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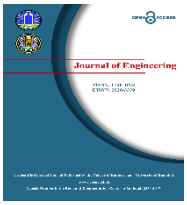

Chemical, Petroleum and Environmental Engineering

The Effect of Total Suspended Solids on the Electricity Generation in Microbial Fuel Cell Treating Actual Potato Chips Processing Wastewater

Dr. Zainab Ziad Ismail*
Professor
Dept. of Environmental Engineering
College of Engineering
University of Baghdad
Email:zismail9@gmail.com

Ahmed Yasir Radeef
Master student
Dept. of Environmental Engineering
College of Engineering
University of Baghdad
Email:ahmed_yasir_radeef@yahoo.com

ABSTRACT

This study aimed to investigate the effect of total suspended solids (TSS) on the performance of a continuously operated dual-chamber microbial fuel cell (MFC) proceeded by primary clarifier to treat actual potato chips processing wastewater. The system was also tested in the absence of the primary clarifier and the results demonstrated a significant effect of TSS on the polarization curve of the MFC which was obtained by operating the graphite anodic electrode against Ag/AgCl reference electrode. The maximum observed power and current densities were decreased form 102.42 mW/m^2 and 447.26 mA/m^2 to 80.16 mW/m^2 and 299.10 mA/m^2, respectively due to the adverse effect of TSS. Also, the internal resistance increased from 40 to 70Ω.

Keywords: Microbial fuel cell, total suspended solids, potato chips processing wastewater, energy generation

تأثير المواد الصلبة العالقة الكلية على توليد الكهرباء في خلية وقود احيائية تعالج مياه الصرف الصناعية الحقيقية الناتجة من معامل انتاج رقائق البطاطا

الخلاصة

تهدف هذه الدراسة الى اختبار وتقييم تأثير المواد الصلبة العالقة الكلية على اداء خلية الوقود الاحيائية ثنائية الحجرة المستخدمة بشكل مستمر لمعالجة نماذج حقيقية لمياه الصرف الصناعية من معامل انتاج رقائق البطاطا ويسبق خلية الوقود الاحيائية حوض ترسيب اولي لازالة المواد الصلبة العالقة. تم اختبار عمل المنظومة بوجود وبغياب حوض الترسيب الاولي. اظهرت

*Corresponding author
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النتائج تأثيرا واضحا للمواد الصلبة العالقة الكلية على منحنى الاستقطاب الخاص بالخلية حيث انخفضت قيم الطاقة والتيار الناتجة من 102.42 ملي واط / م^2 و447.26 مللي أمبير/ م^2 الى 80.16 ملي واط / م^2 و299.10 مللي أمبير/ م^2، على التوالي مع ارتفاع قيمة المقاومة الكهربائية الداخلية من 40 اوم الى 70 اوم عند غياب حوض الترسيب الاولي من نظام المعالجة المتكامل.

الكلمات الرئيسية: خلية الوقود الحيوي، المواد الصلبة العالقة الكلية ، مياه صرف معامل انتاج رقائق البطاطا ، انتاج الطاقة.

1. INTRODUCTION

The microbial fuel cell (MFC) is a new device has a promising future in wastewater treatment; it can simultaneously remove contaminants and generate electricity by using microorganisms as a biocatalyst, (**Choudhury et al., 2017)**.

The potato chips processing industry is one of the most worldwide spread food processing industries. The potato chips processing industry utilize large volumes of fresh water in different subsequent operations such as washing, peeling and blanching during the production of potato chips, slicing, and shredding potatoes. In addition to the high concentration of chemical oxygen demand (COD) in this type of industrial wastewater, high concentration of total suspended solids (TSS) is the one of the major pollutants in these industrial effluents which is a result of various production operations, (**Malladi & Ingham, 1993)**.

The main source of TSS in potato chips processing wastewater (PCPWW) results from processing of raw potato such as washing, fluming, peeling, and cutting operations. The total suspended solids concentration resulted from these operation series could be more than 9700 mg/L, (**Hung et al., 2006)**.

Sedimentation is a primary treatment employed for the removal of TSS from industrial wastewater. These tanks/clarifiers remove TSS by gravity within duration of 2 to 3 hours to protect the following units, including biological unit form the problems of clogging and inefficient performance, (**Davis & Cornwell, 1991)**.

Several studies investigated the effects of many factors on the performance of MFCs such as types of configuration, (**Du et al., 2007**, pH, **Puig et al., 2010)**, electrode materials, (**Sangeetha and Muthukumar, 2013)**, biocatalyst type, (**Ismail and Jaeel, 2013)**, source of substrates, (**Kim et al., 2016)**, anode inclination, (**Jaeel et al., 2016)**, hydraulic retention time, (Arya **et al., 2016)**, cathode environment, (**Kumar et al.,2017)**, temperature, (Tee **et al., 2017)**, and others. However, none of the previously reported studies investigated the influence of total suspended solids on the performance of the microbial fuel cell.

This study investigated the influence of total suspended solids (TSS) on the stability of the anodic biofilm in terms of energy generation in a dual chamber MFC treating real potato chips processing wastewater.

2. MATERIALS AND METHODS

2.1 Description of MFC Integrated System

An integrated MFC system made of Plexiglas material and subsequently consisted of holding-neutralization tank, sedimentation tank, followed by horizontal flow dual-chamber MFC was used to treat the actual potato chips processing wastewater **Fig.1**.

The primary sedimentation tank was designed according to the dimensions illustrated by**,(Davis, 2010)**, who mentioned the dimensions ratio of primary sedimentation tank that provides best removal efficiency of suspended solids with retention time within the range of 1.5-2.5 hours. As shown in **Fig.2,** a rectangular closed tank of dimensions 30cm x 10cm x 8cm, with a total volume of 2400 cm^3 and retention time 2h was used before the MFC.

The MFC was designed as a horizontal flow dual-chamber MFC of dimensions 20 cm x 10 cm x 10 cm, for each compartment. The cation exchange membrane CEM class CMI-7000s was used as a proton exchange facility between the anodic and cathodic compartments. Uncoated plane

graphite electrodes were used in each compartment, with an effective area of 128 $cm^2$for each one. Copper wires were used to connect external electrical circuit with electrodes, to allow the transport of electrons and the passage through resistance box.

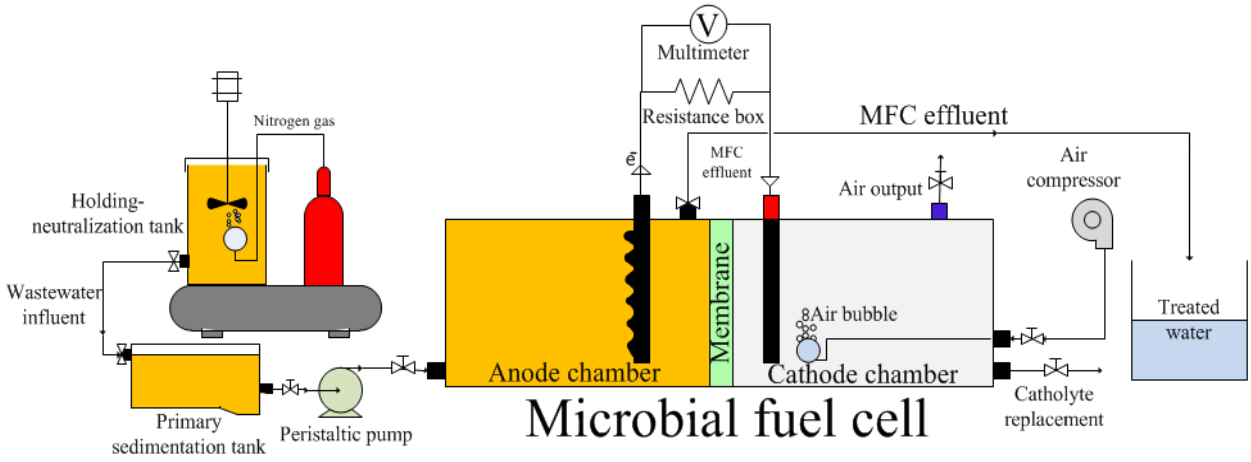

Figure.1 Schematic diagram of the MFC integrated system.

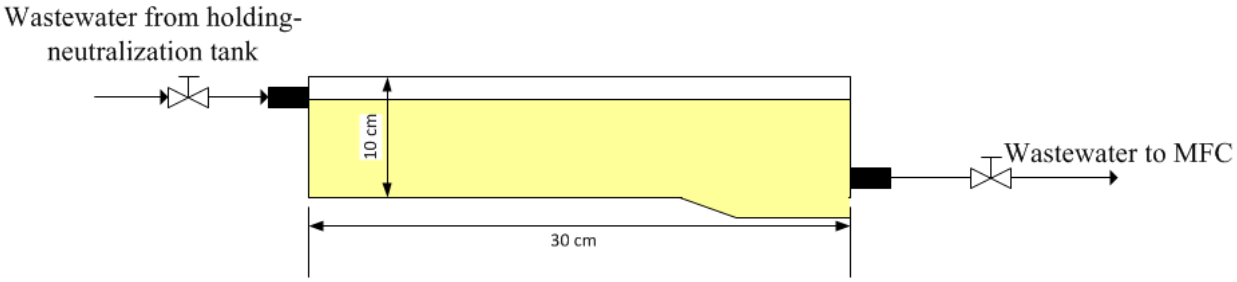

Figure.2 Schematic diagram of primary sedimentation tank.

2.2 Actual Potato Chips Processing Wastewater (Substrate)

Actual potato chips processing wastewater samples were freshly collected from a small local potato chips industry named "Salah Al-din Bakery & Pastry" in Tikrit city. These collected samples had average concentrations of 7900 mg/L, 2900 mg/L, 5800 µS/cm and 5.7 for COD, TDS, EC and pH respectively. The average concentrations of TSS were within the range of 2610 to 2880 mg/L.

2.3 Anaerobic Sludge (Biocatalyst)

A sample of anaerobic aged sludge was collected from the bottom of a local septic tank in Tikrit city. The biocatalyst was used to cover the anodic electrode of microbial fuel cell. Before entering the anodic section, the wastewater was flushed with nitrogen for 10 min to provide and maintain anoxic conditions.

2.4 MFC Start Up and Suspended Solids Effect Detection Strategy

A peristaltic pump was used to feed the actual wastewater to the anodic chamber of the MFC with a flow rate of 60 ml/hr. An air compressor of 10 ml/min was used to provide aerobic condition in the cathode compartment. The cathode chamber was filled with phosphate buffer saline of pH

value (7.2±0.2) as a catholyte. The MFC was fueled for 4 month with actual potato chips processing wastewater which was primarily clarified in the sedimentation tank to remove TSS before entering the anodic section of MFC. The MFC was operated at external resistance of 100Ω. After 4 months of continuous operation of the system at stable conditions achieving high COD removal efficiency (>95%), the primary sedimentation tank was eliminated from the system and the real wastewater was fueled directly to MFC without TSS removal to study the effect of TSS on the MFC stability conditions. The procedure was carried out during a period of 25 days.

2.5 Analytical Analysis and Methodologies

The total suspended solids (TSS) concentrations were measured on daily basis for the influent and effluent in addition to dissolved oxygen (DO), pH, total dissolved solids (TDS), and electrical conductivity (EC) according to the procedure outline in the ***standard methods*** (**APHA**, **2005**). Voltage was continuously and carefully monitored by a voltage data logger (model: Lascar EL-USB-3, USA), and highly accuracy (0.001mV) multimeter (model MT1233C, pro'skit, Taiwan). The data were converted to power according to $P = I * V$, where I is the current, V is the voltage, and P is the power. Then, the power and the current were calculated as a function of the surface area of the anode. Anodic-polarization curves were accomplished by varying external load between 60000 and 5Ω and the potentials were recorded against the reference electrode (Type: Ag/AgCl Beckman Laboratory, USA).

3. RESULTS AND DISCUSSIONS

3.1 Total Suspended Solids (TSS) Removal

The removal of total suspended solids in the MFC integrated system occurred mainly in the primary sedimentation tank which already designed to remove the major concentration of total suspended solids, a slight removal of the remaining suspended solids may occur in the MFC. A suspended solids removal profile for MFC is given in **Fig.3**. In the 10 days that preceded the experimental work of this part of the study, a steady state condition in which more than 98% removal efficiency of TSS was clearly achieved. The fluctuation of TSS concentration in the effluent was observed upon removing the sedimentation tank associated with slight decline of the MFC performance due to the adverse effect of TSS concentration disturbance on the stability of the biofilm. The steady state re-appeared after 10 days with notable decrease in the removal efficiency of TSS ranged from 98% to 70%.

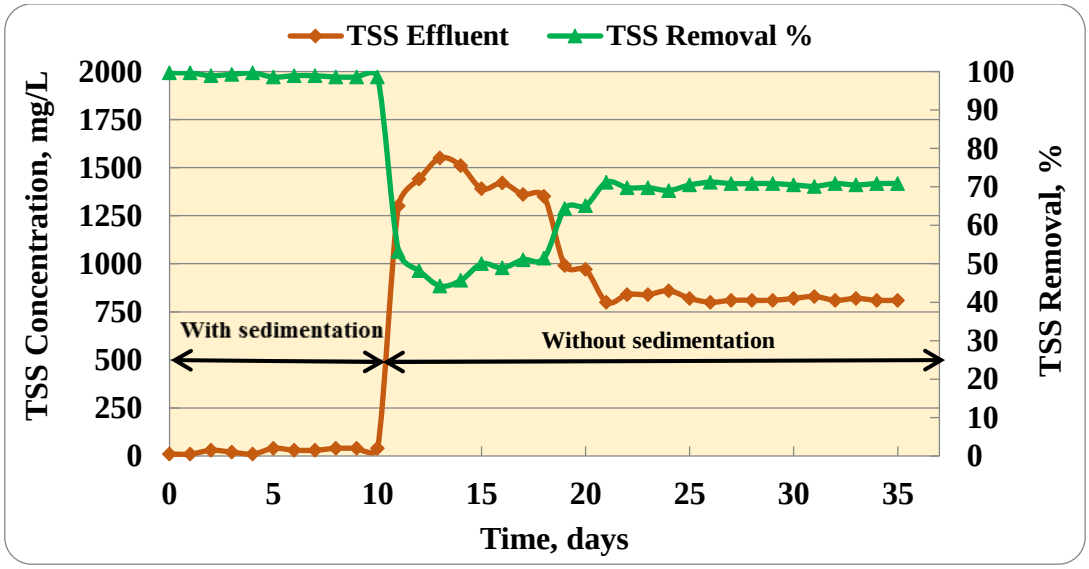

Figure 3. Profile of total suspended solids removal.

3.2 Energy Generation

As shown in **Fig.4**, the voltage started to decrease from 350 mV to 305 mV in the first day after the absence of primary sedimentation tank, and continued to decrease in the following days and achieved 199 mV in the third day and then started to increase and returned to the steady state condition after nine days but the voltage values (average voltage = 310 mV) was less than the values in case of the presence of primary sedimentation tank.

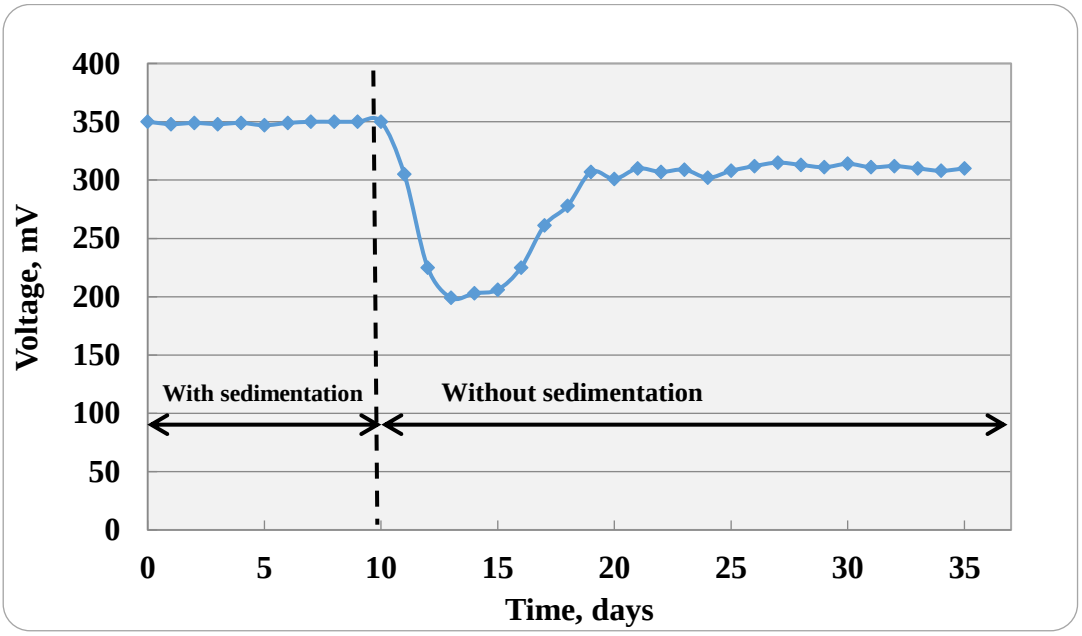

Figure 4. Profile of voltage generation at 100Ω.

3.3 Polarization Curves

The polarization curves are the useful method for the description and analysis of MFCs in which the voltage plots as a function of the current. The available maximum current and power can be produced when the external and internal resistances are equal,(**Liu & Li, 2007).**

In order to compare between the two cases of presence and absence of the sedimentation tank, the two polarization curves were obtained by performing the anode as the working electrode against the Ag/AgCl reference electrode at a stable period to evaluate the TSS effect on the electricity generation as given in **Fig.5**, and **Fig.6**.

In the presence of the sedimentation tank: A maximum power density of 102.42 mW/m^2 and maximum current density 447.26 mA/m^2 with internal resistance of 40Ω were achieved.

When the sedimentation tank was removed from the system, the maximum power and current density decreased to 80.16 mW/m^2 and 299.10 mA/m^2 respectively, with increase in the internal resistance to 70Ω. Also, open circuit voltage decreased from 616 mV to 589 mV.

It can be concluded that the TSS may decrease the biodegradable function of bacteria which may lead to increase the internal resistance of the system because the bacteria responsible for the degradation of organic matter, are generally associated with films or slimes which develop on the

surfaces of the suspended solids particles, (**Zachritz and Fuller,1993; Reddy and D'angelo, 1997).**

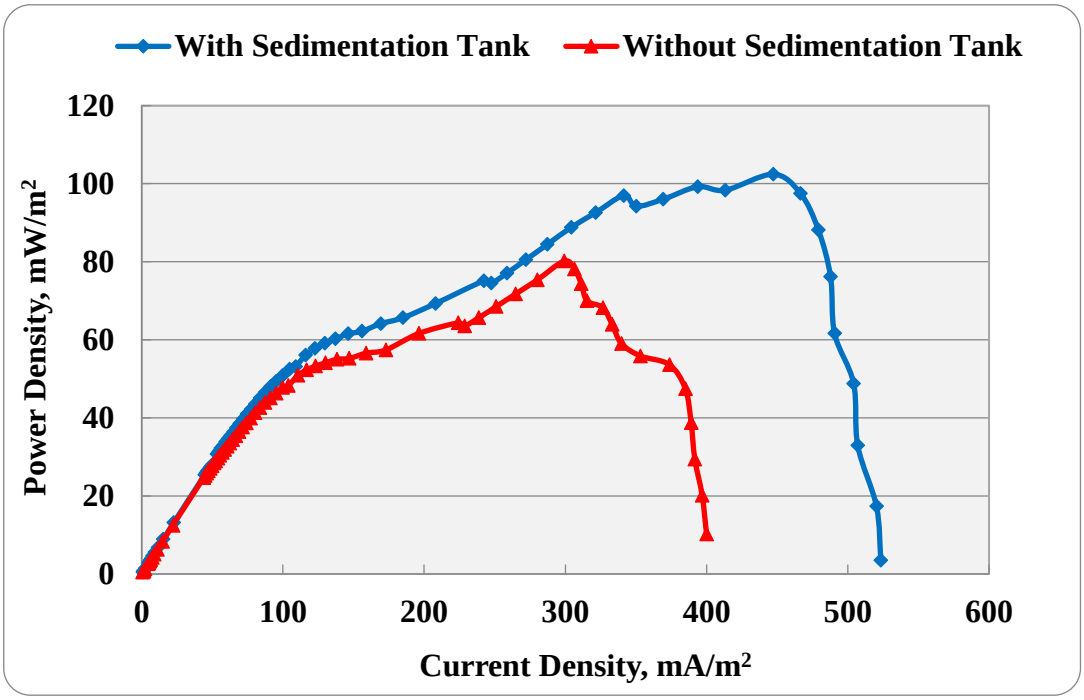

Figure 5. Power-current polarization curves for MFC.

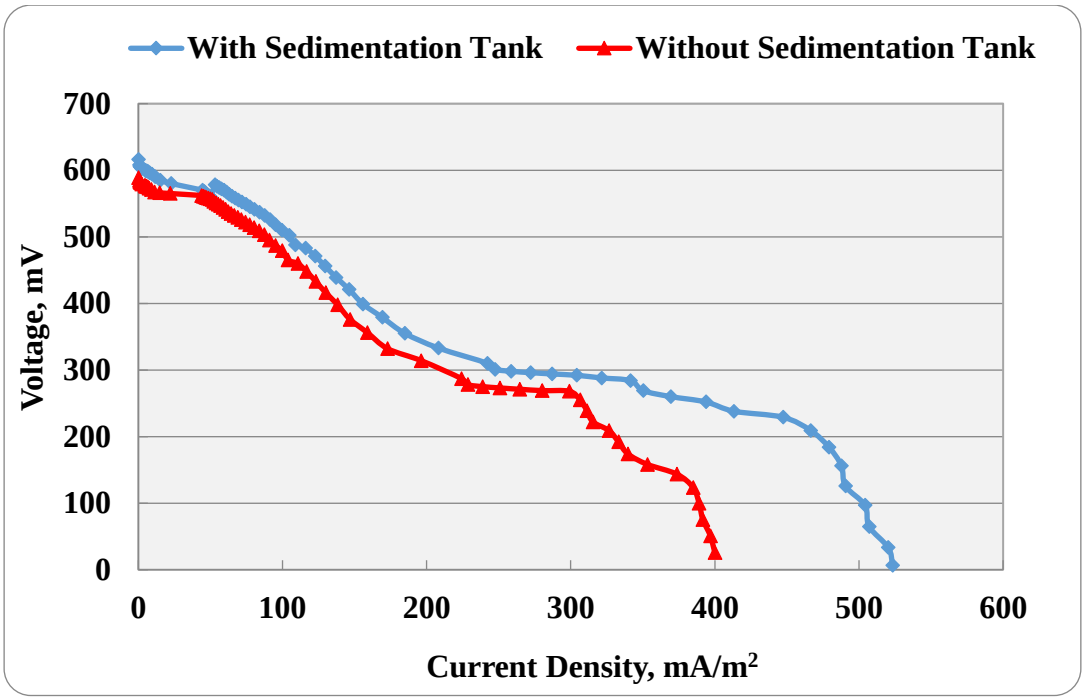

Figure 6. Voltage-current polarization curves for MFC.

4. CONCLUSION

This study investigated the effect of total suspended solids (TSS) on the performance of dual chamber horizontal flow type MFC fueled with actual potato chips processing wastewater. The results demonstrated a significant effect of TSS on the electricity generation in MFC. Maximum current and power densities decreased form 447.26 $mA/m^2$and 102.42 mW/m^2 to 299.10 mA/m^2 and 80.16 mW/m^2, respectively, when the primary sedimentation tank was removed from the system. Finally the internal resistance increased in the case of absence primary sedimentation tank from 40 to 70Ω.

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