

REMOVAL OF CYANOBACTERIA AND MICROCYSTINS FROM WASTE STABILIZATION PONDS BY HYDROGEN PEROXIDE ADDITION

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Abstract

Cyanobacteria and microcystins commonly occur in waste stabilization ponds (WSPs), and are a risk to human and ecological health. Although many studies have investigated their removal from batch cultures and drinking water reservoirs, few have been conducted into their removal from WSPs. Hydrogen peroxide (H₂O₂) has been suggested as an environmentally benign method for removing both cyanobacteria and microcystins from wastewater reservoirs. This study investigates the use of H₂O₂ for the removal of cyanobacteria and microcystins from WSPs, and the determination of an appropriate concentration of H₂O₂ to achieve this. Hydrogen peroxide was shown to decrease cyanobacterial and microcystin concentrations, and thus may be a successful algicidal treatment in WSPs.

Keywords: cyanobacteria; microcystins; waste stabilization pond; hydrogen peroxide; algicide

Introduction

Cyanobacteria are a common occurrence in municipal waste stabilization ponds (WSPs). Several genera produce microcystins, toxins which pose a significant health risk (Fitzgerald 2001). The treated effluent of WSPs is generally discharged for irrigation or to the environmental flow, and thus cyanobacteria and microcystins are a substantial threat to ecological systems, humans and animals (Christoffersen 1996; de Figueiredo *et al.* 2004). Cyanobacteria are also a potential hindrance to wastewater treatment processes. These organisms may suppress the growth of phytoplankton species required for wastewater treatment, and cyanobacterial detritus may accumulate in WSP sludge, treatment facilities, and water supply infrastructure, resulting in treatment inefficiencies and economic issues.

Cyanobacteria and microcystins need to be removed from WSPs. The impetus of most management plans in drinking water and recreational reservoirs is to prevent eutrophication, which reduces the risk of cyanobacterial blooms, or to avoid using water bodies when blooms are present (eg. du Preez *et al.* 2007). However, WSPs are eutrophic by nature, and effluents must be released periodically to avoid overflow of ponds. Waste stabilization ponds must also be treated where cyanobacterial blooms are impacting upon treatment efficiencies.

Several methods of cyanobacterial and microcystin removal have been investigated within the laboratory. Most chemical methods of removal result in the production of harmful by-products, or the accumulation of heavy metals in ecosystems (Tsuji *et al.* 1997; Gromysz-Kalkowska and Szubartowska 1999; van Hullebusch *et al.* 2003). A treatment method is required which is effective at removing cyanobacteria and microcystins during full scale application, whilst also being environmentally benign.

Hydrogen peroxide (H₂O₂) has been shown to decrease cyanobacterial and microcystin concentrations within the laboratory (Rositano *et al.* 1998; Cornish *et al.* 2000; Drábková *et al.* 2007; Barrington and Ghadouani 2008). This potential algicide does not accumulate in the environment, as H₂O₂ is decomposed rapidly via biological, chemical and photochemical mechanisms (Cooper *et al.* 1994; Drábková *et al.* 2007).

It is essential to investigate the behaviour of cyanobacteria and microcystins following the addition of H₂O₂, before it can be recommended as an algicide in WSPs. This study investigates the dynamics of cyanobacteria and microcystins following H₂O₂ addition, and presents a method for determining an appropriate algicidal dose given the initial conditions of WSPs.

Methods

Hydrogen peroxide was added to mesocosm assemblages collected from WSPs in trials 1 to 3. In trials 4 and 5, H₂O₂ was added to full-scale WSPs under field conditions. In the mesocosm trials, H₂O₂ was added by diluting 30 % H₂O₂ in 1 L Milli-Q water, before addition to samples. In both full-scale trials, H₂O₂ was diluted with WSP water before addition via a jet. Both the jet addition and wind forcing mixed the H₂O₂ well throughout the ponds.

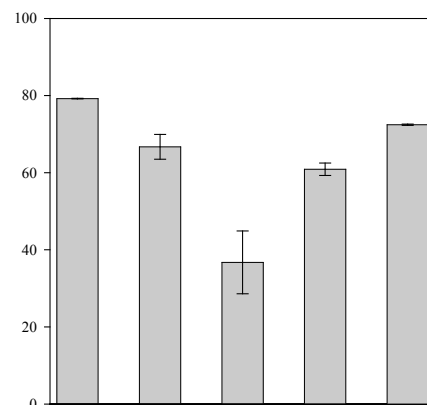
The concentration of H₂O₂ added depended upon the concentration of phytoplankton present in the pond, measured as total chlorophyll-*a* (chl-*a*) by spectrofluorometry. The reduction in cyanobacteria was measured by determining the chl-*a* contributed by cyanobacterial species both prior to and following H₂O₂ addition. Microcystin concentrations prior to and in the days following H₂O₂ treatment were determined by HPLC-PDA in trial 5.

Hydrogen peroxide was added to each mesocosm or pond at the order of magnitude 10⁻⁴ g H₂O₂ / µg chl-*a*, the approximate H₂O₂ dose found to be effective from laboratory and field work. Because the starting concentration of phytoplankton differed in each trial, the H₂O₂ concentration expressed as mg L⁻¹ (the units generally used to describe algicidal doses) differed in each experiment (Table 1).

Results and Discussion

Table 1: Details of trials

Trial	Volume of trial (L)	Initial chl- <i>a</i> (µg L ⁻¹)	H ₂ O ₂ (mg L ⁻¹)
1	20	471	97
2	20	2.19 x 10 ⁴	3632
3	50	134	18
4	3 x 10 ⁶	342	44
5	8 x 10 ⁶	560	95



Hydrogen peroxide reduced cyanobacteria by 40–80% in all trials (Figure 1). In trial 5, both intracellular and dissolved microcystins had decreased to below detection limits within 120 hours of H₂O₂ addition.

There is some concern that H₂O₂ may impact upon other organisms in the WSP environment, particularly phytoplankton and zooplankton. Studies have determined that eukaryotic phytoplankton are less susceptible to H₂O₂ toxicity than cyanobacteria, though in environmental assemblages H₂O₂ does still induce eukaryotic phytoplankton death (Drábková *et al.* 2007; Barrington and Ghadouani 2008). Hydrogen peroxide also has toxic effects on *Daphnia magna* at low concentrations (Meinertz *et al.* 2008).

It is important to consider the impacts of algicides on non-target organisms, as this may further reduce the treatment efficiency of WSPs. However, most conventional algicidal treatments also impact upon non-target organisms (eg. Johnson *et al.* 2008), so H₂O₂ may be the preferable treatment due to its rapid degradation following addition, thus rendering it environmentally benign within hours of application.

Conclusions

Hydrogen peroxide reduces cyanobacteria and microcystins in WSPs. The concentration of H₂O₂ required is dependent upon the initial conditions of phytoplankton in the WSP, and consideration of this will allow an algicidal dose to be determined which will be effective for a particular phytoplankton assemblage. Hydrogen peroxide may impact upon non-target organisms within WSPs. However, if cyanobacteria must be reduced during wastewater treatment, H₂O₂ is probably a more environmentally sensitive algicide than traditional methods which result in harmful compounds accumulating in the WSP and the environment.

References

- Barrington, D. J., and Ghadouani, A. (2008) Application of hydrogen peroxide for the removal of toxic cyanobacteria and other phytoplankton from wastewater. *Environ. Sci. Technol.*, 42(23), 8916–8921.
- Christoffersen, K. (1996) Ecological implications of cyanobacterial toxins in aquatic food webs. *Phycologia*, 35(6), (Supplement).
- Cooper, W. J., Shao, C. W., Lean, D. R. S., Gordon, A. S., and Scully, F. E. (1994) Factors affecting the distribution of H₂O₂ in surface waters. In: *Environmental Chemistry of Lakes and Reservoirs*, American Chemical Society, Washington, D.C., 391–422.
- Cornish, B., Lawton, L. A., and Robertson, P. K. J. (2000) Hydrogen peroxide enhanced photocatalytic oxidation of microcystin-LR using titanium dioxide. *Appl. Catal.*, B, 25(1), 59–67.

de Figueiredo, D. R., Azeiteiro, U. M., Esteves, S. M., Goncalves, F. J. M., and Pereira, M. J. (2004) Microcystin producing blooms – a serious global public health issue. *Ecotox. Environ. Safe.*, 59(2), 151–163.

Drábková, M., Admiraal, W., and Marsálek, B. (2007) Combined exposure to hydrogen peroxide and light – Selective effects on cyanobacteria, green algae, and diatoms. *Environ. Sci. Technol.*, 41(1), 309–314.

du Preez, H., Swanepoel, A., van Baalen, L., and Olwage, A. (2007) Cyanobacterial Incident Management Frameworks (CIMFs) for application by drinking water suppliers. *Water SA*, 33(5), 643–652.

Fitzgerald, D. J. (2001) Cyanotoxins and human health: Overview. In: *Cyanotoxins: Occurrence, Causes, Consequences*, I. Chorus, ed., Springer, Berlin.

Gromysz–Kalkowska, K., and Szubartowska, E. (1999) Aluminium – its ecological role and toxicity for animals. *Med. Weter.*, 55(4), 229–233.

Johnson, B. M., Chao, M. M., Tedrow, O. R., McQueen, A. D., and Rodgers, J. H. (2008) Responses of *Lepomis macrochirus*, *Pimephales promelas*, *Hyalella azteca*, *Ceriodaphnia dubia*, and *Daphnia magna* to exposures of algimycin (R) PWF and copper sulfate pentahydrate. *J. Aquat. Plant Manage.*, 46, 176–183.

Meinertz, J. R., Greseth, S. L., Gaikowski, M. P., and Schmidt, L. J. (2008) Chronic toxicity of hydrogen peroxide to *Daphnia magna* in a continuous exposure, flow-through test system. *Sci. Total Environ.*, 392(2–3), 225–232.

Rositano, J., Nicholson, B. C., and Pieronne, P. (1998) Destruction of cyanobacterial toxins by ozone. *Ozone– Sci. Eng.*, 20(3), 223–238.

Tsuji, K., Watanuki, T., Kondo, F., Watanabe, M. F., Nakazawa, H., Suzuki, M., Uchida, H., and Harada, K. I. (1997) Stability of microcystins from cyanobacteria 4. Effect of chlorination on decomposition. *Toxicon*, 35(7), 1033–1041.

van Hullebusch, E., Chatenet, P., Deluchat, V., Chazal, P. M., Froissard, D., Botineau, M., Ghestem, A., and Baudu, M. (2003) Copper accumulation in a reservoir ecosystem following copper sulfate treatment (St. Germain Les Belles, France). *Water Air Soil Pollut.*, 150(1–4), 3–22.