Occurrence of *Microcystis* Toxic Blooms in Indawgyi Lake, Kachin State

Moat War Dine Naw[1], Dakaw Phong San[2] & Yae Aung[3]

Abstract

Indawgyi Lake is situated in Monyin Township, Kachin State. It is the largest inland lake in Myanmar and one of Ramsar sites in the world. There was a mystery phenomenon during November to January every year, the surface of lake is covered by green scum and fish kill occur. To know the cause of fish kill, this study focused on algal biodiversity and monthly variation of algal blooms in this lake. Algal samples were collected from the whole lake and water qualities were measured. The results show that species of cyanobacteria were the most abundantly occur in this lake. The algal bloom is caused by genus *Microcystis* belong to cyanobacteria. The heavy algal blooms were observed from November to January of the year.

Keywords: Indawgyi, Toxic, Blooms, Cyanobacteria, *Microcystis*

Introduction

Freshwater is precious because it supports us with pure water for drinking, cooking, showering, washing, cultivating, and recreation. Freshwater resources are swamps, springs, streams, wetlands, ponds, and lakes. Lakes and ponds cover only a very small portion of the earth's surface, yet they play important role in the ecological system. Throughout the world there is a tremendous variation in the size and permanence of water bodies. They range in size from small puddles to the huge Great Lakes of North America and Lake Baikal in Russia. Some lakes are millions of years old, whereas at the other extreme ephemeral water bodies are water-filled only during part of the year or perhaps even only during especially wet years (Palmer, 1980). Many lakes and wetlands distribute in different parts of Myanmar. Some famous lakes in Myanmar are Indawgyi Lake in Kachin State, Inlay Lake in Shan State, Ri Lake in Chin State, Moeyungyi in Bago Region, Kandawgyi Lakes in Yangon, Mandalay and Pyin Oo lwin.

Indawgyi Lake is recognized as a Wildlife Sanctuary, an Important Birds Area, and ASEAN Heritage and a Ramsar Site. The area is covered by mixed deciduous forest, wet land, evergreen hill forest and the lake area is the most biologically diverse and most unspoiled in Myanmar. According to the report from Fauna and Fauna International (FFI) and the Forestry Department, there are 165 species of trees, 38 species of mammals, 448 species of birds (including 38 species of migratory water birds), 41 species of reptiles, 34 species of amphibians, 50 species of butterflies and 98 species of fish. So far virtually nothing is known about the phytoplankton and benthic algae of the lake. So it is worthwhile to study the planktonic, benthic algae and the other components of the biodiversity of a lake. This lake supports a substantial fishery for people of the region; there are about 500 fishermen (Zaw Lunn *et.al.* Unpublished). As planktonic and benthic algae are very important and essential components of the aquatic food chain and food web in a lake. Therefore it is also worthwhile to study them to gain knowledge on the aquatic ecology and fishery resources of the lake.

Algal flora of many water bodies of Myanmar were done by researches (Khin Phyu Phyu Aye 2007, Skuja, 1949, West & West 1907). However, the algal flora of Indawgyi, the most important lake of Myanmar, has not been carried out. The excessive bloom in Indawgyi

[1] Professor, Dr.,Department of Botany, University of Mandalay
[2] Assistant Lecturer, Department of Botany, University of Mandalay
[3] Field Assistance, Fauna and Flora International, Indawgyi

Lake was so severe that large green patches of the species as well as floating scums could be seen in the surface water. In most part, the water has become slimy. The local people have a superstitious belief that this was the act of the "nat" (deity) or guardian spirit of the lake. They believed that the guardian spirit had poisoned the lake (or in another sense purified the lake) to get rid of all undesirable elements in the lake, including fish. This phenomenon is called as **Nat se khat**, at that time the surface of lake is covered by green scums and fish kills occurred.

Toxin-producing invasive species are one of the greatest threats to global freshwater resources today (Chorus **&** Bartram 1999). However, there are a few studies on cyanobacterial bloom and toxicological effects of them in Myanmar's freshwater systems (Moat War 2001, 2002, 2004, Tin Tin Moe 2007). Present study has an aim to attract attention to the occurrence of *Microcystis* toxic bloom in the Indawgyi Lake. The objectives of this study were to identify the algal species, to find out bloom forming algae, to document the occurrence and abundance of blooms in Indawgyi Lake.

Materials and methods

Study area

Indawgyi Lake is the largest lake in Myanmar and is situated in Mohnyin Township, Kachin State. It lies between North Lattitute 25° 05' and 25° 25', and East Longitute 96° 30' and 96° 38', at 116 m above sea level. The lake is 24 km long from north to south and 13 km wide from east to west. The maximum depth of lake is 22 m, near the center of lake and the depths at the northwest and southwest are 16 m and 15 m, respectively. Main water sources of the lake are underground springs, small streams and rain waters. Especially, most of the streams transport domestic and agricultural wastes to the lake. There are over 20 villages around the lake.

Sample collection and identification

Planktonic algae were collected from the whole lake in the surface of the lake by plankton net and benthic algae were collected from the bottom of the lake at shallow places. Epiphytic algae were obtained from the aquatic plants. Algal samples were fixed with 1% Lugol's solution and identified by using microscope and relevant literatures (Desikachary, 1959, John, *et al.* 2002, Prescott, 1962, Round, *et al.*1990, Vinyard, 1979.).

Physical and Chemical parameter

The occurrences of algal blooms were surveyed and limnological studies were carried out monthly for 12 consecutive months from January to December 2018, at three points in Indawgyi Lake as shown in Figure 1. The abundance of algal bloom was estimated by the succhi depth. The water quality parameters in situ measured were Temperature (°C), pH, Gauge height or water level (m) and transparency (cm). Water samples were analyzed at Public Health Laboratory, Ministry of Health and sport, Mandalay.

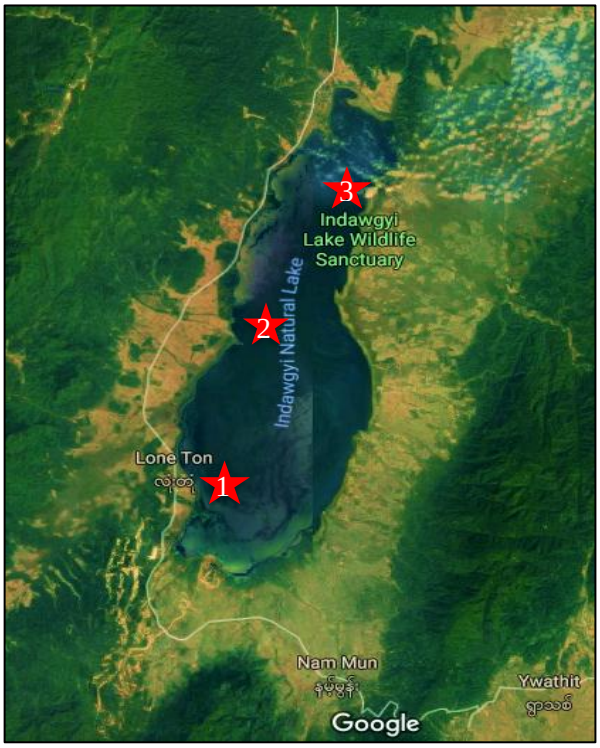


Figure 1. Selected stations for data collection in the lake.

Results and Discussion

Species composition of algae

A total of 70 algal species were recorded from Indawgyi Lake in one day collection. The algae belong to eight divisions: 15 species of Cyanophyta, 1 species of Glaucophyta, 20 genera of Bacillariophyta, 3 species of Euglenophyta, 2 species of Chrysophyta, 1 species of Cryptophyta, 2 species of Pyrrophyta, and 26 species of Chlorophyta (Moat War & Dakaw 2019). According to Zaw Lunn *at el.* (Unpublished), plankton collections were made on 22th November, 2015. Due to extremely excessive bloom (extremely dense growth) of one single species of blue green alga phytoplankton, *Microcystis aeruginosa*, all other phytoplankton were almost totally absent. Only 5 other species, namely *Volvox aureus, V. globator, Pediasrum boryanum, P. duplex* and *Mougeotia* sp (all green algae), were found; all in very few in numbers. Khin Phyu Phyu Aye (2007) recorded 50 algal species from Indawgyi Lake. It is obvious that the continuous sampling and searching will increase in species numbers of algae. Among the algal groups treated in this research, the Chlorophyceae showed the highest number of species, but the Cyanophyceae was the highest cell density in the lake. It may be due to adaptation of Cyanobacteria in this condition of habitat. Diatom is the second highest in species number and abundance of cells.

Many kinds of freshwater algae are as medicines, foods, fodders, bio fertilizer or soil conditioner and used to produce biofuel. Some are environmental indicators (Lembi & Waalang 1988). However, some algae are toxin producers. Toxin producing cyanobacteria were observed in the lake. The toxic cyanobacteria were listed in the Table 1 and Figure 3. The toxic cyanobacteria such as *Aphanizomenon flos-aquae* (L) Ralfs, *Cylindrospermom majas* Kuetz., *Cylindrospermopsis raboskii* (Woloszynska) Seenayya & Subba, *Nudolaria harveyana* (Thuret) Bornet *et* Flahault were newly recorded in Indawgyi Lake. These algae are not bloom formers. *Microcysts aeruginosa* is bloom former and the most abundant species in the lake.

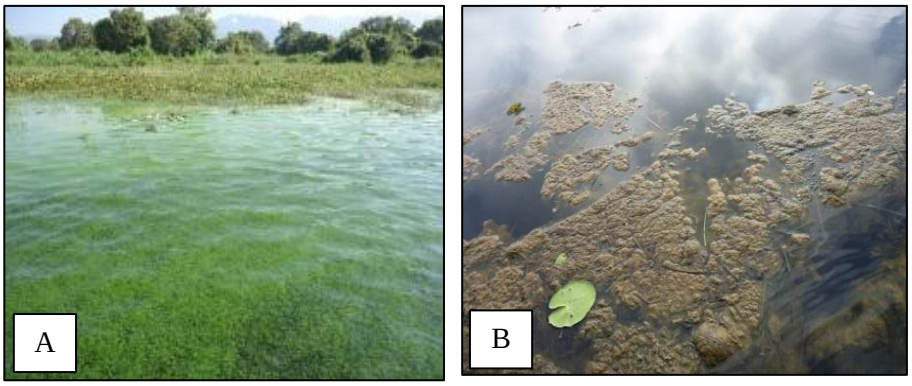


Figure 2. Algal blooms in Lake surface of Indawgyi

(A) *Microcysts* blooms, (B) *Lyngbya* mat

Table 1. List of Toxic Cyanobacteria from Indawgyi Lake (Falconer 1993)

1. *Aphanizomenon flos-aquae* (L) Ralfs
2. *Anabaena wisconsinense* Prescott
3. *Cylindrospermom majas* Kuetz.
4. *Cylindrospermopsis raboskii* (Woloszynska) Seenayya & Subba
5. *Gleotrichia natans* (Hedwig) Rabenhorst
6. *Lyngbya majuscule* Harvey & Gomont
7. *Microcysts aeruginosa* Kuetz
8. *Nostoc carneum* Agardh
9. *Nudolaria harveyana* (Thuret) Bornet *et* Flahault
10. *Oscillatoria Subbrevis* Schimidle

Algal blooms

Massive growth (bloom) of cyanobacteria in ponds, lakes, reservoirs or other freshwater systems have become serious water quality problems which also threaten human and animal health. Occurrences of cyanobacterial bloom typically appear in eutrophic lakes, which either have encountered anthropogenic nutrient loading or are naturally nutrient rich. Blooms of *Microcystis* species are known as one of the most common worldwide. The growth of *Microcystis* produces bad-smelling and unsightly scum, preventing recreational use of water for drinking, and clogging irrigation pipe (Chorus & Bartram 1999)

The members of Cyanobacteria such as *Microcystis, Aphanizomenon, Anabaena, Cylindrospermopsis, Planktothrix* are bloom forming algae. The *Microcystis, Oscillatoria, Lyngbya* and *Anabaena* blooms were observed in eutrophic lakes (Sigee 2004). However, *Microcystis* was dominated and forming massive surface blooms in this lake Figure 2. The *Oscillatoria* mats were found at the surface of water in shallow lake shore and *Lyngbya* mats could be seen as the blanket under the water. This observation indicated that Indawgyi Lake is being polluted by many factors.

Microcystis aeruginosa is formed as spherical or elongated colonies with cells more or less spherical, colony sheath is indistinct and cells are with gas-vacuoles, bringing about floating *M. aeruginosa* occur fresh to moderately brackish water, often forming dense blooms in mid-to late summer and fall to the bottom sediments in autumn. This organism produces a vast number of peptides (microcystins), some of which are highly toxic. Microcystins cause fatal poisoning of livestock and human (Falconer *et. al*. 1983, Falconer 1993).

Cylindrospermopsis has been reported to be subtropical and tropical in origin but has gradually spread to temperate areas (Codd *et. al*. 1997). In Indawgyi Lake, *C. raciborskii* was

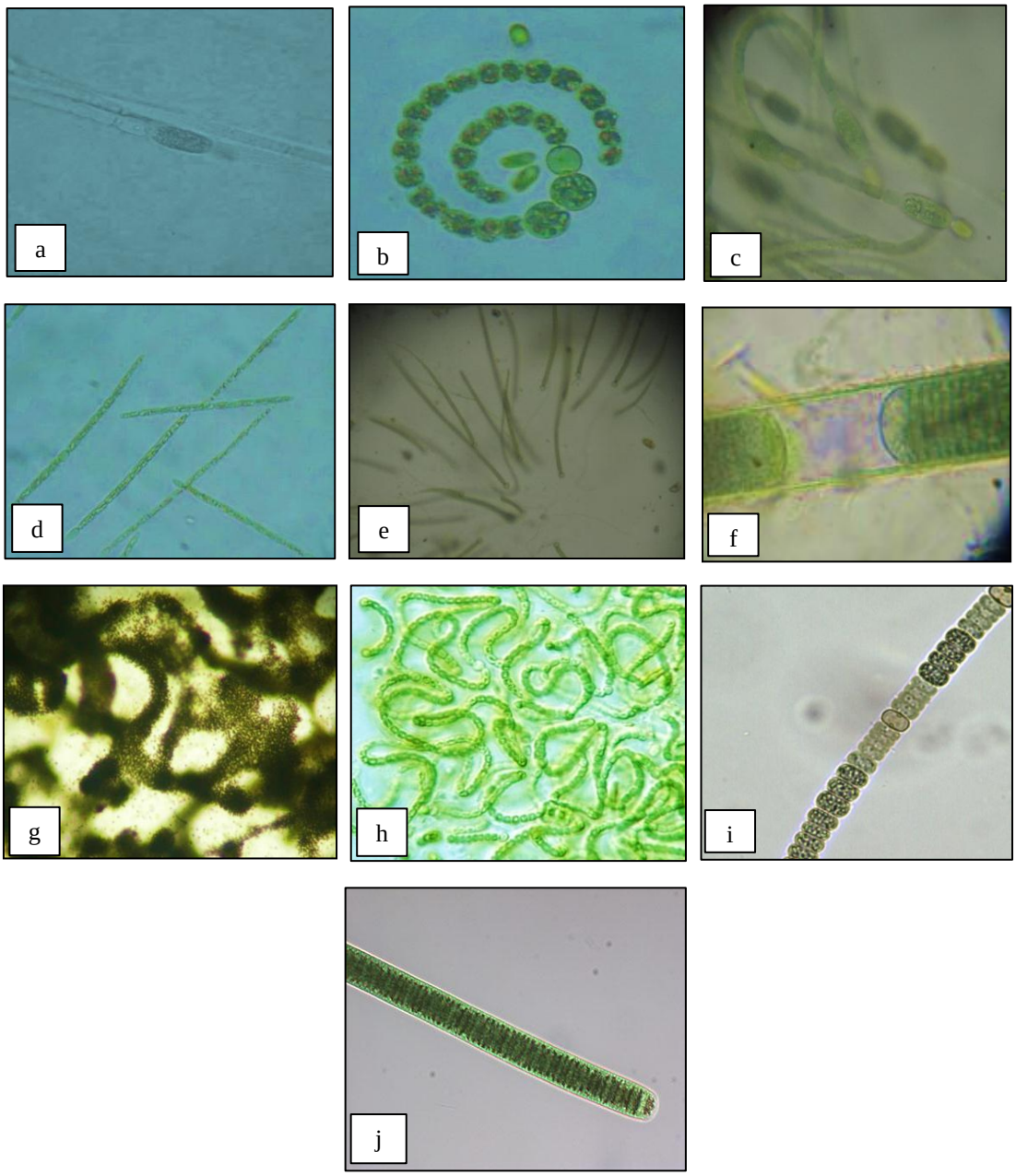


Figure 3. Toxic cyanobacteria from Indawgyi Lake.
(a) *Aphanizomenon flos-aquae* (L) Ralfs
(b) *Anabaena wisconsinense* Prescott
(c) *Cylindrospermom majas* Kuetz.
(d) *Cylindrospermopsis raboskii* (Woloszynska) Seenayya & Subba
(e) *Gleotrichia natans* (Hedwig) Rabenhorst
(f) *Lyngbya majuscule* Harvey & Gomont
(g) *Microcysts aeruginosa* Kuetz
(h) *Nostoc carneum* Agardh
(i) *Nudolaria harveyana* (Thuret) Bornet *et* Flahault
(j) *Oscillatoria Subbrevis* Schimidle

first recorded in this survey. *C. raciborskii* is extremely adaptable; the potential exists for this species to spread to other parts of the inland lakes. Continued monitoring of this taxon's occurrence, abundance, and toxicity is strongly recommended.

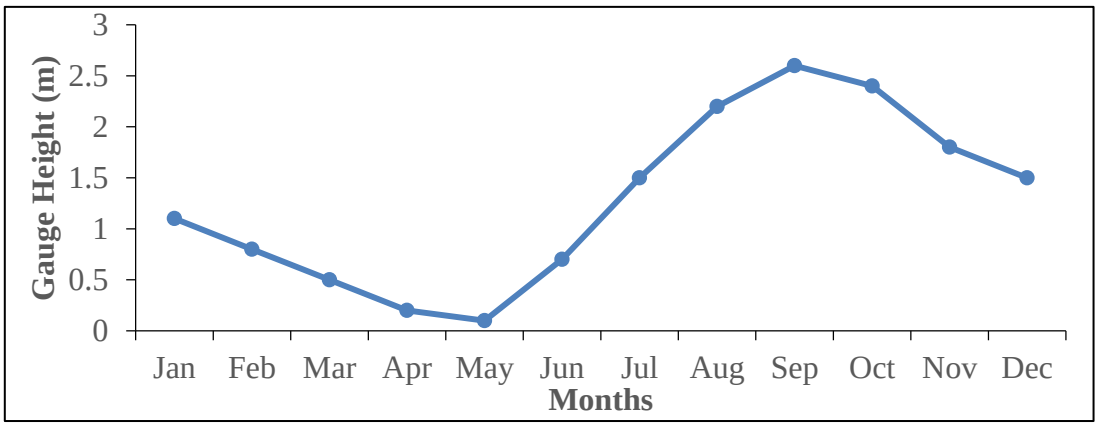
Physical and Chemical Parameters of Water

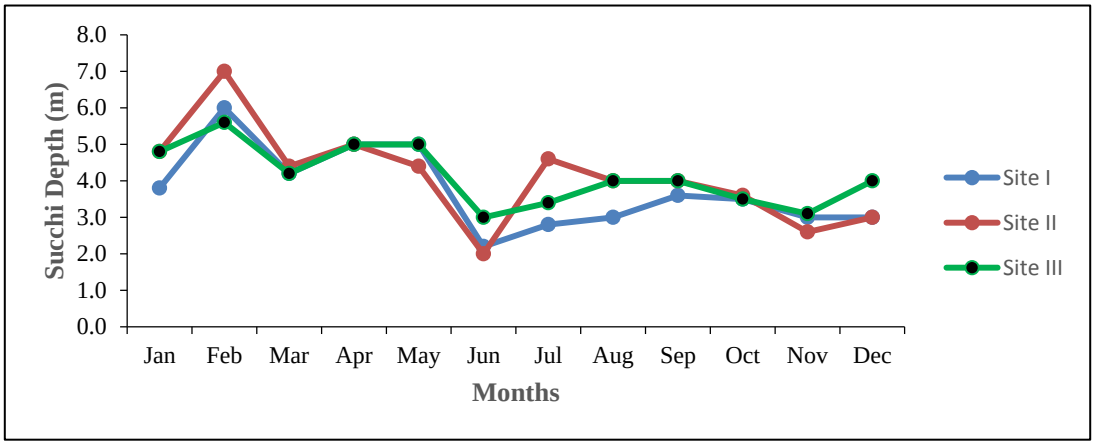
Monthly variation of water level of lake, succhi depth of water apparent, pH and temperature of water were shown in Figure 4. The maximum water level was 2.6 m in September and the minimum was 0.1 m in May (Fig.4A). The highest succhi depth was 7 m in February, followed by May, April and March (Fig.4B). At this time water is clearer than other months. The highest pH values were found in July and November, it was 8. The lowest was found in summer: March, April and May (Fig.4C). The highest water temperature in Indawgyi was 31.2˚C in July and August; the lowest was 21.6˚C in January (Fig.4D). According to results of chemical analysis, the water of Indawgyi Lake is chemically portable.

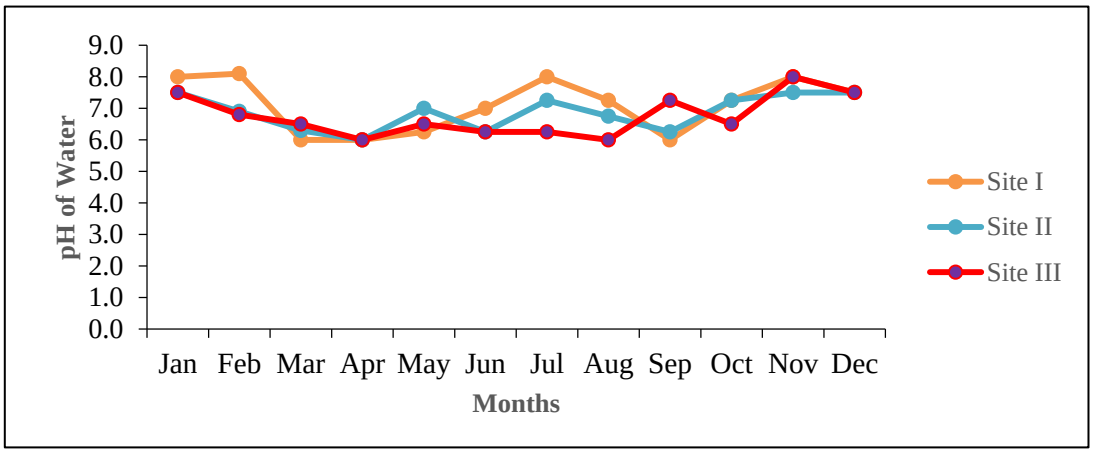
Monthly variation of blooms

There was no bloom in February to May, but a few colonies were observed on the water surface. *M. aeruginosa* formed nonspecific blooms during some seasons in Indawgyi Lake, a few successive blooms were firstly observed in the eastern shore of the lake in June. The blooms were pale green in color, change to dark green, and red. The heavy blooms were formed from November to January yearly. At that time, fish started dying and dead fish were floating on the surface of the water or stranded on the shore. In one spot on the western side of the lake, so far, more than about 150 kilograms of fish has already died (Nay Lin 2015).

These blooms presented a wide range of environmental conditions and responded positively to the high concentration of nutrients in the lake, as well as to seasonal changes of temperature and phytoplankton community. To know the factors affecting on bloom forming, some limnological data were measured. The maximum water level was 2.6 m in September and the minimum was 0.1 m in May (Fig.4A).Water level is not affected on blooming. The highest succhi depth was 7 m in February, followed by May, April and March (Fig.4B). In this time bloom is not occurred. Water transparency is correlated with blooming. The highest pH values were found in July and November, it was 8. The lowest was found in summer: March, April and May (Fig.4C). It can be said that pH is increased by blooming. The highest water temperature in Indawgyi was 31.2˚C in July and August; the lowest was 21.6˚C in January (Fig.4D). The algal blooms were found in both lowest and highest temperatures. In the literatures, cyanobacterial blooms were dominant in the summer, when the temperature reached its annual peak (25˚C) and during this season a bloom of scums type was generated (Palmer 1980) Apparently these conditions together with an increase in wind speed contributed to the development of macroscopic colonies of *M. aeruginosa* dispersed throughout the water column and formed blooms of dispersive type. The highest growth and optimum rates for this species have been reported in temperatures above 25˚C. The same results were observed in this study. In November, water temperature is 25.8˚C and the blooms get at peak.







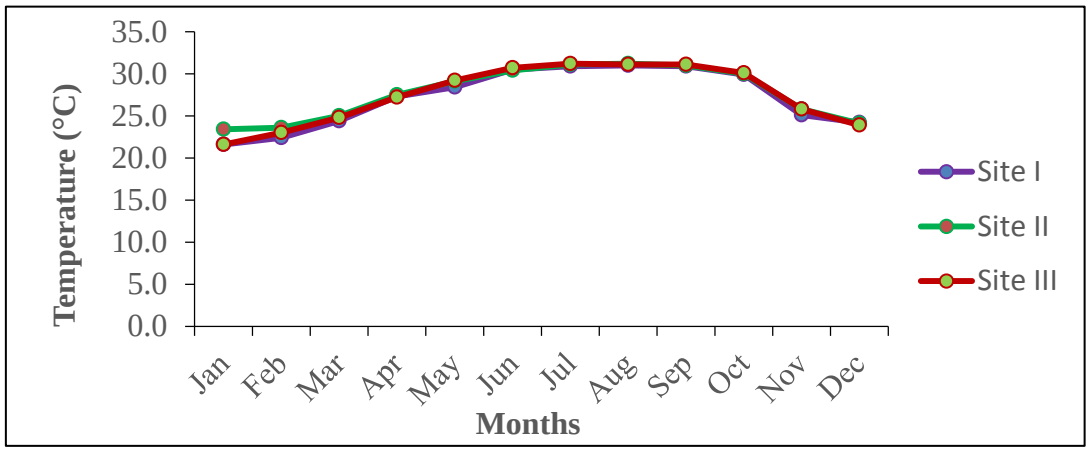


Figure 4. Monthly variation of (A. Water level, B. Succhi Depth, C. pH, D. Temperature)

Conclusion

Freshwater is very important for organisms to survive, but some of freshwater algae produce complex toxins such as okadaic acids, nodularin, microcystins, cylindrospermopsin and others (Chorus *et al.* 2000, Fujiki,1990, MacKenzie, *et. al*. 2002, Nishiwaki *et. al.* 1994). These toxins cause health problems and are toxic to aquatic organisms. Although many environmental problems are severe and approaching disaster in several regions of the world, significant efforts are now being made to attain a more sensible use of freshwaters. It is hoped that this will result in more thorough planning and management of freshwater resources permitting a sustainable development of aquatic ecosystems.

In Conclusion, cyanobacterial cell abundances and toxin concentrations in the Indawgyi Lake must be monitored for human and animal health in the future because the lake is used for fisheries and tourism activities. Moreover, pollution sources which accelerate to eutrophication process of the lake should be obstructed.

Acknowledgement

We would like to express our heartfelt gratitude to Department of Higher Education (Upper Myanmar), Ministry of Education, Rector, Pro-rectors of University of Mandalay and Dr Nu Nu Yee, Head and Professor, Department of Botany, University of Mandalay for their permission. We would like to convey our gratitude to the members of Fauna and Flora International (FFI) and Nature and Wildlife Conservation Division, Indawgyi Wildlife Sanctuary, for their helps in samplings and data collecting.

References

Chorus I, Bartram J. 1999. Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management. Published on the behalf of WHO by E & FN Spon, London.

Chorus I, Falconer I, Bartram J, Salas H. 2000. Health risks caused by freshwater cyanobacteria in recreational water. J Toxicol Environm health 3;323-347.

Codd G.A, Ward C.J, Bell S.G. 1997. Cyanobacterial toxins: occurrence, modes of action, health effects and exposure routes,.Archiv Toxicol 19 (Suppl): 399-410.

Desikachary, T. V. 1959. Cyanophyta. India Council of Agricultural Monographs on Algae. New Delhi.

Falconer I.R, Beresford A.M, Runnegar M.T.C. 1983. Evidence of liver damage by toxin from a bloom of the blue-green alga *Microcystis aeruginosa*, Med J Aust 1:511-514.

Falconer I.R. 1993 Algal Toxins in Seafood and Drinking Water. Academic Press Harcourt Brace and Company, Publishers Landon.

Fujiki, H. 1990. Okadaic acid class of tumor promoters for mouse skin and rat glandular stomach tumor promotion and mechanims of action. In: 15th International Cancer Congress, Hamburg, Germany, August, 116.

John, D. M, B. A. Whitton & A. J. Brook. 2002. The Fresh water algal flora of the British Isles. United State of America by Cambridge University Press, New York.

Khin Phyu Phyu Aye 2007. Plant resources of Indawgyi Wild Life Sanctuary. Ph D Dissertation, Department of Botany, University of Mandalay, Myanmar.

Lembi C. A. Waalang J.R. 1988. Algae and Human Affairs. Cambridge University Press Cambridge.

MacKenzie, L., Holland, P., McNabb, P., Beuzenberg, V., Selwood, A., Suzuki, T., 2002. Complex toxin profiles in phytoplankton and Greenshell mussels (*Perna canaliculus*), revealed by LC-MS/MS analysis. Toxicon 40, 1321–1330.

Moat war Dine Naw, Watanabe M, Hara Yoshiaki 2001. Fresh Water Algae from Myanmar. International Symposium of the Assian Pasific Phycological Association, Yamagata University, Japan.

Moat war Dine Naw. 2002. Biological Study on Freshwater Cyanobacteria Producing Toxins. Ph D Dissertation, Department of Biology, Yamagata University, Japan.

Moat war Dine Naw. 2004. Toxic Cyanobacteria in Fresh Water. J. MAAS, Vol 2, No.5.1-7.

Moat war Dine Naw and Dakaw Phong San, 2019. Algal Species and Monthly Variation of Blooms in Indawgyi Lake. 1st Myanmar International Science and Culture conference, University of Myitkyina, Myanmar.

Nay Lin. 2015. The History of Shwe Myint Zu Bagoda of Indawgyi Lake. Man Khate Offset, Mandalay (In Myanmar).

Nishiwaki Matsushima R, Ohta T, Nishiwaki S, Suganuma M, Kohyama K, Ishika T, Carmichael WW, Fujiki H. 1994. Nodularin, a potention by the cyanobacterioal cyclic peptide toxin microystin-LR. J. Cancer Res Clin Oncol 118:420-424**.**

Palmer, C. M. 1980. Algae and water pollution. Castle house publication Ltd., U.S.A., 1-123.

Prescott, G. W. 1962. Algae of the Western Great Lakes Area. With an illustrated key to the genera of desmids and freahwater diatom.W. C. Borwn Co., Du Buqee, IA. PP 977.

Round, F. E., R. M. Crawford & D. G. Mann. 1990. The diatoms biology and morphology of the genera. Cambridge, UK, Cambridge University Press.

Tin Tin Moe 2007. Effect of Algal bloom in environment. Ph D Dissertation, Department of Botany, Mandalay University.

Sigee, D. C. 2004. Freshwater microbiology: Diversity and dynamic interactions of microorganism, in the aquatic environment.Chicherster, UK, John Willey & Sons pp.524.

Skuja, H. 1949. Flora of Burmas. SER. IV. Vol. 14 Nos. 5. Almqvist and Wiksells Boktryckeriab Uppsala.

Vinyard, W. C. 1979. Diatoms of North America. Eureka Printing Company, Inc. Eureka, California.

West, W. & G. S. West. 1907. Freshwater algae from Burma, including a few from Bengal and Madras. Annals of the Royal Botanic Garden Calcutta. Vol. VI Part II.

Zau Lunn, Nyein Chann, Zeyar Aung, Thazin Saw and Saw Han Shein (Unpublished paper) Contribution to the study of the aquatic flora and fauna of Indawgyi Lake:Plankton and benthos (macroinvertebrates) of Indawgyi Lake. Fauna and Flora International (FFI).