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Assessment of Physical-Chemical surface water quality variation across the wetlands of Metropolitan Colombo

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ABSTRACT

Surface water pollution has been increased due to various activities such as urbanization industrialization, agricultural activities and various anthropogenic activities. Standardized limitations in the water quality parameters for irrigation and drinking purposes such as pH, Electrical Conductivity, Calcium, Magnesium, Total Dissolved Solid, Total suspended solid , Alkalinity, Sodium Potassium, Nitrate and DO should be monitored for drinking and irrigation purposes. In order to assess water quality in canals through a large water quality monitoring network , chemical characteristics and pollution amount were assessed in Wetland surface water, to understand actual water quality variation across the wetlands of Metropolitan Colombo Thirty five water quality monitoring locations across the surface drainage network systems were selected and samples were collected.. Based on PCA analysis, two profiles could be identified. Profile 1 consisted in, Variables Positively correlated to axis PC1 and PC2 (BOD, COD. Phosphate, DO, Ammonia, EC, TDS and Salinity). Profile 2 consisted in variables positively correlated to PC1 and negatively correlated to PC2 (TSS and Nitrate.) Water quality of wetlands of Metropolitan Colombo is not in good condition for irrigation purposes; all the studied chemical parameters showed that the water quality at all of the monitoring stations is unsuitable for drinking and irrigation because of the high levels of pollutants.

1. Introduction

The pollution in surface water has been increased by various activities like urbanization, industrialization, agricultural activities and various anthropogenic activities. In order to use them for drinking purposes as well as for irrigation purposes there are standardized limitations in the water quality parameters such as pH, Electrical Conductivity, Calcium, Magnesium, Total Dissolved Solids, Total suspended solids , Alkalinity, Sodium, Potassium, Nitrate and DO . The quality of water is an important concern as it directly affects the human welfare. In many developing countries, water borne diseases and epidemics are very common due to polluted water.

Even though water is the most widely spread and most abundant natural resource, 97% of that water belongs to sea water, which is unable to be used for human needs. Out of remaining 3%, about 2% of water remains as glaciers where only 1% of water is available to be utilized by human and other living beings (WHO, 2004).

For considerable years, human have been contributing in polluting and destroying this 1% of water by many activities as disposing solid waste, discharging industrial effluents directly to streams and contaminated surface runoff. A common reason for water contamination is disposal of solid waste, sludge manure and industrial wastes in to land. Water soluble substances are being carried out to streams and other water bodies during precipitation. Numerous compounds in this runoff water quickly get attached to fine grained sediments such as clay slit particles and organic matter.

Water quality parameters can be categorized as Physical, Chemical and Biological parameters. Physical parameters are temperature, color, odor, turbidity, sediment and bed material, and suspended sediments (1). Chemical parameters include mainly major and minor elements such as nutrients (i.e Phosphorus and Nitrogen) and heavy metals, Dissolved Oxygen (DO), pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), oil and grease etc. Biological parameters include Bacteria (Fecal Coli-form, *E. coli*), algae, Parasites, Phytoplankton etc.

Chemical characteristics of water provide an image of soils and the rocks that water has been in contact. Other than that agricultural activities, municipal treated waste water, urban runoff also affect these water quality chemical parameters. (2)

Colombo is situated in the Western Province of Sri Lanka along the coast at approximately North latitude 6˚ 6’ 56” and East longitude 79˚ 19’ 51”. Colombo city consist of dense population of approximately 752,993 (Sri Lanka population and housing statistics 2015) and Colombo is the main commercial hub in Sri Lanka. There is a complex network of canals and marshes which are interconnected in this low lying area and they play a major role in control of flood. When concerning the Colombo canal system, quality of the water of those canals is utmost important for the health and wellbeing of the large population who inhabit the immediate environs of the canals. Furthermore, it’s also an indicator of measuring the ecosystem health of the canals and the aesthetics of the region. However the water quality of most of the canals in the Colombo area are at highly degraded level due to industrial waste effluents, solid waste and pollution from domestic waste water.

The purpose of this study is to assess water quality in canals through a large water quality monitoring network in order to know chemical characteristics and pollution level, , to understand water quality variation across the wetlands of Metropolitan Colombo and, Using previous results, trying to improve the monitoring to achieve a better real time understanding of the situation by an appropriate management.

2. Materials and Methods

2.1 Description of sampling sites

Thirty five (35) water quality monitoring locations across the surface drainage network in in Colombo Metropolitan Region (CMR) were selected and samples were collected. The precise monitoring locations across the surface water drainage system were selected considering Topology, Stream order, Stagnant flow rate, Inflows and Outflows of Lake, Depth of water bodies, Direction of surface water flow, Distance from water body, Adjacent land use, Potential pollution risks, Geological and hydrological characteristics and vegetation of the area.

Monthly samples have been collected from all thirty five locations for laboratory chemical analysis. Samples were collected both during the rainy and dry season. Each sample was collected at mid- depth of the water body, stored in clean sampling bottles and kept cool during transportation to the laboratory. Analyses were conducted at an accredited laboratory using standard analytical techniques.

Parameters: Total suspended solids, Ammonia, Nitrate (as N), Phosphate, BOD, COD.

During sampling field data were recorded on a standardized monitoring sheet. Any features or activities which could influence water quality were recorded, such as presence of litter, influent discharge, and morphological disturbance to the channel or substrate or watercourse management activities such as removal of invasive species. A GPS coordinate was taken for each sampling site.

3. Results and Discussion

3.1 Physical and Chemical parameters.

The results of chemical and Physical parameter analysis are as below. **Sri Lankan standards for surface water quality are attached in the appendix.**

3.1.1 pH

pH was the most stable parameter across the canal system. It ranged from 6.3 to 7.4 and can be considered to be non-problematic for aquatic life.

pH was very stable from one location to another, very stable within the water column, Very stable during the four –six sampling times. Maximum variation reached 1.4 in Kolonnawa Canal in the bottom layer. Area around Kolonnawa canal is highly populated. Accumulation of domestic effluents in the canal might have caused a higher value of pH. According to the Sri Lankan standards the pH for irrigation and agricultural purposes should be between 6.0 and 8.5. pH of all the locations were within this range.

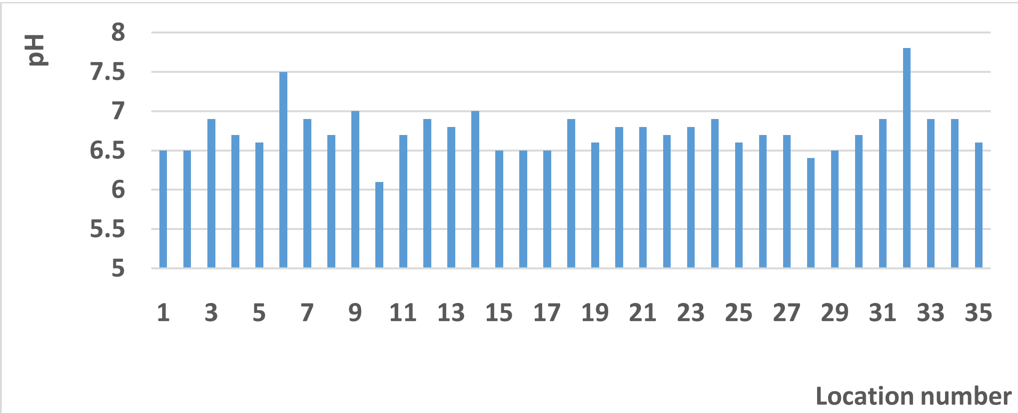


Figure 1 Variation of mean pHacross the sampling locations

2.2 Collection of samples

The monitoring involved a combination of in situ assessments using hand-held water quality meters and the collection of water samples for laboratory analysis.

- In situ water chemistry: For each canal or stream location, up to five in situ points were monitored to assess the cross sectional water quality variation. This includes points adjacent to two canal banks, at the surface, mid- depth and just above channel bed in the middle of the water course.This provides information of how water quality evolves.

Parameters: pH, Electrical conductivity, Salinity, Turbidity, Temperature, Dissolved oxygen.

Insitu monitoring was conducted monthly for a period of six months from April to August 2015.

- Laboratory water chemistry: single sample that provides a picture of the amount of pollution.
- EC ranges all over the stations between 76 .0µS/cm in Atunkedeniyamedaela and 4200.0 µS/cm in Dehiwala canal (bottom layer, 1.20m depth). Mean EC was 330.0 µS/cm but the median value was slightly lower in May and July and slightly higher in June and August correlated with more marine water upwelling. The Dehiwala canal contained conductivity from 255 to 4200 µS/cm. EC between 130.0 and 200.0 µS/cm was recorded in locations without saline influence. It is suitable for freshwater aquatic life. The EC values

within the CMR can be categorized into three as follows; low conductivity in North-West, medium conductivity in Kolonnawa area: and high conductivity and brackish water in Coastal North and South.. Sri Lankan standard of electrical Conductivity for Irrigation and Agriculture is 0.7 ds/cm.

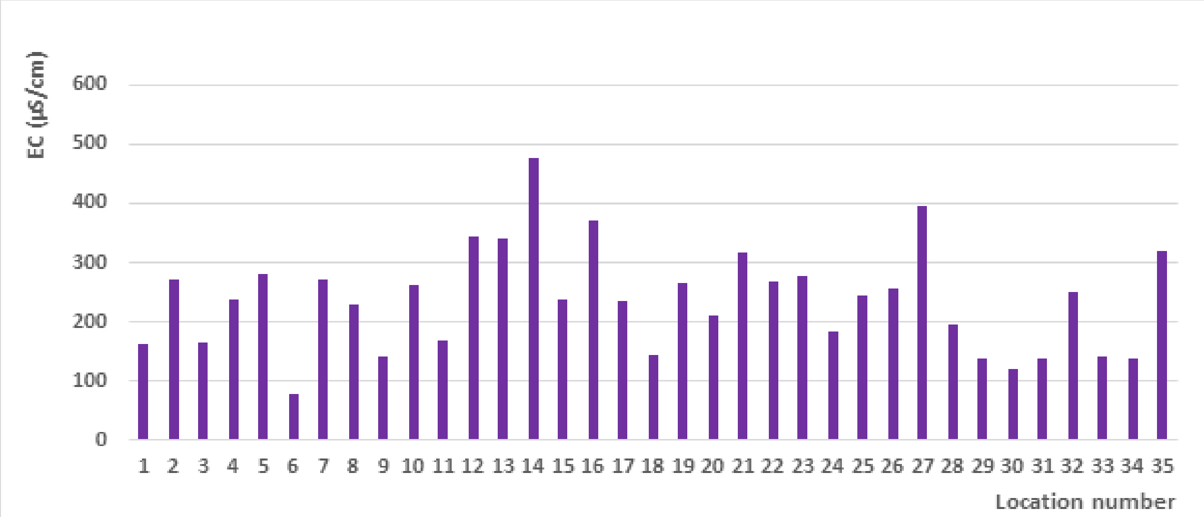


Figure 2. Variation of mean Electrical Conductivity across the sampling locations

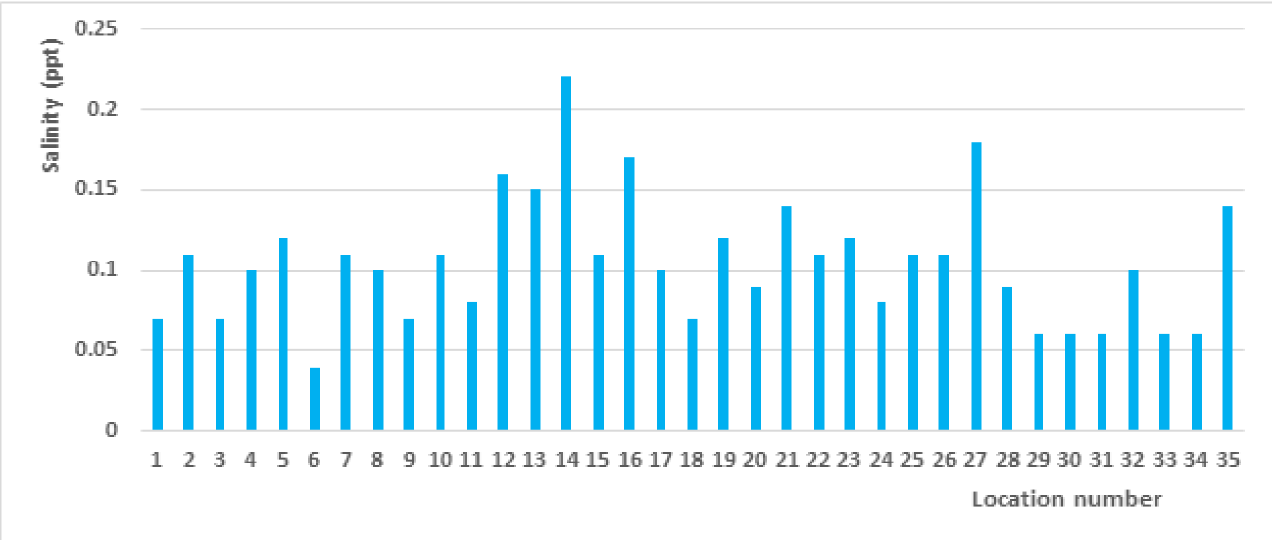


Figure 3 Variation of mean Salinity across the sampling locations

3.1.2 Electrical Conductivity (EC) and salinity

No stratification could be observed along the water column during May, July and August campaigns contrary to July campaign. Conductivity could be observed to increase with depth in Kottawa North canal, Kirulapone canal, Dehiwalacanal and Redbanaela Water flow highly contributes to this variation in the conductivity. With the depth, decrease in the flow rate facilitates sedimentation of minerals in the bottom which increase the EC in the bottom of the canal.

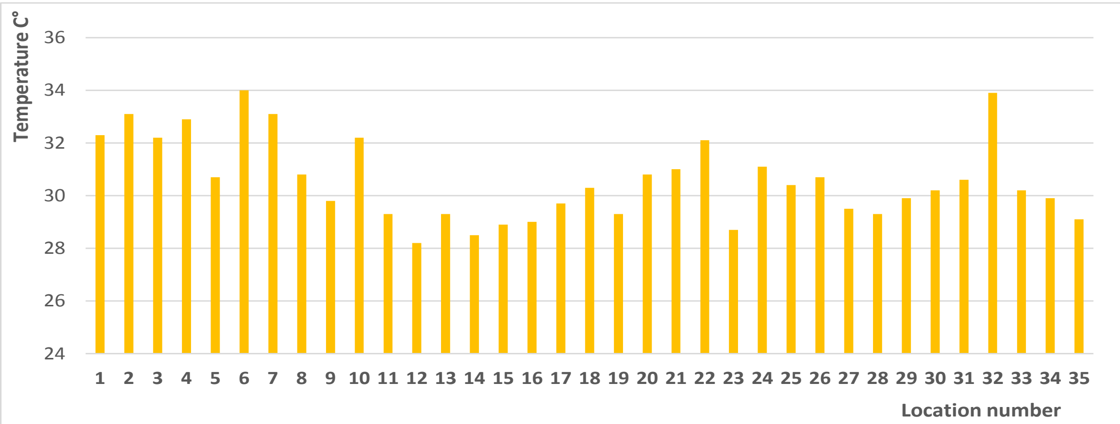


Figure 4 Variation of mean temperature across the sampling locations.

3.1.4 Dissolved Oxygen (DO)

Oxygen concentration in freshwater depends on temperature, gas exchange between water and air photosynthesis/respiration/decomposition phenomena and organic matter mineralization. Therefore, sampling time has a real impact on DO levels. The water quality data through the study period demonstrated a very good range of DO: the main stations were saturated (7.5 mg/l) with oxygen mainly in June and also throughout the sampling period except in August. DO levels recorded in May and July were slightly lower saturation (near 7 mg/l). Concentration among locations in the same campaign was homogenous (very low standard deviation) and it can be considered as fully compatible with the aquatic life. There were no permanent under saturated locations and no difference within the water column (only due to temperature variation creating over-saturated concentration in depth).

However, DO levels in following sampling locations are comparatively less. The reason could be comparatively high pollution levels.

Water inlet to Parliament Lake (St 4)-top layer DO 5.6 mg/l; Dammaladeniyamedaela (St 5)- top layer DO 5.6 mg/l; Dematagoda Canal (St 14)-DO 5.5 mg/l.

The lowest DO value was recorded in Dematagoda Canal (St 23) (DO =5.0 mg/l) this is a highly polluted area and this is a Very paradoxical situation: top and mid layer is relatively saline and over-saturated whereas bottom layer is under saturated and low conductivity.

Norris Canal (St 35): DO level is relatively low (5.3 mg/l) and this can be due to pollution add from adjacent hospital .and stagnated water in the canal.

Finding comparatively less DO values only during August campaign while other parameters remain relatively stable can be an indicator of chronic or seasonal pollution which would require further investigations.

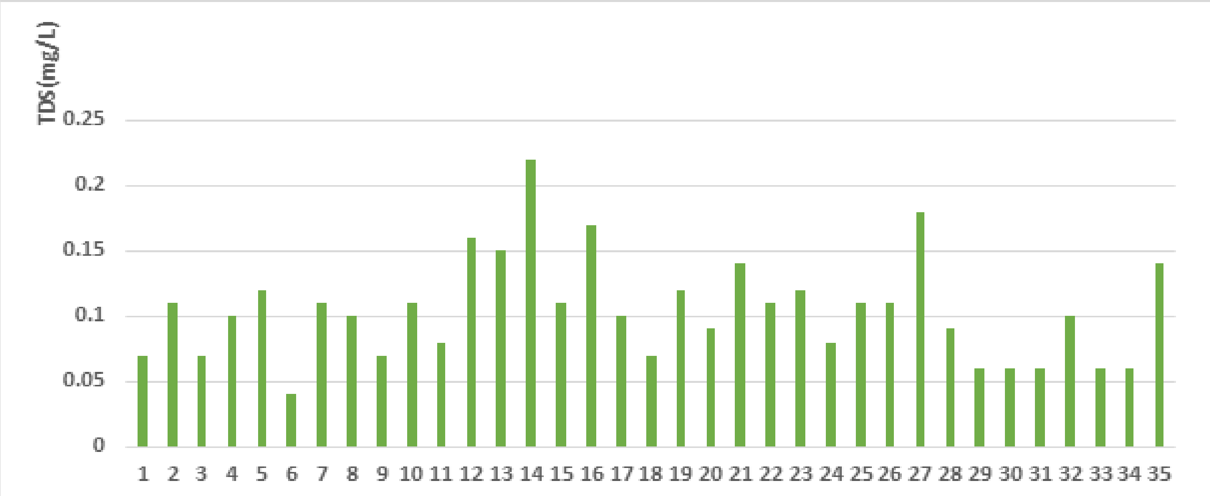


Figure 5 Variation of mean TDS across the sampling locations.

3.1.3 Temperature

The temperature is an unstable parameter and it remained in a range of 25.5 and 34°C. Uneven solar heating throughout the sample locations is the main reason for these variations. Temperature of water affect many other parameters such as pH, DO, Conductivity, oxidation and reduction potential and the density of water.

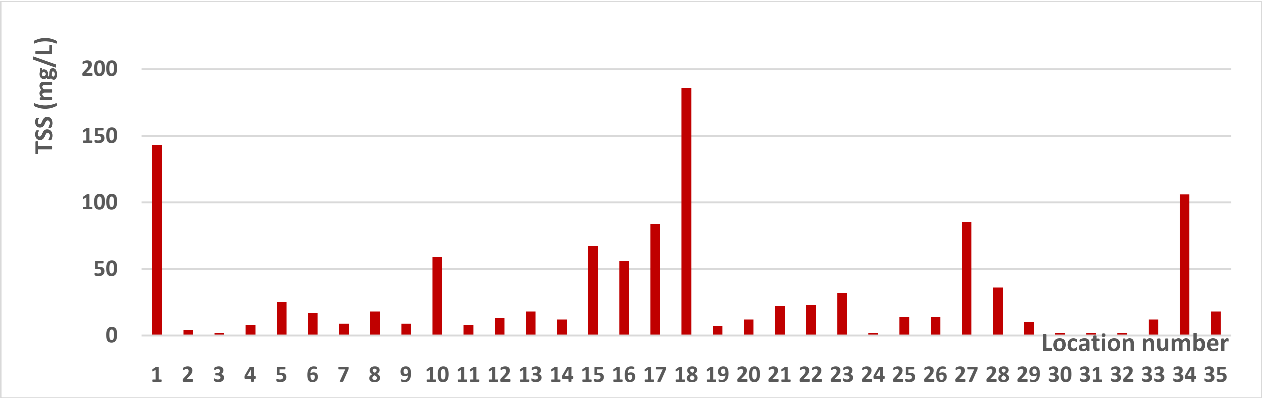


Figure 6 . Variation of mean TSS across the sampling locations.

3.1.5 Total Dissolved Solids (TDS)

TDS remained high during entire sampling period. The lowest value (28.9 mg/l) was recorded in Atunkedeniyamedaela in May.

TDS fluctuated as follows during the sample period: comparatively less in May and July (from 106.0 to 128.0 mg/l) and comparatively high in June and August (203.0 and 201.0 mg/l) showing a normal relationship with rainfall where surface runoff might have caused in increasing the TDS. However, it is interesting to notice that the median range from 100.0 to 125.0 mg/l. Only a few stations show a very high TDS values (more than 250.0 mg/l) correlated to high electrical conductivity levels (more than 500.0 µS/cm): Kolonnawa Canal (St 10) in August, Kittampahuwa canal (St 13) in June and July, Dematagoda Canal (St 14) from June to August, Dehiwala canal (St 22) in June and August, St. Sebastian Canal (St 25) in August and finally Redbanaela (St 27) from June to August. The station 22 and 27 are closer to the sea (it can be brackish water) and also potentially polluted, therefore, source of increased TDS levels is not easy to discriminate.

3.1.7 Biological Oxygen Demand (BOD)

DO is consumed by bacteria when large amounts of organic matter from sewage or other discharges are present in the water. Therefore, a low BOD is an indicator of good quality water, while a high BOD indicates polluted water. According to the results 5 stations were polluted and 3 stations were slightly polluted. Highest BOD values recorded in Kotte Marsh which indicated a higher TSS as well giving the idea that marsh can be highly polluted with domestic and industrial waste disposal.

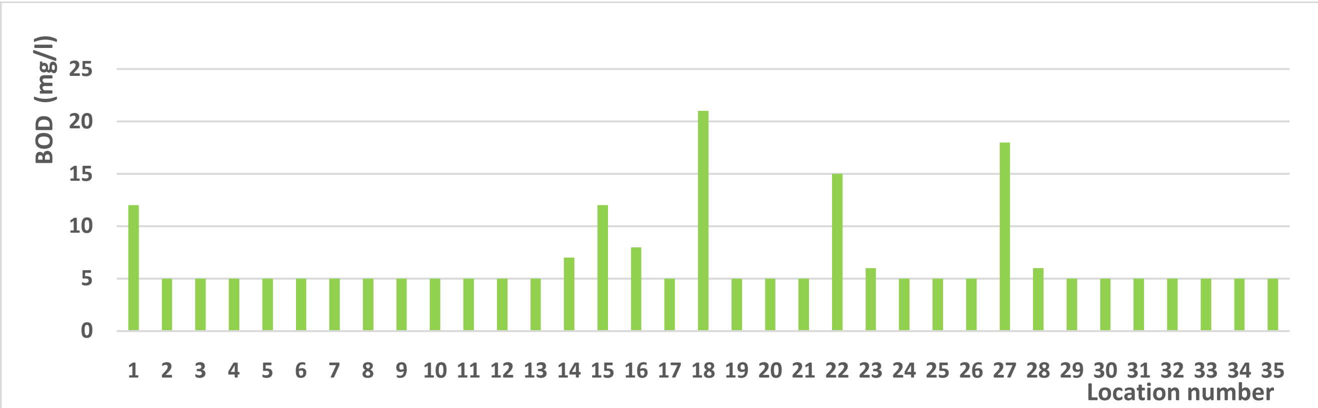


Figure 7.Variation of BOD across the sampling locations.

3.1.6 Total Suspended Solids (TSS)

This parameter shows a better situation than TDS, however 3 stations were heavily polluted and 5 stations were slightly polluted. Kotte Marsh shows the highest TSS values.High level of accumulation of domestic solid waste and wastewater disposal could be the reason for this high TSS concentration.

3.1.9 Free Ammonia

According to the results 43% of the stations presented a very bad score and 11% a bad score (more than 2.0 mg/l). Waste water and agricultural uses are the main potential sources of this pollution. Ammonia levels exceeding 2.0 mg/l can be toxic for aquatic life. Under normal oxygenated conditions Ammonia is not very stable and can become Nitrite or Nitrate.

3.1.10 Nitrate

In contrast to ammonia, nitrate levels recorded were very low for all sampling locations. It is a main paradoxical point because the nitrate is the stable form of nitrogen in water but in 50% of the stations ammonia is higher. Sri Lankan standard for Nitrate amount in irrigation water is 5.0 mg/L.

3.1.11 Phosphate

This parameter also highlights the pollution status of the monitoring stations: 23% are in bad or very bad situation and 23% are in medium status. Sri Lankan standard for – Phosphate amount in irrigation water is 0.7 mg/L.

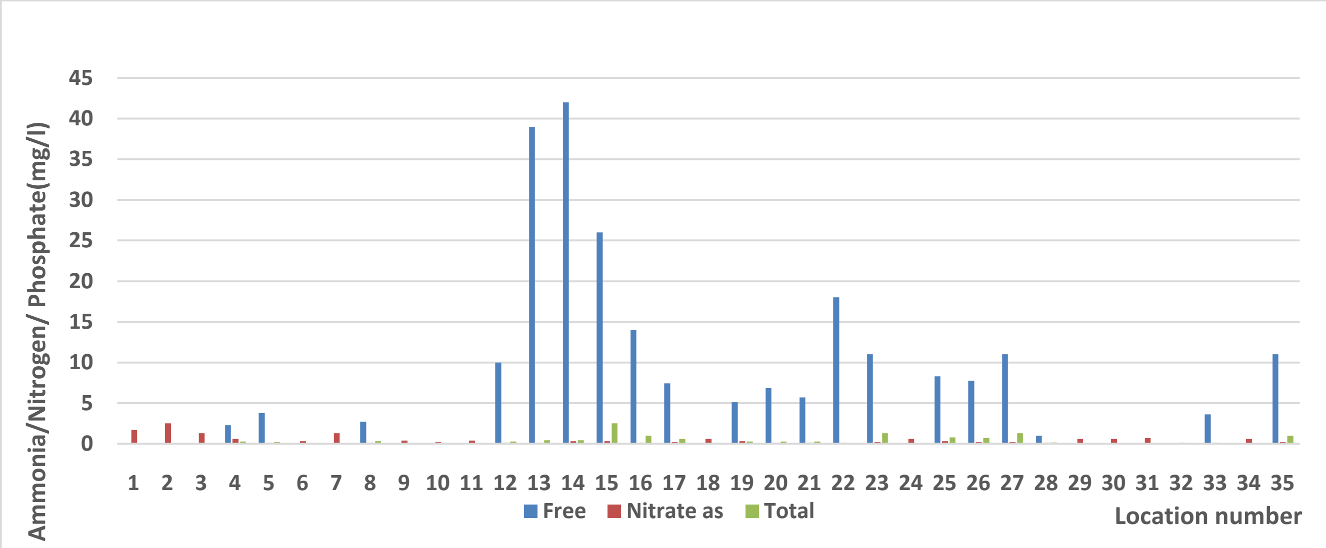


Figure 8. Variation of free Ammonia, Nitrogen and phosphate across the sample locations.

3.1.8 Chemical oxygen demand (COD)

COD is an indicative measure of the amount of oxygen that can be consumed to degrade both organic and inorganic matter in water by a strong chemicalIt could be observed COD of 30% of the sampling stations are in a bad or very bad status and 4 stations in a medium status.

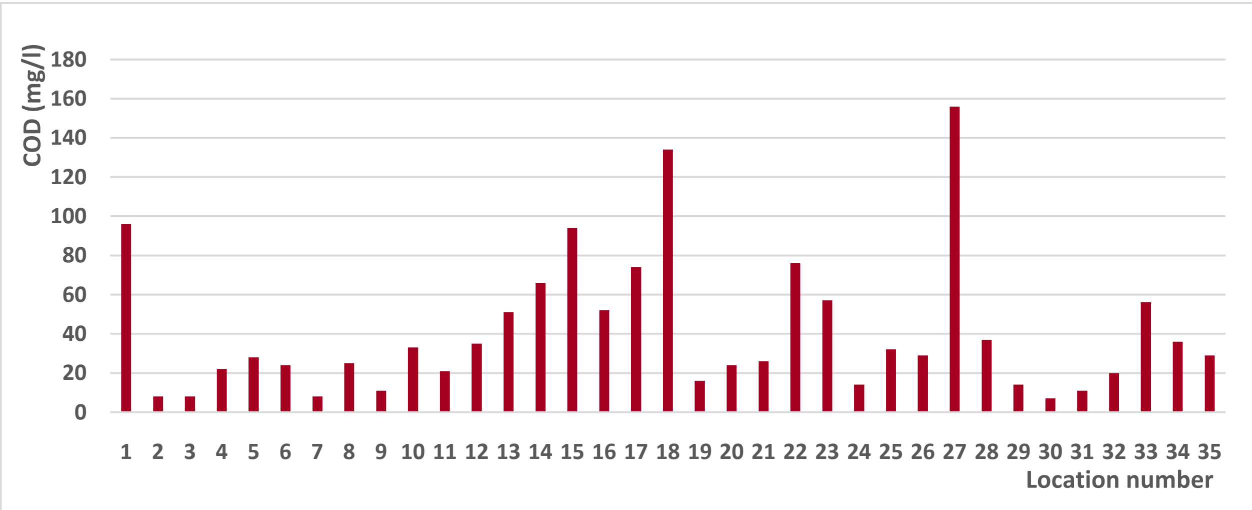


Figure 9. Variation of COD across the sampling locations.

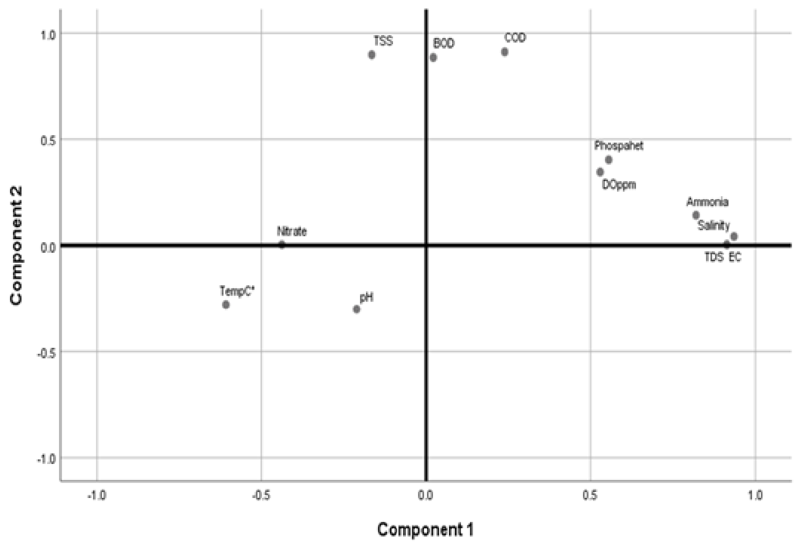


Figure 10 Distribution of Physical and Chemical water quality parameters with respect to the first and second principal component in the sample locations.

Table 2. Correlation between variables and axes as shown by Principal component analysis (PCA)

Rotated Component Matrix		
	PC1	PC2
pH	-.211	-.301
EC	.913	.004
Temp (C°)	-.608	-.279
DO (ppm)	.529	.345
Salinity	.936	.041
TDS	.913	.004
TSS	-.165	.897
BOD	.021	.884
COD	.239	.910
Ammonia	.820	.141
Nitrate	-.438	.004
Phosphate	.555	.402

According to the Pearson analysis at the probability of 0.05, EC and Phosphate, Temperature and Salinity, Salinity and DO, TDS and Phosphate, COD and Ammonia were significantly correlated whereas at the probability of 0.01, pH and DO, EC and salinity, EC and TDS, EC and ammonia, Temperature and Ammonia, Temperature and Nitrate, Temperature and Phosphate, Temperature and DO, Salinity and EC, Salinity and TDS, Salinity and Ammonia, Salinity and Phosphate, Salinity and DO, TDS and Ammonia, TSS and BOD, TSS and COD, COD and BOD, COD and Phosphate, Phosphate and ammonia, DO and Ammonia are significantly correlated.

3.2 PCA profiles of correlation between different parameters

Using the Principal Component Analysis (PCA) Correlation between parameters was profiled. Figure 11 shows the correlation where all the water quality parameters are presented. The first and second principal component respectively explained 37.450% and 61.488% of the total inertia corresponding to total of 98.938%. Table 2 shows the value of the correlation between variables and axes shown by PCA.

Based on PCA analysis, in decreasing order Salinity, EC, TDS, Ammonia, Phosphate, DO, COD and BOD were positively correlated to PC1 whereas, Temperature, Nitrate, pH and TSS were negatively correlated. Compared with axis PC2, in decreasing order, COD, TSS, BOD, Phosphate, DO. Ammonia Salinity and Nitrate were positively correlated whereas; pH and temperature were negatively correlated.

Based on PCA analysis, two profiles could be identified. Profile 1 consisted in, Variables Positively correlated to axis PC1 and PC2 (BOD, COD. Phosphate, DO, Ammonia, EC, TDS and Salinity). Profile 2 consisted in variables positively correlated to PC1 and negatively correlated to PC2 (TSS and Nitrate.)

4. Conclusion

The sampling period does not cover an annual cycle, which should be the minimal length of time for accurate and reliable conclusions. Despite that, the relatively stable climate in Colombo allows some strategic lessons to be learnt. Based on this small dataset, It can be concluded Ammonia, Phosphorus and Total Dissolved Solids (TDS) are the main problematic parameters particularly in the lower part of CMR catchment. This can be due to increased population and comparatively less vegetation cover present in this area. The disposal of domestic wastewater into the canal network is the key issue in this area, which contributes to increased Ammonia, Phosphorous and TDS levels. In addition, industrial and agricultural pollution sources also contribute to the water pollution in this area at different scales.

Therefore, it is required to develop a long term sustainable plan for Colombo watershed for the pollution control and improve water quality.

5. Acknowledgement

This research paper was developed from the water quality study conducted for the Project “Preparation of a Management Strategy for Wetlands and Carrying out an Assessment of Water Quality in the Inland Waterways and Lakes within Metro Colombo Area” through World Bank funded Metro Colombo Urban Development Project and supervised by Sri Lanka Land Reclamation and Development Corporation (SLLRDC).

6. Appendix

6.1 Sampling locations

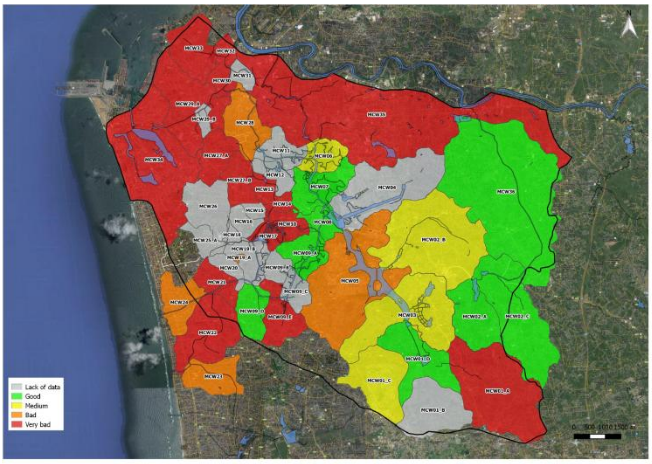
1	Canal at Kottawa North
2	Canal at Pathiragoda
3	Parliament lake
4	Water inlet to Parliament lake
5	Dammaladeniyamedaela
6	Atunkedeniyamedaela
7	Parliament lake
8	Kinda Canal
9	Kolonnawa Canal
10	Kolonnawa Canal
11	Kolonnawa Canal
12	Kittampahuwa canal
13	Kittampahuwa canal
14	Dematagoda Canal
15	Kolonnawa Marsh
16	Serpentine canal
17	Heen Ela Marsh
18	Kotte Marsh
19	Kotte Marsh
20	Kirulapone canal
21	Heen Ela
22	Dehiwala canal
23	Dematagoda Canal
24	Kirulapana Canal
25	St. Sebastian Canal
26	St. Sebastian Canal
27	Redbanaela
28	KarandagahamulaKumburaela
29	Thalahena tank
30	Evarihena tank
31	Canal passing through the paddy Land
32	Mulleriyawa tank
33	Mahawelaela
34	Ambataleela
35	Norris Canal

6.2 Irrigation and agriculture - Sri Lankan status*

Quality Class	**Blue**
Oxydable and orgmatters	
DO (dissolved oxygen, mg/l)	3
BOD5 (mg/l O_2)	5
Nitrates	
Nitrates (mg/l NO_3^-)	5
Substances containing Phosphorus	
Total phosphorus (mg/l P)	0.7

Suspended particles	
TDS/TSS (mg/l)	500
Acidification	
pH min	6.0
pH max	8.5
Mineralisation	
Conductivity (dS/m)	0.7
Sodium absorption ratio (SAR)	6-15
Residual Sodium Carbonate (RSC)	1.25
Chlorides (mg/l)	100
Cyanides (mg/l)	0.005
Sulfates (mg/l)	1000
Trace minerals on raw water	
Manganèse (µg/l)	1000
Mercury (µg/l)	1
Nickel (µg/l)	100
Zinc (µg/l)	1000
Boron (µg/l)	500
Total Arsenic (µg/l)	50
Aluminium (µg/l)	5.0
Micro-organisms	
Total coliforms (u/100ml)	1000

6.2 Water quality distribution in Metro Colombo wetlands catchment



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