International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:02, Issue:05

ASSESSMENT OF WATER QUALITY INDEX FOR GROUNDWATER IN THE KELANI RIVER BASIN, SRI LANKA

MGYL Mahagamage[1], SDM Chinthaka[2] and PM Manage[1]*

[1]Department of Zoology, University of Sri Jayewardenepura, Gangodawila, Nugegoda, 10250, Sri Lanka.

[2]Department of chemistry, University of Sri Jayewardenepura, Gangodawila, Nugegoda, 10250, Sri Lanka.

*Corresponding Author- pathmalal@sjp.ac.lk

ABSTRACT

Kelani river basin is one of the important river basins in Sri Lanka and it is the largest recipient of industrial wastes among all other rivers. Further, it is one of the major sources for agriculture and operation of several productions. Industrialization accumulates detrimental substances to outer environment; these pollutants can be effect on ground water directly or indirectly. Ground water demand in Sri Lanka is increasing in the production sector due to quality and inexpensive attribute of the ground water. Water Quality Index (WQI) is a key to solve the problems of data management and to evaluate management strategies for improving water quality. The paper assesses water quality characteristic Kelani river basin ground water using the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). Thirty (30) ground water sampling locations in the Kelani river basin were selected for the WQI assessment and sampling was done for period of one year from October 2012 to September 2013. CCME WQI was applied for eighteen water quality parameters. Based on the results, the average index values and their ranks for drinking were recorded as poor (33) where water quality for Irrigation and livestock were recorded as poor (37) and excellent (100) respectively. Thus the results of the study alarming continuous water quality monitoring must be priority and need proper water quality management and strategic plan for the river basin to provide safe drinking water.

Keywords: kelani river basin, ground water, water quality management, water quality index, CCME WQI

ISSN: 2455-6939

Volume:02, Issue:05

1. INTRODUCTION

Water is vital for all living organisms, although this valued resource is increasingly being threatened due to increase in human population and anthropological activities. Water becomes a vulnerable due to usage of many activities; domestic, agricultural, industrial, livestock, mining, transportation and power generation. Water is persisting as several phases though ground water play a major role for human consumption because its availability and purity (Chilton, 1996). Ground water is highly susceptible to contamination and it is depend upon its shallowness, geological characters and permeability (Helena etal., 2000). Once the groundwater is contaminated, it's difficult to recover easily (Mahagamage and Manage, 2014). Poor and inefficient water quality management practices in Sri Lanka boost local river systems under a severe risk of water pollution. Therefore, ground water consumption is increasing during the last few decades. In Sri Lanka, around 80% of rural domestic water necessity is supply from groundwater by dug wells and tube wells (Panabokke and Perera, 2005). Kelani river basin is the second largest catchment area in Sri Lanka it drains around 2230 Km^2 and it is originating on the western rim of the central highlands levels above 1,500 m where end with Indian ocean near to capital city Colombo (IGES, 2007; Danish Hydraulic Institue, 1999; Mahagamage et al., 2014). It covers twenty sub basins and seven districts which includes most popularized cities in Sri Lanka. Thus there is a high possibility to contaminate the river basin with large quantity of industrial and agricultural effluents. Therefore, it is a needy requirement management of the Kelani river basin for present and future development of the country (Mahagamage and Manage, 2014). Water quality is determined by measuring physico-chemical and biological parameters thus these factors affected by external and internal quality of the aquatic environments. Water quality guidelines are numerical values that define physical, chemical or biological parameters of water which indicate safe level for consumption (Canadian environmental quality guidelines, 1999). Use of Guidelines for drinking water quality referred for specific recommendations on using a water safety approach incorporating risk identification. Therefore, SLS water quality guideline is based on the considering the results of water quality surveillance done in Sri Lanka and also the WHO Guidelines, wherever applicable (SLSI, 2013). Generally, drinking water quality is determined by comparing the physical, chemical and biological characteristics of water according to the water quality guidelines or standards (Al-Janabi et al., 2012). Considering large number of water quality parameters at the same time it is difficult to come a conclusion but Water Quality Index (WQI) give easier way to compare several water quality parameters at the same time with interpreting summary of the data set (Mahagamage and Manage, 2014). Therefore, WQI is a widely used tool worldwide, to resolve the problems for water quality data management. Further, it is the simplest method to assess water quality conditions in the water and judge success and failures in management strategies for improving water quality in many locations (Salim et al., 2009;Giriyappanavar and Patil, 2013).

ISSN: 2455-6939

Volume:02, Issue:05

The Canadian Council of Ministers of the Environment (CCME) was designed to evaluate ground water quality for the purpose of drinking, recreational and livestock purposes aided with specific guidelines (Giriyappanavar and Patil, 2013). CCMEWQI has been used by several scientists to determine quality of water by various provinces and Ecosystems all across the Canada (Cash et al., 2001; Husain, 2001; Lumb et al., 2002; Paterson et al., 2003; Lumb et al., 2006). It is also used for other countries of the world to determine overall idea about water quality as well. Thus CCME WQI is a tool that can use worldwide (Mahagamage and Manage, 2014;Al-Janabi et al., 2012;Giriyappanavar and Patil, 2013; Munna et al., 2013). The present study pointed to evaluate the application of the CCME Water Quality Index to screen the changes in ground water quality in Kelani river basin for drinking, irrigation and livestock purposes.

2. MATERIALS AND METHODS

2.1 Study area

Kelani river basin is located between Northern latitudes 6° 47' to 7° 05' and Eastern longitudes 79° 52' to 80° 13' with in the area of 2230 km^2 (Mahagamage and Manage, 2015). It is located in western part of the Sri Lanka and belongs to wet zone of the country. The area on an average, receives an annual precipitation of 3,718 mmand generating a surface runoff volume of about 8,600 million m^3 of which nearly 65% discharges into the Indian Ocean (IGES, 2007). Kelaniriver is the fourth longest river (144 km) in Sri Lanka among 103 rivers and central highland is the starting point of the river ends with Mattakkuliya area. Further, it provides home for more than 25% of the Sri Lankan population where most popularized districts are located within the basin (Mahagamage and Manage, 2014).

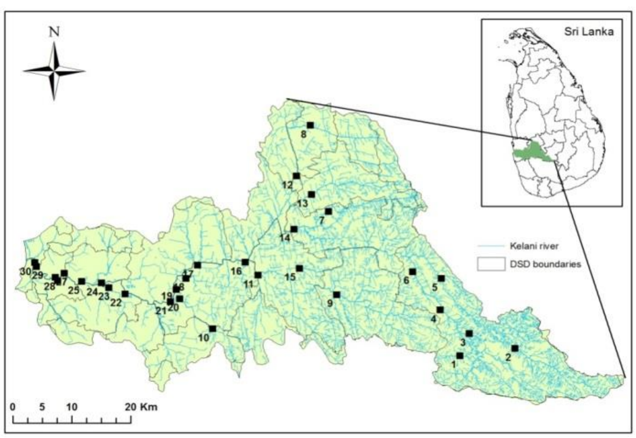

Fig. 1 Ground water sampling locations in the Kelani river basin during the study

ISSN: 2455-6939

Volume:02, Issue:05

Table 1 Sampling locations in the Kelani river basin

No	Location	No	Location	No	Location
1	Wana male	11	Thaligama	21	Pollaththawela
2	Norwood	12	Kotiyakumbura	22	Ranala
3	Lakham	13	Warawala	23	Pahalabomiriya
4	Koththellena	14	Kabulumulla	24	Biyagama
5	Kalaweldeniya	15	Kahanavita	25	Bollagala
6	Bokarabevila	16	Kudagama	26	Kohilawaththa
7	Malalpola	17	Kananpella	27	Kelaniya
8	Pitagaldeniya	18	Akarawita	28	Pilapitiya
9	Deraniyagala	19	Kahatapitiya	29	Paliyagoda
10	Waga	20	Kaluaggala	30	Aliwaththa

2.2 Sampling

Monthly sampling was carried out for thirty groundwater sampling locations including head, transitional and meandering region of the river basin from October 2012 to September 2013 (**Fig. 1; Table 1**). Pre-cleaned polypropylene bottles and sterile glass bottles were used to collect water samples for chemical and microbial analysis respectively (Bartram etal., 1996). Water samples were transported to the laboratory in the cold box within 10 hours after collection and stored under cold room condition. Microbial analysis was done within one day after collection and chemical analysis was carried out within two days of sampling. The GPS coordinates were recorded by GPS (Hand-held Garmin eTrex 30 GPS receiver).

2.3 Water quality analysis

Standard methods were followed during sample collection, preservation and analysis for all water quality parameters [21)]. Water temperature, pH and Dissolved Oxygen (DO) were measured using HQD portable multi meter (HACH - HQ 40D) and Total Dissolved Solids (TDS), Electrical Conductivity (EC) and salinity were measured using the portable conductivity meter (HACH – Sension EC5) at the site itself. Chemical Oxygen Demand (COD) was determined by using closed reflux method where nitrite, nitrates and total phosphate (TP) concentrations were measured by Spectrophotometric (Spectro UV-VIS Double UVD 2960) methods (APHA, 1999). Total hardness was determined by titrimetric method with EDTA and Biochemical Oxygen Demand (BOD5) was measured using Winkler method. Microbiological quality (Total Coliform

ISSN: 2455-6939

Volume:02, Issue:05

(TC) and Feacal Coliform (FC)) was determined by the standard Most Probable Number (MPN) method (APHA, 1999). Atomic Absorption Spectrophotometric method (Thermo scientific iCE 3000 series, graphite furnace) was used to analyze heavy metals in the water samples. Six metals; Pd, Cd, Cr, Cu, Zn, Al were analyzed for the study (Yahaya et al., 2012).

2.4 Theoretical Summary of the CCME Water Quality Index

The detailed formulation of the WQI, as described in the Canadian Water Quality Index 1.0 – Technical report (CCME, 2001), is as follows:

F_1 (Scope) represents the percentage of parameters that not within the guideline

$$F_1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right] \times 100$$

F_2 (Frequency) signifies the percentage of individual tests within each parameter that exceeded the guideline

$$F_2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right] \times 100$$

F_3 (Amplitude) represents the extent (excursion) to which the failed test exceeds the guideline. This is calculated in three stages where first is the excursion; the number of times by which an individual concentration is greater than the objective is termed an “excursion” and is expressed as follows.

When the test value must not exceed the objective:

$$\text{Excursion} = \left[\frac{\text{Failed test value}}{\text{Guideline value}} \right] -1$$

For the cases in which the test value must not fall below the objective, the equation is followed;

$$\text{Excursion} = \left[\frac{\text{Guideline value}}{\text{Failed test value}} \right] -1$$

Then, the normalized sum of excursions (*nse*) is calculated as follows;

ISSN: 2455-6939

Volume:02, Issue:05

$$nse = \frac{\sum_{i=1}^{n} \text{Excursion}}{\text{Number of tests}}$$

F_3 is then calculated using a formula that scales the *nse* to range between 1 and 100:

$$F_3 = \left[\frac{nse}{0.01nse + 0.01} \right]$$

Once the factors have been obtained, the index itself could be calculated by summing the three factors as if they were courses. The sum of the squares of each factor is therefore equal to the square of the index. This method gives the index as a three-dimensional space defined by each factor along one axis. With this model, the index varies in direct proportion to changes in all three factors.

The CCME Water Quality Index (CCME WQI):

$$\text{CCME WQI} = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right]$$

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality. According to the CCME WQI water quality was ranked in the following 5 categories:

Excellent: (CCME WQI Value 95-100) ; Water quality fulfill all criteria for use as a source of drinking water, conditions very close to pristine levels.
Good: (CCME WQI Value 80-94) ;Water quality rarely disturbs criteria for use as a source of drinking water, conditions rarely depart from natural levels.
Fair: (CCME WQI Value 65-79) ;Water quality sometimes violates criteria, possibly by a wide margin, for use as a source of drinking water conditions sometimes depart from desirable levels.
Marginal: (CCME WQI Value 45-64) ;Water quality often violates criteria for use as a source of drinking water by a considerable margin, conditions often depart from natural levels.

Poor: (CCME WQI Value 0-44) ;Water quality does not meet any criteria for use as a source of drinking water, conditions usually depart from natural or desirable levels.

ISSN: 2455-6939

Volume:02, Issue:05

Table 2.Guideline values for drinking, irrigation and livestock (SLSI, 1983; WHO, 2004; Alam et al., 2007; Canadian environmental water quality guidelines, 1999).

Parameters	Drinking		Irrigation		Livestock
	Lower	Upper	Lower	Upper	Upper
FC (MPN value)		0		100	
TC (MPN value)		0		1000	
Conductivity (µS/cm)		750			
Hardness (mg/L)		250			
pH	7	8.5			
TDS (mg/L)		600	500	3500	3000
BOD (mg/L)		2			
TP (µg/L)		2000			
Nitrate (mg/L)		10			100
Nitrite (µg/L)		10			10000
COD (mg/L)		10			
Cd (µg/L)		3		5.1	80
Pb (µg/L)		10		200	100
Cu (µg/L)		50		1000	5000
Cr (µg/L)		50		100	
Al (µg/L)		100		5000	5000
Zn (µg/L)		5000	1000	5000	5000
DO (mg/L)	6				

Large numbers of data sets on the large number of water quality variables calculation is difficult to be carried out. Therefore, the computation of WQI software was developed by using Microsoft Excel and its simple method to analyze CCME WQI values. Therefore, Calculator Version 1.0 (CCME, 2001) was used for index value calculations.

Thirty ground water sampling locations and their variables were computed to calculate CCME WQIs in the Kelani river basin to determine suitability of water for drinking, irrigation and livestock purposes. Drinking water category was based on the Sri Lankan Standards for drinking water guidelines SLS 614/1983 (SLSI, 1983) and World health organization guidelines (WHO, 2004). Drinking water category based on eighteen water quality parameters namely pH value, Total Dissolved Solids, Total phosphate, Nitrite, Nitrate, Hardness, Conductivity, BOD, COD, DO, Al, Cd, Zn, Cu, Pb, Cr, total coliform and feacal coliform counts. Irrigation and livestock variables were based on the Canadian Water Quality Guidelines (CWQGs) (CCME, 2001). Nine water quality parameters; Cd, Al, Zn, Pb, Cr ,Cu, TDS, total coliform and feacal coliform were considered for irrigation water quality and eight parameters namely nitrite, TDS, nitrates, Al, Zn, Pb, Cd and Cu were considered for livestock water quality (**Table2**).

3. RESULTS AND DISCUSSION

pH is one of the most important water quality parameters that describes ground water quality, because pH largely controls the amount of chemicals form of organic and inorganic compounds in ground water. Lowest pH value was recorded at Kaluaggala (3.85) whereas the highest was detected from Aliwaththa sampling location (7.89). Most of the sampling locations of the river basin showed low pH values ranged between 3.85 to 5.5. Electrical conductivity of water is a direct function of its total dissolved ions. Therefore, it is an index to represent the total concentration of soluble salts in water (Harilal et al., 2004). Conductivity, TDS and hardness were ranged between 20.30 to 917.00 µs/cm, 8.33 to 596.05 ppm and 2.00 to 206.66 ppm respectively. Highest conductivity was recorded in Aliwaththa sampling point (917 µs/cm) where the highest hardness value was recorded at Kelaniya (206.66 ppm) sampling point. Primary sources for conductivity and TDS may due to land use practices, residential runoff and point source water pollution discharge from industries (Mahagamage and Manage, 2014). COD and BOD values were varying between 1.33 to 307.28 ppm and 0.1 to 10.19 ppm respectively. Koththellena showed the highest COD value while Aliwaththa sampling point had the highest BOD value. Later part of the Kelani river basin showed high BOD values. Direct discharges of untreated domestic waste and small scale industrial waste water into the river basin will enhance the BOD and COD concentrations in water (Mahagamage et al., 2014; Wijegunawardene, 1995; Lagerblad, 2010). The lowest DO was found at Aliwaththa sampling point (0.80 ppm), may due to high BOD and COD values which are consumed DO for microbial degradations and chemical

ISSN: 2455-6939

Volume:02, Issue:05

reactions in the water column. This also may indicate faecal contamination or amount of dissolved organic carbon in water through anthropological activities and animal sources that can deteriorate ground water (International Standards Organization, 1989). Nitrate, nitrite and phosphate concentrations were ranged between 0.10 to 41.48 ppm, <0.001 to 0.04 ppm and <0.01 to 0.344 ppm respectively. Highest values of nitrate and nitrite were recorded from the later part of the river basin and those values exceeded the SLS guideline values. All most all the sampling locations were contaminated with both total and fecal coliform bacteria during the study period, although this may not cause illness and it can be used as one of the indicators of pathogenic contamination which can cause diseases such as intestinal infections, hepatitis, typhoid fever and cholera (Emmanuel et al., 2009). Pb, Cr, Cu, Zn, Cd and Al metals were recorded within the standards given for drinking water by SLS except Al. The concentrations of heavy metals range between Cd- <0.02- 0.92 ppb; Pb- <0.50-7.15 ppb; Cu- 0.18-21.25 ppb; Cr- <0.025-4.044 ppb, Al- 22.00-264.67 ppb and Zn- 2.98-858.62 ppb respectively.

Table 3.WQI values and rankings for Kelani river basin.

		Drinking		Irrigation		Livestock	
No	Location	CWQI	Category	CWQI	Category	CWQI	Category
1	Wana male	37	Poor	41	Poor	100	Excellent
2	Norwood	40	Poor	44	Poor	100	Excellent
3	Lakham	37	Poor	43	Poor	100	Excellent
4	Koththellena	64	Marginal	75	Fair	100	Excellent
5	Kalaweldeniya	39	Poor	43	Poor	100	Excellent
6	Bokarabevila	38	Poor	43	Poor	100	Excellent
7	Malalpola	37	Poor	40	Poor	100	Excellent
8	Pitagaldeniya	36	Poor	40	Poor	100	Excellent
9	Deraniyagala	37	Poor	40	Poor	100	Excellent
10	Waga	38	Poor	42	Poor	100	Excellent
11	Thaligama	38	Poor	40	Poor	100	Excellent
12	Kotiyakumbura	37	Poor	42	Poor	100	Excellent
13	Warawala	38	Poor	43	Poor	100	Excellent
14	Kabulumulla	64	Marginal	73	Fair	100	Excellent
15	Kahanawita	38	Poor	41	Poor	100	Excellent
16	Kudagama	38	Poor	44	Poor	100	Excellent
17	Kanampella	40	Poor	44	Poor	100	Excellent
18	Akarawita	51	Marginal	65	Fair	100	Excellent
19	Kahatapitiya	39	Poor	46	Marginal	100	Excellent

ISSN: 2455-6939

Volume:02, Issue:05

20	Kaluaggala	41	Poor	51	Marginal	100	Excellent
21	Pollaththawela	35	Poor	41	Poor	100	Excellent
22	Ranala	47	Marginal	53	Marginal	100	Excellent
23	Pahalabomariya	42	Poor	54	Marginal	100	Excellent
24	Biyagama	36	Poor	38	Poor	100	Excellent
25	Bollagala	37	Poor	41	Poor	100	Excellent
26	Kohilawaththa	36	Poor	38	Poor	100	Excellent
27	Kelaniya	35	Poor	37	Poor	100	Excellent
28	Pilapitiya	32	Poor	38	Poor	100	Excellent
29	Paliyagoda	36	Poor	40	Poor	100	Excellent
30	Aliwaththa	36	Poor	39	Poor	100	Excellent

The indices have been mainly developed to reveal changes in the physicochemical and biological quality of ground water for drinking purposes. However, indices are mainly use for giving overall idea about the water quality that can be easily understood by the public. CCME WQI values revealed that average values for Kelani river basin by considering all the sampling locations, it was revealed drinking, irrigation and livestock were 33, 37 and 100 respectively. Parameters like fecal coliform, total coliform, pH, BOD, COD and DO are having considerable weight for many water quality indices use in worldwide thus the Kelani river basin exceed the SLS or WHO guideline values for those parameters. Therefore, average index value was revealed the Kelani river basin ground water is poor for drinking purposes. Canadian water quality guideline expressed that Zn and TDS in water is important for irrigation and that should be high in quantity. However, ground water in Kelani river basin has low concentration of these two chemical parameters and CCME WQI was given low values for irrigation purposes. For livestock all selected water quality parameters were met with guideline values and WQI indicated as excellent for livestock purposes.

Wanamale and Lakham sampling points are springs which are located in the head region surrounded with tea state. During the rainy season fertilizers, pesticides mix with rain water and leach through the soil in to the aquifer. It has been observed improper construction of toilet pits nearby in the same sampling locations of the river basin enhance contamination of ground water by fecal coliform as well. Therefore WQI revealed majority of ground water sampling locations were not suitable for drinking. Norwood sampling location is a dug well which is using for drinking purposes though the distance between well and toilet pit was less than 20 feet. The fecal coliform count was detected as greater than 1100 where WQI was ranked as poor. Koththellena is located in bottom of the seven hills, it's also a spring and nearly 300 houses use this water for their daily consumption. Koththellena surrounded with tea cultivation and during the study period this open spring was contaminated with fertilizers thus recorded high COD and Zn values.

ISSN: 2455-6939

Volume:02, Issue:05

It is the only location ranked as marginal in head region. Bokarabewila, Pitagaldeniya, Deraniyagala and Waga locations were indicated as poor because of the total and fecal coliform contamination. Thaligama, Kotiyakumbura, Warawala and Kabulumulla sampling locations use for drinking purposes but all these locations were showed high COD and microbial contamination throughout the study period. Further, Kahanawita and Kudagama locations located in the transitional zone ranked as poor. Akarawita sampling location ranked as marginal for drinking and fair for irrigation. Kanampella location is a public well surrounded with paddy field and it was contaminated with fecal and total coliform bacteria. Kaluaggala was recorded the lowest pH value (3.85) and the highest Al concentration thus WQI was indicated poor for drinking as well as irrigation. Low pH values aggregate solubility of Al in the water (Xinchao et al., 2005) and therefore, high Al concentrations were recorded in transitional region of the basin which showed low pH values. Pollaththawela and Biyagama locations were poor for drinking where Ranala location was marginal for both drinking and irrigation. Aliwaththa public well ranked as poor for drinking due to high values of pH, BOD, COD, Conductivity, TDS, total and feacal coliform bacteria. It's located in the most popularized and industrialized area in Colombo district and nearly 300 people who living in this area and use this ground water source for their day today activities. All the other sampling locations in the later part of the river basin also indicated as poor for drinking and irrigation due to high concentrations of pollutants in water (**Table 3**).

4. CONCLUSION

Transitional zone of the river basin showed low pH values and all most all the sampling locations in the river basin was contaminated with total and feacal coliform bacteria. Conductivity, TDS, Hardness and BOD showed increasing tendency towards the downstream of the basin. CCME WQI revealed that four sampling locations were in marginal rank and others were poor for drinking purpose since most of the locations not within the drinking water quality standards such as COD, pH, total coliform, feacal coliform, BOD, Al and DO. Three sampling locations were fair, four locations marginal and others were poor for irrigation because irrigation water should content high level of TDS and Zn where most of locations were not fulfilled that requirement. All the sampling locations were ranked as excellent for livestock purposes. The analysis reveals that the groundwater of the Kelani river basin needs some point of treatment before drinking and should aware about the chemical contaminations within the basin from anthropological activities, land use practices and industrial discharges.

ISSN: 2455-6939

Volume:02, Issue:05

ACKNOWLEDGMENT

This study was financially supported by National Science Foundation (NSF) Sri Lanka under the grant number NSF/RG/2011/ES/02. Logistic support for the project was provided by the University of Sri Jayewardenepura.

REFERENCES

1. Al-Janabi, Z. Z., Kubaisi, A. R. and Jwad Al-Obaidy, A. M.(2012): Assessment of Water Quality of Tigris River by using Water Quality Index (CCME -WQI), *Journal of Al-Nahrain University*, 15 , 1: 119-126.
2. Alam, M.J.B., Islam, M.R., Muyen, Z., Mamun, M. and Islam, S.(2007): Water quality parameters along rivers, *International Journal of Environmental Science and Technology*. **4**, 1: 159-167.
3. APHA.(1999): Standard Methods for the Examination of Water and Wastewater. 20th edition, American Public Health Association (APHA), *American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF)*.
4. Bartram, J., Mäkelä. and Mälkki, E.(1996):Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes, *United Nations Environment Programme and the World Health Organization*.
5. Canadian Council of Ministers of the Environment (CCME).(2001): Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0, *Technical Report, Canadian Council of Ministers of the environment*.
6. Canadian environmental quality guidelines.(1999):*Canadian Council of Ministers of the Environment*.
7. Cash, K. J., Saffran, K. A. and Wright, C. R.(2001): Application of Canadian Water Quality Index (CWQI) to PPWB Monitoring Program, *Technical Report, CCME*.
8. Chilton, J.(1996): Ground water, Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring, *UNESCO/WHO*.
9. Danish Hydraulic Institue.(1999):Kelani Ganga basin detailed basin assessment, working document C."Earthtrends" 2003, *Water Resources and Freshwater Ecosystems Country Profile Sri Lanka*.
10. Emmanuel, E., Pierre, M.G. and Perrodin, Y.(2009): Groundwater contamination by microbiological and chemical substances released from hospital wastewater and health risk assessment for drinking water consumers, *Journal of Environmental Science*. 35: 718-726.

ISSN: 2455-6939

Volume:02, Issue:05

11. Giriyappanavar, B.S. and patil, R.R.(2013): Application of CCME WQI in Assessing Water Quality for Fort Lake of Belgaum, Karnataka, *Indian Journal of Applied Research*, **3**, 4: 32-33.

12. Harilal, C. C., Hashim, A., Arun, P. R. and Baji, S.(2004):Hydrogeochemistry of two rivers of Kerala with special reference to drinking water quality, *Journal of Ecology, Environment and Conservation*, **10**, 2: 187–192.

13. Helena, B., Pardo, R., Vega, M., Barrado, E., Fernandez, J. M. and Fernandez, L.(2000): Temporal Evolution Of Groundwater Composition In An Alluvial Aquifer (Pisuerga River, Spain) By Principal Component Analysis, *A Journal of the International Water Association*, **34**, 3: 807-816.

14. Husain, T.(2001): Canadian Water Quality Index Determination for Three EMAN Sites, *Ecological Monitoring and Assessment Network*.

15. Institute for Global Environmental Strategies (IGES).(2007):*Freshwater Resources Management Project*, 3:112.

16. International Standards Organization.(1989): Water Quality Determination of Biochemical Oxygen Demand after Five Days (BOD5). *ISO 5815*.

17. Lagerblad, L.(2010): Wastewater treatment wetlands-case study in Colombo, Sri Lanka, *Uppsala University*.

18. Lumb, A., Halliwell, D. and Sharma, T.(2002): Canadian Water Quality Index (CWQI) to Monitor the Changes in Water Quality in the Mackenzie River–Great Bear, *Proceedings of the 29thAnnual Aquatic Toxicity Workshop*.

19. Lumb, A., Halliwell, D. and Sharma, T.(2006):Application of CCME Water Quality Index To Monitor Water Quality: A Case of the MackenzieRiver Basin, Canada, *Environmental Monitoring and Assessment*, **113**:411–429.

20. Mahagamage, M.G.Y.L. and Manage, P.M.(2014):Water Quality Index (CCME-WQI) Based Assessment Study Of Water Quality In Kelani River Basin, Sri Lanka, *International Journal of Environment and natural resources*, **1**: 199-204.

21. Mahagamage, M.G.Y.L., Chinthaka, S.D.M. and Manage, P.M.(2015): Multivariate analysis of physico-chemical and microbial parameters of surface water in Kelani river basin, *International Journal in Multidisciplinary Studies* (IJMS), **1:** 55-61.

22. Mahagamage, M.G.Y.L. and Manage, P.M.(2015): Mapping spatial distribution of water quality parameters using GIS in groundwater of the Kelani river basin, Sri Lanka, *Proceedings of Academics World 12th International Conference:*10-14.

23. Munna, G. M., Chowdhury, M. M. I., Ahmed, A. A., Chowdhury, S. and Alom, M. M.(2013): A Canadian Water Quality Guideline-Water Quality Index (CCME-WQI) based assessment study of water quality in Surma River, *Journal of Civil Engineering and Construction Technology*, **4**, 3: 81-89.

ISSN: 2455-6939

Volume:02, Issue:05

24. Panabokke, C. R. and Perera, A.P.G.R.L.(2005): Groundwater Resources Of Sri Lanka, *Water Resources Board Sri Lanka*.

25. Paterson, R., Khan, A. Ali. and Khan, H.(2003):*Proceedings of the 30th Annual Aquatic Toxicity Workshop*.

26. Salim, B.J., Gholamreza, N.B., Amir, S., Masoud, T. and Mojtaba, A.(2009): Water Quality Assessment of Gheshlagh River Using Water Quality Indices, Environmental *Science*, **6**, 4: 19- 28.

27. Sri Lanka Standards Institution.(1983): Specification for Potable Water, *SLSI*.

28. Sri Lanka Standards Institution.2013: Specification for Potable Water, Colombo: *SLSI*.

29. WHO.(2004): Guidelines for Drinking-water Quality. **3**, 1: *Recommendations. World Health Organisation*.

30. Wijegunawardene, P. M. K.(1995): Accumulation of Chromium in two species of fish from Kelaniya Estuary, *M. Phil Thesis*.

31. Xinchao, W., Roger, C., Viadero, J. and Karen, M.(2005): Recovery of Iron and Alluminium from Acid Mine Drainage by Selective Precipitation. *Journal of Environmental Engineering Science*, 22: 745-755.

32. Yahaya, A., Adegbe, A. A. and Emurotu, J. E.(2012): Assessment of heavy metal content in the surface water of Oke-Afa Canal Isolo Lagos, Nigeria, *Archives of Applied Science Research*, **4**, 6 : 2322-2326.

