

## Electrosorption Behavior of Activated Carbon Electrodes for Different Cations Based on Activation Energy Index

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**Abstract:** Freshwater is a valuable resource, which is closely related to human life and production. At present, the shortage of freshwater resources has become an important factor restricting social development. In this paper, through the self-designed ACF electrode desalination device, the single factor analysis method was used to study the influencing factors of desalination effect. The electrochemical performance of activated carbon fibers (ACFs) in the process of electroadsorption was analyzed. The kinetics and thermodynamics of electroadsorption were discussed. The selective adsorption properties of ACFs for different cations in multi-component alkali metal and alkaline earth metal cationic solutions were studied. The multivalent cation adsorption rate and adsorption capacity are large, but the desorption rate is low; the monovalent cation adsorption rate and adsorption capacity are small, but the desorption rate is high; the same cation cation, the smaller the cation radius, the easier the cation is adsorbed. Since the by-product of the electrode in the electrosorption operation can inhibit the proliferation of microorganisms, the normally operated electrosorption device is less prone to microbial contamination.

### 1. Introduction

With the increasing shortage of human water resources, the treatment and reuse of waste water and the reduction of waste water discharge, even the desalination of seawater, brackish water and the preparation of high-purity water have become the focus of attention. At present, the main desalination methods used in industry at home and abroad are membrane separation (electrodialysis and reverse osmosis), cation exchange and distillation. Each method has certain application scope, advantages and disadvantages. Therefore, new desalination methods are constantly developing [1]. Electrosorption technology refers to the formation of an electrostatic field by applying a voltage on the electrode sheet, so that cations in the solution move to the plate with opposite charges under the action of the electrostatic field, forming a double layer on the surface of the plate, and the cations are temporarily stored in the double layer to achieve the adsorption effect [2]. Although a large amount of pollutants in water can be removed by conventional coagulation, sedimentation, filtration, etc., the removal of salts that are harmful to water, such as the removal of calcium and magnesium cations, is minimal, so the desalination is in the depth of water treatment. Important [3]. In short, the current desalination and softening technologies all have inevitable problems such as high energy consumption, high cost, and secondary pollution. Therefore, it is particularly important to find a new type of desalination technology with low energy consumption, high efficiency and environmental friendliness.

Electrosorption demineralization has the advantage that other water treatment methods do not have: compared with cation exchange, the electrode regeneration does not require acid, alkali and salt solution, so the secondary pollution is reduced; and the electrosorption is to remove organic molecules (cations). There are also many studies on the concentration and enrichment of biomacromolecules [4]. This supercapacitor utilizes capacitive decationization techniques. The basic idea is to force the cations to migrate to the oppositely charged electrodes by applying an electrostatic field and to be removed from the solution by adsorption of the electric double layer generated on the electrode surface. The cations in the solution are stored in the electric double layer by electrostatic force, and once the electric field is withdrawn, the adsorbed cations are returned to the solution to regenerate the electrodes [5]. Compared with traditional technology,

electroadsorption has the advantages of less pollutant emission, no secondary pollution and energy saving. Moreover, the technology is mature and reliable, and it is easy to be equipped. It has little impact on the environment. It can be operated only by electrification, and the desalination rate can reach 85%-90% [6]. The selective removal of cations by electroadsorption was discussed. Finally, a simple preliminary study on how to improve the efficiency of electroadsorption demineralization was carried out. The series of conclusions drawn from this provide a theoretical basis and reference for the industrial application and further promotion of electroadsorption in reality.

## 2. Methodology

The activated carbon fiber is cut into the required size, first boiled in 1mol/L NaOH solution for 10min to remove the organic substance adhered above, rinsed with distilled water, and then boiled in 1mol/L HCL solution for 10min to remove residual on activated carbon fiber. Inorganic impurities and NaOH, and finally rinsed with distilled water and boiled until the conductivity value remains unchanged. After thoroughly grinding and mixing with a mortar, the mixture was thermocompression bonded to graphite paper having a length of 8 cm and a width of 5 cm at 185 ° C, wherein the effective area of the electrode was 6 cm × 3.6 cm. After cooling, the bamboo charcoal was crushed and ground, and a 100 mesh sieve was taken as a carbonaceous material for preparing a high specific surface area. In the middle, the plastic mesh is separated and placed in a sealing ring made of silica gel plate. The two ends of the electrode are connected with a DC voltage regulator. The outer side of the electrode is equipped with a plastic electrode frame like electro dialysis. Then wash with decaionic water until the pH value of the washing water is neutral and the conductivity is less than 10 ugs/cm. Dry for 2 hours at 125C. The two ends of the electrode are connected with a DC voltage regulator power supply. The outer side of the electrode is equipped with a plastic electrode frame like electro dialysis. The water inlet and outlet holes are opened at both ends of the electrode frame, and then pressed by two stainless steel plates, thus forming an electroadsorption device.

The electrode size of the electroadsorption experiment module was 100 mm×50 mm×2 mm (length×width×thickness). The electrodes were assembled into a desalter, as shown in Figure 1.

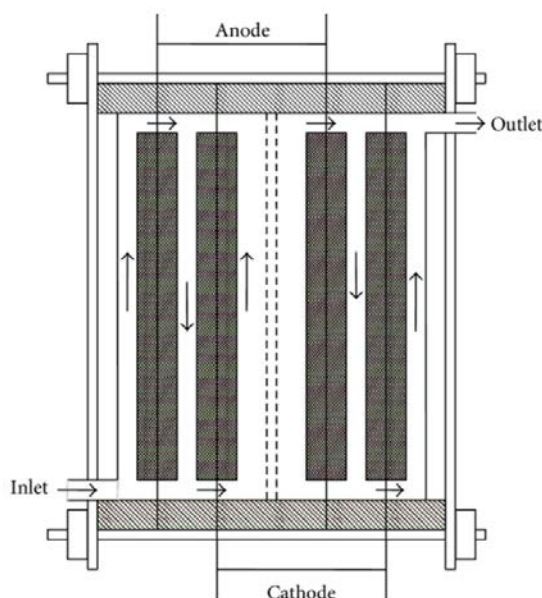


Fig.1. Electroadsorption module

After electrification, the brine first flows through the device at a certain speed, at which time the electrical conductivity of the socket can be tested, as shown in Figure 2.

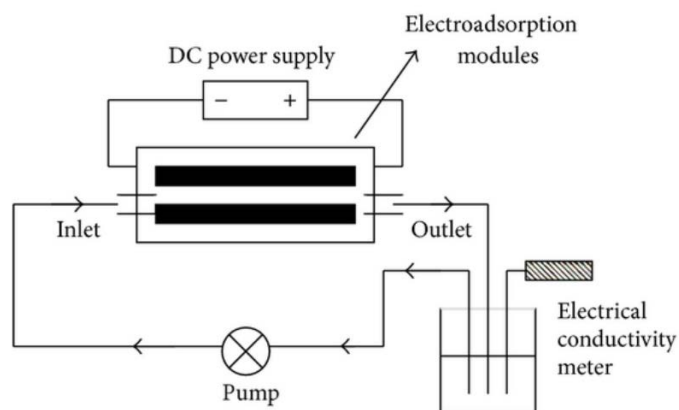


Fig.2. Electrodesorption desalination device

There are two different types of experimental devices for desalination by electroadsorption, by adjusting the settings of electrode plates. The first way is to make the flow direction of the water solution parallel to the direction of the electric field. This type of treatment has a small amount of water and is often used in batch operation. In order to prevent the swing of activated carbon fibers, conductive adhesives were used to paste the activated carbon fibers onto stainless steel plates. The distance between the two electrodes was 15 mm, the mass of the single electrode was 1.5 g, and the volume of the solution was 600 ml. The potential was controlled by a DC voltage regulator. The electroadsorption process was carried out under a magnetic stirrer. Three activated carbon electrodes were placed face to face in an Electrodesorption container with a distance of 1.8cm. The electrodes were connected with a DC voltage regulator. The Electrodesorption experiments were carried out at a voltage of 1.5V. The conductivity of the solution was measured every 30 minutes until the Electrodesorption equilibrium. The conductivity of the adsorbent was measured every 45 minutes after the power was turned on until the conductivity reached equilibrium. The conductivity can reflect the change of the cation in the solution, and the other conditions are controlled. The faster the conductivity decreases, the greater the degree of change, the better the performance of the electrode capacitance.

The raw water of a certain volume and concentration is arranged in the high water tank, and flows downward by gravity, and the flow rate is controlled by the flow meter, and then enters the electric adsorption device, the raw water enters from the lower end of the electric adsorption, and the electric adsorption is performed in the electrode area. The produced water flows out from the upper part of the other end of the electroadsorption device. The electroadsorption reaction device is processed from plexiglass, and two ends are respectively provided with a water inlet and a water outlet, wherein the water inlet is located at the lower end of the reactor, and the water outlet is located at the upper end of the reactor, and the design is favorable for the inlet water solution in the device. Adsorption demineralization is carried out more fully. The electroadsorption occurs on the surface of the electrodes, and the effluent flows out from the top of the other end. Mix it evenly, stirring constantly, adding decationic water and carboxymethyl cellulose in a proper amount in time, and then according to the proportion of material composition. A pair of electrodes were put into the Electrodesorption device. The voltage was adjusted to 2.5V, the distance between electrodes was adjusted to 2mm, the inlet velocity was controlled to about 0.5m/min, and the water conductivity was measured every 2 minutes. This method is simple, rapid, sensitive and does not destroy water samples. It is suitable for monitoring the process of industrial water treatment.

### 3. Result Analysis and Discussion

Because of the effect of adhesives, activated carbon becomes an integral adhesion to graphite paper, but the surface of activated carbon is coated with adhesives, and the holes on the surface are completely covered by adhesives, blocking the internal pore of the electrode. Activated carbon fibers before and after activation are of cross-woven structure. which provides cationic storage

space. The rate of conductivity decrease is the fastest and the conductivity has the minimum value, which indicates that the higher the applied voltage is, the better the effect of electroadsorption and decation is. Theoretically, the higher the voltage on the electrode, the thicker the double layer, and the lower the cationic concentration in the solution after a certain time. With the increase of the working time of electroadsorption, the effluent conductivity of Electroadsorption increases slowly and with little increase. It is shown at this time that the electro-adsorbed electric double layer is still adsorbing ferric cations. At the moment of changing the voltage scanning direction, the current can be quickly stabilized, and the cyclic voltammetry curve is symmetric. The conductivity of the effluent of different concentrations of organic matter is very similar, and the variation curve is basically consistent. This is because the glucose is dissolved in water and does not ionize the conductive cation. The electro-adsorption double layer cannot adsorb glucose. Electroadsorption is affected by the influent flow rate, which is essentially affected by the hydraulic retention time. In addition, the hydraulic retention time is closely related to the original cost of the project.

Figure 3 shows that the removal rate of copper ion by activated carbon fiber electrode is higher than that of lead ion under certain parameters, which indicates that the adsorption effect of electroadsorption on copper ion is better.

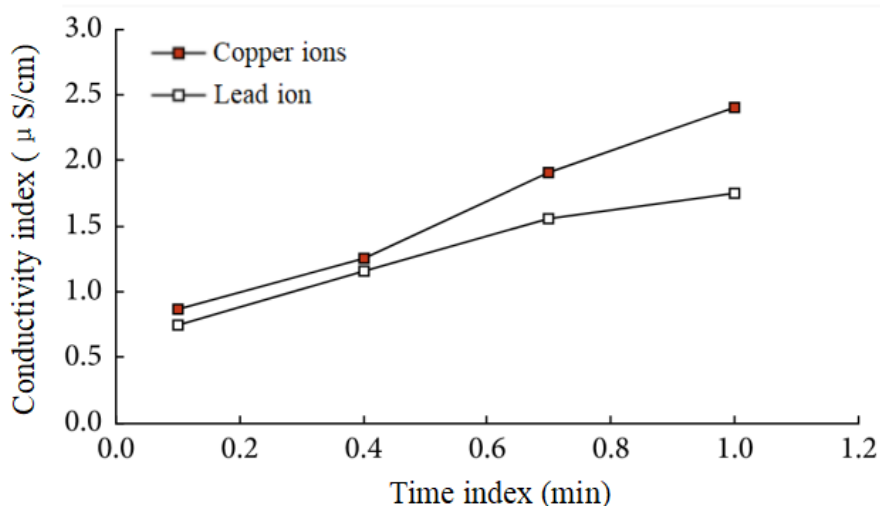


Fig.3. Electroadsorption of different ions

With the increase of voltage, the current increases steadily; with the decrease of voltage, the current decreases steadily. And there is no obvious peak in this process, which indicates that the voltage range is within this range. With the constant rate change of scanning voltage, the response current increases or decreases proportionally before and after activation, which indicates that the charge-discharge reversibility of activated carbon fiber electrode and activated carbon fiber electrode is better. It was found that under the same applied voltage, the adsorption capacity of bamboo charcoal-based activated carbon with high specific surface area increased with the increase of pH value, and the removal rate of cations in the solution also increased. The more the amount of cations adsorbed by the electrode at the same time and unit area, the higher the concentration and the higher the adsorption rate and the amount of adsorption; on the other hand, the larger the concentration of the solution, the more the cation concentration gradient between the solution body and the surface layer of the electrode plate Big. The effluent current of different concentrations of organic matter does not change much, and the variation curve is very similar. This is because the electro-adsorption double layer only adsorbs the charged cations in the water, but although the glucose concentration is increased, it cannot ionize the conductive cations, so there is no excess. The charged cations are adsorbed into the electric double layer. Keeping other parameters in the experiment such as voltage, plate logarithm and spacing, etc., does not change, so the flow rate change can be reflected by the change in flow.

Regarding the mechanism of electroadsorption substitution, there is no clear understanding of theoretical research. The electroadsorption process can be regarded as a dynamic process. Regardless

of whether the electrode material reaches saturation or not, the electrosorption process continues to adsorb and desorb at the same time. Spectrograms with similar shapes in each solution may not form a complete semicircle in the high frequency region due to the frequency of the test. In the study on adsorption, the initial concentration of the solution is a very important experimental condition. During the general adsorption process, the initial concentration of the solution increases and the adsorption rate increases. The adsorption rate of copper cations in solution is faster than that of lead cations, so the removal efficiency of copper cations is better. It is proved again that cations with smaller radius of cations are easier to be adsorbed. On the other hand, the smaller the distance between the electrodes, the larger the capacitance between the two electrodes and the ability to store cations.

#### 4. Conclusion

As a new and efficient desalted water treatment technology, Electrosorption technology has unique advantages over traditional methods, such as good water quality, low energy consumption, no acid-base regeneration, high desalination rate and simple operation. A small electroadsorption reactor was designed and manufactured. Firstly, several environmental factors affecting Electrosorption desalination were discussed, and the optimum reaction conditions were determined. Then, the process and cycle continuity of Electrosorption were analyzed to further demonstrate the reality of its industrial application. According to the pore size distribution of activated carbon fibers, the double layer capacitance consists of microporous capacitance and mesoporous capacitance. Cyclic voltammetry shows that the solution concentration, scan rate, and pore size distribution of the material are the main factors affecting the electric double layer capacitance. The maximum adsorption amount of activated carbon is linearly related to the operating voltage, and the maximum adsorption amount of activated carbon increases with the increase of voltage. In the range of electrolysis voltage of the adsorption liquid, increasing the electrode voltage can improve the electrosorption effect; the smaller the electrode spacing, the better the adsorption effect. The results of single factor experiment showed that the smaller the electrode spacing, the better the adsorption effect; the higher the solution concentration, the larger the adsorption rate and adsorption capacity, but the lower the cation removal rate; in the solution electrolysis voltage range, increasing the electrode voltage can improve the electrosorption effect.

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