Hydrodynamic Cavitation: An Alternative Method for Algae Removal from Water Resources

Hadi Eslami 1 *, Ali Asghar Ebrahimi 2

1 Occupational Environment Research Center, Department of Environmental Health Engineering, School of Health, Rafsanjan University of Medical Sciences, Rafsanjan, Iran.
2 Environmental Science and Technology Research Center, Department of Environmental Health Engineering, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.

ARTICLE INFO
LETTER TO EDITOR

*Corresponding Author:
Hadi Eslami
Email: Hadieslami1986@yahoo.com
Tel: +989177094695

Article History:
Received: 18 December 2019
Accepted: 20 February 2020

Citation: Eslami H, Ebrahimi AA. Hydrodynamic Cavitation: An Alternative Method for Algae Removal from Water Resources. J Environ Health Sustain Dev. 2020; 5(1): 925-7.

Algae in water resources are of great interest to researchers due to their adverse effects on water quality and treatment processes 1. Excessive nutrients, especially nitrogen (N) and phosphorus (P) in surface water sources, which can be caused by agricultural activities and discharge of industrial and municipal wastewater, can cause algae growth in water resources 2. Growth of algae in water resources is important not only for the environment but also for its impact on human health 3. The most important problems caused by algae growth in water resources include taste and odor in water, depletion of water dissolved oxygen (DO), loss of aquatic organisms and turbidity 4. Various studies have also shown that algae can release a variety of neurotoxin toxins in aquatic sources. These toxins can affect the nervous system and can also be a risk factor for various cancers such as liver cancer 5.

Many physical and mechanical, chemical, and biological methods are used to control and remove algae from water sources, such as flotation 6, sand filtration, membrane processes such as microfiltration (MF), ultrafiltration (UF) and nanofiltration (NF) 7, Electrocoagulation 8, oxidation processes such as ozonation, chlorination 9 and the use of copper sulfate 10. Among these processes, chemical methods are the most commonly used and the most important problem of this method is adding a number of chemicals and other pollutants to water resources 11.

The cavitation phenomenon involves the formation, growth, and subsequent destruction of microbubbles in a very short time at the microsecond time, which also releases large amounts of energy 12. The energy released per unit volume of liquid leads to high pressure (100–5000 bar) and high temperature (1000–10,000 K) 13. Also, with the release of vapor molecules trapped in the microbubbles, hydroxyl free radicals (•OH) are formed, which intensify the chemical reactions and destroy organic pollutants 14. If the cavitation is caused by high-frequency transitions, it is called acoustic cavitation or ultrasonication (US), and if it is caused by changes in pressure and fluid flow rate, is called hydrodynamic cavitation (HC) 3, 15. In general, ultrasonic waves can control the growth and removal of algae, but compared to HC, in
terms of economic and energy consumption, especially on a large scale is not affordable 16. The HC process is more efficient for large-scale applications, but there is limited information on the removal of algae 17. The cavitation rate can be adjusted by changing the flow rate (through the pump) or changing the system pressure (inlet air pressure). Because cavitation occurs through both speed variation and air pressure, it is called supercavitation 18. High temperatures and high pressures and the formation of hydroxyl radicals during the HC process can destroy the gas vacuoles, damage the photosynthetic system and the membrane structure in algal cells 11. By destroying the gas vacuoles in the algal cell membrane, the algae settle rapidly; however, the damage to the photosynthetic system and cell structure prevents the algal growth and results in algal cell death 11. Gaseous vacuoles balance the algae cells and elevate them in the liquid column for exposing to light for photosynthesis, which is one of the important factors for algae growth 19.

Overall, the mechanisms of algal removal by the HC process (Fig. 1) include the degradation of gas vacuoles as well as the oxidation of lipids in algal cell membranes. The free radicals produced in the HC process cause the oxidation of lipids in the cell membrane and produce a new compound called Malondialdehyde (MDA) 11. Therefore, the amount of MDA production can be used as a quantitative indicator to determine the amount of lipid oxidation and free radicals produced 13. The effect of shear stress on the removal of algae is another mechanism of HC process (Figure 1) 18. The results of the studies show that shear stress occurs during the process and as a result of the rotation of the liquid stream which can cause algal cell damage. But the effect of this mechanism on the removal of algae is less than other mechanisms 20.

Figure 1: The mechanism of hydrodynamic cavitation for algae removal 18

Finally, it can be said that the HC process does not any chemicals to the water resources. Also, if the chemical is used, the use of the HC process before adding the chemicals reduces the chemical consumption.

This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work for commercial use.

References
1. Mascia M, Vacca A, Palmas S. Electrochemical treatment as a pre-oxidative step for algae removal using Chlorella vulgaris as a model organism and BDD anodes. Chem Eng J. 2013;219:512-9.
2. Zezulka Š, Maršílková E, Pochylý F, et al. High-pressure jet-induced hydrodynamic cavitation as a pre-treatment step for avoiding cyanobacterial contamination during water
purification. J Environ Manage. 2019;255:109862.
3. Dehghani MH. Removal of cyanobacterial and algal cells from water by ultrasonic waves—A review. J Mol Liq. 2016;222:1109-14.
4. Kellali Y, Ghernaout D. Physicochemical and algal study of three dams (Algeria) and removal of microalgae by enhanced coagulation. Appl Eng. 2019;3:56-64.
5. Zhao W, Zheng Z, Zhang J, et al. Evaluation of the use of eucalyptus to control algae bloom and improve water quality. Sci Total Environ. 2019;667:412-8.
6. Gao S, Yang J, Tian J, et al. Electro-coagulation–flotation process for algae removal. J Hazard Mater. 2010;177(1-3):336-43.
7. Huang W, Chu H, Dong B, et al. A membrane combined process to cope with algae blooms in water. Desalination. 2015;355:99-109.
8. de la Fuente A, Muro-Pastor AM, Merchán F, et al. Electrocoagulation/floculation of cyanobacteria from surface waters. Journal of Cleaner Production. 2019;238:117964.
9. Wang H-Q, Mao T-G, Xi B-D, et al. KMnO4 pre-oxidation for microcystis aeruginosa removal by a low dosage of flocculant. Ecol Eng. 2015;81:298-300.
10. Byeon KD, Kim GY, Lee I, et al. Investigation and evaluation of algae removal technologies applied in domestic rivers and lakes. Journal of Korean Society of Environmental Engineers. 2016;38(7):387-94.
11. Batista MD, Anhê ACBM, Gonçalves JCdSI. Use of hydrodynamic cavitation for algae removal: effect on the inactivation of microalgae belonging to genus Scenedesmus. Water, Air, Soil Pollut. 2017;228(11):443.
12. Park J, Church J, Son Y, et al. Recent advances in ultrasonic treatment: challenges and field applications for controlling harmful algal blooms (HABs). Ultrason Sonochem. 2017;38:326-34.
13. Dular M, Griessler-Bulc T, Gutierrez-Aguirre I, et al. Use of hydrodynamic cavitation in (waste) water treatment. Ultrason Sonochem. 2016;29:577-88.
14. Bai M, Zheng Q, Zheng W, et al. •OH inactivation of cyanobacterial blooms and degradation of toxins in drinking water treatment system. Water Res. 2019;154:144-52.
15. Kong Y, Peng Y, Zang Z, et al. Removal of microcystis aeruginosa by ultrasound: inactivation mechanism and release of algal organic matter. Ultrason Sonochem. 2019;56:447-57.
16. Waghmare A, Nagula K, Pandit A, et al. Hydrodynamic cavitation for energy efficient and scalable process of microalgal cell disruption. Algal Research. 2019;40:101496.
17. Thanekar P, Garg S, Gogate PR. Hybrid treatment strategies based on hydrodynamic cavitation, advanced oxidation processes, and aerobic oxidation for efficient removal of naproxen. Ind Eng Chem Res. 2019.
18. Li P, Song Y, Yu S, et al. The effect of hydrodynamic cavitation on microcystis aeruginosa: Physical and chemical factors. Chemosphere. 2015;136:245-51.
19. Wu Z, Shen H, Ondruschka B, et al. Removal of blue-green algae using the hybrid method of hydrodynamic cavitation and ozonation. J Hazard Mater. 2012;235:152-8.
20. Janičula D, Mikula P, Maršálek B, et al. Selective method for cyanobacterial bloom removal: hydraulic jet cavitation experience. Aquac Int. 2014;22(2):509-21.