Key Technology for Constructing Mobile System of Water Purification System in Eutrophic Lakes and Reservoirs

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Abstract: The present paper proposes the treatment technology of mobile water purification system for in-situ treatment in lake and reservoir eutrophication water. This system was composed of water purification unit, mainly including adsorptions unit, microporous aeration unit, micro-current electrolysis unit, instruction control unit, water quality on-line detection unit and power supply unit. The goal of excessive nutrient reduction and harmful algal blooms control could be achieved by nitrogen and phosphorus removal by adsorptions unit and microporous aeration unit, and algal inhibition by micro-current electrolysis unit. The optimal dosage of adsorption material, in-situ adsorption time, aeration intensity, current density, electrolytic time and other technical parameters were achieved by the experiment of adsorption, microporous aeration and micro-current electrolysis using high-performance adsorbents, optimal aeration way and electrode material. Finally, the present study prospects the way to improve the water purification performance and enhance the operation management of mobile water purification system was discussed according to the experimental results and subsequent practical application. Overall, the technology of mobile water purification system is a new and effective technology for eutrophication treatment and will provide solutions for prevention and control of nutrient overloading and algae blooms.

1 INTRODUCTION

Widespread eutrophication in the lakes or reservoirs has become one of the most serious environmental problems. The proportions of eutrophication lakes or reservoirs were 41%, 61% and 77% in 1970s, 1980s and 1990s respectively (Ma and Li, 2002). The water quality survey of lakes during 2007-2010 showed that 85.4% shallow lakes exceeded the eutrophication criteria, in which 40.1% were severe eutrophication (Yang et al., 2010). Eutrophication deteriorated the water quality and caused water resource scarcity crisis, which decreased water utilization efficiency and capability of safe water supply. Eutrophication weakened the supporting role of water resource for the social development and the national economy greatly (Lin et al., 2015).

The prevention of eutrophication includes algae control and excess nutrients (e.g., nitrogen and phosphorus) reduction. For algae control, the traditional methods include removing algae by machinery or chemical method (Zhu et al., 2016). For the reduction of excess nutrients, clean water dilution, absorption and cleanup by plants are the common methods. Those technologies for algal control are usually time and energy consuming. Reduction of excess nutrients typically requires supporting of water diversion construction project or vegetation restoration project. Water diversion project wastes much clean water, while the efficiency of vegetation restoration project is low. Above all, under the condition of controlling external pollution source, choosing suitable technologies to decrease ammonia and phosphorus concentration is the most important issue for solving eutrophication in lakes and reservoirs.

Eutrophication in lakes and reservoirs usually occurs in the bay of lakes and branch of reservoirs

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with slow flow. It is very hard to purify water by pumping water from the water body. In this study, we built a mobile water purification system, which integrated the traditional water treatment technologies such as adsorption and microporous aeration, and new technology such as micro-current electrolysis technology for nutrients reduction and algae control. This mobile water purification system can move on the surface of lakes and reservoirs and purify the water body continuously. It will provide new solutions and technical support for eutrophication in lakes and reservoirs.

2 KEY TECHNOLOGY FOR CONSTRUCTING MOBILE WATER PURIFICATION SYSTEM

2.1 Construction and Work Principle of the System

The mobile water purification system consists of a mobile float platform, water treatment unit (absorption unit, microporous aeration unit, and micro-current electrolysis unit), water quality on-line detection unit, instruction control unit and power supply unit, etc (Figure 1). Mobile float platform is made as a ship. The standard absorption unit and micro-current electrolysis unit is set on the deck of the ship. Microporous aeration unit arranged below the absorption unit and micro-current electrolysis unit. Water quality on-line detection unit, instruction control unit and power supply unit are supporting systems for the mobile water purification system, which are used for controlling and managing the whole system.

The work principles of mobile water purification system are shown in Figure 2. Based on the results from water quality on-line detection unit and analysis the water quality, absorption unit, micro-current electrolysis unit and microporous aeration unit began to work. The system moved on the surface of the water body, and the water treatment units worked together. Then oxygen concentration in the water was increased, and nitrogen and phosphorus in water were absorbed, and the algal growth was inhibited by micro-current electrolysis unit. When the water quality of the treated water meets the requirements, the system enters the new target area. In the whole process of water treatment, the operation parameters of micro-current electrolysis unit and microporous aeration units were controlled by instruction control unit, the moving direction and speed for the system were controlled by power supply unit.

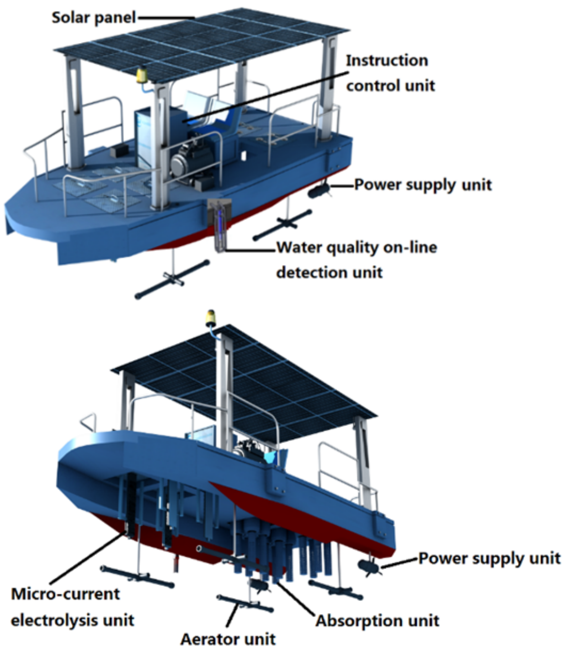

Figure 1: Side view and bottom view of mobile water purification system

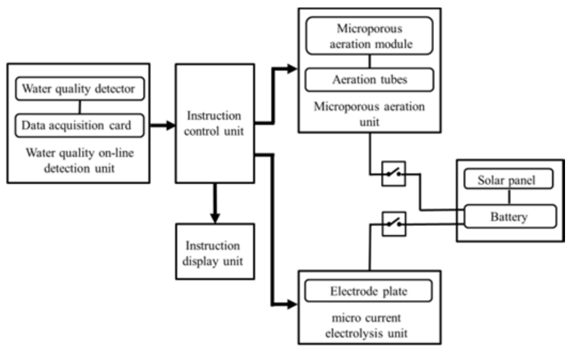

Figure 2: Sketch of circuit connection for mobile water purification system.

2.2 Key Technical Difficulties

The treatment effects of mobile water purification system are depending on the function of the absorption unit, micro-current electrolysis unit and microporous aeration unit. According to the working principle of the mobile water purification system, it is necessary to solve the key technical difficulties by experiments.

(1) Performance and technical parameters of mobile adsorption

In view of the water quality characteristics for eutrophication waters, the selection of adsorption materials for high efficiency and low concentration of nitrogen and phosphorus is the key technical difficulties. The optimal dosage of the adsorption material, adsorption time and service life were important operation factors which are needed to be studied.

(2) Performance and technical parameters of microporous aeration unit

For in-situ microporous aeration unit, aeration intensity, aeration time are the key parameters needed to be explored.

(3) Inhibited algal growth performance and technical parameters for micro-current electrolysis

Based on the results of inhabited algae by micro-current electrolysis, the selection of electrode materials was the key difficulty, whereas the appropriate current density and electrolysis time are the key parameters needed to be studied.

3 EXPERIMENTAL STUDY FOR CONSTRUCTING MOBILE WATER PURIFICATION SYSTEM

Experiments were carried out using natural lake water, pH for lake water was 8.0. The initial ammonia and total phosphorus concentration were controlled as 3.0 mg/L and 0.5 mg/L by adding the nutrient of nitrogen and phosphorus, respectively. Mobile adsorption, microporous aeration and micro-current electrolysis were used for water purification, which make relevant water quality indicators to meet the V class of water standards (ammonia concentration lower than 2.0 mg/L, total phosphorus concentration lower than 0.2mg/L) of national water environmental quality standard in China (GB 3838-2002) (in reference).

3.1 Mobile Adsorption

Phosphorus is the limiting factor for water eutrophication (Tang et al., 2014). Our study results showed that the adsorption capacity of activated alumina was better than that of zeolite (including natural, acid modification, ion modification), manganese sand and ceramsite by indoor experiments (data not shown).

Figure 3 shows phosphorus adsorption mass for activated alumina. With the different dosages of activated alumina including 1 g/L, 2 g/L, 4 g/L, 8 g/L and 16 g/L, the removal efficiency of phosphorus were 64%, 58%,76%, 82% and 84%, respectively. When the dosage of activated alumina was 8 g/L, the phosphorus removal rates haven’t increased with dosages of activated alumina. When the dosage of activated alumina increased from 8 g/L to 16 g/L, the increasing extent of adsorption rate decreased. With the same initial concentration, the phosphorus will diffusion into the surface of activated alumina and absorbed by activated alumina. Considering the phosphorus removal effect and the phosphorus adsorption capacity per unit mass of activated alumina, 8g/L activated alumina was selected for the mobile water purification system.

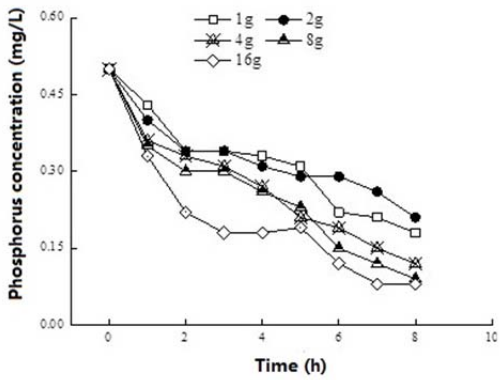

Figure 3: Phosphorous concentration variations with time.

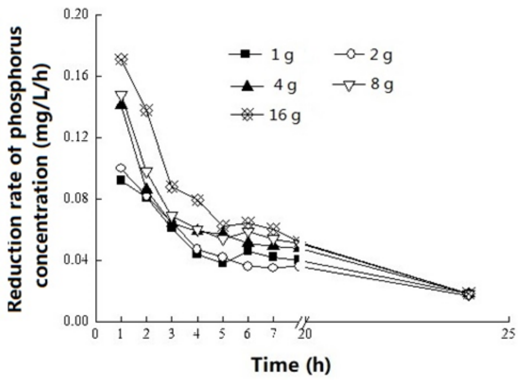

Figure 4: Average decrease rate of phosphorus concentration.

Figure 4 shows the average decrease rate of phosphorus concentration. The average decrease rate was calculated based on concentration difference divided by time difference. The decreasing rates of phosphorus concentration were comparatively consistent with different dosages of active alumina. The rate of the first 2 h was high, then decreased. At the end of the experiment, the decrease rate of phosphorus concentration was 0.018 mg/L/h. From the experiment results, 2 h was selected as the optimum time for mobile water purification system.

3.2 Microporous Aeration

Ammonia is one of the most important indexes to reflect the eutrophication status of the water body. High concentration of ammonia in eutrophic water can lead to damage to the organism. Aeration technology is suitable for treating water polluted by ammonia. The ammonia removal efficiency and the cost between micro-nano aeration equipment and microporous aeration equipment were compared in this study. It is found that the microporous aeration equipment can be used in situ and treat large amount of water. Therefore, it is more suitable for mobile water purification system, whereas the aeration time, strength and effective time of dissolved oxygen were studied.

Figure 5 shows the effect of microporous aeration time on removal of ammonia nitrogen. The initial concentration of ammonia was 3.0 mg/L, which was inferior to V class standard of surface water. The initial pH of natural water was 8.01 and the aeration intensity was 0.5 kg/cm^2. The results showed that microporous aeration time had a certain effect on ammonia nitrogen removing. The effect of ammonia removal increased significantly at first 4 h.

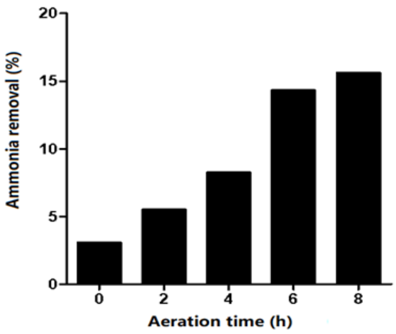

Figure 5: Effect of microporous aeration time on ammonia removal.

Figure 6 shows the effect of microporous aeration intensity on removal of ammonia nitrogen. With the same experimental condition, the ammonia removal efficiency increased with aeration intensity, the removal efficiency of aeration with 1.0 kg/cm^2 was higher than that with 0.5 kg/cm^{2}and 0.2 kg/cm^2. In order to decrease energy consumption and avoid sediment disturbing, 0.5 kg/cm^2 was chosen for aeration equipment.

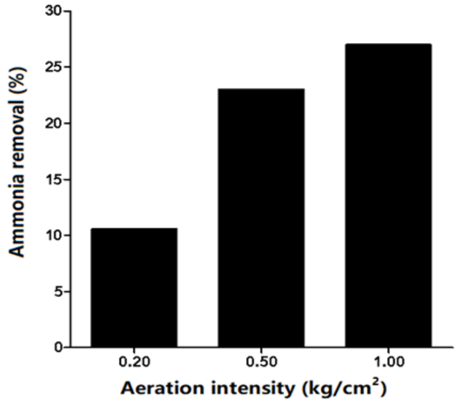

Figure 6: Effect of aeration intensity on ammonia removal.

3.3 Micro-Current Electrolysis

Controlling algae growth is the most effective way to prevent eutrophication. Micro-current electrolysis technology uses micro-current to make the algae inactivate, which inhibited algae growth in their early stages of production, and then prevent the occurrence of algae bloom (Lin et al., 2015). In order to apply micro-current electrolysis technology to mobile water purification system effectively, the key technical parameters such as electrode materials, current density, electrolysis time and electrode effective range were studied.

In order to know whether the remaining algae cells had the potential to survive and grow, the algal solution after electrolysis were poured to a 100 mL conical flask with a gauze stopper, and put into an illumination incubator to culture. Samples were taken from the conical flask at 0, 2, 4, 6, 8 and 15 days. Control samples with no electrolysis were also exposed to the same conditions as the test samples. OD_{680} of algal solution samples which was used as the indirect index of cell viability of algal solution was measured. Chlorophyll fluorescence parameters Fv/Fm was used to determine the photosynthetic activities of algae (Lin et al., 2015).

Figure 7 shows the effect of different anode and cathode materials on algal control by micro-current electrolytic. Under conditions of 100 mL algae solution with 1×10^6 cells/mL, electrode working area of 2.5 cm×5.5 cm, electrolysis plate spacing of 4 cm, electrolysis current density of 20 mA/cm^2, and electrolysis time 10 minutes, 4 kinds of anodes materials include RuO_2/Ti, Pt/Ti, stainless-steel and IrO_2/Ti were chosen by experiments. The results showed that anode materials had a great influence on the inhibition of algae, while the effect of cathode materials was small. RuO_2/Ti and stainless steel were selected as the anode and cathode materials, respectively. Active substances produced by electrolysis played an important role for inhibition of algae (Xu et al., 2014). Based on our study, the height, width and pitch of the electrode plate are suggested to be 50 cm, 20 cm and 2 cm respectively for mobile water purification system.

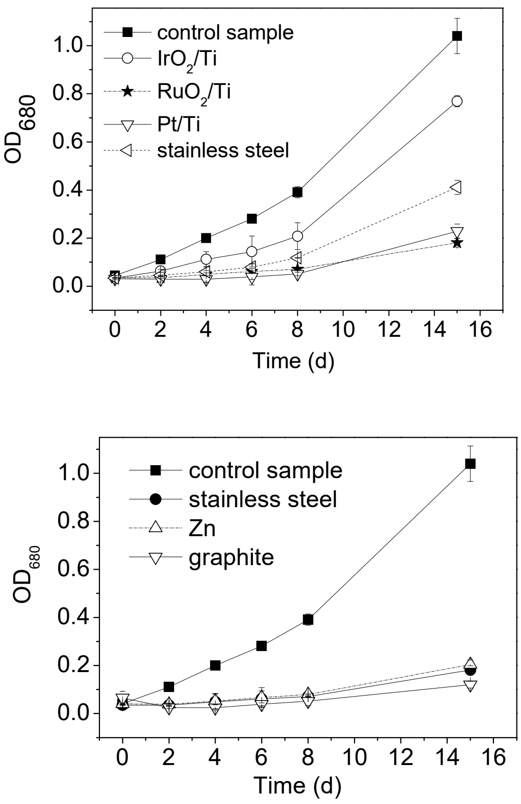

Figure 7: Effect of different anode (left) and cathode (right) materials on algae suppression by micro-current electrolytic (OD_{680} is the optical densities at 680nm of algal cell solution).

Figure 8 shows the effects of different current densities (left) and electrolysis time (right) on chlorophyll fluorescence parameters Fv/Fm. The algae inhibition experiment was carried out with 45 L algae solution (cells density was 5×10^4cells/mL), electrode work area was 50 cm×15 cm, and the spacing between two electrodes was 2 cm. The experiment results showed that algal inhibition increased with the current density, algae cell was completely inactivated with current density above 9 mA/cm^2. Therefore, the suitable current density was 9～12 mA/cm^2 for inhibition algae growth using the mobile water purification system. And 2 h was the suitable electrolysis time.

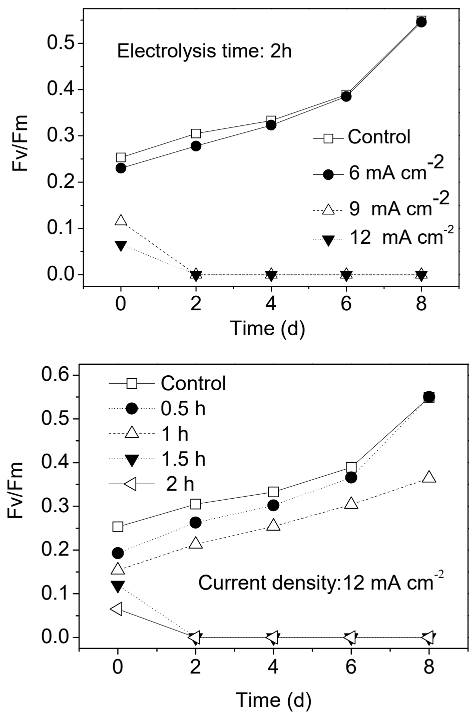

Figure 8: Effects of different current densities (left) and electrolysis time (right) on chlorophyll fluorescence parameters Fv/Fm.

4 CONCLUSIONS

The eutrophication lakes and reservoirs were relatively closed and with very low flow rate. The mobile water purification system which was an in-situ treatment technology was built for this kind of water body. The goals of reduction of nitrogen and phosphorus nutrients and algal control can be achieved by using adsorption, aeration and micro-current electrolysis.

Focused on the function units and key technologies of the system, the adsorption, aeration, micro-current experiment under moving conditions were carried on, which used activated alumina, microporous aeration and RuO_2/Ti anode and stainless-steel cathode, and obtained important technical parameters as follows:

(1) With 0.5 mg/L initial concentration of phosphorus, the optimum amount of activated alumina for adsorbing phosphorus was 8 g/L under moving conditions, the optimum adsorption time was 2 h.

(2) Under 3 mg/L initial concentration of ammonia nitrogen, the optimum treatment time of microporous aeration was 4h, the optimum aeration intensity was 0.5 kg/cm^2.

(3) With 50 cm height and 2 cm spacing of electrode plate and consisted of RuO_2/Ti anode and stainless-steel cathode, the optimum current density of micro-current electrolysis system is 9~12 mA/cm^2, and the electrolysis time was 2 h.

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