2012).

During the sampling coordination’s were taken to prepare sampling location map of the study. The coordinates of localities were determined by GPS (Hand-held Gamin eTrex 30 GPS receiver).

Table 01 - Sampling locations in the head, transitional and meandering zone of the Kelani river basin.

Head zone	**Transition zone**	**Meandering zone**
Kelani ganga (Nallathanniya)	Kelani ganga (Yatiyanthota)	Pussella oya
Sami male canal	We-oya (Aamanawela)	Kelani ganga (Ranala)
Keselgamu oya (Norwood)	Ritigaha oya (Warawala)	Pahala bomariya canal
Dic oya	Gurugoda oya (Ruwanwella)	Raggahawaththa oya
Maskeliya tank	Kahanawita canal (Dehiovita)	Kelani ganga (Kohila waththa)
Castlereigh tank	Seethawaka oya (Thalduwa)	Sebastian canal (Kelanithissa)
Norton tank	Eswaththa oya	Dutch canal
Kandura (Koththalanhena)	Pugoda oya	Hemilton canal
Kelani ganga (Nagampitiya)	Wak oya (Kaluaggala)	Kelani ganga (Mattakkuliya)

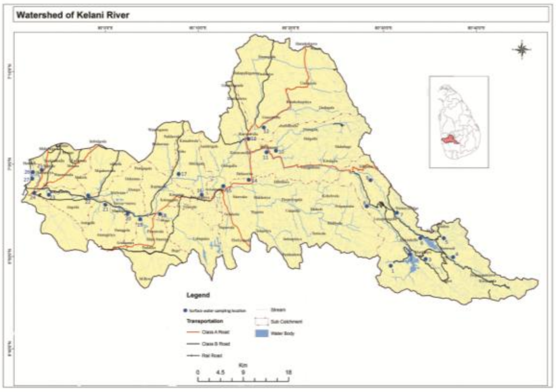

Fig 1. Surface water sampling locations in the Kelani river basin

Principal component analysis (PCA) and Factor analysis (FA)

A PCA reduces the number of dimensions in the data set, while not losing detail or underlying patterns observed in some or all of the observation wells (Lischeid, 2009). The methodology is based on correlation coefficients of the data matrix. The principal components (PCs) are uncorrelated (are orthogonal to each other) and represent the joint variance observed in the data set (Gerbrands, 1981).

Multivariate analysis of the river water quality data sets was performed through factor analysis techniques (Wunderlin et al., 2001). The above statistical analyses were applied on experimental data standardized through z-scale transformation in order to avoid miss classification due to wide differences in data dimensionality (Liu et al., 2003). Factor analysis was performed on correlation matrix of rearranged data (standardized data through z-scale transfer matrix) for three regions. The variance/covariance and factor loadings of the variables with eigenvalues were computed. The varimax rotated factor analyses were carried out for all the variables and factor loading were calculated using eigenvalue greater than 1 and sorted by the results having values greater than 0.4 considering the significant influence towards the geo-chemical processes (Rath et al., 2000).

Data sets were processed using routines taken from Minitab 15 statistical software. Factor and principal component analyses were carried out for 19 parameters of 27 sampling locations. PCA used to determine the differentiation between three regions and factor analysis was used to identify correlations between variables.

3. RESULTS

pH values of most of the samples from transitional zone was deviated from the SLS drinking water standard during the study period (5.41-8.85). Most of the samples recorded high COD values (10.33-322.58 ppm) and showed an increasing trend towards downstream of the river basin as well. High BOD values were detected in meandering zone compare to the head and transitional zones and the values were ranged between 0.27-10.67 ppm. The conductivity, TDS and hardness were ranged between 9.23-25200.00 µs/cm, 5.91-16381.00 ppm and 2.00-401.33 ppm respectively. Acceptable concentrations of phosphate (0.006-0.303 ppm) and nitrate (0.09-10.42 ppm) were detected. In the river basin 80% sampling locations were contaminated with total coliform and feacal coliform bacteria. Heavy metals tested in the river basin (Cd, Al, Zn, Pb, Cr, Cu) were remained within the SLS standards for drinking water. The Cd-0.1183-0.775 ppb, Al-13.94-255.86 ppb, Zn-1.059-31.44 ppb, Pb-0.078-5.34 ppb, Cr-0.00156-3.50 ppb, Cu-3.11-

14.44 ppb concentrations were detected respectively.

The sorted rotated factor analyses results along with percentages of variance for total stations of Kelani river basin presented in Table 02. Rotation of the axis defined by factor analysis produced a new set of factors, each one connecting primarily a sub set of the original variables with a slight overlap as possible, and therefore the original variables are divided into groups.

Table 02. R-mode varimax rotated factor analyses of hydrological parameters in surface water of Kelani river basin (total no. of observations = 27)

Rotated Factor Loadings and Communalities Varimax Rotation

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Cu						0.843
Al					-0.707	
Cr	0.549					
Cd				-0.896		
Pb					-0.697	
Zn				-0.576		
Phosphate			-0.594			
Nitrate	-0.425					
DO	-0.355					
Hardness	0.917					
COD					-0.688	
Temperature		-0.612				
pH				0.426		
Conductivity	0.955					
BOD			-0.860			
TDS	0.955					
Salinity	0.955					
TC		-0.959				
FC		-0.960				
Variance	5.1119	3.0395	2.4480	1.8834	1.7749	1.3837
% Var	26.9	16.0	12.9	9.90	9.30	7.30
Cumulative	33.1	50.5	60.6	68.9	76.1	82.3

A varimax rotation (raw) of the different varifactors of eigenvalue greater than 1, were further filtered up by this technique and in varifactors original variables participated more clearly (Table 2). Liu et al., 2003 divided into three classes of factor loading as ‘‘strong’’, ‘‘moderate’’ and ‘‘week’’ corresponding to absolute loading values of >0.75, 0.75–0.50 and 0.50– 0.40 respectively.

There are six factors or PCs, explaining 82.3% of the total variance for surface water quality in Kelani river basin, which is enough to give a good idea of data structure. Factor-1 accounted for 33.1% of the total variance, which is strong positively loaded with conductivity, salinity, TDS and hardness, weekly loaded with nitrate and dissolve oxygen and Cr was moderately loaded with the first factor which can be interpreted as a ionic component of the surface water. The second factor explained 17.4% of the total variance is found to be strongly negatively associated with total coliform bacteria, feacal coliform bacteria and moderately negative loaded with temperature because second factor can be verified as microbial contamination component of water. The third factor explained 10.2% of total variance and this factor explained about the organic matter content of the surface water in Kelani basin which explained strongly negatively associated with BOD and moderately negative loaded with the total phosphate. Factor four contributed 8.3% of the total variance and explained strong negatively loaded with Cd and moderate loading of Zn. pH positively loaded with the factor four. 7.3% explained from the fifth factor and moderate associated with the Al, Pb and COD. Sixth factor explained 6.2% of the total variance which only contributing to the Cu amount of the ground water.

Table 03. General MANOVA test for PC scores

MANOVA for R

s = 2 m = 1.5 n = 8.5

	Test		DF		
Criterion	Statistic	F	Num	Denom	P
Wilks'	0.11248	6.275	12	38	0.000
Lawley-Hotelling	4.93938	7.409	12	36	0.000
Pillai's	1.21946	5.208	12	40	0.000
Roy's	4.24403				

Table 04. One-way ANOVA test for PC1 versus three regions

```
Source  DF      SS     MS      F      P
Region   2   76.56  38.28  10.59  0.001
Error   24   86.76   3.61
Total   26  163.31
S = 1.901   R-Sq = 46.88%   R-Sq(adj) = 42.45%

                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level  N    Mean  StDev  ----+---------+---------+---------+-----
1      9  -1.461  0.428  (------*-----)
2      9  -0.898  0.743     (------*-----)
3      9   2.359  3.179                 (------*-----)
                         ----+---------+---------+---------+-----
                           -2.0       0.0       2.0       4.0

Pooled StDev = 1.901

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of R
Individual confidence level = 98.02%

Region  = 1 subtracted from:

Region    Lower  Center  Upper  --------+---------+---------+---------+-
2        -1.674   0.563  2.800              (-------*-------)
3         1.583   3.820  6.057                         (-------*-------)
                                --------+---------+---------+---------+-
                                      -3.0       0.0       3.0       6.0

Region  = 2 subtracted from:

Region   Lower  Center  Upper  --------+---------+---------+---------+-
3        1.020   3.257  5.494          |               (-------*-------)
                               --------+---------+---------+---------+-
                                     -3.0       0.0       3.0       6.0
```

PCA analysis was done for the determine of the differentiation among the three regions. According to the PCs scores differentiation between three regions were determined by using general MANOVA and one-way ANOVA with tukeys test. The *p* value ($p< 0.05$) of MANOVA test, (Table 03) research hypothesis which is there was a difference between each region was accepted. According to PC1 in to ANOVA test (Table 04) there was no significant difference between head region and transitional region confirmed by the pair wise comparison given by the tukeys test and also there was significant different between head region and meandering region (1^{st} comparison). 2^{nd} comparison explained there was significant difference between transitional zone and meandering zone due to the six month physico-chemical and microbial data, revealed that high values of conductivity, TDS, salinity, hardness, total phosphate concentration, Al concentration, BOD and COD detected in the meandering region compare to other head and transitional regions. Therefore statistics also confirmed the contamination status of meandering zone and its pollution compare to other two regions.

4. CONCLUSION

Factor analysis for nineteen water quality parameters of Kelani river basin, factor one revealed the high positive loading of ions along with negative scores of DO demonstrate that comparatively ionic nature of sewage/effluents are the major contribution of chemicals and mostly the DO is utilized to proceed to react with ions. 2^{nd} factor explained the microbial quality depend on the temperature. Third factor explained the BOD subsists on the phosphate concentration. PCA analysis revealed that there was no significant difference between head and transitional region and there was a significant difference between meandering region and the other two regions.

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