NUISANCE ALGAE IN WATER SUPPLY PROJECTS IN SRI LANKA

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Abstract
Sri Lanka is a tropical continental island which consists of 103 rivers and about ten thousand man made tanks. There are over 250 water supply systems constructed using these water bodies since later part of the nineteenth century, reservoirs which are used extensively for domestic and agricultural practices. It is reported that most of these water sources are constantly becoming contaminated with different types of algae making the water unsuitable for human consumption. The present study was carried out to identify toxin producing, filter clogging, taste and odor forming nuisance algae and some physico-chemical parameters in some selected water bodies namely Labugama, Kalatuwawa, Parakramasamudra, Kondawatuwana, Mahaweli intake at Neelapola and Kantale. Sampling for algae and physico cemical parameters were carried out for a period of one year from April 2009 to April 2010. The results of the present study showed that all physico-chemical parameters in the water bodies were within the drinking water quality standards recommended for Sri Lanka. However Species diversity and density of phytoplankton was different in the water bodies. In Labugama and Kalatuwawa, total algae population consisted 10% of cyanotoxin producing *Microcystis aeruginosa,* 10%, 20% and 60% of taste and odor forming *Peridinium* sp., *Microcystis* sp. and *Staurastrum* species respectively. In contrast, 89% of cyanotoxin producing cyanobacteria in Kondawatuwana tank, 50% in Parakramasamudra, 40% in Neelapola and 95% in Kantale were detected. Total filter clogging algae in Parakramasamudra, Neelapola, Kondawatuwana and Kantale were 29%, 69%, 72% and 15% respectively while taste and odor forming algae were 22%, 36%, 72% and 11% respectively. Among the water bodies under study Neelapola recorded the highest occurrence (34%) of filter clogging diatom while the highest percentage of cyanotoxin producing *M. aeruginosa* (62%) and *Cylindrospermpsis* sp. (85%) were recorded from Kondawatuwana and Kantale tanks respectively. During the study period, the lowest percentages of toxic producing algae were recorded from Labugama and Kalatuwawa reservoirs which are exclusively used for drinking purposes indicating their suitability as drinking water sources. In contrast, the highest percentages of toxin producing, filter clogging and taste and odor forming algae were recorded in Kondawatuwana drinking water tank. As for the other water bodies studies showed that there is no immediate threat due to algae.

Key words: cyanotoxin, filter clogging, nuisance, phytoplankton, taste & odor forming,
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1. Introduction

Cyanobacteria are a group of prokaryotes found all over the world (Carmichael, 1994) and grow in light habitats and prefer neutral or alkaline conditions. Algae have an economic importance and considered as major primary producers which contribute globally to soil and water fertility. Use of algae in food production and in solar energy conversion holds promising potential as a solution for energy crisis (Skulberg, 1995). The great increase in population and the rapid development of agriculture and industry have caused a phenomenal increase in the use of water in recent years and have brought about many difficulties in meeting the demand for water. In addition industrial, agricultural and economic development of the world may on the other hand cause nutrient enrichment in water bodies which may enhance the massive production of algal blooms. These algal blooms may have wide range of social, economic and environmental problems such as formation of foul odours (Silvey & Roach, 1975), depletion of oxygen in underline waters and potential harmful effect on human health due to production of algal toxins (Manage et al, 2009; Gorham & Carmichael, 1988; Falconer, 1989, 1996; Song et al., 1998), water chemistry and subsequent fish kills (Bury et al., 1996), accumulation of toxin in aquatic animals (Lykke & Kirsten, 1999 (*Daphnia magna*)), death of animals (Galey et al., 1987 (Cattle); Matsunaga et al., 1999 (bird), 1988; Zohary & Roberts, 1989).

Among the cyanobacteria, filamentous *Anabaena, Oscillatoria, Nostoc, Aphanizomenon, Hapalosiphon*, *Cylindrospermopsis* and unicellular *Microcystis* sp. are well known all over the world as common bloom-forming cyanobacteria in ponds, rivers, lakes, reservoirs which are used for irrigation and drinking purposes. Also, it has been documented that some species of algae and cyanobacteria can become nuisance species (Carmichael, 1996). Some species of blue green algae and green algae which produce secondary metabolites lead to foul tastes and odors in water and some species of diatoms causes filter clogging problems in water purification systems when they become abundant in the environment (Palmer, 1959). Furthermore, over 100 of cyanobacteria species belonging to 40 genera have been recognized as toxic. Among them *Microcystis*, *Anabaena*, *Lynbya*, *Nostoc*, *Nodularia*, *Cylindrospermopsis*, *Oscillatoria* are some of the most common toxigenic cyanbacteria species (Jayatissa et al, 2006, Pathmalal, 2009).

Sri Lanka, has 103 rivers radiating from hill country and about ten thousand man made tanks and several water supply systems have been constructed since later part of the 19th century.(Ferdinando, 2006). Some drinking water bodies have built by damming across the rivers and some are by diverting the rivers. For example, the Kalatuwawa reservoir which supplies water to Colombo and greater Colombo area, has been built by damming across the Kelani River, while Amban ganga feeds Parakramasamudra which supplies water to Polonnaruwa area through a diversion anicut (Ferdinando, 2006). Most of these water bodies are used both as drinking sources and also for irrigational purposes. However some reservoirs are used exclusively as drinking sources (eg: Labugama and Kalatuwawa).

Recent studies have been revealed that some of the water bodies in Sri Lanka have contaminated by toxigenic cyanobacteria (Jayatissa et al, 2006, Pathmalal, 2009). In such studies, about forty species of cyanobacteria belonging to twenty four genera have been reported from drinking, irrigation and recreational water bodies. Of these *Microcystis aeruginosa* was recorded as the most common nuisance cyanobacteria in most of the water bodies in Sri Lanka (Silva and Wijeratne, 1999; Pathmalal, 2009).

The objective of the present study was to identify the nuisance algae in some selected water bodies which are being used as drinking water sources.

2. Materials and Methods

2.1 Study area

The Kalatuwawa, Labugama, which are used for drinking purposes, Parakramasamudra and Kantale reservoirs; Neelapola intake of Mahaweli river and Kondawatuwana tank which are used for drinking and irrigation purposes were selected to collect water and plankton samples for the present study. The water bodies are situated in lowland wet zone i.e Labugama and Kalatuwawa reservoirs and low land dry zone i.e Parakramasamudra and Kantale reservors, Neelapola intake, Kondawatuawna tank of the country (CEA, 2006).

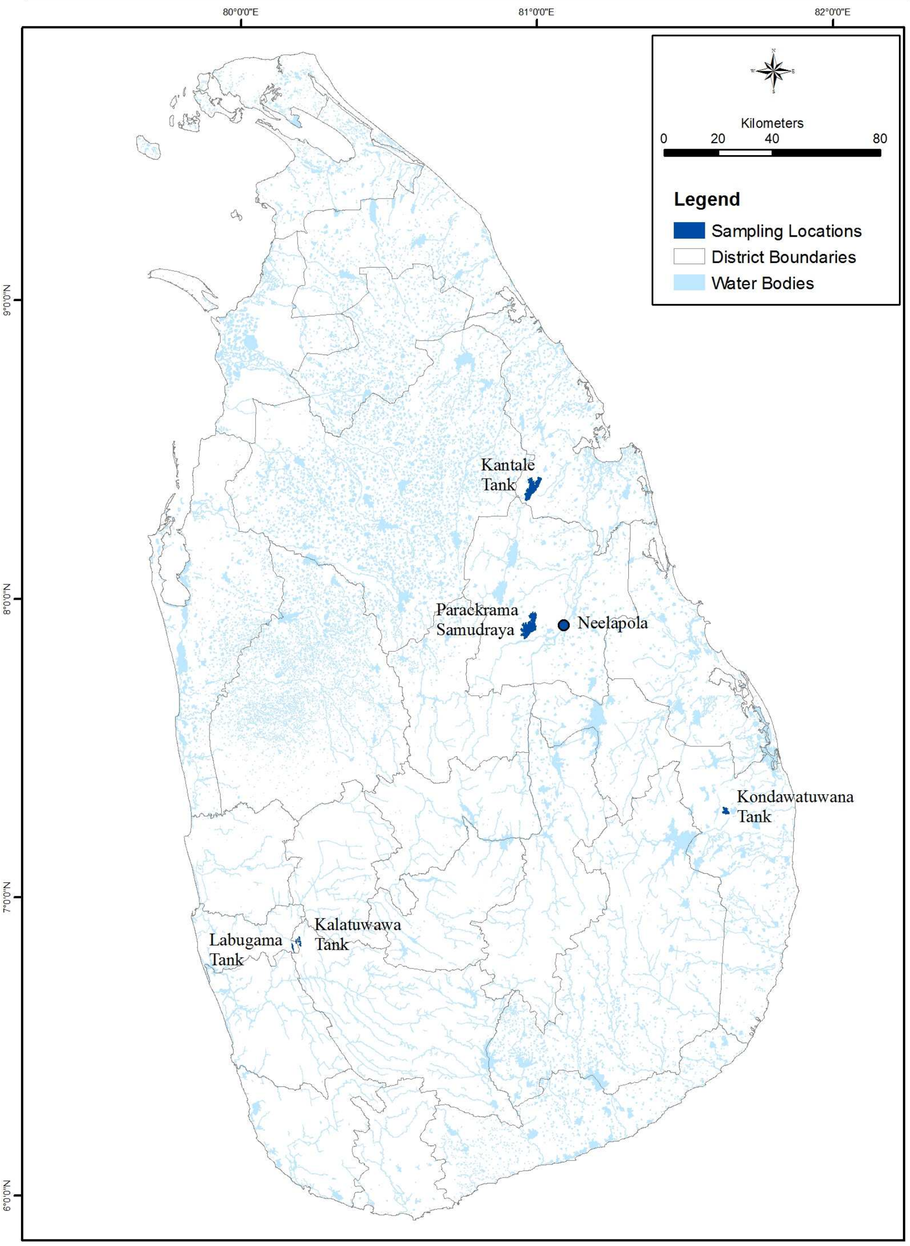
Labugama reservoir is an impoundment of Wak Oya in the Kelani basin and has a catchment area of 2835 acres at an elevation of 360 ft above the sea level (Ferdinando, 2006). Kalatuwawa reservoir was build-up by damming across a sub tributary of Kelani River and its submerged area is 482 acres and the catchment area is 3320 acres (Ferdinando, 2006). Parakramasamudra is fed by perennial water source from Ambanganga through a diversion anicut and the capacity is 1110,000 Acft (Kamaladasa, 2007).

Kondawatuwana tank is a shallow and stagnant water body situated in Ampara district and used for drinking and irrigation purposes. Kantale reservoir receives irrigation water diverted from Mahaweli River and Neelapola intake of Mahaweli River distributes water to eastern part of the country and expects to develop as drinking water source under the secondary town and rural community base water supply and sanitation project of 4th phase of the ADB project.

2.2 Sampling

Sampling was carried out from April 2009 to April 2010. Water samples in triplicate were collected during 9.00 am to 11.00 am at 10 cm below the surface. Water temperature, pH, conductivity and dissolved oxygen were measured at the site using a thermometer, pH meter (330 I/ Set, WTW Co., Weilheim, Germany), a conductivity meter (340A-Set 1. WTWCo., Weilheim, Germany) and an oxygen meter (Oxi 320/ Set, WTW Co., Weilheim, Germany) respectively. Spectrophotometric analysis of nitrogen in the form of nitrate (NO_3^{-1}-N),) and total phosphate (PO_4^{-3}-P), were done in the laboratory.

To determine species composition of algae, five surface plankton samples from five sampling points in each water body were collected using 55µm plankton net while moving the boat for a known period of time. Immediately after collection, a 100 ml sample was fixed with acidified Lugol's solution to a final concentration of 1% and kept overnight for natural sedimentation. Enumeration was done using a



Sedgwickrafter counting chamber under a light microscope.

Fig. 1 sampling locations of the present study

3. Results

pH ranged between 7.3-8.2 both in Labugama and Kalatuwawa reservoirs. pH in Parakramasamudra ranged between 7.8- 8.5 and in Kondawatuwana, Kantale and Mahaweli Neelapola intake the pH values remained with in the range of 7.3 to 7.6. Mean temperature of Kalatuwawa and Labugama reservoirs and Parakramasamudra were 29.0 ±0.02 ºC during the study period. In contrast, Kondawatuwana (30.1 ±0.2 ºC), Neelapola (32.3 ±0.02 ºC) and Kantale (30.0 ±0.04 ºC) reservoirs showed higher mean temperatures compared to the lowland wet zone reservoirs. Mean conductivity of Labugama and Kalatuwawa remained at 16.8±0.02 μS/cm and the mean conductivity values of Parakramasamudra, Kondawatuwana, Neelapola and Kantale reservoirs varied and are shown in Table 1. The concentration of alkalinity, total phosphate and nitrate in each water body was different and given in the table(Table 1). All physico-chemical parameters of the water bodies tested were within the drinking water standard recommended by NWSDB and BOI.

Table1: *Mean values of some selected physico-chemical parameters in the reservoirs during the study period.*

Water body	**pH range**	**Temperature ºC**	**Conductivity μS/cm**	**Alkalinity ppm**	**PO_4^{-3} mgl^{-1}**	**NO_3^{-1} mgl^{-1}**
Labugama	7.8-8.5	29.0±0.02	16.8±0.2	30±0.6	0.06	<0.1
Kalatuwawa	8.12-8.32	29.0±0.02	16.9±0.11	42±0.5	0.07	<0.1
Parakramasamudraya	7.8-8.5	29±0.2	215±1.5	107±0.9	0.46	<0.1

Kondawatuwana	7.3-7.6	30.1±0.2	113±0.9	49±0.8	1.5	<0.1
Neelapola	7.3-7.6	32.3±0.06	191.1±2.5	91±0.6	0.44	<0.1
Kantale	7.2-7.6	30.0±0.04	327.3±1.6	125±1.1	0.60	<0.1
Recommended BOI Standards (maximum permissible level)	6.5-9.0		3500	600	2.0	45

Table 2: *Toxin producing, filter clogging and taste and odor forming algae found in the present study*

Reservoir	**Toxic algae**	**Filter clogging algae**	**Taste & Odor forming algae**
Labugama	**Cyanobacteria** *Microcystis aeruginosa**	**Cyanobacteria** *Microcystis* sp.	**Cyanobacteria** *Microcystis* sp. **Chrysophyta** *Peridinium* sp.
Kalatuwawa	**Cyanobacteria** *M.aeruginosa**	**Cyanobacteria** *Microcystis* sp.	**Cyanobacteria** *Microcystis* sp. **Chrysophyta** *Peridinium* sp.
Parakrama samudraya	**Cyanobacteria** *M. aeruginosa** *Cylindrospermopsis* sp.* *Anabaena* sp.**	**Bacillariophyta (Diatoms)** *Melosira* sp. *Fragilaria* sp. **Cyanobacteria** *Anabaena* sp. *Microcystis* sp.	**Cyanobacteria** *Microcystis* sp. **Chrysophyta** *Peridinium* sp.
Kondawatuwana	**Cyanobacteria** *M. aeruginosa** *Cylindrospermopsis* sp.	**Cyanobacteria** *Microcystis* sp.	**Cyanobacteria** *Microcystis* sp.
Neelapola	**Cyanobacteria** *M. aeruginosa** *Cylindrospermopsis* sp.* *Anabaena* sp.**	**Bacillariophyta (Diatoms)** *Melosira* sp. **Cyanobacteria** *Microcystis* sp. *Anabaena* sp.	**Bacillariophyta (Diatoms)** *Melosira* sp. **Cyanobacteria** *Microcystis* sp.
Kantale	**Cyanobacteria** *M. aeruginosa** *Cylindrospermopsis* sp.*	**Bacillariophyta (Diatoms)** *Melosira* sp. *Navicula*sp. **Cyanobacteria** *Microcystis* sp.	**Cyanobacteria** *Microcystis* sp.

- *Hepatotoxic (microcystins/Cylindrospermposins**Nurotoxic (Anatoxin-a/ Anatoxin (s)*

Table 2. illustrates the species composition of toxin producing, filter clogging and odor forming algae detected in the present study. Species composition of algae was different in each water body. All water bodies tested in the present study were contaminated with toxin producing, filter clogging and taste and odor forming algae during the study period (Table 2).

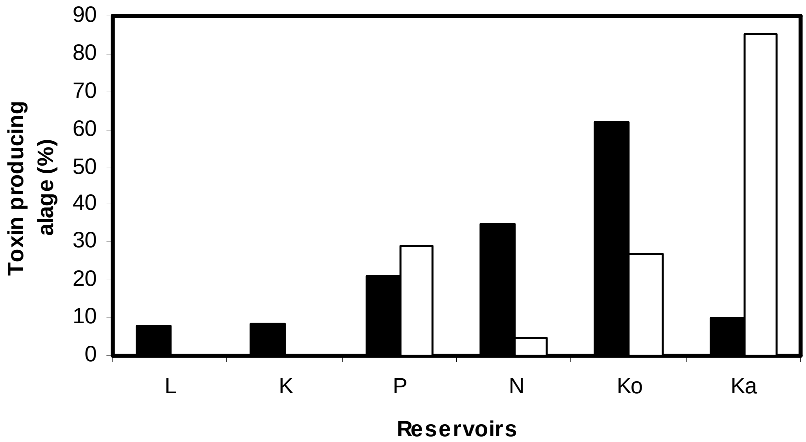


Fig 2:Percentage of toxin producing algae in Labugama (L), Kalatuwawa (K), Parakramasamudra (P), Neelapola (N), Kondawatuwana (Ko), and Kantale (Ka) reservoirs (■*M. aeruginosa,* □*Cylindrospermopsis* sp.)

The toxin producing algae, *M. aeruginosa,* 8% and 8.5% of the total algae population respectively in the Labugama and Kalatuwawa reservoirs (Fig.2). Comparatively, percentages of *M. aeruginosa* (21%) and filamentous *Cylindrospermopsis* sp. (29%) in the total algae population were high in Parakramasamudra. The highest density of *M. aeruginosa* (62%) was detected in Kondawatuwana tank while 27% of *Cylindrospermopsis* sp. In the Neelapola Mahaweli water intake the two species *M. aeruginosa* (35%) and *Cylindrospermopsis* sp. (5%) were reported and in Kantale reservoir *M. aeruginosa* (10%) was low compared to other low land dryzone reservoirs. *Cylindrospermopsis* sp (85%) was the dominant cyanobactera found in Kantale reservoir.
Microcystis sp. which is considered as filter clogging algae recorded in Labugama and Kalatuawawa reservoirs were 9.5% and 10% respectively (Fig.3). In the Parakramasamudra *Microcystis* sp. (21%) *Melosira* sp. (7%), *Aanabaena* sp. (0.5%) and *Fragilaria* sp. (0.1%) were recorded as filter clogging algae and in the Neelapola Mahaweli water intake considerable densities of *Microcystis* sp. (35%) and *Melosira* sp. (34%) were recorded. In Kondawatuwana *Microcystis* sp. (72%) was identified as the dominant species and in Kantale reservoir three filter clogging algae namely *Microcystis* sp. (10%), *Melosira* sp. (5%) and *Navicula* sp. (0.5%) were detected during the study period.

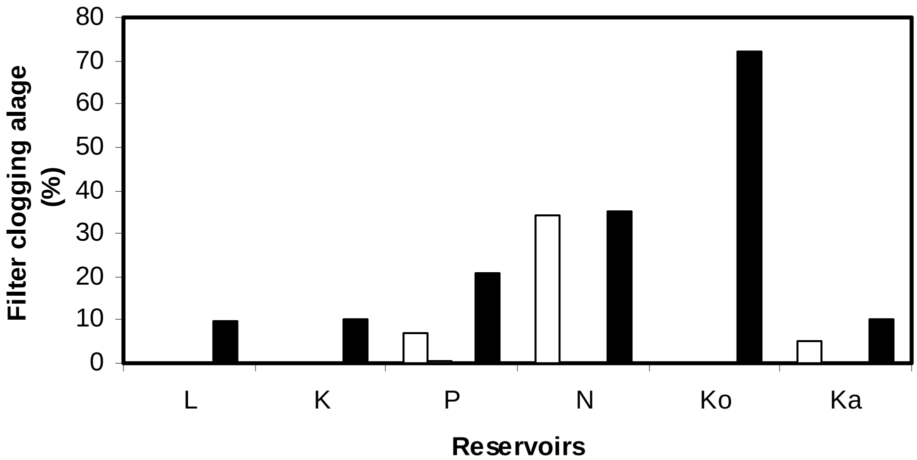


Fig 3:Percentage of filter clogging algae in Labugama (L), Kalatuwawa (K), Parakramasamudra (P) Neelapola (N), Kondawatuwana (Ko) and Kantale (Ka) reservoirs (■ *Microcystis* sp., □ *Melosira* sp.)

In Labugama reservoir *Microcystis* sp. and *Peridinium* sp. were detected as taste and odour forming algae and they constituted 9.5% and ˜% of the total algae population respectively (Fig.4). *Peridinium* sp., *Microcystis* sp. and *Staurestrum* sp. were identified as taste and odour forming algae in Kalatuwawa reservoir and they contributed 15%, 10% and 45% of the total algae population respectively. Percentage contribution of taste and odour forming *Microcystis* sp. was detected as 21% and *Peridiniun* sp. and *Scenedesmus* sp. were less than 0.5% in Parakramasamudra where as in Neelapola Mahaweli water intake 35% of *Microcystis* sp. and 0.85% of *Scenedesmus* sp. were recorded. In addition, 1.2% of *Closterium* sp. was also recorded as taste and odour forming algae in Neelapola and 0.2% of *Scenedesmus* sp. (data not shown) and 10% of *Microcystis* sp. were recorded in Kantale reservoir. In Kondawatuwana 72% of *Microcystis* sp. was recorded as taste and odor forming algae.

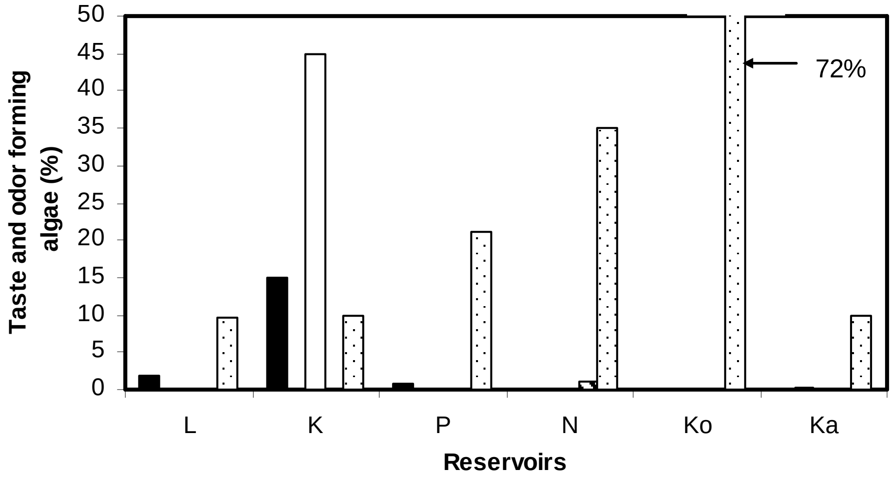


Fig 4: Percentage of Taste and odor forming algae in Labugama (L), Kalatuwawa (K), Parakramasamudra (P) Neelapola (N), Kondawatuwana (Ko) and Kantale (Ka) reservoirs(■ P*eridinium* sp., □ *Staurastrum* sp., ⬚ *Microcystis* sp., □ Closterium sp.)

4. Discussion

Filter clogging, toxin producing, taste and odor forming algae were detected in different percentages in different water bodies. Previous studies have shown that the phytoplankton community varied from reservoir to reservoir irrespectively of their geographical locations and hydrological regime (Silva and Wijeratne, 1999). pH, temperature, conductivity and alkalinity values remained within the drinking water quality standards during the study period. These parameters were also favourable for growth of algae. The generally accepted phenomenon is that the occurrence of cyanobacteria is triggered by nutrient enrichment (Hutchinson, 1973).For instance the Kondawatuwana tank had higher concentrations of total phosphate (value the recommended standards) compared to the other water bodies which may have led to have high growth of cyanbacterium *M. aeruignosa* than all other water bodies.

The most common toxin producing algae *M. aeruginosa* in Labugama and Kalatuwawa reservoirs were the lowest compared to the other water bodies which show less or no contamination of cyanotoxins. This is a good indication that the water in these two reservoirs is suitable for drinking and domestic uses. The low levels of *M. aeruginosa* may be due to limiting nutrients such as nitrates and phosphates for the cyanobacteria growth in the catchment of these two reservoirs. It is known that most toxin producing and bloom forming cyanobacteria needs high concentrations of phosphorous for their mass growth and it has been reviewed that in lowland reservoirs in Sri Lanka, phosphorous is known to be a limiting factor (Jayatissa et al, 2006) and both Labugama and Kalatuwawa reservoirs situated in lowland wet zone thus, the limited phosphorous concentrations of the reservoirs may be the reason for the low abundance of bloom forming *Microcystis* species.However the two reservoirs, showed highest percentages of taste and odor forming *Peridinium* sp. *and Staurastrum* sp. *Staurastrum* sp. gives a grassy odor to drinking water while *Peridinium* sp. and *Microcystis* sp. give fishy and septic odors to water when they are abundant (Palmer, 1959). The results of the present

study is indicating that continuous monitoring of algae and water quality of these two reservoirs is needed to evaluate the level of algae density to ascertain the potential impact of odor forming algae.
The results of the present study showed that the highest percentages of toxin producing, filter clogging and taste and odor forming algae such as *M. aeruginosa*, other *Microcystis* sp. and *Cylindrospermopsis* sp. are recorded in Kondawatuwana water tank. This is an indication that the water in this reservoir contaminated, toxin producing, filter clogging and taste and odor forming algae thus needs a proper treatment scheme before using as drinking and domestic water source. The generally accepted phenomena is that nitrogen limited aquatic environments promote the growth of cyanobaceria when phosphorous is not limited (Silva and Samaradivakara, 2005). In Kondawatuwana nitrogen limitation may not be the single factor of having high percentages of cyanobacteria.
Compared with the other water bodies studied, a considerable percentage of nuisance algae were present in Parakramasamudra which is situated in lowland dry zone. This may due to the effect of hydrological flushing and dilution on the limnetic biomass with the water level in Parakramasamudra which governs the high densities of phytoplankton (Silva & Schiemer). Dissolved silica and its relationship to other reactive micro nutrients may be a key factor regulating the growth of centric diatom *Aulacoseira granulate* in the humid tropics (Adeniji, 1977, Silva & Samaradivakara, 2005). In Neelapola water intake the highest percentages of filter clogging algae, *Melosira* sp. was reported and it may be due to the concentration of dissolved silica during the rainy season resulting an increase in the relative proportion to total phosphorous which in turn may have enhanced the growth of *Melosira* sp.
The findings of the present study indicate that favorable physico-chemical factors and nutrients, especially phosphorous which is a limiting factor have favored the growth of algae particularly certain species which have increased to nuisance levels which are capable of producing toxins, clogging filters and forming foul odors and tastes in these water sources under study.
Therefore, the results of the present study emphasises the importance of carrying out further monitoring studies, including catchment and runoff monitoring to identify the potent nutrient input to reservoirs, water quality and reservoir management practices and ascertain potential impact of anthropological and natural activities on water quality which positively affect nuisance algae production. These information can help in introducing control measures to control the nuisance algae in order to supply safe drinking water for future generations.

Acknowledgements

This study was financially supported by the University of Sri Jayewardenepura, grant in aid for research (ඇ.ශි.පු./06/පර්/2009/20) for the university academics. We grateful to the National Water Supply and Drainage Board (NWSDB) for their support during the study period. Also, we thank academic and non academic members of the department of zoology for their support extended to the research work.

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