5.0 Discussion

Eutrophication has been identified as a major water pollution issue in Sri Lanka. Due to careless and uncontrolled land use practices, many water bodies of Sri Lanka are threatened. Kandy Lake is one of the examples. Therefore it is a prior necessity to restore this water body through proper Lake Management practices. First hand information on trophic status of the water body is very useful in planning the Lake management programme.

Biological monitoring of a water body is an integral part for the management of the total ecological health of the water body and it is becoming increasingly important in water quality monitoring assessment. Organisms respond to multiple interactions of lake conditions and therefore, usage of bio indicators and diversity indices as a tool in predicting trophic status of the lake will be an added advantage in determination of water quality.

This study is an effort to develop such bio monitoring tools which is cheaper and affordable to a developing country like Sri Lanka in eutrophication monitoring.

5.1 Physico chemical properties

5.1.1 Water Transparency

Secchi disk transparency values observed for the Kandy Lake during the study period indicates typical values for a eutrophic Lake. The values observed were in the range of 45cm to 95 cm. According to the OECD (1982) programme for assessment of trophic status (Table 2.7) lakes are classified into three categories depending on the Secchi disk transparency

values. As indicated in Table 2.7 the Secchi depth value >2 indicate the eutrophic status of the lake.

According to these values Kandy Lake belongs to hyper eutrophic status where growth of algal mass is high, which influence the water transparency to a very low level shifting the Secchi disk values below 1m. Similar low values has been recorded in many eutrophic lakes in Sri Lanka such as Victoria reservoir, Kotmale reservoir (Piyasiri 1991,1995) Baticaloa lagoon (Sathanandan-1994). This indicates low secchi disc transparency values >1 as in Kandy Lake is typical for eutrophic status of a Lake.

5.1.2 Thermal properties

Kandy Lake is a shallow water body. Thermal properties along the vertical column of the water body clearly indicate the mixing nature. Mixing along vertical is a common phenomenon in many shallower lakes. Similar conditions have been observed in the Beira Lake, Rantambe reservoir (Piyasiri 1991) and this thermal behavior often tends to accelerate the blooming process via nutrient mixing.

5.1.3 Dissolved Oxygen content

Kandy Lake along the vertical profile during the study period indicates the lake mixing. Oxygen depletion in the bottom regions of Kandy Lake is an observed feature and it is indication of the accumulated organic load in the bottom sediments of the Kandy Lake. Bottom regions of the eutrophic lake are anoxic due to stratification (Abel - 1989). However anoxic condition was not found at the bottom of the Kandy Lake probably due to its mixing nature.

5.1.4 pH

pH values observed for the Kandy Lake varied between 6.92 - 10.45 . These high values could be mainly due to degeneration of its algal bloom. Similar high values have been observed even in Kotmale reservoir during its blooming condition in 1991 (Piyasiri 1995, 2001). This condition can be simply explained by the fact that the buffer capacity of water depends on the concentration of OH- ions. As DO increased, H+ ions become OH- ions and the pH obviously increased and vise versa.

5.1.5 Conductivity

The specific conductivity of the Kandy Lake varies 0.16 mS-0.32 mS/cm. According to Dissanayaka-1982 high values indicates an abundant input of free ions into the Lake water the effluent load receiving form domestic waste water, the weathering of the more basic rocks and also from the sediment.

5.1.6 Nutrients

High nutrient levels recorded during this study indicates high nutrient loading of the lake. (Average values of Nutrients varied in between as Orthophosphate 512.95µg/L -204.65µg/L and Nitrate 0.243 mg/L-0.114 mg/L).

According to the Guidelines for lake and reservoirs on Eutrophication survey (Table 2.4) these values indicate the Eutrophicated nature of the Lake. This high nutrient values may be due to receiving of high nutrient loads from its catchment. Being situated at a low elevation in the city as many as 29 drains of varying sizes from various sources like hotels, hospital and nursing homes restaurants, sewer lines etc. discharge effluents into the lake. This location also leads to washouts from roads in to the lake during the rainy season. In addition leaves and flowers from the trees surrounding the lake and bird droppings fall in to the water.

All the above reasons may lead to show high nutrient values in the Kandy lake which has been attributed to heavy algal growth that observed during the study period.

According to the observations of the laboratory experiments it was clear that high levels of nutrients lead to high density of phytoplankton in the lake.

5.1.7 Chlorophyll –a

During this study recorded levels of chlorophyll was 100-250 mg/m^3.Such elevated chlorophyll a levels are, however, largely due to natural input of nutrients exacerbated by anthropogenic influences like agriculture runoff and sewage. Same situations has been recorded in lake Washington in 1960 - 1965 (Mason -1991). According to the Classification of the New Zealand lakes Table 2.7 b & Table 2.7 a (Vollenweider, 1981) Kandy Lake belongs to the category of Hypereutrophic Status.

5.2 Phytoplankton and Species diversity index in the Kandy lake.

5.2.1 Phytoplankton

Only few (Six -06) Phytoplankton species in grater abundance were recorded in Kandy Lake during the study period. A number of surveys have demonstrated that pollution produces striking changes in biotic community. These structural changes can be quantified numerically and are very useful in assessment of water quality based on the principle that polluted water supports always low diversified flora and fauna while clean water supports high community diversity.(Triverdi- 1981). This low species diversity found in Kandy lake indicates the highly polluted status of the Lake.

The major Phytoplankton species found in Kandy Lake were *Microcystis*, *Melosira* and *Pediastrum*. According to Prescott (1939) the differences in the dominant phytoplankton assemblage of the lake reflects their trophic levels. He reported that oligotrophic lakes are characterized by Chlorophycean flora while the eutrophic lakes were found to be dominated by Cyanophycean forms. During the study it was revealed that most dominant species is *Microcystis* that belongs to Cyanophyceae. According to results of the study density of *Melosira granulata* was also highly significant in Kandy Lake. *Melosira granulata also* indicates high organic pollution of the water. (Pearsall-1932, Sawyer -1947, Prescott-1951). It is a well established indicator of Eutrophication (Rawson- 1956).

5.2.2 Species diversity index in the Kandy lake

According to the calculated values for water samples of Kandy lake, the diversity index values for the entire lake throughout the investigation period are below 1.0.According to Wilhm and Dorris -1968 diversity index <1 is highly polluted and >3 is clean water. It was proven by the Staub et al in 1970 based on their study on the effects of industrial waters on primary planktonic producers in the Mississippi River. Therefore values obtained for the Kandy Lake indicate highly polluted status. Even during different seasons the values have never increased indicating permanent eutrophic status of the Kandy lake.

According to the comparison made by Tiverdi - 1980 on diversity index (based on Shannon and Weavers formula) and species richness (based on Margalef's formula and Menhinick's formula) shows a little variation which is not very significant. Therefore the degree of severity can also be judged by the species richness in such situations. The same situation

was recorded in this study and the Margalef's and Menhinick's values were also below 2 indicating the heavy pollution of the Lake.

6.0 Conclusion and Recommendations

6.1 Conclusion.

- According to the physico chemical & biological observations of the present investigations of Kandy Lake water, it is already eutrophic and therefore its bottom sediment may contains high nutrient concentrations adsorbed to the bottom sediment. Therefore even with the further nutrient inputs are controlled the blooming could occur due to accumulated nutrient loads in the bottom
- The phytoplankton diversity is very low and represented by only 06 species namely, *Microcystis aeruginosa, Microcyctis incerta, Melosira granulate Pediastrum duplex, Merismopedia tenuissima, , Diatoma elongate.*
- Out of them the highest density was observed for *Microcystis sp.* and secondly high densities were observed for *Melosira granulate* .
- *Pediastrum* was found in almost all the samples but densities were very low.
- The diversity index values found for Kandy Lake was well below one through out the investigation period for the entire lake indicating that the lake is eutrophic.
- During lake management practices the trends in diversity values could be used as a monitoring tool in eutrophication management.

6.2 Recommendations

- The diversity index value of <1 found for Kandy lake could be used as a reference value to monitor the trends during restoration of the lake.

- Diversity index values could be used as a monitoring tool in management of Kandy Lake against eutrophication even without time consuming & costly chemical analysis procedures.
- As nutrient loads accumulated in the bottom sediment due to eutropication there is a need for quick remedial efforts if the Lake is to be saved from this bad situation. Therefore it is highly recommended to oxidize the bottom organic matter of the lake using appropriate techniques.

References

Abel. P B, (1989), Ellis Harwood Series in Wastewater Technology - Water Pollution Biology Ellis Harwood Limited, England.

Abeywicrama,B A (1979): The genera of the fresh water Algae in Sri Lanka, Part I.UNESCO Man and Biosphere national Committee of Sri Lanka. Pub.No.6 pp 1-25

Abeywicrama, B A; & Abeywicrama Lilani; Arulgnanam pp; and Jenson,M A B (1986); Part II.UNESCO Man and Biosphere national Committee of Sri Lanka. Pub.No.15 pp 1-44

Almond D C (1994): Solid –Rock Geology of the Kandy Area Sri Lanka, Institute of Fundamental Studies.

Bartram, Jamie & Balance, Richard (1996): Water Quality Monitoring –A practical guide to the design & implementation of fresh water quality studies & monitoring programmes, E & FN Spon , an imprint of Chapman & Hall, UK

Bechtel, T J and Copelands, B J (1970): Fish species diversity indices as indicators of pollution in Galveston Bay Texas: Contr. Mar. Sci 15 :103 -132

Brown, R M, Mc Clelland, M J, Dininger, R A and O'Connor, M F (1975): A Water quality Index; In Indicators of Environmental Quality ed. Thomas W A Plenum Press 173-82

De Silva,P K & K H G M de Silva, (1984): An ecological study of the meso and macro fauna of the litoral region of Lake Kandy in Sri Lanka Arch.Hydrobiol.102(1):52-72

de Zwart, D (1995): Monitoring water quality in the future Vol 3, Biomonitoring. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.

Dirk Van Damme, (2001): Biological Assessment of water quality: simple methods and guidelines, Water lines, Vol.20 NO 1

Dissanayaka L & Pereira R (1998): Restoring Beira Lake, An integrated Urban Environment Planning Experience in Colombo – Sri Lanka

Dissanayaka C B et al (1982): The Environmental Pollution of Kandy Lake, A case study from Sri Lanka, Environment International, Vol. 7, pp343-351.USA

Dissanayaka, C B et al (1987):Heavy Metal abundance in the Kandy Lake, An Environmental case study from Sri Lanka, Environ Geol Water Sci Vol. 10 No 2 pp 81-88 , Spriger Verlag New York

Dorris, J C & Wilhem, J L (1968): Biological parameters for the water quality criteria. Bioscience 18; 477-81

Ellis, K V, While G & Warn A E (1989), Surface Water Pollution & its control, Macmillan, London.

Gaedeke A. & Sommer U. (1986): The influence of the frequency of periodic disturbances on the maintenance of phytoplankton diversity. *Oecologia* (Berlin) 71: 25-28.

Golterman, H. H. Clymo, R. S. (1970): Method for chemical analysis of fresh water.

Gunatilaka. A. Peter. Diehl and Heike, Puzicha. (1998) The evaluation of Dynamic Daphnia program.

Hellawell, J M(1986):Biological indicators of freshwater pollution & environmental management Elsevier applied science publishers Ltd.

Henderson-Sellers, B. & Markland, H.R. 1987, Decaying Lakes: The Origin and Control of cultural Eutrophication, Great Britain: John Wiley & Sons.

http://www.commonwealthknowledge.net/repindpr.htm

Hynes, H B N (1966): Biology of polluted waters, Liverpool Univ. Press

Joy, C M and Ammini Joseph. (1995), Diatoms as indicators of Water Quality, *Pollution and Biomonitors* Rana, B C ed., – Tata Mc Grow- Hill publishing co-op. Ltd., New Delhi.

Kelly, M.G. and B.A. Whitton (1995) "The Trophic Diatom Index: a new index for monitoring eutrophication in rivers." *Journal of Applied Phycology.* 7: 433-444.

Koenings, J P & Edmundsoon, J A (1991): Secchi disk and photometer estimates of light regimes in Alaskan lakes: Effects of yellow colour turbidity. Lomnol. Oceanogr., 36(1): pp 91-105

Krishan Kannan, (1991), Fundamentals of Environmental pollution – S Chand & Company Ltd. Ramnagar, New Delhi (pg 288-301)

Landres. P.B., Verner, J. and Thomas, J.W. (1988): Ecological uses of vertebrate indicator species: a critique. Conservation Biology 2: 316-328.

Liyanage U S P K, (2001) Trophic status of the Kandy Lake & an assessment of the effect of land use practices on Eutrophication and Blooming using GIS as a tool.

Lorenzen C J (1967): Determination of chlorophyll & Pheo-pigments: Spectrophotometric equations – limnol. Oceanogr 13 : 343 -6

Mahalekame, K (2000): Preliminary Survey of Biological Indicators in Kandy Lake, M Sc Thesis- 2000

Mason, C. F. (1991): Biology of fresh water pollution. Second Edition. England. Longman Scientific and Technical. PP. 95-119

Master plan for Development of Kandy lake(2002) :Deputy director of Irrigation, Kandy Range, Kundasale,

Murphy and Reley (1962): Determination of Orthophosphate. Anal Chem. PP 27-31

Natural Resources of Sri Lanka, (2000): National Science foundation-Colombo, Sri Lanka (213-248)

Needham J G & Needham P R (1972) : A guide to the study of fresh water biology,5th Edition, Holden –Day Inc., San Francisco. Pp 10-125

Nygaard G (1949): Hydrobiological studies of some Denish ponds and Lakes II Biol.Sci.7: 293

Olive, J H (1971): A Study of Biological Communities in the Scioto River as Indices of water quality; ohio boil serv. & Water resources centre. The Ohio State univ. Res. Prop. Completion report.

Pearsall, W H (1932): Phytoplankton in the English Lakes II The composition of the phytoplankton in relation to dissolved substances. J, Ecol. 20:241-262

Perera, N. M. P. (1998). Fish plankton interactions and controlling *Microcystis* blooms at the Kotmale reservoir. M. Phil thesis.

Piyasri, S (2001), Fresh water resources and their management. Published by the Open University of Sri Lanka.

Piyasiri, S (1991), Limnology projects at Mahaweli reservoirs some physical and chemical properties of Kotmale, Victoria and Randenigala reservoirs. Vidyodaya journal of science.

Piyasiri, S. (1995) Eutrophication and blue green algal bloom problem of Kotmale reservoir in Sri Lanka.

Prescott, G W A (1951): Algae of the western Great Lake area. Institute of science Buletin 31: 946pp

Rana, B C and Jameson, J, (1995): Algal Bioassays for Monitoring Heavy Metal Pollution Rana, B C ed., *Pollution and Biomonitors* – Tata Mc Grow- Hill publishing co-op. Ltd., New Delhi.

Rast & Holland (1988): In Biology of fresh water pollution. Second Edition. Mason C. F. (ed), England. Longman Scientific and Technical.

Reynolds, C. S. (1988): Functional Morphology and adaptive strategies of freshwater phytoplankton. p. 388-433. In: C. D. Sandgren, ed., Growth and reproductive strategies of freshwater phytoplankton. Cambridge University Press, Cambridge.

Rowson, B S (1956): Algal indicators of trophic lake types,Limnol.Oceanogr.1: 18-25

Sawyer, C N (1947): Fertilization of lakes by agricultural and urban drainage, J New Wat.Wks.Ass.51:109-27

Seven Erik Jorgensen, (1995): The application of ecological indicators to assess the ecological condition of a lake, *Lakes & Reservoirs*: Research & Management 1: 177-182

Silva, E I L (1996): Water quality of Sri Lanka, A review of 12 water bodies.

Singh, R N (1953): Limnological relations of Indian inland waters with special reference to water blooms. Verh. int. Verein. Theor. angew. Limnol.12:831-36

Sladecek, V (1979): Continental systems for the assessment of river water quality, In : Biological indicators of water quality.(ed) James A & Evison L ,Wiley j Son S N Y. Chapter 11

Staub, R. Appling J.W. Hopstetter A.M. (1970): The effect of industrial wastes of Memphis and Shelby country on primary planktonic producers.

Talling, J.F. & I.B. Talling, (1965): The chemical composition of African lake waters. *Int. Revue ges. Hydrobiol.* 50: 421-463.

Trivedy, R C (1981): Use of Diversity Index in Evaluation of Water Quality, Biological Indicators and Indices of Environmental Pollution . Central Board of Prevention and Control of water pollution, Hyderabad, India

Trivedy, R.K. Goel P.K, (1986): Chemical and Biological Methods for Water Pollution Studies, Environmental Publications, Karad, India.

Urban Development Authority (1993): Beira lake restoration study Vol. 2

US Environmental Protection Agency - Water quality (1996)

Venkateswarlu, V (1981): Algae as indicators of river water quality and pollution, Biological Indicators and Indices of Environmental Pollution . Central Board of Prevention and Control of water pollution, Hyderabad, India

Victorian Project on Blue Green Algae, Department of Conservation and Natural Resources, Second Edition (1995)

Vollenweider, R.A., and Kerekes, J. (1982): Eutrophication of Waters. Monitoring, Assessment and Control. Organization for Economic Co-Operation and Development (OECD), Paris.

Weinbauer, M.G. and Höfle, M.G. (1998): Distribution and life strategies of two bacterial populations in a eutrophic lake. *Applied and Environmental Microbiology*, vol. 64, p. 3776-3783.

Wenderoth, D. and Reber, H. (1999): Development and comparison of methods to estimate the catabolic versatility of metal-affected soil microbial communities. *Soil Biology and Biochemistry*, vol. 31, p. 1793-1802.

Whilm, J. L. (1970): Range of diversity index in Benthic macro invertebrate population

Whitford, C D & Schumacher,G J (1973): A manual of fresh water algae. Sparks press publishers, Raleigh, N C pp 12-231

www.ew.govt.nz/ourenvironment/indicators/inlandwater/lakes/lake9/techi

Yunus M, Singh N, (2000): Environmental Stress: Indication, Mitigation and Eco-conservation Kluwer Academic Publishers, The Netherlands. A Comparative Survey of the phytoplanktonic Flora in Three Lagoons on Southern Sri Lanka with special reference to their usage as Biomonitors – De Silva M P and Priyadarshana D G T (Pg259-268)

Zafar, A R (1981): Algological Evaluation of Water Pollution, Paper presented at WHO Workshop on Biological Indicators and Indices of Environmental Pollution Cent. Bd. Prev. Cont. Water Poll. / Osm. Univ. Hyderabad – India

Zutshi, D P (1981): Evaluation of Eutrophication in Fresh Water Lakes using Phytoplankton and primary production as indicators, Biological Indicators and Indices of Environmental Pollution , Central Board of Prevention and Control of water pollution, Hyderabad, India