THE USE OF ULTRASONIC SOUND WAVES TO TREAT ALGAL BLOOMS

Literature Review

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OVERVIEW

- This literature review explores the use of Ultrasonic sound waves as an algal treatment method in waterbodies
- Ultrasonic treatment is able to treat various species of algae, and is an ideal approach for treating water intended for drinking, livestock watering and irrigation
- Ultrasonic treatment uses high frequency sound waves to cause vibrations in algal cells, resulting in their death
- Ultrasonic treatment is an effective medium-to-long term algae treatment strategy that is capable of treating a large area of water (100m–200m range from transducer)
- For drinking water and irrigation, Ultrasonic treatment is an ecologically sustainable treatment approach that also maintains the Australian Certified Organic and similar accreditations of waterbodies

INTRODUCTION

Blooms of algae in waterbodies are a major problem around the world as they pose serious health hazards to humans, animals and aquatic life[1,2] and are a direct result of eutrophication via pollution[2]. Algal blooms are often filamentous and free-floating, thus equally causing disruptions to leisure activities like fishing, boating and swimming, and to economic activities like irrigation, water pumping and filtration[3]. However, the biggest implication of most algae is the increased toxicity of any water that these algal blooms establish in. Cyanobacteria, commonly referred to as blue-green algae, produce toxic compounds that have direct health impacts on both humans and animals (liver damage, neuron toxicity and tumour promotion[4]) that may consume or come in contact with the contaminated water. These toxic algal compounds are called microcystins and are repeatedly released into the water during the algae's life cycle.[4] Microcystins reduce the overall health of a waterbody, preventing the use of contaminated water for irrigation, drinking and livestock watering.[5]

Although microcystins in water tend to break down naturally over time, the sudden spike in water microcystin levels typical of algal blooms can be of concern if the treated water needs to be used immediately, for example, for drinking or irrigation. In such cases, it is best to use a treatment method where the microcystins are contained within the algal cell upon treatment, more so if the treated water is strictly intended for irrigation, livestock watering or human consumption, where direct contact with humans and animals is inevitable.[5]

HOW IT WORKS

Ultrasonic sound waves are released into the water by an electronic transducer, and these high frequency sound waves propagate throughout the entire waterbody. These sound waves are specifically tuned to cause resonance in specific types of algae; when an algal cell comes into contact with one of these sound waves parts of the cell begin to vibrate intensely. Specifically, the gas vacuole used to regulate the vertical position of algae in the water column begins to vibrate, and eventually ruptures from the repeated mechanical stress.[6] These gas vacuoles are essential for the blue-green algae's ability to photosynthesise; without these vacuoles the algae lose their buoyancy and ability to move within the water body to receive optimum sunlight, simply sinking to the bottom as a result.[7] The conditions of low-light and low-aeration here are not ideal for the survival of algae, and so they eventually die off. The likelihood of treated algae recovering from these conditions is highly improbable, thus the results of ultrasonic treatment are long-lasting. Since ultrasonic sound waves rupture the hollow membranes of the algal gas vacuoles while still maintaining the main membranes and cell walls of algal cells, none of the material contained inside the algal cells are able to leave the cell and leak into the water, including the toxic microcystin compunds[6]. This ensures that ultrasonic treatment does not increase water toxicity via microcystin release into water, making it a highly safe and effective treatment method.

IMPACTS OF ALGAL BLOOMS IN WATER

Environmental	▪ Cyanobacteria blooms form dense mats that prevent light and oxygen from entering the water[8] ▪ Cyanobacteria blooms release toxic compounds that alter water quality and reduce beneficial bacteria necessary for local water dynamics[8] ▪ Toxins released by Cyanobacteria blooms endanger the lives of local wildlife and reduce overall biodiversity[9,10]
Economic	▪ Algal mats block irrigation equipment (intakes, filters, pipes & pumps), reducing pumping efficiency and increasing pumping time and cost[11] ▪ Mats of algae obstruct commercial fishing nets resulting in reduced fish production[12] ▪ Cyanobacterial toxins prevent the usability of water for drinking, irrigation, livestock watering, etc.[9,12,13]
Social	▪ Cyanobacteria blooms release toxic compounds that cause serious illness in humans and domestic pets[8,9] ▪ Algal blooms contaminate water with unpleasant tastes and odours[8] ▪ Algal blooms alters the colour of open water bodies, reducing their natural beauty[8,12] ▪ Dense algal mats prevent recreational activities like swimming and fishing[12]

ULTRASONIC TREATMENT

- Ultrasonic treatment is a physical method of algal cell disruption rather than a biochemical response, as it uses high frequency sound waves higher than the audible limit of human hearing to treat algae[3]
- Ultrasonic treatment targets and destroys specific organs contained inside algal cells that are essential for the cells' survival,[6] and therefore is not likely to cause a sudden microcystin release into the water
- Ultrasonic treatment is ideal for use in water bodies that restrict the use of conventional chemical algaecides (protected water bodies, municipal drinking water reservoirs) or for waterbodies that want to maintain their Australian Certified Organic accreditation[6]
- The use of ultrasonic sound waves is an ecologically sustainable algae treatment approach as it only targets algal cells and does not affect nearby aquatic wildlife[6]

BENEFITS OF USING ULTRASONIC TREATMENT

ENVIRONMENT

- ✓ 'Green' solution since sound waves are utilised and low operating power required[13]
- ✓ Is ecologically safe as it does not directly alter water quality of the local environment[3,6]
- ✓ Safe to use in waterbodies with aquatic life as there is little to no impact on non-target organisms[13]

PERFORMANCE

- ✓ Ultrasonic treatment is a medium-to-long term treatment strategy that successfully treats algae over a long period of time[14]
- ✓ Ultrasonic treatment is effective at treating algae over a large area (100m–200m range) compared to conventional treatment options[14]
- ✓ Ultrasonic treatment is not affected by temperature or dissolved gases in the waterbody[6]
- ✓ Ultrasonic treatment is a multi-method approach, because in addition to rupturing essential gas vacuoles in algae, Ultrasonic treatment directly interferes with the photosynthetic system of algae[3,6]

SOCIAL

- ✓ Does not negatively affect appearance, smell or taste of treated water[6]
- ✓ Ultrasonic treatment uses sound waves above the human audible range and therefore causes no noise pollution[3]
- ✓ Environmentally friendly approach makes it ideal for use in drinking and irrigation water, and for waterbodies that are protected or used for recreation[6]

FAVOURABLE CONDITIONS FOR ULTRASONIC TREATMENT

- Ultrasonic treatment is most effective in uniform waterbodies. If dealing with algal blooms in irregularly shaped waterbodies, strategic placement of ultrasonic transducers will be required to prevent treatment blind spots[15]
- Ultrasonic treatment is highly effective in waterbodies with low turnover rates as it allows repeated exposure of algae to ultrasonic sound waves[9]
- Ultrasonic treatment enhances the coagulation processes of algae, and is able to clear water of dead algae faster when used in conjunction with flocculants or coagulants[16]
- Ultrasonic treatment demonstrates faster results when treating cyanobacteria and other common algae species that are known to contain gas vacuoles[3]

REFERENCES

1. Organisation Du Traité De L'atlantique Nord. Advanced Study Institute. Algae and man. New York: Plenum Press; 1964.

2. Jackson DF, Syracuse University. Algae, man, and the environment: Proceedings of a symposium. Syracuse, N.Y.: Syracuse University Press; 1968.

3. Wu X, Joyce EM, Mason TJ. The effects of ultrasound on cyanobacteria. Harmful Algae. 2011 Sep;10(6):738–743.

4. Chorus I, Welker M. Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management. Boca Rataon: Crc Press; 2021.

5. World Health Organization. Guidelines for drinking-water quality. First addendum to third edition, volume 1, Recommendations. Geneva: World Health Organization; 2006.

6. Lee TJ, Nakano K, Matsumara M. Ultrasonic Irradiation for blue-green algae bloom control. Environmental Technology. 2001 Apr;22(4):383–390.

7. Reynolds CS. Growth, gas vacuolation and buoyancy in a natural population of a planktonic blue-green alga. Freshwater Biology. 1972 Jun;2(2):87–106.

8. Selezneva AV, Seleznev VA, Sayriddinov SS. Nanofiltration to purify drinking water from cyanobacteria and microcystins in Water Supply Systems. IOP Conference Series: Materials Science and Engineering. 2021 Mar 1;1079(2).

9. Kotut K, Ballot A, Krienitz L. Toxic cyanobacteria and their toxins in standing waters of Kenya: implications for water resource use. Journal of Water and Health. 2006 Jun 1;4(2):233–245.

10. Mateos-Sanz MA, Carrera D, López-Rodas V, Costas E. Toxic cyanobacteria and widlife conservation: Proposal of a procedure to demonstrate waterbird mass mortalities by microcystin. Acta Botanica Malacitana. 2009 Dec 1;34:5–10.

11. Mohamed ZA, El-Sharouny HM, Ali WSM. Microcystin production in benthic mats of cyanobacteria in the Nile River and irrigation canals, Egypt. Toxicon. 2006 Apr;47(5):584–590.

12. Yu W. Regional Algae Bloom: Natural disaster causes economic setback in private fishing charter in Southwest Florida. IOP Conference Series: Earth and Environmental Science. 2021 Feb 20;657.

13. Codd GA, Metcalf JS, Beattie KA. Retention of *Microcystis aeruginosa* and microcystin by salad lettuce (*Lactuca sativa*) after spray irrigation with water containing cyanobacteria. Toxicon. 1999 Aug;37(8):1181–1185.

14. Mason TJ. Sonochemistry and the environment – Providing a “green” link between chemistry, physics and engineering. Ultrasonics Sonochemistry. 2007 Apr;14(4):476–483.

15. Qiu YJ, Rong F, Yang F, Li JP, Long H, Wu W. Ultrasound frequency impacts on the removal of indigenous blue-green algae taken from Lake Taihu. Advanced Materials Research. 2011 Nov;383-390:3758–62.

16. Schneider OD, Weinrich LA, Brezinski S. Ultrasonic treatment of algae in a New Jersey reservoir. Journal - American Water Works Association. 2015 Oct;107(10):533–542.

17. Shi H-X, Qu J-H, Liu H-J, Mu Y-L, Xiao K-T, Wang L. Effect of ultrasonic irradiation on the coagulation and inactivation of *Microcystis*. Journal of Water Supply: Research and Technology-Aqua. 2008 Mar;57(2):101–108.