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Investigation of the efficiency of microbial desalination cell in removal of arsenic from aqueous solutions

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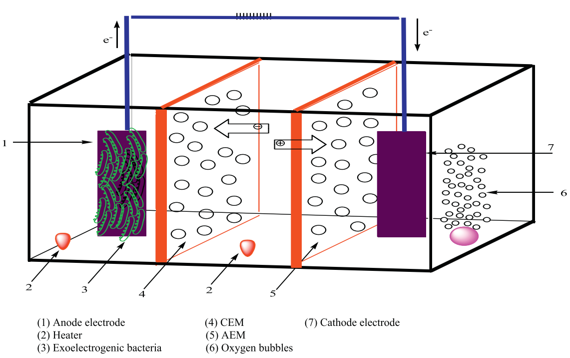
GRAPHICAL ABSTRACT



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ABSTRACT

Microbial desalination cell (MDC) is an environmentally friendly technology and a new method for desalination. The aim of this research is to investigate the extent of removal of arsenic (As) from aqueous solutions by MDC. To examine the efficiency of the process, synthetic As were prepared with concentrations of 100–600 μg/L in deionized water. The removal efficiency was examined at retention times of 30–120 min, at psychrophilic, mesophilic, and thermophilic temperatures and dissolved oxygen of 2–6 mg/L. The real water sample of Bardsir region in Kerman as well as the synthetic wastewater sample was experimented with to examine removal efficiency under the optimal conditions. The optimal conditions for removal of As were obtained as 600 mg/L of As, 6 mg/L of dissolved oxygen, temperature of 25–30 °C, and retention time of 120 min. Under these conditions, As removal efficiency in the synthetic samples of As, real water sample of Bardsir region, and synthetic wastewater sample was obtained as 75, 68, and 56%, respectively. Considering the relatively high efficiency of MDC in removal of As and its advantages including being environmentally friendly and saving energy, it is an effective method in removal of As from aqueous solutions.

1. Introduction

Arsenic contamination in natural waters has caused global environmental concerns, as water contaminated with arsenic can threaten human life owing to high toxicity and carcinogenicity [1–3]. Millions of people around the world are exposed to drinking water

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contaminated with arsenic, which naturally exists in groundwater and is known as a carcinogenic compound. Exposure to arsenic can lead to diseases such as diabetes, liver diseases, cardiovascular diseases, skin disorders, and cancer [2].

The maximum arsenic contamination level in drinking water was suggested as 10 μg/L in 2006 by world health organization (WHO). Therefore, development of new processes and technologies for removal of arsenic from wastewater and water resources is crucial [1]. Generally, physiochemical processes including ion exchange, oxidation-reduction, precipitation, ultrafiltration, and many other methods are used for removal of heavy metals [1–6]. Many metals which exist as trace metals can be removed through precipitation during primary treatment of wastewater. Removal of the soluble form of metals depends on the type of metal. The alternative method to physiochemical processes is use of microorganisms [7].

Microbial fuel cell is a type of bio electrochemical systems. In this method, treatment of wastewater and energy recycling occur concurrently [8,9].

Microbial desalination cell (MDC) is one of the new methods for desalination, which is also environmentally friendly and consumes low energy. The energy of MDC is supplied by microbial metabolism of organic compounds, i.e. degradation of organic compounds by the microorganisms that present in aqueous solutions. This desalination cell consists of three parts: anode, cathode, and desalination chamber (middle chamber), located between the anode and cathode [10–12].

In this method, conversion of chemical energy to electric energy occurs through exo-electro genic bacteria [12]. “Exo” means extracellular and “Electrogenic” is electron transfer potential. The generated electricity causes transfer of cations and anions through ion exchange membranes (IEM) and their absorption to cathode and anode electrodes [11–13].

As heavy metals in water in the middle part of MDCs have a positive charge, they move through cation-exchange membrane (CEM) and are absorbed by the cathode. Further, negatively charged particles move through anion-exchange membrane (AEM) and are absorbed by the anode. Exoelectrogenic bacteria are absorbed by the anode electron to supply the energy required for electron transfer [12–15].

Cao et al. first fabricated MDC in 2009 with a capacity of 3 mL of brine [16]. In Iran, Mirzaienia et al. [14] employed MDC with the aim of removal efficiency of Nickel and Lead from Industrial Wastewater by Using MDC [14]. Malakootian et al. [12] in Iran investigated the extent of removal of removal efficiency of Cu and Zn from Industrial Wastewater by Using MDC [12]. As the efficiency of this method in removal of arsenic has not been the searched, this study has dealt with it. The aim of this research is generation of electricity from wastewater by exoelectrogenic bacteria and removal of arsenic from water by MDC reactor. This is a new method for removal of heavy metals in water treatment plants through consumption of less irrecoverable energies through supplying bioenergy and reducing the incidence of diseases resulting from heavy metals present in drinking water.

2. Materials and methods

This study is experimental conducted in environmental health engineering research center of Kerman University of medical sciences.

2.1. Fabrication of the reactor and running it

The material of the MDC reactor used in this research was made of plexiglass with a thickness of 1 cm with a total useful volume of 8.073 L. the reactor consisted of three parts including anode, middle, and cathode chambers, with the dimensions of each chamber being $14 \times 14 \times 14\ cm^3$ and volume of around 2.74 L.

The anion exchange membrane (fumasep FTAM-E Gmbh Co., FuMA-Tech, Germany) and cation exchange membrane (fumasep FTCM-E Gmbh Co., FuMA-Tech, Germany), which were soaked in deionized water for 48 h were devised between the anode, middle, middle, and cathode chambers. The membranes were placed between the two reticular plexiglass planes to prevent degradation. The material of the anode and cathode electrodes was graphite carbon (Iran, Pariz Fan Co.) with dimensions of 4 (L) × 1 cm (W) × 14 cm (H). Before usage, the electrodes were soaked in deionized water for 24 h. To connect the electrodes, copper wire was used, and eventually the electrodes were connected to a digital Ohm-meter device.

Table 1
Physical-chemical characterizations of wastewater from Kerman University of Medical Sciences.

Parameter	Amount
COD	425 (mg/L)
BOD_5	257 (mg/L)
TSS	17 (mg/L)
TDS	543 (mg/L)
TKN	75 (mg/L)
Phosphate	16.5 (mg/L)
Nitrate	16.2 (mg/L)
Sulfate	348 (mg/L)
pH	7.1

The anode chamber contained return sludge and domestic wastewater. The return sludge was the source of microorganisms, and the domestic wastewater was the source of organic compounds. Both of them were taken from wastewater treatment plant of Kerman University of medical sciences. The physiochemical properties of this wastewater have been provided in Table 1. The cathodechamber contained phosphate buffer 0.1 M, which was aerated by aquarium air pump and the level of dissolved oxygen was measured by a digital oxygen-meter. The middle chamber contained a synthetic sample of arsenic. The pH of the solution was adjusted at 7 using sulfuric acid 0.1 *N* and sodium hydroxide 0.1 *N*. Fig. 1 represents a schematic of the MDC and its function.

The effect of each of the factors including level of dissolved oxygen 2, 4, and 6 mg/L, contact time 30, 60, 90, and 120 min, Psychrophilic (5–15 °C), mesophilic (25–30 °C), and thermophilic (50–60 °C) temperature ranges, initial concentration of arsenic 100, 200, 400, and 600 μg/L was examined. In order to obtain the optimal values of each variable, the experiments were performed by altering each effective factor at different values while keeping other factors constant at optimal value. To enhance the confidence factor and accuracy, the experiments were replicated three times.

2.2. Real water sample and synthetic wastewater

After obtaining the optimal conditions, the experiments were also performed on a real drinking water sample of Bardsir region in Kerman as well as a simulated wastewater sample. To prepare the simulated wastewater, a compound of materials including glucose, galactose, sucrose, dipotassium hydrogen phosphate (K_2HPO_4), potassium dihydrogen phosphate (KH_2PO_4), sodium chloride (NaCl), magnesium sulfate ($MgSO_4 \cdot 7H_2O$), calcium carbonate ($CaCO_3$), calcium chloride ($CaCl_2$), ferrous ammonium sulfate ($Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$), and yeast extract in distilled water were used. The quality of the fabricated wastewater was determined using the methods cited in the standard methods for examinations of water and wastewater and arsenic with a concentration of 600 μg/L was added to the wastewater synthetic solution. Also, to examine the extent of removal, the experiment was conducted under optimal conditions. To further study the extent of arsenic removal of drinking water in Bardsir region in Kerman, samples were taken from five areas randomly. All of the samples were mixed together and kept at 4 °C, which were then transferred to laboratory within less than 2 h. the extent of soluble arsenic in the samples was measured by Atomic Absorption Spectrometer with furnace method

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