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Review Paper

A review on the removal of heavy metals from wastewater by microbial fuel cells

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1. ABSTRACT

Heavy metals are extremely harmful environmental pollutants due to their toxicity, non-biodegradability and environmental accumulation that can affect people and the environment. Microbial fuel cells are a type of bioelectrochemical approach in which bacterial species remove organic pollutants and metal ions from synthetic and industrial wastewater and simultaneously generate electricity. Currently, the real applications of these devices in the world are limited due to the low level of production density. According to the investigations carried out in this article in recent years, microbial fuel cells have been used as one of the ways to remove heavy metals from industrial effluents, and 10 to 100% removal rates were achieved for metals such as gold, chromium, copper, lead, cadmium, mercury, zinc, arsenic and nickel. Also, the parameters affecting the amount of removal were evaluated in these studies, and the optimal conditions are in most cases in the range of neutral pH and in some cases in pH=2, at a temperature of 22 to 35 ^{0}C and an external resistance of 200 to 1000 ohms.

Keywords: Microbial fuel cell; removal of heavy metals; wastewater; energy.

2. INTRODUCTION

Two global issues today are environmental threats such as water pollution and energy crisis [1]. Microbial fuel cell is a new technology to produce electricity and purify wastewater at the same time [2]. Environmental pollution caused by heavy metals is considered as one of the important issues in its durability, toxicity and bioaccumulation [3]. There are various methods to treat industrial wastewater containing heavy metals, such as solvent extraction, filtration, ion exchange, coagulation, sedimentation, oxidation and absorption [4]. These techniques have disadvantages such as: high cost, low removal efficiency, regeneration and the problem of secondary contamination [4]. Therefore, an effective but low-cost method is necessary to treat wastewater containing medium to low concentrations of metals [5].

3. REMOVAL OF HEAVY METALS BY MICROBIAL FUEL CELL

The use of microbial fuel cells to remove or recover heavy metals from wastewater streams and soil has been studied in recent years [5]. For example, some of the reviewed articles in this field are briefly explained below:

In the survey conducted by Asim Ali Yaqoob et al. in 2021, In a two-chamber microbial fuel cell that used local oil palm trunk sap (OPTS) as an organic substrate to improve bacterial activity, removal rate of 70.1, 75, 80, 60, and 75% was achieved for cadmium, chromium, nickel, mercury and lead, respectively [1].

In 2021, Swee Su Lima and colleagues investigated the possibility of removing zinc metal from industrial wastewater by microbial fuel cell. In this study, the removal of zinc in a microbial fuel cell from industrial wastewater with an initial concentration of less than 2 mM reached more than 96% after 22 hours of device operation. The study was started with half-cell setup (without a bioanode). The setup consisted of an abiotic anode and cathode separated by an anion exchange membrane [5].

Also, in the study reported by Sameer Al-Asheh et al. in 2022, the gold removal efficiency increased to 98.86% after 48 hours of operation for a waste sample with an initial gold concentration of 250 ppm. In this study, MFC of rectangular

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acrylic blocks was used. This cell consisted of two chambers, the first chamber of which is the anodic chamber containing the microbial medium and the anode where continuous, which needed continuous mixing [4].
Minh Hang Do in 2022 concluded that using the double chamber MFC-B made of Plexiglass and in the shape of a rectangle with the working volume of the anode and cathode chambers of 300 and 400 ml, respectively, a linear decrease in cell voltage and copper and arsenic concentration was observed with $R^2 = 0.989$ and 0.982, respectively [3]..

4. RESULTS AND DISCUSSION

According to the reviewed articles, it is possible to remove heavy metals by microbial fuel cell. The metals examined here were removed with significant percentages, but among them, gold and zinc metal had a higher removal rate than other metals in the experiments with a removal percentage of over 96% [4,5].

5. CONCLUSION

According to the extensive results in the field of microbial fuel cell application in treating various types of wastewater and removing heavy metals, the outlook of this technology is very positive. This technology is always growing. Since heavy metal pollution is becoming a global problem due to its non-biodegradability and toxic effects, microbial fuel cells are a developing and significant method that is used today as an effective solution to remove heavy metals. They convert chemical energy into electrical energy using bacteria that act as catalysts. Microbial fuel cells are recognized as a sustainable technology for energy generation and removal of toxic pollutants from wastewater sources due to their stability. In this article, different types of industrial and synthetic wastewaters were investigated in a microbial fuel cell, which removed 70-80% for cadmium and lead, 40-100% for chromium, 96-97% for zinc, 60% for mercury, and 80-90% for nickel, 13 to 98% for copper and 98 to 99% for gold were achieved under optimal test conditions. Operating conditions such as pH, temperature, external resistance and the initial concentration of metals play an important role in the removal rate and output power of the microbial fuel cell.

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