REMOVAL OF NATURAL ORGANIC MATTER USING ELECTROCOAGULATION AS A FIRST STEP FOR DESALINATION OF BRACKISH WATER

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ABSTRACT

In the present study, electrocoagulation method was employed to remove natural organic matter from brackish water. This study explores the potential of brackish water as a source of potable water. Two electrochemical variables, potential and contact time, were tested to determine their effect on the treatment efficiency defined in terms of the reduction of the absorbance at the wavelength of 254 nm (A_{254}). Both potential and contact time were found to influence the removal efficiency of the method, and the best result was obtained from the experiment using the potential of 8 V and contact time of 60 min, resulting in 69.5% reduction of the absorbance. Very clean treated water was produced with much lower conductivity (12.06 mS/cm) as compared to that obtained for the sea water sample from a location near to the sampling site (133.9 mS/cm).

Keywords: *electrocoagulation, brackish water, natural organic matter, absorbance*

INTRODUCTION

Population growth and intensification of industrial activities have inevitably caused severe climate change and environmental deterioration, with dramatic consequences for fresh/potable water availability in many parts of the world. Increasing demand for water to support various needs, including domestic, agriculture and industrial sectors has placed water resources under very serious pressure. This unbalanced situation between demand and supply has led to fresh water shortage in many countries.

Declining water quality has become an acute problem around the world, particularly in developing countries where there are very significant increases in agricultural and industrial production, coupled with unreliable water management system. In many developing countries, the situation is complicated by a lack of adequate wastewater treatment technologies as well as very loose environmental policies.

As the world comes to the realization that scarcity of fresh water is a very serious threat, there is growing concern that the reliance on traditional sources of fresh water needs to be reduced. For this reason, there has been increased interest in producing potable water from sea water using various methods of desalination, mostly membrane desalinations in the forms of reverse osmosis and electro dialysis. However, it should be acknowledged that desalination of sea water is still an expensive and highly inefficient process, primarily due to the expensive of the membranes and high energy costs, coupled with very high concentration of salts in the water.

In searching for new potable water sources, brackish water is a reasonable option to consider. This source is an easily accessible and infinite resource for coastal regions therefore it could be developed as a solution to water shortage. From a practical point of view, brackish water is more amenable to the desalination process for its significantly lower salt content than sea water. However, brackish water also contains substantial amount of naturally occurring organics, commonly known as natural organic matter (NOM). The presence of these organics is an obstacle which hinders direct desalination, particularly in using the techniques involving membrane since natural organic matter is known to cause serious fouling of membranes, leading to their rapid deterioration.

Natural organic matter refers to a naturally occurring mixture of structurally complex organic compounds found in terrestrial environments, originating from a decomposition of plant and animal residues through a complex network of various formations processes which involve both chemical and biological degradations [1-2]. In a drinking water industry, NOM is a main concern since the content and characteristics of this matter in source waters have been found to adversely affect the treatment processes and the quality of the water produced.

Aesthetically, the yellowish-brown color of many waters contain NOM is considered unacceptable by the public. In addition, some components of NOM have been known to be responsible for undesired tastes and odors of water [3]. Although they are not necessarily harmful, tastes and odors are aesthetically undesirable and, therefore, reduce the acceptability of water to

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consumers. Another problem associated with NOM is the fouling of membranes used in advanced systems of water treatment such as microfiltration and reverse osmosis, leading to a shorter membrane lifetime [4].

In addition to color, the UV-Vis absorption is another unique characteristic of water sources containing NOM extensively studied. Unlike the UV-Vis spectrum of pure organic compounds, the UV-Vis spectrum of NOM is fairly featureless without distinct maxima or minima as a result of overlapping absorptions of heterogeneous components of the NOM. Despite this featurelessness, the UV-Vis spectra of NOM samples show an increase in absorbance with increased amount of the NOM. The absorbance at 254 nm is of particularly importance since this specific parameter has been acknowledged to correlate well with the content of NOM present in natural waters [5-7]. For this reason, application of this parameter has been reported in a number of water treatment studies [8-10].

To take advantage of its lower salt content, pretreatment of brackish water to remove NOM is an attractive approach since this removal of organics will make the water more susceptible to desalination process without any complication from fouling. Based on this approach, this study investigates the efficacy of electrocoagulation method to remove NOM from a brackish water sample obtained from a private water well located in a coastal region. A series of experiments using aluminum (Al) rod as electrodes was conducted to investigate the effects of electrochemical potential and contact time on the removal efficiency of the method.

In this study, electrocoagulation method was applied since this method has been reported to work effectively in removing a wide range of organics from different types of water. Electro coagulation has been adopted successfully to treat various industrial effluents such as domestic wastewater [11], textile wastewater [12], landfill leachate [13], restaurant wastewater [14], and laundry wastewater [15]. In addition, selection of this method was based on the fact that electrocoagulation requires no coagulant as in the case of conventional coagulation methods. One of the advantages from this feature is elimination of secondary waste (anionic species) produced in the application of chemical coagulants, such as chloride ions from aluminum chloride or iron chloride. In electrocoagulation, the anodic reaction will oxidize the metal electrode applied as anode (sacrificial electrode) and produce metal cations. The cations produce function as coagulating agent in a similar way the cations produced by dissolution of chemical coagulants in conventional coagulation. Using Al metal as electrode, the overall process involves the electrolytic oxidation of the metal to produce Al^{3+}, accompanied by oxidation of water to produce O_2 gas and reduction of water to produce H_2 gas

In this study, the efficiency of the method investigated was evaluated on the basis of the reduction of the absorbance of the water sample at wavelength of 254 nm. In addition to this main parameter, the conductivity of the samples was also measured since this characteristic is a measure of salt content, which is an important factor in water using desalination technique.

EXPERIMENTAL SECTION

Materials

Sample investigated in this study was obtained from a private 5 m deep water well located in a residential area of Panjang coastal region, the City of Bandar Lampung. The well is located about 150 meters away from the coastal line. The water is characterized by very intense yellowish-brown color and salty taste, and therefore it is not used as drinking water but only for limited cleaning/washing purposes. Aluminum rods with diameter of 1.2 cm and 20 cm long were used as electrodes.

Instrumentation

Electrocoagulation equipment used in this study is a laboratory fabricated system.1. The electrochemical reactor was made from transparent glass having a dimension of 10 cm x 10 cm x 20 cm, equipped with a thick plastic cover on top for electrode positioning. The reactor was connected to a sample container made from plastic, using a circulation pump for flow rate adjustment to achieve the specified contact time. Four aluminum rods were used as electrodes, two as anodes and two others for cathodes respectively. The electrodes were washed with dilute acid to remove impurities on the metal surface. The UV-Vis spectrophotometer used was a Varian Cary 50 Probe UV-Vis Spectrophotometer. The conductivity measurement was carried out using an Orion Model 162 Conductivity Meter.

Procedure

The experimental setup is depicted in Fig. 1. The experiments were carried out under different electrochemical potentials and contact time. A treated sample from each of the experiments was collected and filtered. The filtrate was analyzed using UV/Vis spectrometric method, by scanning the sample over a wavelength range of 200 to 700 nm, using distilled water as a blank. The removal efficiency of NOM was

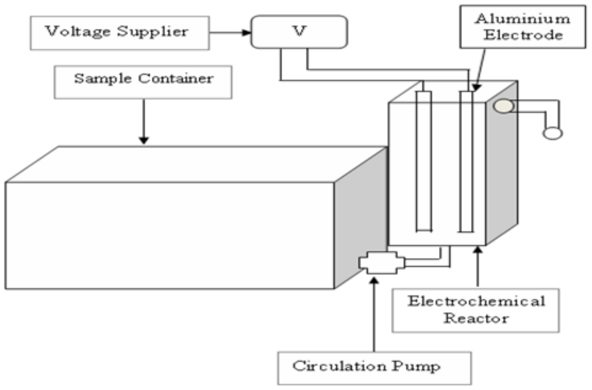

Fig 1. Experimental setup used in this study

Fig 2. Sample of brackish water investigated in this study

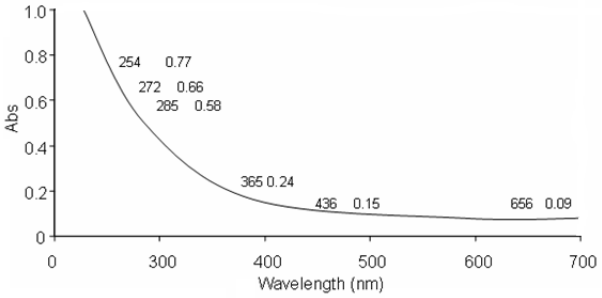

Fig 3. UV/Vis spectra of raw brackish water sample investigated in this study

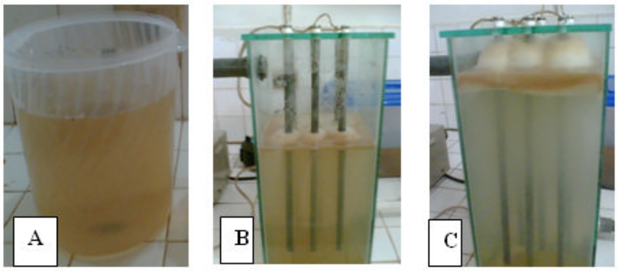

Fig 4. A typical result showing the progress of the electrocoagulation process observed in this study. **A.** The original sample, **B.** After a 30 min treatment, and **C.** After a 60 min treatment

measured from the decrease in the absorbance of the sample at wavelength of 254 nm.

RESULT AND DISCUSSION

Characteristics of brackish water

The brackish sample investigated was characterized by a very intense yellowish- brown color as can be seen in Fig. 2. The very intense color imparted by the sample indicates that the sample contains NOM in substantial amount.

A typical spectrum, produced from the raw water sample investigated, is presented in Fig. 3. The spectrum is marked by considerably high absorbance at the wavelength of 254 nm, with a continuous decrease with increasing wavelength, which is in accordance with the typical feature of the UV-Vis spectra of water containing NOM as has been previously mentioned.

General Features of the Electrocoagulation Process

The removal of NOM from the treated sample was very obvious as indicated by the progressive change of color with experimental time. A typical set of results is presented in Fig. 4.

As previously mentioned, electrocoagulation is a process involving in situ generation of metal cations acting as coagulant which destabilizes colloidal organics present in the water sample. This destabilization will lead to induction of flocks and finally the aggregation of the induced flocks, which could be separated from the water using simple techniques such as filtration or sedimentation. This means that the effectiveness of the electrocoagulation process depends on the amount of the cations available, which could be controlled by electrochemical variables, such as potential, current, and time. In this study, the fixed potential mode was selected, which means that the current changed following the progress of the process as a result of the change in the resistance of the sample. Due to this constant change of the current, the effect of the current density could not be obtained, which is the main different to the electrocoagulation carried out at constant current.

The results in Figure 4 also display evident flotation of the aggregate, which is commonly known as dissolved air flotation or electroflotation [7]. This phenomenon is a result of oxidation of water to produce O_2 gas and reduction of water to produce H_2 gas. These two gases act as flotation agents which drive the aggregate to the surface of the sample.

The Effect of Potential

In electrochemistry, potential is one of the main variables affecting the performance of electrochemical

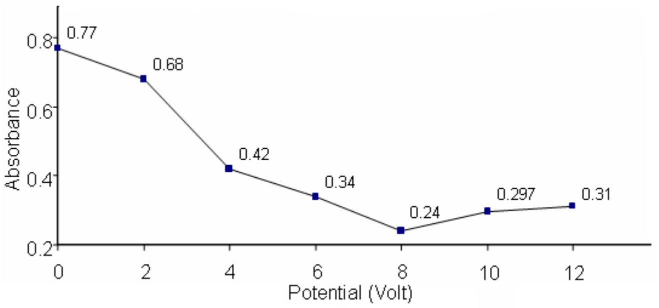

Fig 5. Effect of potential on the absorbance of the sample

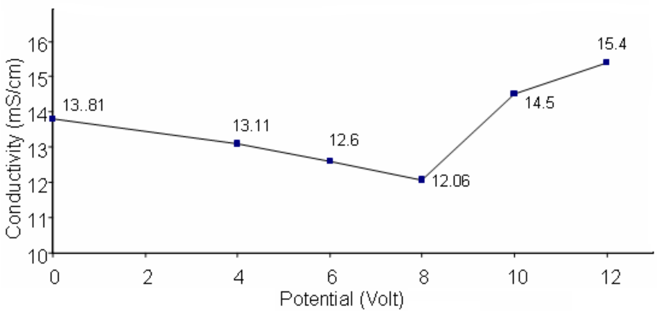

Fig 6. Effect of potential on the conductivity of the sample

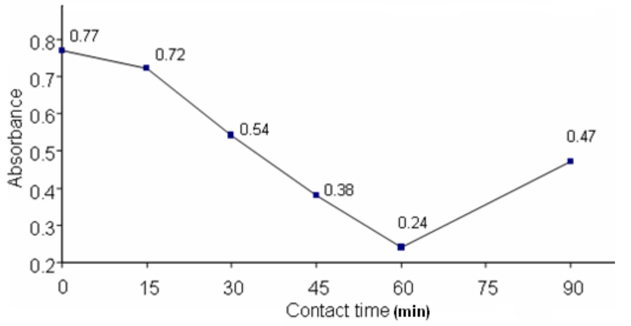

Fig 7. Effect of contact time on the absorbance of the sample

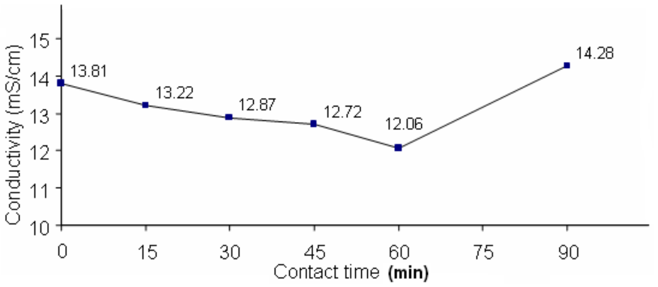

Fig 8. Effect of contact time on the conductivity of the sample

processes. In electrocoagulation, this variable determines the amount of cation produced, and therefore, determines the effectiveness of the process to produce flocs. Recognizing the role of this factor, in this study a series of experiments was carried out at different potentials with fixed contact time of 60 min. The absorbances of the sample at the wavelength of 254 nm (A_{254}) as a function of the potential applied are presented in Fig. 5.

As displayed in Fig. 5, the role of potential is very obvious. As can be seen, the trend is marked by progressive reduction of the absorbance of the sample with the application of potential up to 8 V, followed by the steady increase when higher potentials were applied. These results suggested that the amount of Al^{3+} produced was sufficient to effectively remove the NOM present in the sample investigated. This finding of optimum potential is in agreement with the results reported by others [11,16-17], who also reported the existence of optimum potential, with the magnitude depends on the types of the sample treated. The results in Fig. 5 also indicate that the highest reduction of the absorbance is 69.5%, which is in a very good agreement with the results for model-colored water [7], in which the absorbance (A_{254}) reductions in the range of 64.7 to 71% were reported.

The increase of the absorbance from the minimum value as a result of higher potentials applied is most likely due to excessive production of electrolytic gases produced from electrolysis of water (O_2 and H_2), causing the breaking of aggregates and leading to a release of some organics back to the water. Another possibility is that the production of Al^{3+} cations might exceed the required amount for coagulating the organics. The unused cations remaining in the water most likely contribute to the increase of the absorbance of the sample.

Fig. 6 displays the conductivity of the sample as a function potential applied. As can be seen, the conductivity of the original sample is 13.81 mS/cm. This value is much lower than 133.9 mS/cm, which is the conductivity of sea water sample near the sampling site. This value implies that the treated brackish water has better potential than sea water for further treatment using membrane technologies, such as reverse osmosis, for clean water production.

The results in Fig. 6 show that application of potential up to 8 V only produced small decrease in the conductivity of the sample. This means that the Al^{3+} cations produced from the electrochemical dissolution of aluminum metal applied as anode were effectively used to coagulate the NOM in the sample. The increase in the conductivity of the sample as a result of application of potentials higher than 8 V supports the production of Al^{3+} cations in excessive amount. The unused cations then contribute to the increased conductivity observed.

The Effect of Contact Time

The second operating variable investigated in this study is contact time. For this purpose, a series of experiments was carried out with a fixed potential of 8 V, which is an optimum potential obtained from previous experiments. The results obtained are presented in Fig. 7.

As can be seen, Fig. 7 clearly demonstrates that the role of contact time is similarly important as that of potential. Evident reduction of absorbance took place in a practically linear trend starting from a 15 min contact time up to 60 min treatment. Extension of the contact time to 90 min was found to result in an increase in the absorbance of the sample. This trend is in accordance with the feature of electrochemical reactions, in which the amount of products is proportional to the reaction time. In this respect, the increase in the absorbance is most likely due to the excessive production of electrolytic gases, which led to breaking of the aggregates, releasing some of the NOM components back into the treated water.

Fig. 8 displays the conductivity of the sample as a function reaction time, produced from the experiment carried out using the potential of 8 V. The results show a continuous decrease of conductivity up to 60 min contact time, followed by the increase when the contact time was extended to 90 min. This trend of the effect of contact time is practically similar to that observed for the effect of potential presented in Fig. 6, suggesting the role of residual Al^{3+} in both cases.

Fig. 9 shows the color of the sample before and after the sample was treated using the potential of 8 V and contact time of 60 min. As can be seen, the electrocoagulation treatment produced clear water from yellowish-brown raw brackish water. This color change as a result of treatment demonstrated the effectiveness of the method in removing the organics from the sample. The treated water was found to have a conductivity of 12.06 mS/cm. This value is much lower than 133.9 mS/cm, which is the conductivity of sea water sample near the sampling site. This value implies that the treated brackish water has better potential than sea water for further treatment using membrane technologies, such as reverse osmosis, for clean water production.

CONCLUSION

The effectiveness of the electrocoagulation technique in removing natural organic matter from brackish water has been demonstrated. Both potential and contact time was found to influence the performance of the method, and the best result was achieved using the optimum potential of 8 V and contact time of 60 min. The application of the method produced clear water, with considerably lower conductivity than that found for sea water, indicating the potential for the production of clean water using a combination of electrocoagulation and membrane technologies.

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