Netherlands: Risks of toxic cyanobacterial blooms in recreational waters: guidelines

Ibelings, Bastiaan Willem

NETHERLANDS:

Risks of toxic cyanobacterial blooms in recreational waters: guidelines

Bas W. IBELINGS

Netherlands Institute of Ecology (NIOO-KNAW) – Centre for Limnology – Department of Foodweb Studies.
Rijksstraatweg 6, 3631 AC, Nieuwersluis, The Netherlands. E-mail: b.ibelings@nioo.knaw.nl

Introduction

God created the earth, but the Dutch created Holland. This old proverb nicely emphasises the crucial role of watermanagement in the Netherlands. Protection against flooding has always been crucial for survival of the country. The earliest regional waterboards were already founded in the 14th century, and Rijkswaterstaat, responsible for watermanagement at the national level celebrated its 200th anniversary in 1998. Traditionally the focus of watermanagement has been purely on management of water quantity, but since 1970 water quality management was added to the responsibilities of the waterboards. Nowadays policies are firmly founded upon integrated watermanagement in which the all functions of water systems (e.g. production of drinking water, shipping, recreation, nature) are weighed and balanced. The current central aim of water management in the Netherlands has been described as: "to obtain and maintain a safe country and to preserve and strengthen healthy, resilient water-systems that ensure sustainable use of water". The use of surface waters for recreation, which is the subject of this paper, is thus only one of a number of functions of lakes and rivers in the Netherlands. The specific responsibility for the quality and safety of recreational water lies with the provinces and not with the waterboards, although waterboards have the responsibility to carry out the monitoring.

Most of the lakes in the Netherlands are man-made. In the densely populated western part of the country these lakes are the result of extensive peat-digging in the 19th century. Almost all of these lakes are highly eutrophic, despite large and costly efforts to reduce nutrient loads to the surface waters. Especially concentrations of phosphorous (P) have dropped strongly over the last decade or so, partially as a result of the reduction in P levels in the Rhine to which most of these peat lakes are connected. Lake restoration has been successful in some cases, but many lakes are still turbid and without the extensive submerged vegetation that once characterized them. Blooms of cyanobacteria are a conspicuous attribute of many of the lakes. Both more or less permanent blooms of filamentous cyanobacteria (genera like *Planktothrix* and *Limnothrix*) and (summer)blooms of colonial genera like *Microcystis* occur frequently. Other cyanobacteria that are often observed in the phytoplankton are *Anabaena* and *Aphanizomenon*. Dense *Microcystis* blooms are not only found in the smaller regional waters, but also in the major lakes like the IJsselmeer (1136 km^2) and Volkerak Zoommeer (61.5 km^2), and surface scums of *Microcystis* may cover tens to hundreds of square km in these lakes. Another string of large lakes (Randmeren), including lakes Veluwe and Wolderwijd used to have year round blooms of *Planktothrix agardhii*, but here a combination of restoration measures (reduction of P-loading, flushing, removal of bream) have resulted in a regime shift. *Planktothrix* has completely disappeared and *Chara* meadows have been restored to their former glory.

In summary it is clear that the potential for recreational exposure to (toxic) cyanobacteria in the Netherlands is rather large. We have numerous lakes that are eutrophic and support dense blooms of cyanobacteria in a crowded country with a high demand for water related recreational activities. For many years the authorities did not seem to take the risk of cyanobacterial blooms too seriously, but this has changed somewhat over the last few years, at least in parts of the country. The general public is relatively well informed about the health risks of swimming in lakes. There are special hotlines where information about the waterquality of specific waterbodies can be obtained ('Zwemwatertelefoon') and there are dedicated websites (e.g. www.waterland.net – link 'Zwemwaterkwaliteit') with clickable maps of the provinces, showing whether swimming is unsafe in particular waterbodies. Nowadays most warnings and even closure of lakes are related to blooms of toxic cyanobacteria. In the next two paragraphs we will discuss regulations with respect to cyanobacteria and their toxins that have been developed in the Netherlands and we will briefly present data from surveys about health complaints and microcystin concentrations in Dutch lakes to put the relevance of the guidelines into perspective. In the discussion special attention will be given to the accumulation of toxic cyanobacteria in surface scums, which pose the largest threat to swimmers. One paragraph will be dedicated to cyanobacterial toxins in drinking water.

Guidelines for microcystin in recreational waters

In 2002 the Health Council of the Netherlands published the report: "Microbial risks of recreational waters" (link: http://www.gr.nl/pdf.php?ID=92). The report gives advice to the government on epidemiological research, control measures (the 'safety chain'), legislation etc. The focus is not just on cyanobacteria but also on other agents in surface water that may transmit a disease, e.g. *Leptospira, Clostridium botulinum, Naegleria fowleri* or *Acanthamoebae*. Since in the Netherlands microcystin (MC) has by far the most widespread occurrence of all the cyanobacterial toxins, the report only gives an exposure limit for this hepatotoxin, and not for neurotoxins. Based upon the tolerable daily intake in food (MC-LR < 0.04 µg per kg bodyweight), from which the provisional WHO guideline for drinking water (MC-LR < 1 µg L^{-1}) was derived, and assuming that a swimmer ingests 100 mL of water (and bathes 365 days per year – more likely this would be less than 35 days) an exposure limit of 20 µg MC-LR per litre of bathing water is derived. Note that this value is just a guideline, there are no legal requirements to monitor microcystin levels or to act upon levels exceeding 20 µg MC-LR L^{-1} (the only legal requirement with respect to microbial risks in recreational waters is for faecal contamination).

At an earlier stage a working group of cyanobacterial experts had advised the Committee on Integrated Watermanagement (CIW – now LBOW) on a guideline about the risks of toxic cyanobacteria for recreation. Such a guideline, issued by CIW advises the different authorities (waterboards, provinces etc) on management of specific waterborne problems. The guideline on cyanobacteria aimed to achieve that - nationwide - authorities would use the same criteria for microcystin in recreational waters. This ambition had some success, most provinces use the guideline. The following values are used in the guideline:

- MC-LR > 10 µg L^{-1}: issue warning
- MC-LR > 20 µg L^{-1}: issue warning and continued monitoring; if levels are persistently high close bathing facility
- Presence of scums: at least a warning and continued monitoring

Figure 1 shows which actions should be taken by the responsible authorities on basis of the CIW guideline. In the top row of the figure an attempt is made to focus the monitoring efforts on relevant waterbodies only. There are simply too many lakes with a recreational function to monitor MC in all. Criteria that are used to select lakes are based upon historical (reputation of a waterbody, i.e. earlier problems with cyanobacteria) and recent (e.g. health complaints or strong discoloration of the water) information. Based upon the level of MC one of the actions outlined above is required: i.e. no further action; issue warning, or in the most severe cases ban swimming. Presence of surface scums in a lake should always result in either a warning or closure of the lake for recreation. Personnel in many cases has been instructed to take samples for microcystin analysis especially where cyanobacteria are concentrated in a surface bloom. Obviously the chances that MC will exceed 20 µg L^{-1} and that swimming will be banned are much increased by sampling the scums.

This was for instance the case in May 2004 in Lake Zwemlust. Microcystin concentrations rose to 390 µg L^{-1} in an ephemeral surface bloom which had accumulated near the shore. The lake was closed for recreation by the province of Utrecht. Elsewhere in the lake (outside the scum) MC did not exceed 2 µg L^{-1}, and was usually much less than 1 µg L^{-1} . The water was clear and the bottom was visible in the lake. The problem for Zwemlust was not that the water quality was all that bad, the problem was that the cyanobacteria had accumulated (both vertically and horizontally) at a position in the lake where the risk of exposure to the scum was reasonably large. Because there was plenty of water of good quality available in the lake, a solution was found in mixing the lake artificially (using Flygt mixers). Microcystin levels immediately decreased to acceptable levels and the risk of scum formation was much reduced. The lake was re-opened for recreation. This is obviously an exceptional case and this type of solution was only made possible because Zwemlust is a small lake (1.5 ha) and has constant supervision, but the Zwemlust example does emphasize the crucial role of buoyancy and scum formation in the risks of toxic cyanobacteria for swimmers.

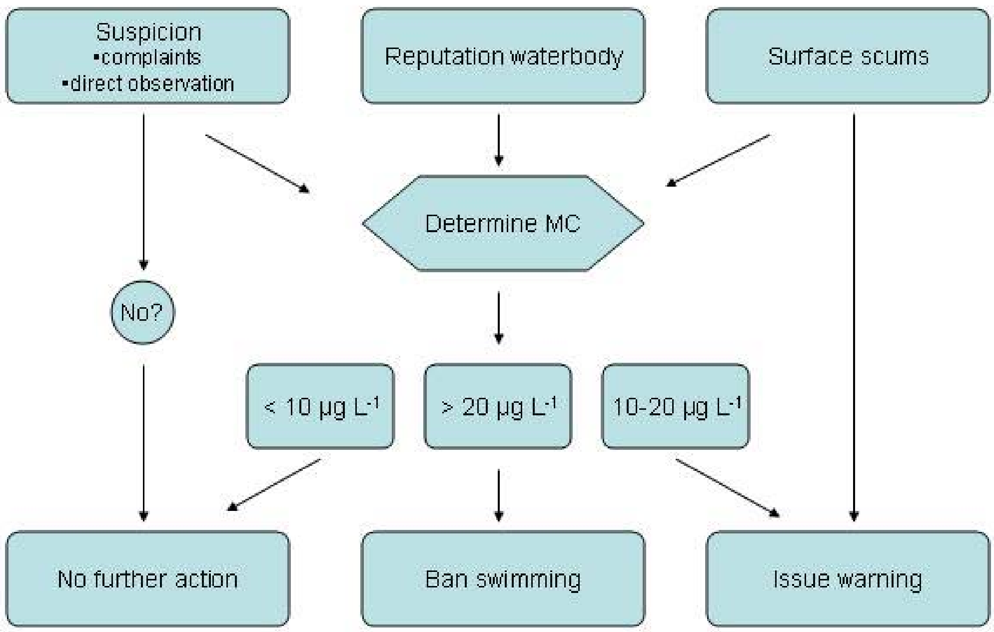

Fig. 1. Guidelines for watermanagement, developed to minimize the risk of exposure to microcystin in recreational waters in the Netherlands

Survey of health complaints related to recreation in surface waters

An inventory of health complaints related to recreation in surface waters was conducted by a survey among Municipal Health Services and provinces. In the summer of 1999 approximately 43% of the respondents reported such complaints. Identified were gastro-intestinal complaints (15 incidents with 80 patients) and skin complaints (22 incidents with 120 patients). Some complaints made a direct reference to the presence of cyanobacteria (22 incidents). The incidents usually concerned small numbers of patients, isolated in time and place. The microbiological quality of the water met the current legal water quality standards. A few notifications (4 incidents) related to health problems of dogs were made (Leenen, 2000). The specific contribution of exposure to toxic cyanobacteria to all these health problems remained unknown.

Survey of MC-LR values in Dutch lakes

Two surveys of the presence of (toxic) cyanobacteria have been carried out in the last 6 years: 1998 and 2003. In 1998 48 recreational waters with a presence of cyanobacteria were sampled by AquaSense consultancy, and in the great majority of cases (83 %) potentially toxic cyanobacteria were found (*Anabaena, Aphanizomenon, Gloeotrichia, Microcystis* and *Planktothrix*) in concentrations between 500 – 147.000 particles mL^{-1} (Stowa, 2000). The lower WHO guidance level of 20.000 cells mL^{-1} was exceeded in 35% of the cases; the higher guidance level of 100.000 cells mL^{-1-} was exceeded at 10% of the sampled locations. Microcystin (total of all microcystins, expressed as MC-LR equivalents and analyzed on HPLC-DAD) was nearly always found, in concentrations varying 0.15 – 147 µg L^{-1}. Neurotoxins were not found. The CIW guidance level of 20 µg MC-LR L^{-1} was exceeded in 21 % of the cases. This was found even at relatively low chlorophyll-a levels (starting from 22 µg L^{-1}).

Data on microcystin level in lakes in the summer of 2003 were gathered from the monitoring activity by various waterboards. A quickscan was published by Krot & Visser (2003). Some waterboards by 2003 had started microcystin analyses, but the extend to which different authorities treat toxic cyanobacterial blooms as a serious problem varies greatly. Some waterboards take no samples at all, others only when a problem is obvious (e.g. presence of scums), or even only when health complaints have been reported. In a few cases MC analyses are carried out by the waterboard for all their swimming locations but only 1 to 5 times a year. Some waterboards state that they do not monitor cyanobacteria since bathing water quality is the responsibly of the provinces.

A disadvantage of the 2003 survey is that different techniques were used by the different waterboards for analysis of MC (ELISA, HPLC and LC-MS). Moreover (and potentially more damaging for the interpretation of the results) different extraction protocols were used, and in some cases (e.g. freezing and thawing only once) it is very unlikely that all microcystins would have been extracted. Like in 1998, also in 2003 all different microcystins were converted to MC-LR equivalents. Microcystin concentrations in the great majority of cases were relatively low (326 samples), in a small number of samples (13) MC-LR varied between 10-20 µg L^{-1}, and in a somewhat larger number of samples MC-LR exceeded 20 µg L^{-1} (33). No relationship with chlorophyll-a levels was found. The latter group of locations with a high microcystin level consisted of 13 different lakes under control of 5 different waterboards. It is not clear in all cases which actions were taken in response to MC levels > 20 µg L^{-1}. Lakes were closed for recreation by at least two different provinces (Utrecht and Zeeland). Warnings were issued more often and the province of Zuid Holland advised against bathing in all recreational waters on 7 August 2003, because cyanobacteria were abundantly present.

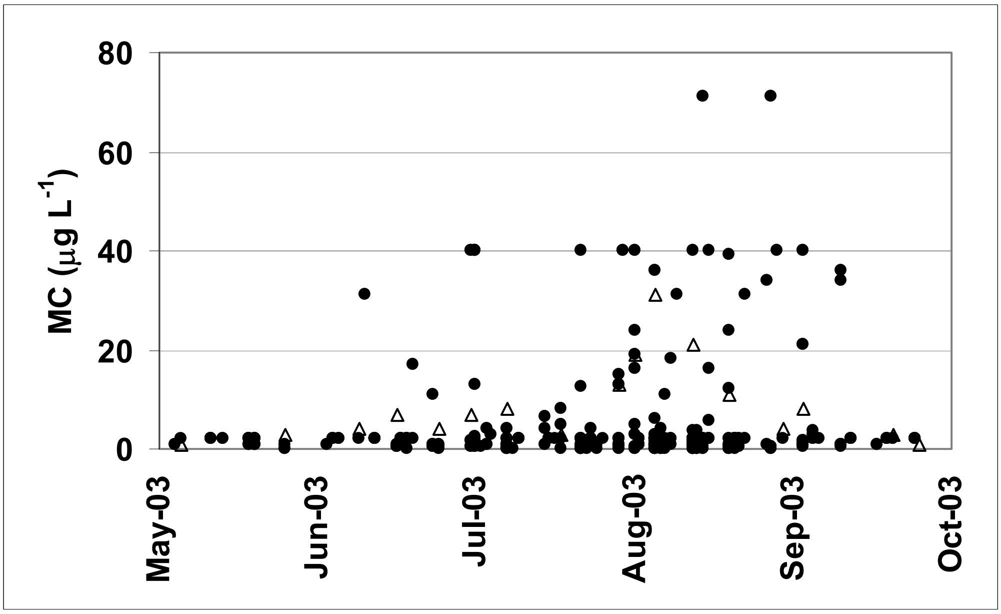

Fig. 2. Concentration of MC-LR equivalents (closed symbols) from samples taken from a number of different Dutch lakes during the summer of 2003. The open symbols represent the number of reports – per week - on scum formation in these lakes.

Discussion

The situation with respect to (monitoring) toxic cyanobacteria in the Netherlands is problematic and potentially puts the public at risk. There are a number of arguments for this: i) recreation (swimming, surfing, sailing) is intense; ii) many lakes support high densities of potentially toxic cyanobacteria; iii) microcystin levels in two surveys were shown to reach relatively high levels in different lakes and at various moments in the summer; levels on several occasions exceeded 20 µg L^{-1}; iv) there is no legal requirement to monitor the presence of toxic cyanobacteria or their toxins; v) hence there are only (voluntary) guidelines, set by CIW and the Health Council (it is possible that the CIW guidelines will obtain a legal status in the coming years); vi) different provinces and waterboards have different approaches to monitoring cyanobacteria (varying from no monitoring at all to several times per year); vi) sometimes it is unclear who has the responsibility to manage the risks of cyanobacteria; vii) the methodology for measuring microcystin is inadequate in some cases.

At this point I would like to emphasize that although cyanobacteria were inadequately monitored in all waterbodies, reliable monitoring of toxic cyanobacteria and their health risks is not a trivial task. To start with the latter, the National Institute for Public Health and the Environment (RIVM) has developed a standard protocol (PLONZ) that should facilitate the collection of health complaints from the Municipal Health Authorities. In case of a multitude of complaints for one location RIVM can instigate a more specific investigation. The lack of good epidemiological data is probably one of the reasons why the risks of toxic cyanobacteria are not always taken seriously. Monitoring the actual presence of cyanobacteria in a lake is equally hard. Not only does the number of cyanobacteria in the water vary at relatively short intervals through growth and loss processes, the formation of surface scums of floating cyanobacteria is even much more dynamic, and varies at a time scale of hours. Monitoring these dynamics with routine means is impossible; it requires an innovative approach. Arguably, scum formation is what we should be really worrying about. Whereas normally one would have to drink one to several buckets of lake water to ingest a lethal dose of toxin, once concentrated in a surface scum a small sip may be lethal. It may perhaps be unlikely that people enter (dense) scums, the presence of extremely high concentrations of a potent toxin is certainly a reason for concern (especially with little children playing at the lake shore where the chances of getting into contact with concentrates of cyanobacteria are higher). Which other toxin in watersystems has the capacity to concentrate 1000 fold or more in a time scale of just a few hours? How to keep an eye on this potential threat to the health of swimmers and surfers?

Ibelings et al (2003) published a fuzzy logic model that predicts the formation of surface scums on basis of i) the biomass of cyanobacteria, suspended in the watercolumn, and ii) the long term weather forecast, giving relevant information to derive buoyancy of the cyanobacteria and water column stability. Surface scums will develop whenever a population of buoyant cyanobacteria is present in a lake with a stable water column. Biomass of cyanobacteria may be obtained from traditional models or from routine optical monitoring (see e.g. Gons, 1999). The model was validated on basis of a long term data set of NOAA satellite images and proved to be reliable. This approach could relatively easy be made into an online warning system, where the authorities receive an automatic warning when there is a risk of scum formation in the next three to five days in one or more of their waterbodies.

Finally a paragraph about the potential exposure to microcystin via drinking water in the Netherlands. An growing proportion of drinking water in the country is obtained directly from surface water (now approaching one third of the total volume of drinking water produced yearly – Leltz personal communication), with the IJsselmeer as the main freshwater reservoir. Blooms of toxic cyanobacteria are present every year in the IJsselmeer, and Ibelings et al (in press) report microcystin concentrations (MC-LR equivalents) of up to 68 µg L^{-1}. In one drinking water reservoir 'De Gijster' an extreme microcystin concentration of 52000 µg L^{-1} was measured in surface scums (Hoogenboezem et al, 2004). Drinking water companies take the risk of microcystin increasingly seriously. A theoretical worst case scenario demonstrated that the provisional WHO guideline for drinking water (MC-LR < 1 µg L^{-1}) could be exceeded in the Netherlands, with values reaching 2.9 µg L^{-1} in the purified water (Carpentier et al, 1999). The authors concluded however that exposure to microcystin levels exceeding 1 µg L^{-1} was no more than a theoretical risk, resulting from various assumptions in the worst case scenario. Hoogenboezem et al (2004) however argue that some of the assumptions regarding the concentrations of microcystin in the (raw) intake water were quite realistic, backed up by measurements of microcystin in the intake water of several drinking water companies. Hoogenboezem et al (2004) hence conclude that "for evaluation of possible threats for drinking water production in some purification plants a special analysis is needed to make sure that toxin removal is adequate".

Concluding, although much progress has been made in managing the risks of toxic cyanobacteria for recreation and the production of drinking water, there remains work to be done in the Netherlands.

Acknoweldegements

Figure 2 was kindly provided by Petra Visser of the University of Amsterdam

References

Carpentier CJ, Hoogenboezem W & Ketelaars HAM (1999). Cyanobacterietoxines en drinkwater bereid uit oppervlaktewater. Een worst case benadering

Gons, HJ (1999). Optical teledetection of chlorophyll a in turbid inland waters. Env. Sci. Technol. 33, 1127-1132

Hoogenboezem W, Wagenvoort AJ & Blaauboer K (2004). The occurence of toxic cyanobacteria. In some Dutch surface waters used for the production of drinking water. RIWA report.

Ibelings BW, Vonk M, Los HFJ, van der Molen DT, Mooij WM (2003). Fuzzy modeling of cyanobacterial surface waterblooms: Validation with NOAA-AVHRR satellite images. Ecol. Appl. 13, 1456-1472

Ibelings BW, Bruning K. De Jonge J, Wolfstein, K, Dionisio Pires LM, Postma, J & Burger T (2005). Distribution of microcystin in a lake foodweb: no evidence for biomagnification. Microbial Ecology (in press)

Krott, B & Visser, PM (2003). Inventarisatie naar de concentraties van cyanotoxins in Nederlandse meren gedurende de zomer van 2003 en naar eventuele hiermee samenhangende incidenten, een Quick Scan. Report University of Amsterdam

Leenen, EJTM (2000). Gezondheidsklachten in verband met recreatie in oppervlaktewater in de zomer van 1999. Infectieziekten Bulletin 11, 133-135

Stowa (2000). Toxische blauwalgen in binnenwateren. Stowa report 2000-20