

# Efficacy and Mechanism of Temperature-Regulated ECT-MFC for Heavy Metal Removal from Mine Water

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## Abstract

Nowadays sustainable development has gained widespread attention, making people pay more attention to water pollution problems. However, fast industrial development makes water pollution increasingly serious, especially heavy metal pollution in water. Traditional wastewater treatment methods cost much to operate and often produce secondary pollution with poor removal results. Microbial fuel cells can recycle electricity while cleaning sewage, so they have obvious comprehensive advantages. We applied a modified eight-chamber ECT-MFC to treat composite heavy metal wastewater in this test, and the device maintained stable operation and great treatment performance. Temperature controls microbial metabolism and electrode reaction efficiency, which largely changes the overall removal effect. Test results show low temperatures strongly inhibit system reactions; high temperatures raise the initial removal speed but damage microbial activity and cut treatment efficiency after long-term running. The study confirmed that the optimal synergistic effect of reactions occurs under medium-temperature conditions (30°C), and these findings can provide a reference for temperature control in practical equipment applications. By comparing all test working conditions, medium temperature provides the optimum reaction synergy and counts as the best running temperature for the reactor, and all conclusions from this research can offer practical support for field temperature control of such devices.

## Keywords

Microbial Fuel Cell; Eight-chamber ECT-MFC; Heavy Metal Wastewater; Temperature Regulation; Wastewater Treatment.

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## 1. Introduction

### 1.1 The Harm of Heavy Metal Wastewater and Current Treatment Status

Surface runoff and rainwater carry materials from open-pit mines, tailings, and waste rocks into natural surface water bodies, resulting in large volumes of heavy metal wastewater that typically contains iron, manganese, zinc, and other such pollutants<sup>[1]</sup>. These pollutants exist in both dissolved and particulate states, and conventional techniques are unable to decompose heavy metals completely. Relevant treatment can only relocate pollutants or change their physical and chemical forms to realize separation<sup>[2]</sup>. Common approaches include chemical precipitation, solvent extraction, membrane separation, adsorption and ion exchange. However, traditional water treatment processes use a lot of energy and can't produce any energy themselves—they don't fit the needs of green governance<sup>[3]</sup>. So, developing new low-energy, energy-generating technologies has become a key focus in mine wastewater treatment research.

## 1.2 An Overview of Microbial Fuel Cell Research

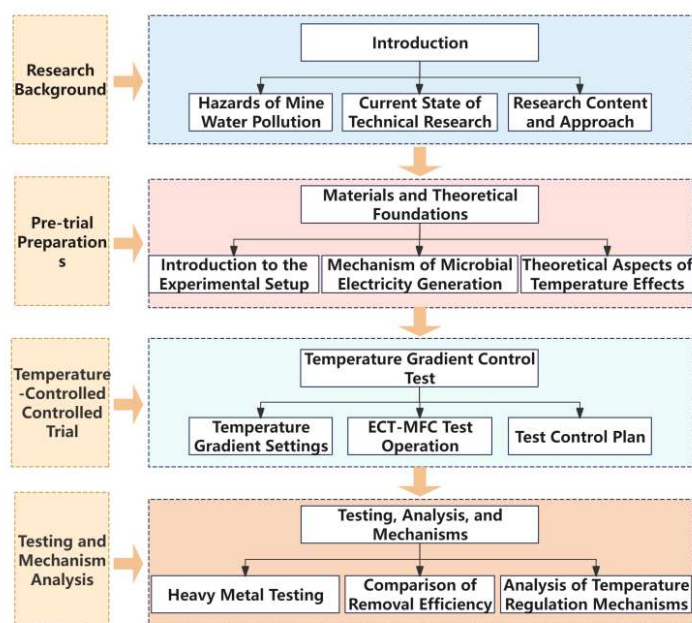
Microbial Fuel Cells (MFCs) are a fusion of microbial and battery technologies-devices that use intact microorganisms as catalysts to convert fuel into electrical energy. Ordinary two-chamber MFCs have quite a few functional shortcomings, so they cannot be put into practical use for industrial wastewater that contains various complicated substances<sup>[4]</sup>. The improved eight-chamber ECT-MFC adopted in this test strengthens the coordination between biological and electrochemical reactions to a great extent, and the overall treatment effect on wastewater mixed with iron, manganese and zinc heavy metals is greatly enhanced<sup>[5]</sup>. Temperature largely decides how the whole device performs, as it directly changes microbial activity and the speed of electrode reactions. Most existing research focuses on MFCs with traditional structures and wastewater polluted by only one heavy metal<sup>[6]</sup>. There are few studies discussing how temperature acts when eight-chamber ECT-MFC deals with mixed heavy metal wastewater. Considering this insufficient research foundation, we carried out this set of experiments to find the most suitable working temperature of the reactor<sup>[7]</sup>. The obtained results can enrich current research achievements and supply practical data support for the real engineering application of this treatment technology.

## 2. Experimental Ideas and Technical Routes

### 2.1 Experimental Design and Temperature Gradient Arrangement

This batch of experiments was arranged to explore how temperature affects the working performance of the eight-chamber ECT-MFC, with iron picked as the representative heavy metal pollutant. The single-variable rule was followed for all test groups. Device assembly, circuit wiring and surrounding environmental conditions remained consistent in every trial. Only temperature was adjusted to record iron removal data and identify the most appropriate operating temperature<sup>[8]</sup>. Such a test setup can rule out outside interferences and clearly reveal how temperature acts on all internal reactions inside the equipment. In accordance with microbial growth characteristics and actual on-site operating conditions, three constant temperature groups of 20 °C, 30 °C and 40 °C were set up. By comparing the operating status of the device at different temperatures, we analyzed the correlation between temperature and treatment effect, and the conclusions can provide practical references for temperature control in engineering practices.

### 2.2 Evaluation Methods and Technical Routes



**Figure 1.** Technical framework of the experiment on heavy metal remediation of mine water by ECT-MFC

Heavy metal removal rate was adopted as the main evaluation index in this study. We collected water samples at regular intervals during the experiment and calculated relevant removal rates to assess the actual treatment capacity of the reactor. The device was firstly commissioned to achieve stable operation before we carried out temperature-controlled tests in different groups. After all experiments were completed, we sorted out and analyzed the collected data to explore the action mechanism of temperature, and finally confirmed the most suitable operating parameters.

### 3. Experimental Results and Analysis

#### 3.1 Effects of Different Temperatures on Ferric Ion Removal

Ferric ions are removed jointly through electrode reduction, chemical precipitation and microbial adsorption<sup>[9]</sup>. All three test groups presented similar changing trends: the reaction proceeded rapidly at the initial stage and gradually became stable afterwards. At 20 °C, microbial activities and electrode reactions were obviously restrained. The removal rate of ferric ions was only 38.9% within 12 hours, and the system reached a steady state after 48 hours of operation, with a final removal rate of 82.00%. The overall reaction system operated optimally at 30 °C. The removal rate hit 64.94% in 12 hours and stabilized at 84.77% after 72 hours, which was the best result among all groups. At 40°C, the reaction system exhibited the fastest rate in the initial phase, achieving a removal rate of 72.50% within 12 hours. However, prolonged high temperatures impaired the microbial community-this led to a decline in later-stage treatment performance, resulting in a final removal rate of 84.50%.

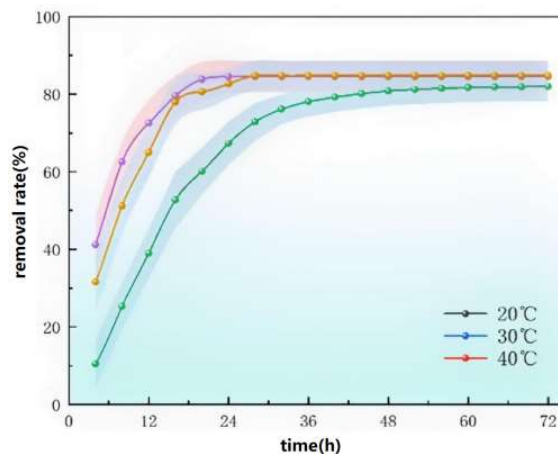


Figure 2. Fe removal rates across different temperatures

#### 3.2 Analysis of the Regulatory Mechanism of Temperature on the Eight-chamber ECT-MFC System

The experimental results indicate that temperature directly affects the synergistic operation effect between microbial metabolism and electrode reactions in the eight-chamber ECT-MFC system. Low temperature inhibits system reactions, making it only suitable for short-term operation; ambient temperature ensures the efficient synergy of various reactions, meeting the requirements for long-term stable operation of the device<sup>[8]</sup>. Although high temperature can improve treatment efficiency in the short term, long-term operation will disrupt the microbial community, leading to a decline in the treatment performance of the device. By analyzing test data of iron pollutants, we can see temperature greatly alters how microbial activity matches electrode reactions within the equipment. Low temperatures suppress microbial vitality and hold back electrode reactions together. The whole system cannot coordinate properly under such conditions, which only works for short-term emergency treatment and fails to handle wastewater continuously over a long period. Moderate temperatures let microbes carry out normal metabolic processes, meanwhile electrodes maintain fast reaction rates. Multiple reactions such as adsorption, reduction and precipitation take place at the same time, so the device can run steadily for a long time without interruption.

High temperature exerts dual influences on the reaction system. In a short running period, it can speed up internal reactions and boost the removal rate of heavy metals. But if the device keeps running at high temperature all the time, the internal microbial groups will get damaged step by step, the original stable balance of reactions will be disrupted, and the treatment capacity will keep decreasing. We sorted through all test data from this experiment and found that running at around 30 °C can secure decent removal efficiency while keeping stable operation and extending service life, so this temperature is the best working condition for the eight-chamber ECT-MFC.

## 4. Conclusion and Prospects

### 4.1 Test Conclusion

This study verifies that temperature exerts a remarkable impact on the heavy metal removal performance of the eight-chamber ECT-MFC, and no simple linear correlation exists between temperature and removal efficiency. Equipment cannot sustain stable long-term running at 20 °C or 40 °C, yet 30 °C turns out to be the most appropriate running parameter. At this temperature, the steady-state removal rates of iron, manganese and zinc reach 84.77%, 85.47% and 79.68% respectively. Appropriate temperature enables coordinated progress of biological and electrochemical reactions, maximizing the overall treatment capacity of the reactor. The temperature control rules summarized in this experiment can be directly adopted to guide practical on-site treatment work.

### 4.2 Limitations and Future Prospects

This test merely set temperature as the single research variable, and joint experiments together with organic loading and other related factors were not arranged. The test ran in static mode, which creates a noticeable gap against real industrial scenes with continuous water intake. Follow-up work may carry out tests coupled with multiple parameters. Researchers can also modify electrode materials and screen heat-resistant microbial strains. These improvements will expand the available temperature scope of the device and make the overall process more suitable for practical engineering use.

## Acknowledgments

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