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

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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

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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].

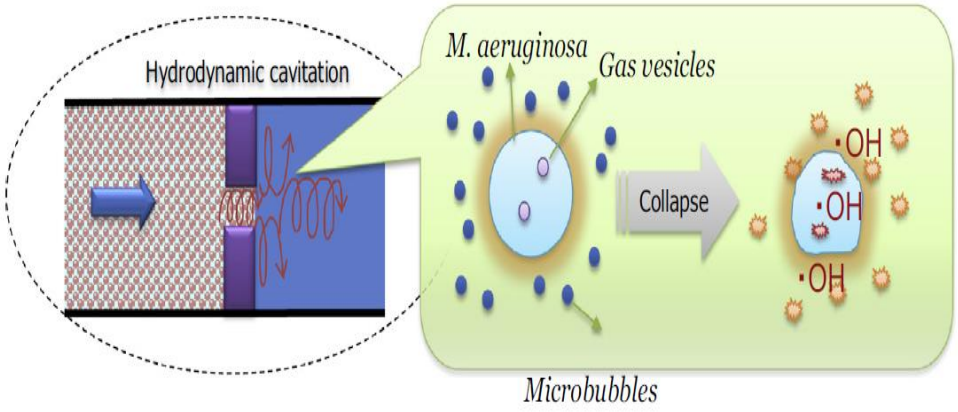

Figure 1: The mechanism of hydrodynamic cavitation for algae removal [18]

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.

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