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Modelling vertical mobility of Microcystis colonies and understanding their scum formation

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Extended abstract

Increasingly, *Microcystis aeruginosa* appear in recreational lakes and drinking-water reservoirs and may form scum layers at the water surface and occasionally become toxic.

For forecasting these harmful events Deltares designed and tested an early warning system (EWACS) based on coupling our 3D model systems. These systems include hydrodynamics (transport, mixing and temperature stratification), water quality, algal growth as well as the mutual competition among algae species. The coupled model system is driven by meteorological forecasts. A lacking ingredient is the diurnal and seasonal vertical mobility of *Microcystis* determined by their buoyancy status and turbulent mixing depending on thermal stratification. This presentation focuses on numerically modelling the vertical mobility of *Microcystis,* understanding their scum formation and the processes of bubble plumes that reduce or avoid scums.

A *Microcystis* cell contains gas vesicles making it close to neutral buoyancy in water thereby out-competing other species that sink in thermally-stratified lakes. Photosynthesis increases and respiration decreases the mass density of the cell's tissue (Visser *et al.*, 1997) yielding sinking or rising modes, respectively. Usually, *Microcystis* cells are embedded in mucus and form colonies of sizes up to millimetres. The mucus consists of rarefied polysaccharide strings due to the over-production of carbohydrates. Therefore the mucus has a mass density very close to water and the entire colony responds to water motions as a solid object.

Rather than tracking individual colonies we ensemble-average the colony paths affected by turbulence and changes in cell-tissue density. This averaging yields the so-called Fokker-Planck equation for the vertical colony distribution. The latter we solve in conjunction with our model for turbulent mixing in a thermally-stratified lake.

For 5m and 30m deep Dutch lakes we compare our model to observations (Ibelings *et al.*, 1991) of the vertical distribution of *Microcystis* colonies. The results show a good agreement with the observations of diurnal changes in vertical position. The simulations show that on a daily cycle, small colonies (50-200 µm) remain highly concentrated in the centre of the epilimnion whereas large colonies (≥ 800 µm) migrate to greater depths but temporarily concentrate near the surface. We believe the latter stage is the prelude to scum formation and its harmful consequences for e.g. recreation and water quality.

We have evidence for understanding the actual formation of a scum as follows. After a sunny period with mild wind and one or several *Microcystis* bloom periods, more oxygen is produced below the water surface than released to the atmosphere, yielding dissolved oxygen (DO) super saturation. At less than 0.5 meter depth the partial pressure at 150-180% super saturation allows bubble growth. The buoyancy of even a few small oxygen bubbles easily overwhelms the increase of cell-tissue mass density by photosynthesis. Hence the

colonies become permanently buoyant and form the scum. In support of this postulate, we have collected the following evidence.

By *in-situ* compression, Riebesell (1992) concludes that gas bubbles make marine snow at least neutrally buoyant. For her Ph.D. Evelyn Aparicio Medrano repeated Riebesell's experiment and showed that *Microcystis* colonies sink when compressed in rising mode. We can demonstrate that sinking cotton wool rise after super saturating water with carbon dioxide.

These findings shed a different light on methods of suppressing scums e.g. by bubble plumes. For instance, in a 30m deep thermally-stratified lake we observed that bubble plumes reduce DO levels from 180-200% super saturation in *Microcystis* blooms to just saturation level. Regarding the vertical mobility of microcystis, bubble plumes destroy their particular physical advantages such that other algae may prevail.