

THE DYNAMICS OF CYANOBACTERIA AND POTENTIAL THREATS OF CYANOTOXINS IN UGANDA: A CASE OF MURCHISON BAY AND NAPOLEON GULF, NORTHERN LAKE VICTORIA

ABSTRACT

Eutrophication leads to cyanobacterial blooms and have an impact on the sustainable utilization, management, monitoring and protection of surface water resources. From the extensive review, Lake Victoria has hydrodynamically distinct closed and open bays and gulfs (B&Gs) with a great diversity of cyanobacterial taxa including both nitrogen fixers and non-nitrogen fixers. However, there is an underlying dominance by either *Dolichospermum* or *Microcystis* across the B&Gs and Open Lake (OL) stations of Lake Victoria. This suggests that the B&Gs and OL are subjected to different levels of nutrient loading and are consequently exposed to varying toxigenic cyanobacteria and concentrations of microcystins (MC). Over the years, up to 31 congeners of MC have been identified in the lake with MC-LR, MC-RR and MC-YR as the commonest.

Then, this study assessed the patterns of phytoplankton diversity, dynamics of cyanobacteria, factors controlling the cyanobacteria and cyanotoxins, and potential health risk associated with cyanotoxin exposure routes in two bays in Lake Victoria. Such an integrated study helps to assess the sanitary risks associated with toxigenic cyanobacteria and cyanotoxins in the advent of increasing eutrophication of the lake. Data were collected from the lake, water treatment plants (WTPs) and mesocosm experiments in Napoleon Gulf (NG) and Murchison Bay (MB) between November 2016 and October 2019.

From the comparative assessment of the spatial and temporal changes of phytoplankton community, biomass, and diversity in open (NG) and closed (MB) embayments, different levels of eutrophication status (eutrophic vs. hypertrophic), and connection to the OL exist. Much as there is high nutrient loading into MB, a gradient in the limnological parameters were observed towards the OL because of the mixing and dilution effect. Furthermore, significant differences in phytoplankton richness and diversity were observed, suggesting suitable ecological niches to support diverse phytoplankton species (PERMANOVA test, $p = 0.001$). Although the phytoplankton community was similar, their dynamics and any dissimilarities were driven by the dominant cyanobacteria, *Microcystis flos-aquae* and *M. aeruginosa* in MB and *Dolichospermum circinale* and *Planktolyngbya circumcreta* in NG. This makes closed embayments, such as MB more susceptible to toxigenic cyanobacteria with potential cyanotoxin production.

Indeed, the most toxigenic cyanobacteria were from the genera *Dolichospermum*, *Microcystis*, *Oscillatoria*, *Pseudanabaena* and *Raphidiopsis* that resulted in the detection of two classes of cyanotoxins: MC and homoanatoxin (HTX) an analogue of anatoxin-a (ATX). Considering MC, significantly higher concentration (5-10 $\mu\text{g MC-LR equiv. L}^{-1}$) was detected in MB compared to NG (Mann-Whitney test, $p < 0.001$) resulting from the high biovolume of toxigenic cyanobacteria. This frequently exceeded the WHO sanitary threshold of $>100,000 \text{ cells}\cdot\text{mL}^{-1}$ and $1 \mu\text{g}\cdot\text{L}^{-1}$ of MC-LR. This implies that fishers and local population drinking contaminated water could be harmed, and that the recreational activities in the nearshore expose populations to cyanotoxins. The WTPs efficiently removed the cyanobacterial cells, intracellular and dissolved MC to below

the WHO guideline value for exposure via drinking water. The observed MC have been related to the biovolume of *Microcystis*, influenced by solar radiation, mean wind speed (N-S direction) but also turbidity in the water column.

The in-situ mesocosm experimentation indicated that continuous eutrophication would enhance phytoplankton biomass and specifically increase the growth of cyanobacterium *Microcystis* and resultant increase in MC production. Nile tilapia consumed green algae, such as *Scenedesmus* sp. and cyanobacteria, such as *Microcystis* sp. causing responsive changes in the planktonic community. This suggests that Nile tilapia has the potential to control cyanobacterial biomass however, it resulted into significant transfer of MC into the intestines (up to 27.5 µg/g FW of MC-LR) in fish mesocosms from MB than NG (< 0.44 µg/g FW of MC-LR). In some instances, there was MC detected in the target organ (liver) (up to 0.48 µg/g of MC-LR FW) and muscle (up to 0.3 µg/g FW of MC-LR) in MB. Thus, MC accumulate in the different organs of fish and increases the exposure of humans to cyanotoxins through fish consumption. Therefore, for risk assessment, consumption of such muscles exceeds the total daily intake (TDI) (0.04 µg MC-LR kg⁻¹ day⁻¹) for an adult consuming 200-300g of fish.

Finally, due to the dominance of toxigenic *Microcystis* in the embayments, regular sensitization of people during bloom events and biovolume estimation are proposed to prevent health threats. Furthermore, locals should desist from using contaminated lake water for domestic purpose (cooking, drinking) but rather use treated water, and reduce recreational activities during bloom events. In addition, warning signs, and closure or discontinuation of swimming or bathing during blooms in recreation areas should be undertaken. For the WTPs, integration of *Microcystis* cell counting and biovolume estimation is encouraged for proper treated water safety from Lake Victoria. From this perspective, there should be dedicated fish monitoring from water bodies with toxigenic cyanobacteria and evaluate the potential exposure risks to humans.