REDUCED GROWTH OF THE CYANOBACTERIUM *MICROCYSTIS* IN AN ARTIFICIALLY MIXED LAKE AND RESERVOIR

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The cyanobacterium *Microcystis* can cause much nuisance in lakes and reservoirs due to bloomforming and production of toxins and off-flavours. *Microcystis* is often abundant in deep lakes, which have high stability in the water column during the summer months due to temperature stratification. *Microcystis* benefits from a stable water column in which it exploits the advantage of buoyancy (provided by gas vacuoles) to stay in the euphotic zone and consequently suffers only low sedimentation losses. Non-buoyant algae, like green algae and diatoms, have high sedimentation losses in a stable water column and are thus outcompeted by *Microcystis*. Artificial deep mixing eliminates the competitive advantage of *Microcystis* and reduces its growth rate. At the same time, the abundance of non-buoyant algae in the water column can be stimulated by deep mixing as sedimentation losses are reduced. The growth rate of the phytoplankton, however, will be lower in a deep mixed lake due to a lower received irradiance as compared to the irradiance in a shallow mixed layer of a stratified lake.

In Lake Nieuwe Meer (Amsterdam), artificial deep mixing was tested as a method to reduce the nuisance caused by *Microcystis* scums. In this highly eutrophic, deep lake with an area of 1.3 km², *Microcystis* dominates during the summer months. Reduction of the nutrient loading is the best solution to reduce the biomass, but it takes years to get results. Artificial mixing was thought to be a suitable short term solution to reduce growth of *Microcystis* and prevent scum formation. An air pumping system was chosen, as this is the most efficient way to mix a lake. Tubes were placed just above the bottom of the lake (about 20–25 m deep) and from two compressors on the shore, air was pumped through small holes in the tubes providing circulation of the water column. It was taken into account that the vertical mixing velocity should be higher than the vertical rising velocity of *Microcystis*. The calculations for the system were made by Jungo Eng. Zurich, Switzerland.

In 1990 and 1991, the situation without mixing was monitored. In 1993, the mixing was continuous from April through September while in 1994 the mixing regime was intermittent in spring and continuous in

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summer. In the intermittent mixing regime, the mixing installation was turned on or off depending on the temperature or oxygen profiles. The mixing was successful as the average number of *Microcystis* colonies per m² diminished as compared to the years before mixing; nuisance due to scums hardly occurred. In contrast, the numbers of non-buoyant algae, green algae and diatoms per m² were higher, probably due to reduced sedimentation losses. In 1994, *Microcystis* biomass was higher than in 1993 (but still much lower than in 1990 and 1991), which was probably due to a much warmer summer in 1994 with higher irradiance. The numbers of non-buoyant algae, however, were lower in 1994 compared to 1993. The sedimentation losses of these algae had probably increased during the periods without mixing.

To get more insight in the growth of *Microcystis* at deep mixing conditions, measurements were performed in a storage reservoir, which is artificially mixed to reduce the growth of phytoplankton. The depth of a large area of the reservoir (30% of the total surface) along the shores is 4–6 m. The aim of the study was to determine if growth of *Microcystis* in the artificially mixed reservoir is due to a low vertical mixing velocity ("escape" of *Microcystis* to upper, illuminated layers) or due to the morphometry of the reservoir (growth in the shallow part of the reservoir only). A mixed population, entrained in the shallow part, will receive a higher daily light dose than a deep mixed population and consequently will have a higher growth rate.

In the deep mixed part of the reservoir hardly any loss in buoyancy of the *Microcystis*-colonies was found during the day, which indicates that a low amount of carbohydrates was synthesised due to a low received light dose. This indicates that the vertical velocity in the deep part of the reservoir was sufficient to keep *Microcystis* entrained in the turbulent flow. In the shallow part of the reservoir, however, 50–60% of the population lost buoyancy in the afternoon. This was not due to a higher stability at this site but it was due to a higher received light dose by the shallow mixed population. This buoyancy loss, due to a higher carbohydrate synthesis, indicates a higher growth rate. From this research, it was concluded that the large shallow area in the reservoir was responsible for sustained growth of *Microcystis*.

The method of determining the buoyancy state to obtain an indication of the light history was used to investigate the mixing efficiency in Lake Nieuwe Meer. When *Microcystis* is able to escape the mixing regime and stay in the upper illuminated layers, it will receive a higher light dose, can synthesise more carbohydrates and will have a higher percentage of colonies sinking than a deep mixed population. In this way, it is possible to distinguish between sufficiently mixed parts and insufficiently mixed parts in the lake. Determinations of the buoyancy state of *Microcystis* were performed in Lake Nieuwe Meer during artificial mixing in 1994. Samples were taken in the afternoon of a sunny, calm day. Samples at the very shallow locations along the shores were taken as a reference because shallow mixing will result in a high percentage of colonies sinking. At all of these sites 30 and 40% of colonies sinking were found. The deeper locations in the middle of the lake showed a variety in percentages. The locations close to the plumes of air bubbles had a very low percentage of colonies sinking, which indicates that the colonies were mixed throughout the whole water column and received a much lower light dose and consequently could not synthesise a high amount of carbohydrates. At greater distances from the plumes, the percentages of colonies sinking was much higher. At these locations, *Microcystis* could escape the mixing and received a higher light dose. This was checked by determining the depth distribution of *Microcystis* colonies. At most locations with a high concentration of colonies in the upper layers, the percentage of colonies sinking was high, while at locations with a homogeneous distribution a low percentage was found. In those parts of the lake, where the *Microcystis* population could "escape" the mixing, the growth rate is expected to be higher than in the deep-mixed parts.

For possible similar projects in the future, determination of the buoyancy state of colonies at various locations of a lake or reservoir can be used as a method to investigate the entrainment of *Microcystis* in the turbulent flow. If *Microcystis* remains abundant despite artificial mixing, those parts responsible for sustained growth can be determined. With that knowledge, it will be possible to adjust the mixing installation in such a way that all parts of the lake or reservoir will be sufficiently mixed.