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***Research Article***

# Electro-membrane Bioreactor Combined Solar Powered Processes: MATLAB Modelling

Gamze Nalçacı[1], Gülizar Kurtoğlu Akkaya[2]

[1*] Necmettin Erbakan University, Faculty of Engineering, Departmant of Electrical and Electronics Engineering, Konya, Turkey, (ORCID: 0000-0000-0000-0000), gnalcaci@erbakan.edu.tr
[2] Necmettin Erbakan University, Faculty of Engineering, Departmant of Environmental Engineering, Konya, Turkey, (ORCID: 0000-0000-0000-0000), gakkaya@erbakan.edu.tr

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**Abstract**

In this study, it is researched that could use (PV) panel for solar energy instead of DC power supply used in leachate treatment by submerged electro membrane bioreactor for Antalya in Turkey. The study was made the analysis and modeling by MATLAB Simulink of electric energy obtained solar powered or PV panels and present an engineering approach. SMEBR was operated under electrokinetic conditions at a current density of 24 mA/cm2 (11,5 A), exposure time 3+3 minutes. As a result, in the light of SMEBR electrokinetic experimental results, it was found that a pair of PV panels connected in parallel provide 11.5 A for the SMEBR process for this region. In obtained modelling, it was determined the number of panels increases dependent on the amount of volume. Also, it was understood that PV system can work without battery via a control mechanism turn off the system, and it provides direct current. If a battery is added to the system, it can continue treatment without interruption. But since this system will run for about six minutes, no battery cost will be required.

**Keywords:** Electro Bioreactor, Electrocoagulation, Leachate, Solar Energy, PV Panel, MATLAB.

# Elektro-membran Biyoreaktör Kombine Güneş Enerjili Prosesler: MATLAB Modelleme

**Öz**

Bu çalışmada, Türkiye'de Antalya için batık elektro membran biyoreaktör ile sızıntı suyu arıtımında kullanılan DC güç kaynağı yerine güneş enerjisi için (PV) panel kullanılabileceği araştırılmıştır. Çalışma, güneş enerjili veya PV panellerden elde edilen elektrik enerjisinin MATLAB Simulink ile analizi ve modellemesi yapılmış ve bir mühendislik yaklaşımı sunmaktadır. SMEBR, 24 mA/cm2 (11,5 A) akım yoğunluğunda, 3+3 dakika maruz kalma süresinde elektrokinetik koşullar altında çalıştırıldı. Sonuç olarak, SMEBR elektrokinetik deney sonuçları ışığında paralel bağlanmış bir çift PV panelin bu bölge için SMEBR işlemi için 11.5 A sağladığı bulunmuştur. Elde edilen modellemede hacim miktarına bağlı olarak panel sayısının arttığı tespit edilmiştir. Ayrıca PV sistemin aküsüz çalışabileceği bir kontrol mekanizması ile sistemi kapattığı ve doğru akım sağladığı anlaşılmıştır. Sisteme pil eklenirse çalışmaya ara vermeden devam edebilir. Ancak bu sistem yaklaşık altı dakika çalışacağı için herhangi bir pil maliyeti gerekmeyecektir.

**Anahtar Kelimeler:** Elektro Biyoreaktör, Elektrokoagülasyon, Sızıntı Suyu, Güneş Enerjisi, PV Panel, MATLAB.

## 1. Introduction

In the last decades, waste production has increased significantly due to the overpopulation and the changing consumption habits [1]. Landfilling is the most used final waste disposal method around the world. In a landfill, leachate production is an inevitable consequence of leaking through the decomposition and separation of waste. Leachate is depending on factors such as landfill age, precipitation, seasonal air exchange and waste composition, the character varies and pollution load is higher than other wastewaters [2], [3]. Therefore, its treatment is relatively difficult [4]. The inability to achieve well treatment of leachate is seriously affecting the receiving environment [5] [6]. Therefore, effective treatment of leachate is becoming increasingly important in order to protect the earth and groundwater resources [2]. Leachate needs to be treated prior to its discharge into receiving waters and the removal of organic matter and ammonium is always a pre-requisite. Given the complexity of the leachate composition, previous studies suggested that a combination of technologies is usually required.

Akkaya et al. [7] researched leachate treatment with new hybrid method called Submerge electro membrane bioreactor (SMEBR). SMEBR, a novel method for wastewater treatment has been combined with the membrane bioreactor (MBR) and the electrokinetic processes [8]. Electrokinetic processes in this method contains electrochemical phenomena such as electrocoagulation (EC), electroosmosis and electrophoresis. For EC processes in SMEBR, sacrificial metal electrodes (as anode and cathode) are used to produce coagulating agent to dose the polluted water and electrolytic gases are generated.

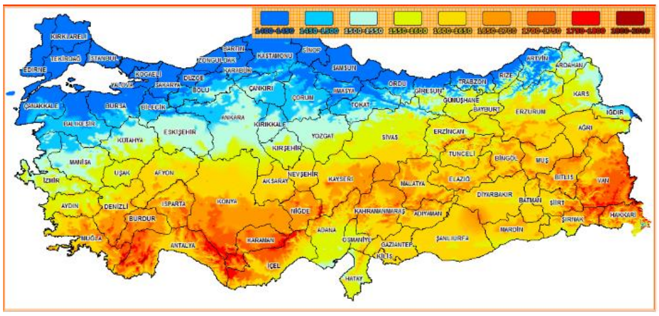
Electrodes are connected to a direct current (DC) power supply. The electrical current applied power supply causes the dissolution of metal into wastewater. When the metal ions began to appear on the anode side in wastewater solution it reacted with hydroxide ion (OH−) produced on the cathode side producing aluminum hydroxide according to the following equations (for aluminum anode/cathode) [9]:

At the anode: $Al \rightarrow Al^{3+} + 3e^{-}$ (1)

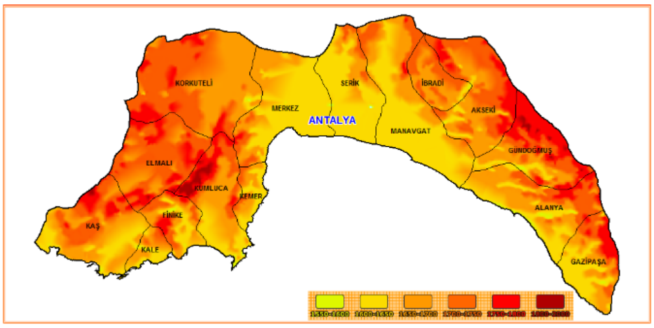
At the cathode: $3H_2O + 3e^{-} \rightarrow 1.5H_{2(g)} + 3OH^{-}$ (2)

In solution: $Al^{3+}_{(aq)} + 3H_2O \rightarrow Al(OH)_{3(s)} + 3H^{+}_{(aq)}$ (3)

Electric energy is required in EC processes. Recently, several authors researched that electrical energy in EC is obtained environmentally friendly and renewable methods [10], [11], [12], [13], [14]. Solar powered EC systems were improved because direct sunlight is potentially the most powerful renewable energy source. In this system, it was used DC supply directly from photo-voltaic (PV) panel instead of power supply for EC. In less than an hour, the Earth receives the same amount of energy from the sun as is used globally by mankind in a year. In contrast to most of the other energy technologies, solar energy is only limited by the cost of conversion and the intermittency in time [15]. The utilization of sunlight can be made with a wide variety of technologies that use the physical principles of energy conversion.



(a)



(b)

Figure. 1(a) and (b). The solar radiation resource possessed in Turkey and Antalya respectively

Turkey represented in Figure 1(a) is in a very fortunate position than many other countries in terms of efficient and solar energy potential with the current geographical location. One of the most solar energy potentials as shown in Figure 1(b) is Antalya in Turkey. In this study, it is researched that could use (PV) panel for solar energy instead of DC power supply used in leachate treatment by SMEBR for Antalya. The aim of this work is the analysis and modeling by MATLAB Simulink of electric energy obtained solar powered or PV panels and present an engineering approach.

## 2. Experimental Setup

### 2.1. SMEBR System

Leachate treatment by SMEBR was studied in the working volume of 5.0 L. Aluminum (Al) was the material preferred for both anode and cathode electrodes in SMEBR. In order to achieve a homogenous mixture and sustain homogenous circulation, 1 mm thick cylindrical and perforated Al anode and cathode electrodes were used with the same surface areas (238.5 cm2) and the perforation of 73.3 and 15.6%, respectively (Figure 2). The diameters of the perforated anode and cathode electrodes were 15.8 and 5 cm, respectively and the distance between the electrodes was 5.4 cm. Al electrodes were immersed inside the mixed liquor approximately 18 cm from the bottom of SMEBR. SMEBR was operated under electro-kinetic conditions at a current density of 24 mA/cm2 (11,5 A) at 180 s/day for 25 days (Stage I) and 360 s/day for 25 days (Stage II) [7].

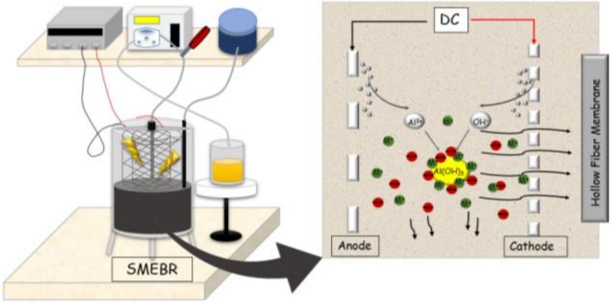



Figure 2. SMEBR experimental setup

## 2.2. Model

SMEBR system presented in Figure 3 is modeled on MATLAB Simulink 2020a environment. A renewable source, PV panel, is the electric supply of the system. Irradiance and temperature values are input variables for PV array, including two high power SunPower SPR-415E-WHT-D panels connected parallel for the SMEBR process needing 11.5 A. A storage capacitor is connected to the output of the panel groups. The capacitor provides a constant voltage of approximately 1.2 V source for electrodes. In Figure 3., the MATLAB Simulink model is represented. In this model, a resistor simulates electrodes as an electrical element.

# 3. Results and Discussion

The efficiency of SMEBR in the treatment of young leachate was investigated by Akkaya et al. [7]. An electrical field of 360 s/day was applied for another 25 days in the same current density with 12-hour intervals during 5 days of HRT (Stage II). At end of this study, results demonstrated that the formation of electro-kinetic conditions within a SMEBR with the addition of the electrical field provided important contributions in terms of the effluent quality. While the chemical oxygen demand (COD) which is water pollution parameter, removal efficiency improved by 3-6% in Stage I, it almost doubled in Stage II and was 6-15%. Also, in SMEBR the temperature value was 25±4 °C depending on the ambient conditions.

SMEBR system integrated with a PV panel system presented in Figure 3 operates at 25℃ and 950 W/m2 irradiance. The panel supplies depend on the solar irradiation and the temperature of the PV module which in turn is affected either in a continuous way or suddenly depending on the weather conditions [12]. According to the Antalya irradiance map (Figure 1.), the operating point is an approximate and optimum value for the year. In the light of experimental results [7], a pair of PV panels connected in parallel provide 11.5 A for the SMEBR process for this region.

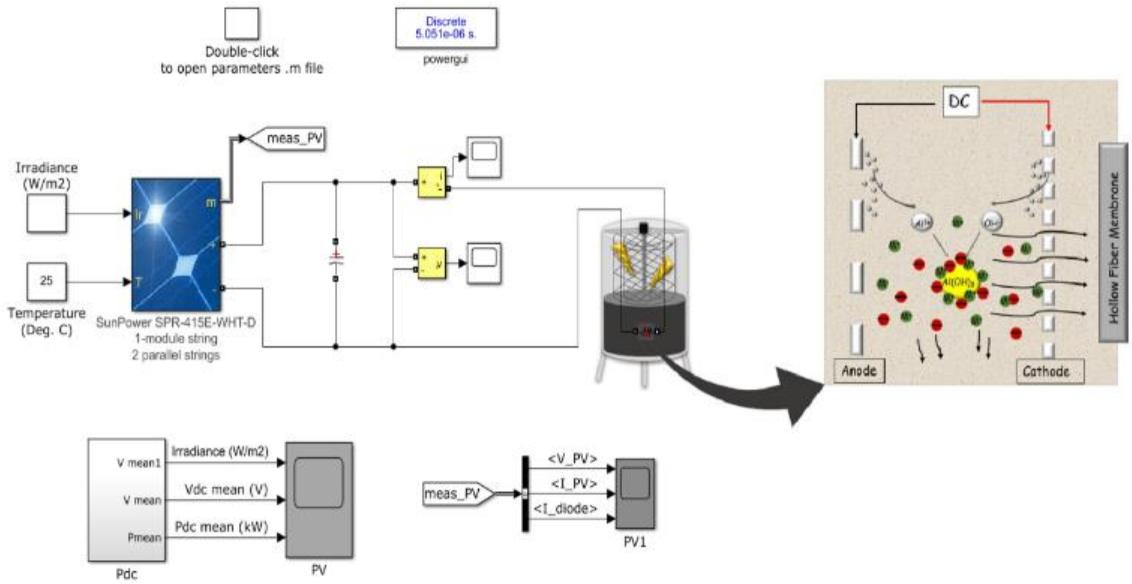
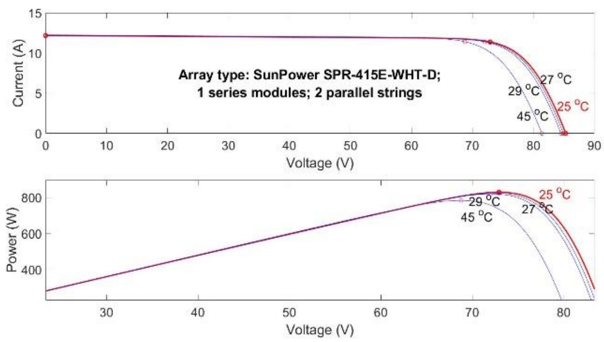


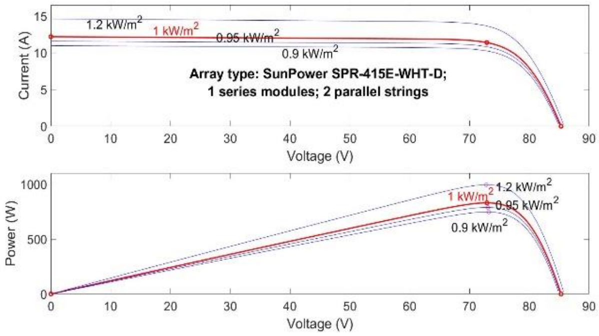

Figure. 3. MATLAB Simulink model of SMEBR system powered by PV source

The number of panels increases dependent on the amount of volume. Turkey has 4-11 hours of insolation durations changing by months, as reported by Turkish Energy Map, GEPA. The best time for irradiance for our system is at noon. On the other hand, this system does not work at night because of no battery. PV system can work without battery via a control mechanism turn of the system, and it provides direct current if the sun. If a battery is added to the system, it can continue treatment without interruption. But since this system will run for about six minutes, no battery cost will be required.

The PV panel characteristics used in Figure 3 has been investigated and extracted in Figure 4(a) and 4(b). In Figure 4(a) case, SunPower PV panel connected to 1 series modules and 2 parallel strings is tested 25 °C, 27 °C, 29 °C and 45 °C, and obtained current and power graphs as shown. When temperature rises, the panel voltage will decrease. In Figure 4(b) case, the irridation is changed for 0.9 kW/m2, 0.95 kW/m2, 1 kW/m2 and 1.2 kW/m2 tests. If irridation increases, current and power are also increase.

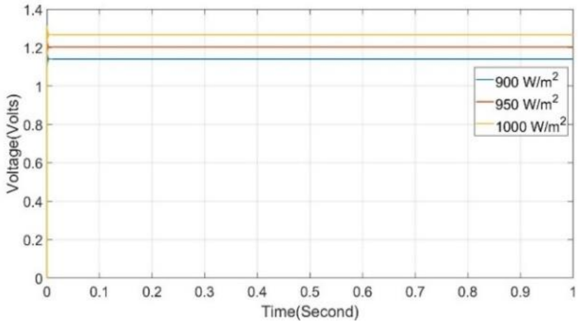



(a)

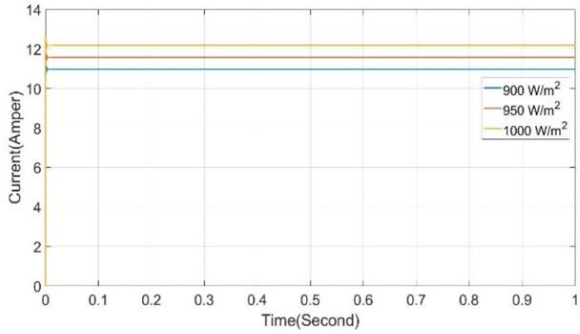



(b)

Figure. 4. PV panel properties of the system under (a) varying temperatures and (b) irridation conditions



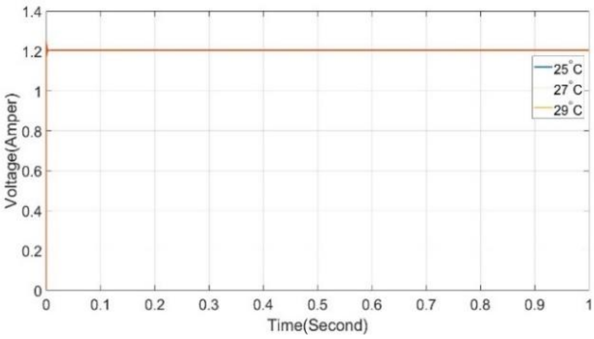

(a)



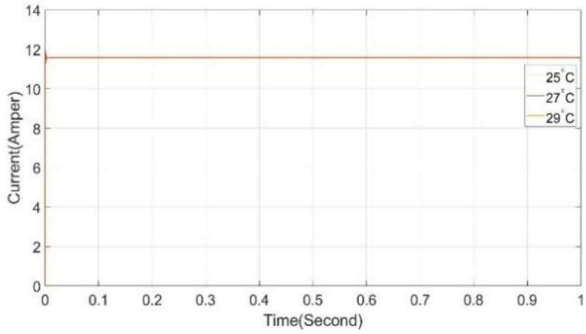

(b)

Figure. 5. Simulation results of PV system for varying irridations at 27℃ temperature (a) voltage graph and (b) current graph

Output voltage and current waveforms are presented in Figure 5(a) and 5(b) respectively. According to the graphics, high level of irridation causes higher current and voltage. This situation can be an advantage for using SMEBR system.




(a)




(b)

Figure. 6. Simulation results of PV system for varying temperatures at 950 W/m$^2$ irridation value (a) voltage graph and (b) current graph

Figures 6(a) and 6(b) show the output voltage and current waveforms, respectively. The graphics show that a high level of temperature results in the nearly same current and voltage.

It is widely recognized that any treatment method powered by renewable energy such as PV panel has significance all over the world where the solar energy is abundant throughout the year.

# 4. Conclusion

In this study, the use of solar energy, which is a renewable energy source, and a hybrid treatment method, SMEBR, were investigated. Instead of the electrical energy used in SMEBR, it is aimed to use solar energy thanks to PV panels. Here, Turkey's most solar region, Antalya, was selected and the electrical energy obtained from PV panels was analysed and modelled with MATLAB Simulink model and an engineering approach was presented. It was concluded that a pair of PV panels connected in parallel would be sufficient for the 11.5 A and 3+3 mins reaction time required to treat the wastewater. Moreover, it was determined that the number of panels increased depending on the amount of volume in the modelling created. In addition, it has been stated that if the system is operated in continuous mode day and night, battery may be needed, but since it has a short reaction time, no battery cost will be required.

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