TOXIC CYANOBACTERIA IN FINNISH LAKES

Tore Lindholm, Department of Biology, Åbo Akademi University, SF-20500 Åbo, Finland

Abstract

Blooms of toxic cyanobacteria were frequently observed in eutrophic lakes and reservoirs in Finland in the 1980s. Both neurotoxic and hepatotoxic species were documented and sometimes suspected as the cause of mortality among fish and domestic animals. Neurotoxicity usually occurred in association with blooms of *Anabaena flos-aquae* and *A. circinalis*. Important hepatotoxic species were *Anabaena* spp., *Microcystis aeruginosa* and *Oscillatoria agardhii*. Hepatotoxic blooms of *Nodularia spumigena* were observed in the Baltic Sea.

KEYWORDS; toxic cyanobacteria, fish lakes, Baltic Sea, hepatotoxic, neurotoxic

Introduction

Many species of planktonic cyanobacteria produce toxic substances, such as neurotoxic alkaloids and hepatotoxic peptides (Carmichael 1988). Toxic cyanobacteria, which form extensive blooms in eutrophic lakes and reservoirs, have caused great concern in many countries (Skulberg et al. 1984, Carmichael et al. 1985, Gorham and Carmichael 1988). Blooms of toxic cyanobacteria were frequently observed in eutrophic lakes and coastal waters in Finland, especially in the years 1984 -1985. There were also some reports on fish and bird kills (Eriksson et al. 1986) and mortality among domestic animals (Persson et al. 1984 and Sivonen 1990). Therefore, several studies concerning toxic cyanobacteria (occurrence, toxicity, toxin structures and effects, etc.) were initiated. This resulted in several doctoral theses (Eriksson 1990, Meriluoto 1990, Sivonen 1990) and many other publications and reports.

Toxic cyanobacteria species

Toxic cyanobacteria have been observed in lakes in most parts of Finland (Fig. 1) but toxic blooms are more common in Southern Finland where there are more eutrophication problems. An extensive survey of "suspected" lakes in Finland showed that almost 50 % of the blooms are associated with toxicity (Sivonen et al. 1990). Both neurotoxic and hepatotoxic species were observed. Important species were *Anabaena flos-aquae*, *A. lemmermannii*, *A. circinalis*, *Microcystis aeruginosa*, and *Oscillatoria agardhii*. Neurotoxicity was usually associated with *Anabaena* spp., which produce anatoxin-a (Sivonen et al. 1989a). Although toxic strains of *Aphanizomenon flos-aquae* have been

observed, this species is mostly non-toxic (Sivonen et al. 1990). Hepatoxic peptides are produced by many genera, e.g. *Anabaen*, *Microcystis*, *Nostoc* and many strains of *Oscillatoria agardhii* (Sivonen et al. 1990, Sivonen 1990).

Toxic cyanobacteria and drinking water

Various strains of *Oscillatoria agardhii* occur in many lakes which serve as drinking water supplies (Eriksson et al. 1986, Lindholm et al. 1989, Sivonen et al. 1990). Several lakes have been closed for shorter or longer periods. Special studies have been made to find treatment procedures to ensure safe drinking water (Keijola et al. 1988, Himberg et al. 1989). The water companies have also invested much money in improved purification techniques.

Studies of toxins and their effects

The knowledge concerning toxin analysis and types and structure of toxins of cyanobacteria occurring in Finnish lakes has increased greatly during the 1980s (e.g. Meriluoto & Eriksson 1988, Sivonen et al. 1989a, Sivonen 1990, Meriluoto et al. 1989, Meriluoto 1990). There are detailed studies of the effects of toxins at the cellular level (Eriksson et al.1989a, Eriksson 1990). There are also studies which show that peptide hepatotoxins accumulate in the food chain (Eriksson et al. 1986, 1989b, Lindholm et al. 1989). Although there are some quantitative data concerning toxin distribution (Fig. 2), the knowledge on the dynamics of blooms and toxin production in nature has not increased very much. We still know relatively little about the overall ecological effects and the fate of toxins in natural waters.

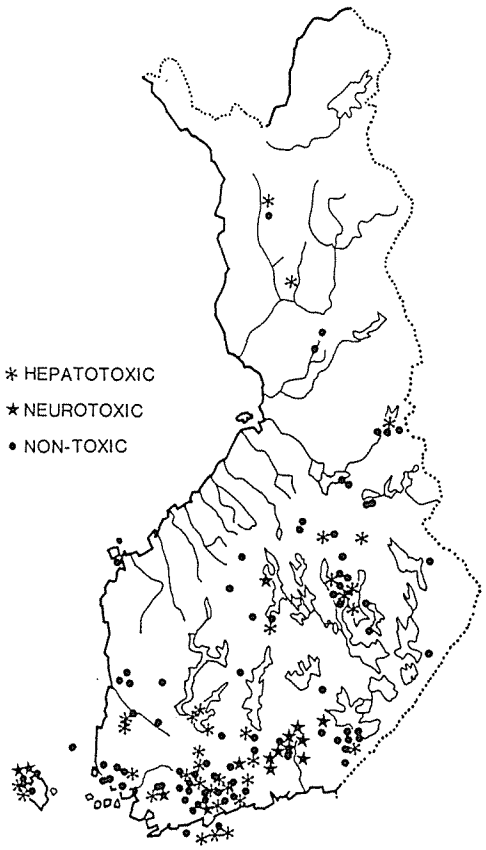

Fig. 1. Geographical distribution of cyanobacterial bloom samples revceived during a survey conducted in Finland in 1985 and 1986. Type of toxicity or non-toxicity indicated by different symbols. Reprinted, with permission, from K. Sivonen et al. 1990 "Toxic cyanobacteria (blue-green algae) in Finnish fresh and coastal waters", Hydrobiologia 190, 267-275. Copyright Cluwer Academic Publishers, Belgium, 1990.

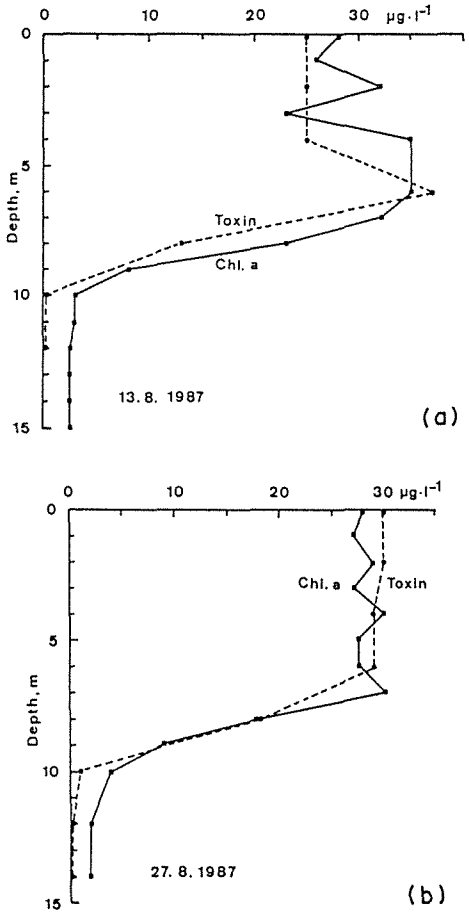

Fig. 2. a and b. Vertical distribution of chlorophyll a and *Oscillatoria agardhii* toxin in Lake Östra Kyrksundet (Åland, SW Finland) on 13 August and on 27 August 1987. Reprinted, with permission, from T. Lindholm et al. 1989 "Toxic cyanobacteria and water quality problems - examples from a eutrophic lake on Åland, SW Finland". Water Research 23, 481-486. Copyright Pergamon Press PLC, Oxford, UK, 1989.

Toxic cyanobacteria in the Baltic Sea

The Baltic Sea is a strongly stratified brackish inland sea where blooms of cyanobacteria often occur in high summer. The dominant species are *Nodularia spumigena*, *Anabaena lemmermannii* and *Aphanizomenon flos-aquae*. Toxicity of blooms in the Baltic Sea is usually linked to *Nodularia*, which produces a hepatotoxic pentapeptide called nodularin (Eriksson et al. 1988, Sivonen et al. 1989b). Several cases of mortality among dogs due to ingestion of toxic *Nodularia* have been reported (references in Eriksson et al. 1988).

Increased eutrophication of lakes and coastal waters also lead to an increased risks for problems caused by blooms of toxic cyanobacteria. Thus, it is essential to be aware of the risks and to develop monitoring programs, especially for important water supplies.

References

Carmichael, W. W. 1988. Toxins of freshwater algae. In "Handbook of Natural Toxins. V. 3. Marine Toxins and venoms", edited by A. T. Tu. Pp. 121-147. Marcel Dekker, New York.

Carmichael, W. W., Jones, C. L. A., Mahmood, N. A. & Theiss, W. C. 1985. Algal toxins and water-based diseases. CRC Critical Reviews Environmental Control 15, 275-313.

Eriksson, J. E. 1990. Toxic peptides from cyanobacteria -

characterization and cellular mode of action. PhD-thesis, Department of Biology, Åbo Akademi University, Åbo, Finland 1990.

Eriksson, J. E., Meriluoto, J. A. O., Kujari, H. P., Österlund, K., Fagerlund,. K. Hällbom, L. 1988. Preliminary characterization of a toxin isolated from the cyanobacterium *Nodularia spumigena.* Toxicon 26, 161-166.

Eriksson, J. E., J. A. O. Meriluoto and T. Lindholm 1986. Can cyanobacterial peptide toxins accumulate in aquatic food chains? In "Perspectives in Microbial Ecology", edited by F. Megusar and F. Gantar. Proc. 4th Int. Symp. Microbial Ecol., Ljubljana (Yugoslavia). Pp. 655-658. Slovene Society for Microbiology, Ljubljana.

Eriksson, J. E., Meriluoto, J. A. O. & Lindholm, T. 1989 b. Accumulation of a peptide toxin from the cyanobacterium *Oscillatoria agardhii* in the freshwater mussel *Anodonta cygnea.* Hydrobiologia 183, 211-216.

Eriksson, J. E., Paatero, G. I., Meriluoto, J. A. O., Codd, G. A., Kass, G. E. N., Nicotera, P. & Orrenius, S. 1989 a. Rapid microfilament reorganization induced in isolated rat hepatocytes by microcystin-LR, a cyclic peptide toxin. Experimental Cell Research 185, 86-100.

Gorham, P. R. & Carmichael, W. W. 1988. Hazards of freshwater blue-green algae (cyanobacteria). In: "Algae and Human Affairs",

edited by C. A. Lembi and J. R. Waaland. Pp 403-431. Cambridge University Press.

Himberg, K., Keijola, A-M., Hiisvirta, L., Pyysalo, H. & Sivonen, K. 1989. The effect of water treatment processes on the removal of hepatotoxins from *Microcystis* and *Oscillatoria* cyanobacteria: a laboratory study. Water Research 23, 979-984.

Keijola, A. M., Himberg, K., Esala, A. L., Sivonen, K., Hiisvirta, L. 1988. Removal of cyanobacterial toxins in water treatment processes: Laboratory and pilot-scale experiments. Toxicity Assessment 3, 643-656.

Lindholm, T., Meriluoto, J. A. O. & Eriksson, J. E. 1989. Toxic cyanobacteria and water quality problems - examples from a eutrophic lake on Åland, South West Finland. Water Research 23, 481-486.

Meriluoto, J. A. O. 1990. Liquid chromatographic analysis of cyanobacterial peptide hepatotoxins. PhD-thesis, Department of Biochemistry and Pharmacy, Åbo Akademi University, Åbo, Finland.

Meriluoto, J. A. O. & Eriksson, J. E. 1988. Rapid analysis of peptide toxins in cyanobacteria. Journal of Chromatography 438, 93-99.

Meriluoto, J. A. O., Sandström, A., Eriksson, J. E., Remaud, G. Grey Craig, A. & Chattopadhyaya, J. 1989. Structure and toxicity of a

peptide hepatotoxin from the cyanobacterium *Oscillatoria agardhii*. Toxicon 27, 1021-1034.

Persson, P.-E., Sivonen, K., Keto, J., Kononen, K., Niemi, M. & Viljaamaa, H. 1984. Potentially toxic blue-green algae (cyanobacteria) in Finnish natural waters. Aqua Fennica 14, 147-154.

Sivonen, K. 1990. Toxic cyanobacteria in Finnish fresh waters and the Baltic Sea. PhD-thesis, Department of Microbiology, University of Helsinki, Helsinki, Finland.

Sivonen, K., Himberg, K., Luukkainen, R., Niemelä, S-I.,Poon, G-K. and Codd, G. A. 1989 a. Preliminary characterization of neurotoxic cyanobacteria blooms and strains from Finland. Toxicity Assessment 4, 339-352.

Sivonen, K., Kononen, K., Carmichael, W. W., Dahlem, A. M., Rinehart, K. L., Kiviranta, J. & Niemelä, S. I. 1989 b. Occurrence of the hepatotoxic cyanobacterium *Nodularia spumigena* in the Baltic Sea and structure of the toxin. Applied and Environmental Microbiology 55, 1990-1995.

Sivonen, K., Niemelä, S. I., Niemi, R. M., Lepistö, L., Luoma, T. H., & Räsänen, L. A. 1990. Toxic cyanobacteria (blue-green algae) in Finnish fresh and coastal waters. Hydrobiologia 190, 267-275.

Skulberg, O. M., Codd, G. A. and Carmichael, W. W. 1984. Toxic blue-green algal blooms in Europe - A growing problem. Ambio 13, 244-247.