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Review: Performance Analysis of Bioelectrochemical System for Domestic Wastewater Treatment in Student Center Building Campus E University of Sultan Ageng Tirtayasa

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Abstract

Bioelectrochemical systems (BES) are an umbrella term for a family of technologies that have evolved from traditional electrochemical systems and in which the electrodic processes are related, either directly or indirectly, to the metabolic activity of particular microorganisms. Despite the fact that BES have not yet reached the commercial scale, these technologies show significant promise because they enable for the valorization of various liquid and gas waste streams. The potential of BES in waste management and valorization is investigated in this chapter. To be more precise, it examines the pragmatics of utilizing BES for energy valorization of wastewaters and CO rich streams. Here, BES is demonstrated to be competitive with standard wastewater treatment methods in terms of energy usage by making use of the energy content of certain compounds found in wastewater. Furthermore, it investigates the potential for BES to allow wastewater treatment plants to be used as a load regulation mechanism for electrical grids. Some of the ways in which BES can help the energy-intensive fertilizers business save money include explaining how it can be used to extract fertilizers from trash. The most important examples of scaling up from the field are discussed as a final section.

Keywords: *Performance Analysis, Bio-electrochemical System, Domestic Wastewater Treatment*

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INTRODUCTION

The overall amount of freshwater on Earth greatly exceeds human needs. Approximately 97% of the total water resources on Earth are found in the oceans, while the remaining 3% is available for direct exploitation; nevertheless, it is estimated that only one- tenth of this 3% is usable by people (Oteng-Peprah et al., 2018). The availability of potable water that fulfills quality standards is decreasing at the same time that the demand for such water continues to rise. To achieve water sustainability, limit groundwater extraction, and maximize available water resources, effective water management is essential. Untirta has a liquid waste treatment technology that is used to recycle liquid waste that is stored in the SCU pool, making it possible for the university to take a step toward sustainability. Bioelectrochemistry or Bio-electro systems are used in the water and wastewater treatment technology at the Untirta site.

Wastewater that does not include any traces of toilet water is called greywater. It's considered a high volume, low strength wastewater with great potential for reuse and use. Greywater consists of a wide range of substances, which change depending on factors including the individual's way of life, the plumbing in their home, and the weather (Katukiza et al., 2014). Reusing greywater is an age-old tradition that persists in water-poor regions today. If properly addressed, this practice has the potential to lessen our dependency on freshwater supplies and the pollution brought on by the release of untreated greywater into these supplies. It can also be used to enhance existing water supplies in locations experiencing a severe water shortage or in arid climates. Some examples of non-potable uses of recycled greywater are agricultural irrigation and toilet flushing, although there are many more. Public health views and the lack of suitable equipment have been the primary obstacles to widespread greywater reuse (Oteng-Peprah et al., 2018).

Greywater's chemical make-up reflects the habits of the home's occupants and the products they use in the bathroom, laundry room, and kitchen. The greywater characteristics are also influenced by the water supply quality and the type of distribution network. The composition of greywater will change significantly across time and space, and this may be a result of differences in water consumption and the resulting discharge volume. Chemical and biological degradations of some compounds during transport and storage may potentially alter the composition. Most of the basic ingredients and readily biodegradable organic elements found in greywater come from domestic sources.

The field of bioelectrochemistry has been the subject of extensive study and investigation in the past. Many studies have been conducted on bioelectrochemistry because of its unique ability to treat waste while also producing energy. Under varied process configurations (microbial electrolysis cells) and process circumstances, Bio electrochemical systems can be used as a suitable technology in applications including clean power generation, waste remediation, resource recovery, and value chemical manufacture (microbial electrosynthesis). By integrating plants and photo-synthetic microorganisms like microalgae, BES can harness solar energy for the creation of surplus biomass and electricity (Gude, 2018).

Bio electrochemical systems can be divided into two types of MFCs and enzymatic fuel cells, depending on the bioctalayst used (EFCs). MFCs, MECs, MDCs, and MSCs are all types of BESs that are used for different purposes (MSC). All the facets of MSC have been explained in length. Organic waste, such as weak wastewaters and lignocellulosic biomass, contains chemical energy that can be converted into electricity or hydrogen/chemical products in microbial fuel cells (MFCs) or microbial electrolysis cells (MECs), or other products formed at the cathode by an electrochemical reduction process, making bio electrochemical systems (BESs) one-of-a-kind. Unlike traditional fuel cells, BESs may function in milder environments, are flexible in the organic substrates they can usage, and rarely require the use of costly precious metals as catalysts (Pant et al., 2012).

METHODS

The system design process is carried out by applying research principles that have been studied in the supporting literature and research that has been conducted previously in order to obtain the design criteria that must be met in order to construct a Domestic Liquid Waste Treatment Plant, namely: a) a 50-liter treatment volume. b) Incorporating a semi-continuous processing system. c) Comprises four processing components: the aerobic tank, the clarifier/settlement tank, the filtration tank, and the disinfection tank. d) The materials utilized include glass fiber material and glass, with angle iron serving as the shelf. e) The aerobic process in the aerobic (contact) tank was conducted for three days, followed by filtration and disinfection using the sun's ultraviolet radiation. f) The treatment results do not exceed the threshold value of class III water quality regulations, which limit COD test parameters to 50 mg/l, TSS to 400 mg/l, and total coliform after treatment to 10,000.

Making the system based on the calculations contained in the preliminary research results, which are then adapted to the design of the system to be created (compact) so that the expected outcomes are identical to the preliminary research. Testing is performed once the processing unit is operationally ready. Before processing, it is necessary to conduct a leak test, a resistance test to determine the state of the processing unit (temperature), and a bacterial seeding process. Molasses Making,the goal of this starter is to propagate aerobic bacteria that have been conditioned with existing home wastewater samples, so that current bacteria can instantly adapt to and function well in the reactor for further processing of liquid waste.

Molasses is molasses juice (sugar source). Molasses is used to create a starting for aerobic microorganisms. One can make molasses by dissolving white sugar in clean water in a 1:1 ratio. Bacterial Germination, this investigation begins with the production of aerobic bacteria starter. After collecting 1.8 liters of liquid waste samples, a 5 liter plastic pail is filled with these samples. In order to produce aerobic conditions in wastewater, 100 ml of EM 4 and 100 ml of molasses were added along with an aerator and the bucket was kept open for one week. EM4 (effective microorganism) is a mixture of five classes, ten genera, and eighty species of helpful microorganisms. Composed of aerobic and anaerobic bacteria in the form of a brownish solution with a pH between 3.5 and 4.0. One of EM4's functions is to activate solubilizing bacteria so that they can ferment organic matter into amino acids; consequently, in addition to being readily available and inexpensive, EM4 can be used as a starter for bacteria in the bacterial seeding process.

In home wastewater treatment, which happens in an aerobic environment, seeding is performed once to initiate microbial life. In order for the microbes contained in the seeding results to adapt to the waste to be processed (acclimatization) and ensure that microbial growth will always occur during the administration of liquid waste influent, the seeding process is continued by combining the seeding with the waste sample to be processed in the aerobic tank. continue to do. Samples A1, B1, and C1 were taken from the influent before processing (running the tool) and analyzed for COD, TSS, and total coliforms. Samples E1, F1, and G1 were taken from the effluent after processing and analyzed for COD, TSS, and total coliforms (running). tools) designated as samples A2, B2, and C. Chemical Oxygen Demand (COD) is the amount of oxygen required to decompose all organic materials in water (Boyd, 1990). The value of the COD parameter can be larger than or equal to the BOD value, but the BOD value cannot be greater than the COD value. The COD parameter is the primary parameter for determining the level of household wastewater pollution. Therefore, the parameter that will be checked for COD is not BOD.

RESULTS & DISCUSSION

This residential treatment equipment consists of four major components: a) an aerobic tank; b) a clarifier tank; and c) a sludge tank. b) Filtering Tank d) Tank for disinfection. This treatment device works by introducing waste into an aerobic tank containing a bacterial starter, the volume of waste introduced is 50 liters, then turning on the stirrer motor and leaving it for three days. After that, the waste is pumped into the clarifier tank for four to six hours until sludge deposition occurs at the bottom of the tank. The last tank after the wastewater has passed through the filtration process is the disinfection tank, which is used to degrade any remaining bacteria or microorganisms in the effluent.

This home wastewater treatment instrument was tested three times in a row at Sultan Ageng Tirtayasa University's Student Center Building Campus E Using Domestic Waste. One run's processing time is five days, therefore three runs require a total of fifteen days. The samples that were tested included influent and effluent samples. COD, TSS, and Total coliform were the metrics examined. Influent samples for 3 times running continuously are sequentially coded A1, B1, and C1, whereas effluent samples for 3 times running continuously are sequentially coded A2, B2, and C2. Regarding this waste treatment system, this includes the type of treatment utilizing a semi-continuous system, in which the domestic sewage treatment process is not completely continuous, because control is still required in the flow of effluent to each component, and additionally, the processing that occurs in each tank uses a pour system. (batch) with a specific detention time. The EC's waste water was viewed as feed for the MFC. The MFC's setup and layout mirrored those of the EC. As an alternative to using a bare carbon brush as the anode, this study utilized a biofilm that had adapted to the electrochemical environment of the carbon brush. Bioelectricity was produced by this biofilm throughout its six-month use in PW treatment. Without altering the pH or concentration, the effluent collected from the EC during each voltage fluctuation was stored at 4 C and fed to the anode chamber of the MFC (Mohanakrishna et al., 2021).

Bio-electrochemical processing (BEPS) employs microbial activity to degrade organic compounds. Several elements, such as ambient conditions, optimal nutrition, and the presence of microorganisms, affect the efficiency of this processing procedure. This trash is thought to include organic compounds that can be broken down by the microorganisms used in the treatment procedure. Microorganisms contained in the activated sludge were adapted or acclimatized to the liquid waste to be handled in order to acquire those capable of decomposing these organic compounds. The goal of this procedure is to isolate the most resilient microbes capable of decomposing garbage. Bacteria-type microbes, which are the most common, can form flocs in liquid waste and decompose and use the organic and inorganic components within.

The waste is initially placed in an aerobic tank, where it is mixed with activated sludge and a bacterial starter that has been prepared and aerated for 1 week, during which time the microorganisms undergo a lag (exponential) development phase. When this stage is in effect, it is time to activate the application. Pre-made bacterial starters, consisting of 1.8 liters of collected liquid waste and 3.5 liters of water, are provided as nutrients. To produce aerobic conditions in wastewater, 100 ml of EM 4 and 100 ml of molasses were added, the aerator was turned on, and the bucket was kept open for 1 week (Mulyana et al., 2013). For a time before a larger floc may be formed and deposited, the aerobic tank will have a brownish to blackish brown color, indicative of the aeration process of biologically degradable waste that forms activated sludge. As an aerobic process, activation of sludge requires a minimum oxygen concentration of 0.5 mg/l. Traditional activated sludge systems have oxygen as a limiting element. Waste often contains a negligible amount of dissolved oxygen, so it is necessary to provide supplemental oxygen to ensure that microbes have enough to live on.

The nature of bioelectrochemical systems

A BES is an electrochemical system in which the anodic or cathodic electrode reaction is biologically mediated (Rabaey et al., 2007). Like conventional electrochemical systems, their primary distinguishing feature is that they are operationally reversible; that is, they may be operated either as galvanic cells (where the redox reactions occur spontaneously) or as electrolytic cells (the redox reactions are non-spontaneous and require a certain amount of electrical energy to proceed). Early versions of BES used galvanic mode labels like "microbial fuel cells" (MFC), whereas electrolytic mode labels like "microbial electrolysis cells" were more common (MEC). This language has been somewhat superseded due to the proliferation of BES typologies and architectures over the past decade (Wang & Ren, 2013), but it is still helpful because it mirrors the two fundamental modes of operation in electrochemical systems. The basic workings of BES systems are depicted in Figure 1.

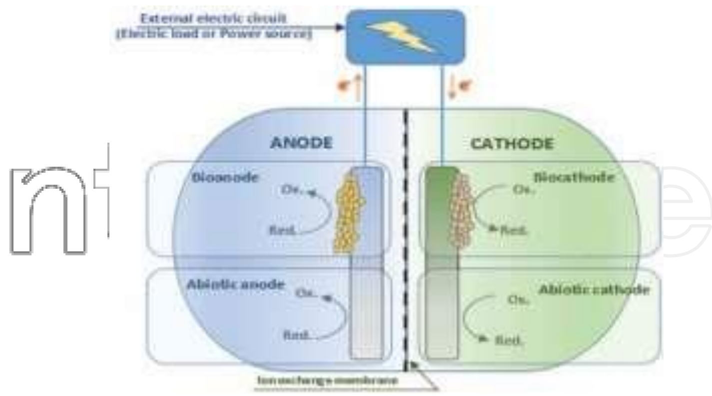

Figure 2. Flowchart showing how a BES works in theory

Valorization of wastewater through BES

Some of the earliest research on MFC and MEC technologies focused on optimizing the operating factors (pH, temperature, etc.) that affect their performance and developing new reactor configurations and tactics to maximize their figures of merit. In order to maintain control over substrate composition, most of these studies were conducted with synthetic media as electro- lytes. The practical potential of MEC and MFC was then learned by follow-up laboratory testing using actual wastewaters. To what extent does the presence of a genuine substrate affect the performance of a reactor? That's what these investigations helped to quantify. For instance, compared to the hundreds (Liu et al., 2005), and even thousands of mWm2 (milliwats per square meter of electrode) achievable with synthetic eluents (Cheng & Logan, 2007). MFC fed with actual wastewater produced power densities (normalized to the surface are of the electrodes) in the range of several tens mWm2 (Rodrigo et al., 2007). Power generation in MFC has not significantly improved despite recent advancements in electrode materials and reactor configurations (Hindatu et al., 2017). Problems with conductivity and buffer capacity are commonly stated as the primary causes of the reported poor results (Rozendal et al., 2008). Without a doubt, MEC has to deal with the same difficulties, but the economic feasibility standards appear to be less strict (Sleutels, Tom H J A dkk). It has been calculated that 80 mm2 of total internal resistance is required for MEC technology to be cost effective, whereas for MFC, this aim becomes considerably more stringent (40 mm2). The additional difficulty of scaling up stems from the fact that a microbial MFC has a fundamentally different design from that of a MEC. When working with an MFC on a small scale, such as a pilot plant, allowing air to reach the cathode might cause a number of complications. The cathode of a MEC is anaerobic, which simplifies the design of a larger system and bodes well for MEC**.**

BES for treatment of wastewater and chemical energy storage

Because of its pervasiveness and the huge annual volumes produced around the world (Sato et al., 2013). For MECs, urban wastewater is one of the simplest waste streams to manage. Although hydrogen recovery was modest (10% of the theoretical maximum), the irst MEC to operate on urban waste water (batch with retention durations between 30 and 108 h) showed great promise in terms of removal of organic pollution (nearly 100% removal eiciency) (Ditzig et al., 2007). An updated study found that hydrogen may be produced at a rate of 0.3 LH2 L1 Rd1 (liter of hydrogen per liter of reactor per day) in a 100 mL (total volume) continuously operating MEC (hydraulic retention durations between 3 and 24 h) (Escapa et al., 2012). Typical energy consumption igures for conventional wastewater processes are around 1.5 WhgCOD1. However, the MEC's hydrogen generation dropped significantly (0.01 LH2 L1 Rd1) and energy consumption skyrocketed when scaled up to a greater volume (3.3 L). Energy recoveries of up to 121% with respect to electrical input have been reported in a more recent investigation conducted at a larger scale (130 L) (Baeza et al., 2017). In spite of the fact that MECs currently face significant obstacles (Escapa, Adrián dkk), the data presented here demonstrates the technology's promise for tapping into the largely unrealized energy potential of WW. (Heidrich et al., 2011). This becomes more evident when we consider that traditional waste-water treatment plants not only tap into this potential, but also necessitate substantial amounts of energy.

In Spain, for instance, the treatment of wastewater uses up about one percent of the country's overall energy supply. With BES, wastewater treatment plants might serve dual purposes as electrical regulation systems, removing excess energy from the grid and storing it as hydrogen or methane. Thus, redox low bateries (RFB), which might become a crucial partner in MEC implantation, could present fresh opportunities to improve MEC's energy management capacities. There is a unique property of RFB electrochemical energy storage systems. As a result, the reducing power achieved in MEC reactors handling waste streams could be conveniently stored in an electrolyte solution for later use in electricity production or another electrochemical process. New methods, such all-organic RFB, could open a larger ield compared to the traditional ones used in well-known RFB like vanadium systems, which have significant environmental drawbacks for their use in enormous energy storage applications. Here, the leading candidates are compounds based on quinones, which have been investigated before in BES because they may serve as intermediaries in electron transport pathways. In addition to municipal wastewater treatment plants, MECs have a lot of potential in industrial settings. If there is a higher concentration of organic matter in the WW, then the MEC will produce more hydrogen while using less energy. Because of the high quantity of organics it often contains, industrial wastewater is a good candidate for MEC's waste eluent. For instance, Lue et al. accomplished a remarkable 2 LH2L1 Rd1 hydrogen generation rate with an electrical energy eiciency of 287% by feeding the eluent from an ethanol-producing reactor into a MEC. However, there may be significant drawbacks to using industrial eluents in MEC. However, their makeup isn't always optimal, and they may need to be supplemented with nutrients, which isn't always a viable option from a financial or ecological standpoint. However, wastewater in MEC can present a significant issue when dealing with high organic contraction because it can promote the growth of bacteria that inhibit the electrogenic bacteria's efficiency.

CONCLUSION

Bioelectrochemical systems (BES) refer to a collection of cutting-edge technologies that have the ability to convert numerous types of waste into usable energy. One of the most obvious places for BES to be put to use is in the field of wastewater treatment, where it might help to increase the process' energy efficiency by transforming the organic matter in the water into electricity or fuel gas. Indeed, these goals inform the design of the vast majority of existing pilot scale experiences. Additionally, BES enable for the recovery of valuable compounds and nutrients like ammonium and phosphorus, which may open up new avenues for wastewater valorization due to their operational adaptability. One further source of materials that BES can use is rich waste streams. This has the potential to provide a low-cost, environmentally-friendly approach to reducing atmospheric CO2 levels.

In a nutshell, BES refers to a suite of technologies that can be used to extract value from a wide variety of liquid to gaseous waste streams. Powering a BES takes a substantial amount of electricity, which is often turned into chemical energy (methane, hydrogen, etc.) and stored until it is needed again (fuel cells, cogeneration, etc.). This capability would open up new market potential for BES by allowing it to function as an electrical regulating system.

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