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Seasonal Water Quality Variation in Two different Cascade Systems in the Dry Zone of Sri Lanka

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Abstract: Although Sri Lanka is blessed with 103 natural rivers which feed thousands of manmade reservoirs, freshwater availability in both lentic and lotic systems varies significantly across river basins and seasons. Monsoonal weather patterns are known to influence the spatial and temporal variation of water availability within the country. The current study was conducted to assess if the water quality (physico-chemical and biological) vary in reservoirs in two different regions of the Dry Zone of Sri Lanka during the wet and dry seasons. Physicochemical and biological analyses were done according to standard procedures at three months interval for a period of one year from January 2011 to January 2012. Twenty four reservoirs, which fed by the Mahaweli river (Region I) and the Gal oya basin (Region II) were selected for the study. Data analyses were done using SYSTAT version 9.0.Correlation of physicochemical variables was assessed using Pearson Correlation coefficients with Bonferroni-adjusted probabilities. The results reveal that during both wet and dry seasons, alkalinity (Alk), conductivity (Cond.), total phosphorous (TP) and chlorophyll a. (Chl. a) were positively and significantly correlated in Region I dry zone reservoirs fed by Mahawli river. During both seasons, Gal oya basin reservoirs (Region II) show positive correlations between turbidity (Turb.) & ammonia (NH_3), Turb. & temperature (T) and SO_4 & Chl a. However during wet season dissolved phosphorous (DP) and dissolved oxygen (DO) showed a negative correlation while it is positively and significantly correlated during the dry season. Further, Alk. and nitrite (NO_2) were positively correlated during the wet season while it was negatively correlated during the dry season. Plankton analysis also reveals a variation in plankton communities especially phytoplankton during wet and dry seasons in both systems. In both seasons reservoirs fed by Mahaweli river, Chlorophyceae was the dominant group and Bacillariophyceae and Cyanophyceae were also common. Gal oya basin reservoirs were dominated by Bacillariophyceae during the wet season and during the dry season Chlorophyceae became dominant. Thus the study confirms that the majority of limnological variables show seasonal variation in both systems.

Keywords: *Dry Zone Reservoirs, Plankton, Water Quality, Seasons, Gal-Oya Basin, Sri Lanka*

I. Introduction:

Although Sri Lanka is blessed with 103 natural river basins that support thousands of manmade reservoirs, freshwater availability in both lentic and lotic systems varies significantly across river basins and seasons. Monsoonal weather patterns significantly influence the spatial and temporal variation of water availability within the country. Depending on the rainfall the country is divided into four major climatic regions, wet, dry, intermediate and arid zone. Among them dry zone receives water from the north-east monsoon during October to March (maha season), leaving large period of the year with severe water shortages (yala-season). However the total annual precipitation falling on Sri Lanka is ~1,370 million m^3 out of which only ~31% is discharged to the sea by the river network[1].

Mahaweli, the longest river which originates from the central hills that reaches the Indian Ocean at Trincomalee drains large amount of country's freshwater. However, during the journey to the sea, it feeds thousands of manmade lakes of ancient and recent of origin and thus help cultivate thousands of agricultural lands. In addition, the reservoir cascade system which fed by the Mahaweli river is also identified as unique, may be due to the influence of the large catchment with different human activities of the 334 km long river. Additionally Mahaweli cascade system can further divide into different regions and majority are located in the dry zone of the country. In contrast the basin of the Gal Oya River is also identified as a unique system of Sri Lanka that lies in the same dry zone climatic region[11] . Therefore quantity and quality of surface water of Sri Lanka appear to vary due to various environmental factors including seasonal variation.

The current study was undertaken to compare the water quality characteristic (physical, chemical and biological) of two cascade systems located within the dry zone of Sri Lanka during wet and dry seasons.

II. Materials and Methods:

A. Study Sites:

Twenty four reservoirs in the dry zone belonging to the Mahaweli cascade (Region I) and Gal Oya basin (Region II) of the same climatic region were selected for the study. The reservoirs selected were range in size from <1 km^2 to ~ 30km^2. The catchments of the reservoirs include variety of urban, rural and agricultural lands. Geographically, Mahaweli cascade reservoirs are situated between 80° 13' - 81° 05' E and 7°25' – 8° 23'N and Gal Oya basin reservoirs are situated between 81° 25' – 81° 40' E and 7°14' – 7° 18'N. All the reservoirs studied located in the lowland of the country with the elevation above mean sea level from 30 to 100 m.

B. Collection of Environmental Data:

Because the winds were typically high during the day, most of the sampling and field measurements were carried out either during the morning or early evening. Sampling was done at three months interval for a period of one year covering the wet and dry seasons, from January 2011 to January 2012. Limnological variables were measured using portable field instruments and laboratory analysis. Water samples were obtained from a depth of ~ 0.5 m for laboratory analyses of nutrients (Total Phosphorus-TP; Dissolved Phosphorus- DP; Nitrite-NO_2^-; Nitrate –NO_3^-; Ammonia) alkalinity (Alk), dissolved oxygen (DO), Chl.a. and sulphate (SO^-_4). The samples for laboratory analysis were collected in 500-ml polyethylene bottles that were rinsed with lake water prior to sampling. Preservation of water samples followed the APHA [3] . The samples were stored in a cooler and transported to the Institute of Fundamental Studies (IFS) Kandy, Sri Lanka within 24 hrs of obtaining the samples. Onsite measurements of temperature and conductivity (Cond.), were taken at 0.5-m of the reservoir with a field instrument (Thermo Orion- Model 105). Field measurements of pH were obtained using Orion® Model 230A portable pH meter, using a two-point calibration, which encompassed the measured value. Turbidity (Turb.) measurements were also done from the same sampling location using portable EUTECH© - TN-100 turbidity meter. Statistical analysis of the chemical data was done by the computer programme SYSTAT 9.0. The Correlation of physicochemical variables was assessed using Pearson Correlation coefficients with Bonferroni-adjusted probabilities. Two-tailed t-tests were used to detect significant differences in limnological variables between dry and wet seasons of the two study regions.

C. Collection of Plankton Data:

Plankton samples were collected from the selected sites using plankton nets with the pore size of size 10 µm and 50 µm. Samples were preserved in acid Lugol's iodine for phytoplankton analysis and in 5% formalin for zooplankton analysis. The identification of species was done using a research microscope (OLYMPUS CX 31) and identification keys prepared by[4], [5], [14] [8].

III. Results:

A. Chemical Data:

The reservoirs studied belong to the two different cascades explain variation in their limnological characteristics and the average physical and chemical characteristics of the study reservoirs during wet and dry seasons are summarized in Table 1.

The temperature range of the surface waters in the Region I reservoirs varied from ~ 28 -34 °C during the dry season and 29 -32°C during the wet season. The Region I reservoirs show little variation in temperature during wet and dry season having the maximum of 35 °C in the dry season and 31 °C during the wet season. Statistical analysis also (t-test) shows that temperature of the Region I significantly vary during wet and dry seasons (Table 2).

Table 1: *Average Values of Environmental Data of Study Reservoirs in Selected Regions During Wet and Dry Seasons.*

	Mahaweli Cascade Gal Oya Basin			
	Region I		Region II	
	Dry Season	Wet Season	Dry Season	Wet Season
Temp. (°C)	31.14	29.77	32.9	31
Turb, (NTU)	17.35	9.98	6.62	21.87
pH	8.22	7.65	7.99	7.4
Cond,(µs)/cm	324.05	275.84	81.75	56
Alk. (mg/l)	133.03	115.01	49.28	37.38
NO_2 (ppb)	29.89	37.01	15.03	42.81
NO_3 (ppm)	1.24	1.19	0.02	0.18
NH_3 (ppb)	73.9	86.69	29.67	101.35
TP (ppb)	59.42	57.07	65.05	68.71
DP (ppb)	8.37	21.72	2.4	21.76
SO^-_4 (mg/l)	3.32	4.8	1.44	2.92
Do (mg/l)	7.07	6.45	6.35	5.92
Chlo-a (mg/l)	25.67	17.03	34.05	33.38

Values of dissolved oxygen of the surface waters of the study reservoirs were closer to saturation or less especially during the wet season. Further TP, DP and Chlo.a values indicate that all the reservoirs are eutrophic with relatively high productivity.

Conductivity values indicate that region I reservoirs have relatively higher values of whereas Region II reservoirs have low conductivity values. However results of the t-test show that conductivity values of both regions are significantly different during wet and dry seasons (Table 2). In addition alkalinity also vary in both regions during wet and dry season.

Table 2: *Results of Two-Tailed t-Test. * Indicates Variables Significantly Different Between Two Given Seasons. Abbreviations: DR = Dry Zone; GOB (DR) = Gal-Oya Basin in Eastern Dry Zone.*

VARIABLE	Region I	Region II
Temperature	*	
Turbidity		
pH	*	
Conductivity	*	*
TP		
DP	*	*
Chl. a		
Nitrite		
Nitrate		
Ammonia		*
DO	*	
SO_4		*
Alkalinity	*	*

The pH of the study reservoirs ranged from 7 to 9.2. However significant differences of pH during wet and dry seasons were only detected within the Region I reservoirs. Alkalinity values also indicate that the both systems are well buffered however significantly vary during wet and dry season. The average values of the species of nitrogen, such as ammonia-N (NH_3), nitrate-N (NO^-_3) and nitrite-N (NO_2^-) were high during the wet season except in the Region I where average Nitrate was high during the dry season. However results of the two tailed t-test indicated that NH_3 was significantly different in dry and wet seasons in the Region II (Table 2). Further, values of SO_4 significantly different between wet and dry seasons within the reservoirs of Region II only. Results of the Pearson correlation analysis show that there is higher correlation between more variables during the dry season than the wet season. Average values of chlorophyll a (Chl. a), show that Region I reservoirs are less productive especially during the wet season. Turbidity measurements indicate, although Region II reservoirs become highly turbid during the wet season the values become are very low during the dry season. Pearson correlation indicates that the Turbidity is positively and significantly correlated to major nutrients and Chl. a. especially during the dry season. Sulphate (SO_4^-) values were high during the wet season, however only in Region II reservoirs show a significant variation during wet and dry seasons.

B. Plankton Data:

Plankton analysis also reveals a variation in plankton communities especially phytoplankton during wet and dry seasons in both systems. In both seasons reservoirs fed by Mahaweli river, Chlorophyceae was the dominant group and Bacillariophyceae and Cyanophyceae were also common. Gal oya basin reservoirs were dominated by Bacillariophyceae during the wet season and during the dry season Chlorophyceae became dominant.

IV. Discussion:

Reservoirs constructed throughout Sri Lanka are now estimated to cover ~4% of the total land area, play an important role in the development of Sri Lanka by supporting agriculture, domestic water supply, inland freshwater fisheries, and hydroelectric power generation. Therefore it is evident that the deterioration of the water quality can negatively affect the economy of the country. Unfortunately many of the reservoirs have now started to show the signs pollution which can damage the ecological balance of the system as well as other environmental problems. Such deterioration of water quality of many reservoirs is connected to human activities and some can be explained as natural reasons. Among the natural changes, patterns of rainfall could affect the quality of water creating seasonal changes of water quality that could ultimately cause serious environmental and social problems [[7],[10]] . Especially during less rainfall period increase of the salinity due to concentration of ions in water cannot be avoided as the evapotranspiration is high in tropical regions. Ionic composition of freshwater systems in Sri Lanka dominate by Na and Cl [8] which is also different from temperate systems where HCO_3^- is the dominant anion and Ca^{2+} is the dominant cation [12] . Further increase of salinity along the temporal and spatial gradient has also being identified as a common problem exist especially in Sri Lankan lentic water systems [15].

Our survey of 24 reservoirs from Mahaweli cascade system (Region I) and Gal Oya basin (Region II) during wet and dry seasons characterizes the annual water quality changes. According to [12] the three main processes that govern the ionic composition and concentration of surface waters include: the balance between the evaporation and precipitation, atmospheric fallout, and the influence of the geology. Our study suggests that the reservoirs in Sri Lanka are largely influenced by the nature of the precipitation and the resulting concentration of ions by evaporation. However, this explanation become debatable when consider the low salinity and low conductivity values exist within the Region II where the same climatic condition exists as the Region I. The best possible reason for this would be the geological influence and

the high flushing rate of the region. In addition, Mahaweli cascade system receives water from a larger catchment of the longest river Mahaweli of Sri Lanka which flows through variety of human settlements and natural systems. According to the results of Pearson correlation analysis, concentration of SO_4^- is positively and significantly correlated with the conductivity during the dry season of the both regions which is different from the findings of Yatigammana, 2004 that records low concentration of SO_4^- in Sri Lankan systems. Additionally concentrations of measured nutrients (TP, DP, NO_2^-, NO_3 & NH_3) and associated variables (turbidity and chlorophyll a) were high and above the ranges found in other studies from Sri Lanka([8], [16]) and other tropical regions [13] . It is apparent that the both regions experience concentration effect of nutrients during the dry season. However Region II appears to have high production than the region I where the difference between TP and DP was high during both seasons (Table 1). Further DP is high during wet season in both regions and the t-test confirms that the values are significantly different in the two seasons in both regions. Such a condition could be due to the high surface runoff which brings lot of nutrients from the top soil especially from agricultural lands of the catchment.

However, Pearson correlation indicates that during the dry season major nutrients (TP, DP and species of nitrogen), turbidity and Chl. a are positively and significantly correlated which is not been encountered by previous studies in Sri Lanka ([6], [8])but a very common phenomenon in natural lakes [17] . Therefore, the present condition could be related to reservoir aging, high water retention time coupled with low flushing rate may be due to recent climate change scenarios of the world. In addition according to Yatigammana,2004 many of our reservoirs were P limited which is also questionable with today's situation where TP exhibits a positive and robust relationship with primary production and turbidity.

Elevated levels of dissolved oxygen (DO) were also observed in the reservoirs during the dry season, a condition which is common among the eutrophied lakes [9] . However Region II reservoirs show high values during the wet season may be related to time of sampling during higher photosynthesis period and also the effect of mixing due to the changes of temperature and atmospheric circulation. The primary production of the study reservoirs also indicates a relationship with the pattern of precipitation, where many reservoirs recorded high values of Chl. a. during the dry season, when nutrients are concentrated within the system. Finally Pearson correlation analyses indicate that concentration of nutrients (e.g.TP & DP) strongly related to primary production and turbidity during both seasons which is a warning for year around eutrophic conditions of the reservoirs.

According to plankton analysis Region I is dominated by members of Chlorophyceae although Bacillariophyceae and Cyanophyceae were also common in both seasons. In contrast Gal oya basin reservoirs were dominated by Bacillariophyceae during the wet season and during the dry season Chlorophyceae became dominant. Hence the study suggests that the most common planktons belong to the group Chlorophyceae, another indication of the reduction of diversity of freshwater planktons. This condition also could be related to deterioration of the health of the reservoir ecosystem.

According to Townsend, 1996 tropical reservoirs are structurally and functionally different from natural lakes, especially those from temperate regions. Our study of twenty four reservoirs suggests that the reservoirs in Sri Lanka are gradually absorbing to natural landscape of the country warning the authorities that the deterioration of the health of the water quality could be permanent.

V. Conclusion:

Accordingly, seasonal climatic changes appear to affect the limnological conditions in the reservoirs in different cascade systems of Sri Lanka. Among the chemical variables, conductivity and pH show high values during the dry season in many reservoirs, while nutrients and primary production do not show such a pattern.

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