WaSAf

Performance assessment of two water treatment plants (Gaba and Walukuba in Uganda) in eliminating cyanotoxins from drinking water

Summary Notes n°5

Performance assessment of two water treatment plants (Gaba and Walukuba in Uganda) in eliminating cyanotoxins from drinking water

Many cyanobacteria blooming in freshwater ecosystems produce harmful cyanotoxins.

The most frequent cyanotoxins found during blooms are microcystins, a peptide toxin family containing >200 structural variants. These microcystin variants are more or less toxic to humans and animals. Consequently, many countries have developed guidelines for microcystins in drinking water and recreational waters. Most drinking water guidelines are based on the World Health Organization(WHO) provisional value for drinking waters of 1.0 µg/L microcystin-LR. However, recent studies performed on the toxicity of microcystins show that these products have reprotoxic effects (i.e., they impact sperm motility, resulting in a potential decrease in fertility), and some countries, such as France, have lowered the threshold to 0.2 µg/L for drinking water.

Lake Victoria is associated with cyanobacterial blooms, particularly in its numerous bays and gulfs (B&Gs). During these blooms, high microcystin concentrations are sometimes recorded in water, which raises the safety issues of the drinking water produced from these B&Gs. A comparative study was conducted on the performances of two Ugandan drinking water treatment plants (WTPs), Gaba III (near Kampala) and Walukuba (near Jinja), in eliminating cyanotoxins from drinking water. The main interest in comparing these two WTPs is that (i) the Gaba WTP takes water from Murchison Bay (MB), which is hypereutrophicated and experiences persistent and recurrent blooms; and (ii) the Walukuba WTP takes water from the Napoleon Gulf (NG), which is less eutrophicated with fewer cyanobacterial blooms.

I. Design of the study

In the Gaba III and Walukuba WTPs, raw water undergoes a conventional treatment process made of chemical coagulation using polyaluminum chloride (PAC) (30-60 mg L-1 in Gaba; 8-18 mg L^{-1} in Walukuba) and flocculation, sedimentation and clarification; sand filtration; and chemical chlorination before distribution. The main difference between the two WTPs is that prechlorination is performed upstream of the treatment process

in Gaba III due to the high phytoplankton biomass in raw water.

Weekly water sampling was performed in MB and NG from November 2016 to January 2017 between 8 and 11 am and 2 hours later in the respective water treatment plants. In each WTP, two liters of water samples were obtained from designated sampling points during the treatment process: raw water, clarified water, sand filtered water and final chlorinated water. The water samples were collected to determine the phytoplankton composition (only in raw water), chlorophyll-a, phytoplankton biomass and microcystin concentrations during the water treatment process. For microcystins, dissolved (free toxins in the water) and intracellular forms were quantified by ELISA.

II. Variations in phytoplankton biomass in lake water and during the water treatment process in the two WTPs

As shown in Figure 1A, the phytoplankton biomass (expressed as chlorophyll-a) in lake water was much higher in MB than in NG. This result agrees with the data collected during the one-year comparative monitoring performed at these two sites in the WaSAf project (see Summary Notes n°2). As shown for this monitoring, the dominant phytoplankton species were cyanobacteria.

During the study, cyanobacteria represented >90% of the total phytoplankton biomass in the lake water of the Gaba III WTP. *Microcystis* was the dominant cyanobacterial genus, representing >70% of the total cyanobacteria biomass, this colonial cyanobacteria being known to be able to produce microcystins. Other genera/species, such as *Aphanocapsa sp.*, *Dolichospermum* (*Anabaena*) *sp.*, *Chroococcus sp.* and *Merismopedia sp.*, contributed to <10% of the cyanobacteria biovolumes. In the Walukuba WTP, *Planktolyngbya* was the dominant genus, followed by *Microcystis* and *Aphanocapsa*, with the two latter genera being able to produce microcystins.

In agreement with these data, higher phytoplankton biomasses were also found in the raw water of the Gaba III WTP. However, it is interesting to note that in both WTPs, the phytoplankton biomasses in the abstracted raw water were lower than those recorded in the lake, demonstrating that the water abstraction depth allowed us to reduce the phytoplankton biomass in raw water at the beginning of the treatment process (Figure 1B).

During water treatment, the clarification process in the Gaba III WTP was more efficient than in Walukuba, where the initial phytoplankton biomass, which was three times higher in Gaba raw water, was reduced to similar biomasses after clarification (Figure 1B).

Our data also showed that after the first treatment step, the phytoplankton biomasses were very low in both WTPs (from < 10 µg L-1 after clarification to < 2 µg L-1 in the final water). Thus, intracellular (cell bound) concentrations of microcystin should also be very low and do not present any hazard to human populations. However, the presence of dissolved microcystins (dMCYS) due to the cell lysis of cyanobacteria during treatment can be suspected.

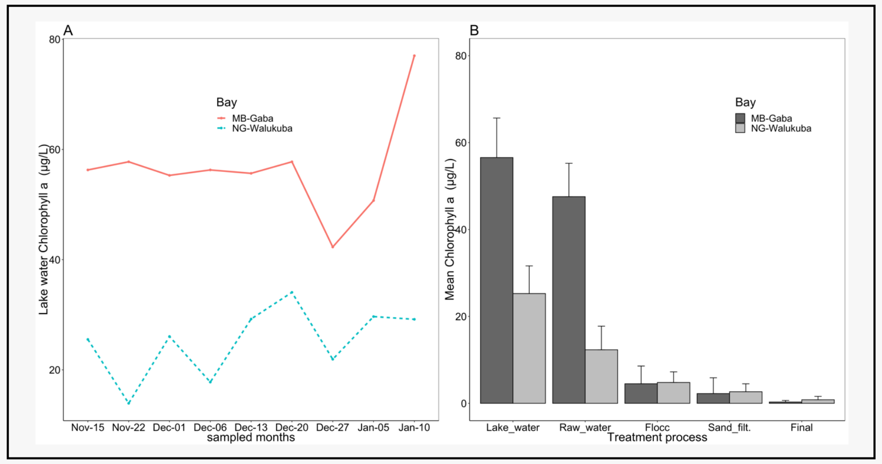

Fig 1. Evolution of the total phytoplankton biomasses (A) in the lake water in Murchison Bay (MB) and Napoleon Gulf (NG) and (B) during the water treatment process in the Gaba III and Walukuba WTPs

III. Variations in dissolved microcystin concentrations during the water treatment process

As shown in Figure 2, the determination of dMCYS by ELISA during the water treatment process revealed increasing dMCYS concentrations in the Gaba III WTP up to the sand filtration stage and then a drastic decrease after chlorination. These data suggest the occurrence of (i) a large release of dMCYS during the treatment process, probably due to the lysis of cyanobacterial cells; and (ii) very efficient oxidation of microcystins at the chlorination stage, with final dMCYS concentrations far below the threshold defined for drinking water.

In the Walukuba WTP, the dMCYS concentrations were very low during the entire treatment process, with no evidence of a release of dMCYS during the water treatment process.

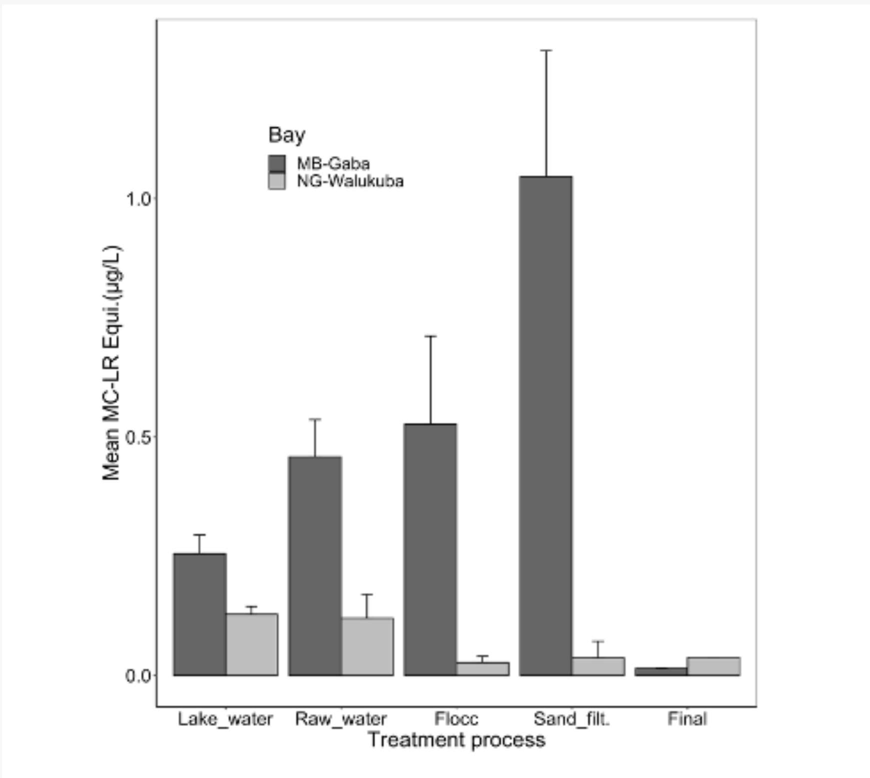

Fig 2. Mean concentration of dissolved microcystins (ELISA data) in the lake and during the water treatment process in Gaba III and Walukuba WTP

IV. Conclusions

This study revealed that both WTPs were able to eliminate cyanobacterial cells and dMCYS. However, in the Gaba III WTP, which is prone to high cyanobacterial biomasses, the increasing dMCYS concentrations found until the sand filtration stage suggest an inefficiency in removing intact cyanobacterial cells and their toxins. Fortunately, the final chlorination was efficient in removing dMCYS in treated water.

However, these data raise the issue of the potential formation of undesired microcystin-associated disinfection byproducts resulting from the chlorination of dissolved microcystins, as has already been shown in several studies. Similarly, prechlorination at the beginning of the water treatment process in Gaba III and our data showing that cyanobacterial cells were broken during the water treatment process may also lead to the production of harmful disinfection byproducts such as trihalomethans. Consequently, it would be necessary to more deeply investigate the potential risks associated with the formation of all these disinfection byproducts in the Gaba WTP.

In the Walukuba WTP, where the cyanobacterial biomass in raw water was 2 to 3 times lower than in Gaba III, there was a progressive decrease in phytoplankton biomass during the water treatment and no release of dMCYS. This finding suggests that this WTP was able to remove intact cyanobacterial cells.

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