Study on a new algal-inhibition based on Microbial Desalination Cell reactor and its performance

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Abstract: Water resources are an important source of energy for Human existence. Water shortages and Water environmental pollution are receiving more and more attention. Desalination of seawater and brackish water, recovery and utilization of municipal wastewater and industrial wastewater are two important ways to increase water resources. In this paper, the Microbial Desalination Cell is coupled with the bio-algae-inhibiting technology. Based on the original MDC, the water purification system, the algal inhibition system and the water delivery system are established, and the design parameters are optimized. A new reactor of algal-inhibition based on Microbial Desalination Cell (A-MDC) with anti-algal function was designed and constructed, and preliminary study of its algae-inhibiting performance. The maximum inhibition rate of algae can reach 79.41%. Compared with other treatment methods and technology, Microbial Desalination Cell (MDC) has obvious technical characteristics and advantages, and has great development potential.

1. Introduction
The eutrophication of water has aggravated the problem of water shortage and water pollution[1–2]. At the same time, the algae explosion seriously is threatening the water environment security, which has become the focus of global water environmental problems[3]. Desalination of seawater and brackish water, wastewater treatment and recycling will be the effective ways to improve the water environment.

Microbial Desalination Cell is a device that uses microbes to degrade organic matter and convert chemical energy into electrical energy. It produces electricity energy while removing contaminants or desalination[4–5]. Throughout its development trend, the use of Microbial Desalination Cell in the treatment of algae-containing salt wastewater combined with algae-inhibiting technology. In this paper, a new reactor of algal-inhibition based on Microbial Desalination Cell (A-MDC) was designed to provide the algae-containing salt wastewater treatment technology with low cost, low energy consumption, simple operation, good treatment effect and recycling ability. And it reflects the concept of resource conservation and environmental friendliness, and actively participates in the construction of an environment-friendly society.
2. Design content

2.1. Design of A-MDC system

The purpose of this paper is to provide a circulating microbial desalination cell that can be used for purification of algae-containing salty wastewater, that is, a new reactor of algal-inhibition based on Microbial Desalination Cell (A-MDC), which is composed of a water purification system, an algae-inhibiting system, and a water delivery system.

2.1.1. Water purification system. The water purification system is a Microbial Desalination Cell comprising an anode chamber, a desalting chamber, and a cathode chamber. The Microbial Desalination Cell is made of polycarbonate or plexiglass, the anode chamber and the cathode chamber contain an electrode material composed of carbon rod and anode graphite felt, the anode chamber bioelectrode will use an anaerobic microorganism to hang membrane, and cathode chamber bioelectrolyte used aerobic microorganism to hang membrane. Then, the electrodes are connected by an external circuit[6]. The desalting chamber is between the cathode chamber and the anode chamber, and two nylon mesh spacers are placed between the three chambers. The spacing between the two separators is about 2cm, and an ion exchange membrane is placed there in. The separator between the cathode chamber and the desalting chamber is placed with a cation exchange membrane, and the separator between the anode chamber and the desalting chamber is placed with an anion exchange membrane, and the exchange membrane can be replaced.

The desalination process of the water purification system is to push the algae-containing salty wastewater to be treated into the desalting chamber, and the anions and cations in the water will be adsorbed on the anion and cation exchange membranes, thus realizing desalination of saltwater. The electricity production process of the water purification system is that the water enters the anode chamber, the organic matter is oxidized and decomposed by the electricity-producing microorganisms, and the electrons are transmitted to the anode, and then the external current is transmitted to the cathode through the external circuit to realize the external current. The external current is directed from the cathode to the anode, the internal current is directed from anode to the cathode, and under the driving of the electric field, ions on the ionic exchange membrane are desorbed to realize the regeneration of the exchange membrane[7].

2.1.2. Algae-inhibiting system. The algae-inhibiting system includes an algae-inhibiting chamber, a biogenic algal inhibitor, a filtration system, and an algal cell activity detection system, etc. The algae-inhibiting chamber is anode and cathode electrode chamber of a Microbial Desalination Cell, the biogenic algal inhibitor is derived from a plant extract, and the filtration system and the algae cell activity detection system are respectively membrane filtration and microscopic examination of cells.

The algae-inhibiting process of the algae-inhibiting system is to add the biogenic algaecide to the algae-inhibiting chamber after the water purification system operates normally, and take advantage of the allelopathic effect inhibiting the algal cell growth, where in the algal-inhibiting substance is derived from the plant extract. The algae cells were precipitated and discharged into the filtration system at the water outlet, sampled and the cell density determination inhibition efficiency was counted under a microscope.

2.1.3. Water delivery system. The water delivery system includes a rich algae salt-containing wastewater collection basin, a water purification collection basin, a water delivery pipeline, and a water quality detector. The rich algae salt-containing wastewater collection basin collects the water to be treated, and the water purification collection basin collects the available water that has been purified and it is connected with the water pipeline. The water quality detector is used for monitoring the effluent of microbial desalination battery (MDC) and algae suppression system. The purpose of this paper is to determine the range of circulating water use according to the effluent quality. Taking standardized surface water quality (GB3838-2002), Class III water will be used for recycling in the
water purification collection basin, and the rest will be returned back to the algal salt containing wastewater catchment for reprocessing.

The operation process of the water delivery system is that the rich algae salt-containing wastewater collection basin collects the water to be treated into the water purification system and the algae-inhibiting system, and then treats the wastewater, and then collects the effluent separately into the water purification collection basin according to different effluent water quality, or the algae-containing salty wastewater collection basin is treated again. The water of water purification collection basin will be used for plant drip irrigation, etc., and the rich algae salt-containing wastewater collection basin will further purification of wastewater.

3. Illustration with drawings

As shown in Figure 1, it is a concept-map of a new reactor of algal-inhibition based on Microbial Desalination Cell (A-MDC).

![Fig.1 Concept-Map of A-MDC](image-url)

As shown in Figure 2, it is a functional diagram of a new reactor of algal-inhibition based on Microbial Desalination Cell (A-MDC).
As shown in Figure 3, it is a simulated diagram of the microbial desalination cell, each marked as follows: 1 leather pad, 2 screw, 3 ion exchange membrane, 4 plexiglass plate, 5 graphite felt, 6 (7, 8) inlet and outlet, 9 connected conduits, 10 wires, 11 meters for measuring electricity, 12 peristaltic pumps.

As shown in Figure 4, the simulated diagram of algal-inhibition system is as follows: 1 algaecide inhibitor, 2 algae cells, 3 water inlets, 4 water outlets.
Fig. 4 Schematic diagram of algal-inhibition system

As shown in Figure 5, it is a schematic diagram of the water delivery system.

Fig. 5 Schematic diagram of water delivery system

4. Study on algae inhibition performance of A-MDC

4.1. Experimental materials

The Chinese herbal medicine *Gynostemma pentaphyllum Makino* and *Chlorella pyrenoidosa* were selected as the test materials. *Gynostemma pentaphyllum Makino* was collected from the herbal grass planting base of Sanming City, Longyan City, Fujian Province. *Chlorella pyrenoidosa* was purchased from Guangda of a variety of product base algae species library, Guangzhou, Guangdong Province.

4.2. Experimental methods

In the experiment, *Gynostemma pentaphyllum Makino* extract was used to inoculate *Chlorella pyrenoidosa* into a 250mL Erlenmeyer flask, add sterilized BG-11 medium, a certain amount of pure water, and 5 treatment groups were set to make the concentration of the extract 0, 5, 10, 25, 50g/L, the total volume of the system is 200mL[9]. Three parallels were set for each experimental group, and the initial protein *Chlorella pyrenoidosa* density was 10^6 cells/L. The experiment of inhibiting the growth of algae lasted for 15 days, and the concentration of algae cells was determined by blood cell counting plate counting method under microscope under 0, 3d, 6d, 9d, 12d, 15d, and the inhibition rate was calculated[10-11].

Inhibition rate calculation: \[ IR = \frac{(No - Ns)}{No} \times 100\% \]
Where, $IR$ is the inhibition rate, $N_0$ is the control group algal cell density, and $N_S$ is the treatment group algal cell density.

4.3. Effect of extract on the growth of Chlorella pyrenoidosa

The growth inhibition rate of *Gynostemma pentaphyllum* Makino extracts with different mass concentrations on *Chlorella pyrenoidosa* is shown in Figure 6. The control group of *Chlorella pyrenoidosa* grew well during the experiment, and the *Gynostemma pentaphyllum* Makino extract significantly inhibited the growth of *Chlorella pyrenoidosa*, and the inhibitory effect increased with the increase of mass concentration. When the concentration of the extract was 25g/L, the maximum inhibition rate was 79.41% after 15 days of culture.

![Fig.6 Growth inhibition rate of gynostemma pentaphyllum extract on Chlorella Proteinuclear Chlorella](image)

The experimental results show that the allelopathic effect of *Gynostemma pentaphyllum* Makino on *Chlorella pyrenoidosa* shows a phenomenon of “low promotion and high inhibition”. The reason may be that the low concentration of the extract changes the permeability of the algal cell membrane, making the algae cells more easily absorbed in the solution. At the same time, the extract itself may also contain some nutrients, thus promoting the growth of algae[12]. When the concentration of the extract is greater than or equal to 10g/L, it has obvious allelopathic inhibitory effect increased on the *Chlorella pyrenoidosa*, and with the concentration of the extract increasing, the ability of algae inhibition is enhanced.

5. Conclusion

The new reactor of algal-inhibition based on Microbial Desalination Cell (A-MDC) not only embodies the advantages of MDC are low energy consumption, diversified functions and strong safety, but also reflects the simple preparation of Chinese herbal medicine bio-source algae inhibitor, and effectively exert the effect of algal inhibition and enhance the treatment of the rich algae salt-containing wastewater with MDC, and so on. Therefore, compared with other treatment methods and technologies, Microbial Desalination Cell (A-MDC) has obvious technical characteristics and advantages, and has great development potential, which will surely become a new research direction.

Acknowledgments

This study was supported by Major Science and Technology Program for Water Pollution Control and Treatment (Grant No. 2013ZX07101014-004), Construction on Think Tank of Higher-Education Institution (Grant No. A1-2053-18-0001), and the Shanghai Ocean University Ph.D Start-Up Fund (Grant No. A2-0203-00-100356). The author thanks to my tutors Professor Zhang Yinjiang and Zhao Zhimiao, the project team and my family.
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