The Potential Benefits of Microbial Fuel Cells in the Context of the Sustainable Development Goals

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Abstract The microbial fuel cell is a versatile technology that belongs to the broad category of technology referred to as microbial electrochemical systems. It has the potential to treat wastewater and produce electricity. In some instances, it has been used for hydrogen gas production, nitrate removal, algae cultivation, and heavy metal reduction. The bioelectricity potential of the technology is promising and has been explored in biosensors and related devices. The diverse applications of the MFC technology makes it a commendable technology for sustainable development. Thus, it's potential to support the achievement of some sustainable development goals has been discussed in this chapter. These goals are goal 2 (Sustainable agriculture), goal

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3 (Healthy lives and wellbeing for all), goal 6 (Access to water and sanitation for all), goal 7 (Access to affordable, reliable, sustainable, and modern energy for all), goal 9 (Resilient infrastructure, sustainable industrialization, and foster innovation), goal 12 (Sustainable production and consumption), goal 13 (Combat climate change), goal 14 (Protect life under water), and goal 15 (Protect life on land). Given the outlined potential that this technology has for our sustainable development, it is recommended that considerable funding is provided for extensive research on how to improve the efficiency of the technology for commercialization.

1 Introduction

Sustainable development is that type of development that seeks to satisfy the needs of both present and future generation without compromising on environmental quality [62]. To achieve this ambitious agenda, goals must be set and all nations must work towards the achievement of the set goals. In respect of this, members of the United Nations have agreed upon 17 goals and various measures are being put in place towards the realization of these goals. These include policy revision, technological changes/improvements, behavioral changes, and political and intergovernmental actions. Among promising technologies that can contribute to the achievement of most of the sustainable development goals (SDGs) is the microbial fuel cell (MFC). Out of the 17 SDGs, MFCs have the potential to contribute directly to the achievement of 9 of the goals (Fig. 1). MFC is a technology that converts chemical energy in wastewater into electricity [65]. It has several applications as discussed in the

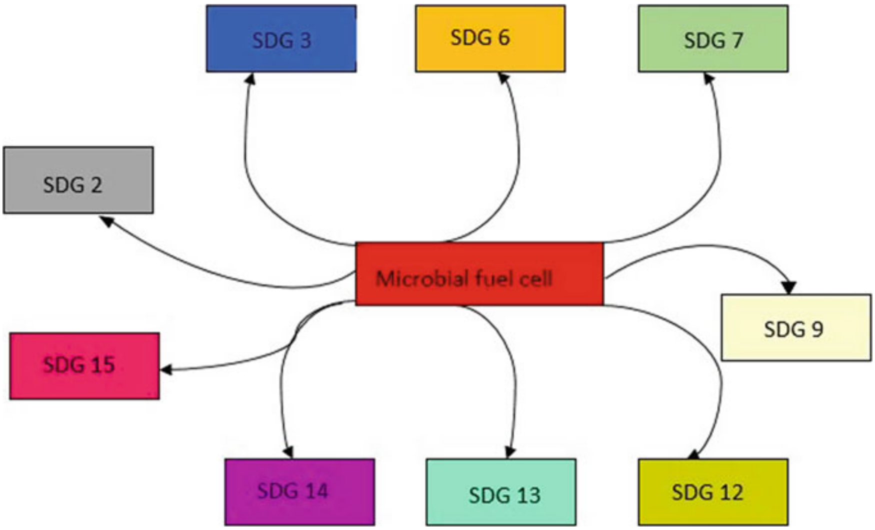

Fig. 1 SDGs that MFCs have the potentials to contribute to their realisation

sections below. Though a very versatile technology, it is yet to reach commercial use because of some operational challenges detailed in [20]. This chapter presents the potential benefits the MFC technology can offer to the world when commercialized.

2 Microbial Fuel Cell for Sustainable Agriculture (SDG 2)

2.1 Treatment of Wastewater with MFC for Irrigation

Water is essential for the proper growth and development of living organisms. Wastewater usually has low oxygen content and transports various microbial pathogens to crops and animals. MFCs treat wastewater [5] to acceptable levels. In some cases, by combining the potential of some algae to utilize carbon dioxide and produce oxygen [13], MFCs have been used for algae production. *Chlamydomonas reinhardtii* and *Chlorella* sp. have been assessed for their abilities to support electricity production and have been employed fairly in wastewater treatment [13]. The electrical energy, so generated from MFCs, can be used to power some farm implements (i.e., water pumps) for the improvement of agriculture output in places with poor electricity supply [52]. Excessive boron in irrigation water could deteriorate plant health [42]. An anion-exchange membrane MFC was able to remove 40–50% of boron during pre-treatment of water and removed 80–90% of boron during the post-treatment process [42]. The effluent produced met the requirement of water used in irrigation [42], thereby, underlining the potential of MFC technology for the treatment of contaminated water for reuse [67]. The MFC technology's potential for the estimation of hunger, the achievement of food security, and improving nutrition and sustainable agriculture should be considered and exploited to support the realization of the generality of human wellbeing.

2.2 Safeguarding Food Security Using MFC

Biofuel has been proposed as an alternative to fossil fuels [29] in terms of its ability to produce environmentally friendly residues [8]. The dependence on first-generation biofuels, which rely on crop plants as feedstock, has raised food security concerns. MFC technologies that rely on agricultural waste, algae-based technology, among others can be used to generate electricity and fertilizer for farming [9, 44]. These technologies will rely on second- and third-generation biofuel energy sources to generate energy thereby reducing the potential burden that such energy generation schemes (biofuels) may place on food production, availability, and access.

Reliance on waste from food crops such as soy, rice, maize, and sugarcane, among others as primary substrates for microbial electrogens will reduce the need to spend massively on cultivating such crops for energy purposes [46]. This approach could help mitigate food insecurity [46]. Sustainable agriculture promises to be a backbone of bioenergy generation by providing raw material (organic waste) for bioelectrochemical systems [11]. The organic matter produced as residues from MFCs could also be used to improve (fertilize) crop yield, thereby improving food security [46].

2.3 Management of Agricultural Waste Using MFC

Produce from agriculture is used to feed humans and animals worldwide generating large quantities of waste in the process. Agricultural waste, food waste, and hazardous waste are major solid wastes obtained as unavoidable by-products of agricultural activities globally [56]. Agricultural waste, most of which is organic in nature, is projected to increase due to the increasing use of intensive farming methods [6]. Bioenergy technologies such as MFCs could help manage these large volumes of residues and also produce electricity in the process [6]. Microorganisms well adapted for harsh conditions often present in composts have been studied and their electrigenicity (ability to generate electricity) fairly assessed. These organisms are employed in the digestion of various kinds of organic matter realized as residues from the activities of agriculture. Archaebacteria, such as *Haloferax volcanii* and *Natrialba magadii*; Acidobacteria, such as *Geothrix fermentans* and *Arcobacter* sp.; Cyanobacteria, such as *Synechococcus elongates* and *Nostoc* sp.; Firmicutes, such as *Clostridium butyricum* and *Thermincola* sp.; Proteobacteria, such as *Rhodospirillum rubrum* and *E. coli;* Yeast, such as *Saccharomyces cerevisiae* and *Arxula adeninivorans;* and Algae, such as *Chlamydomonas reinhardtii* and *Chlorella* sp., have been employed as useful electricigens in various MFCs [13] for the breakdown of organic matter. The breakdown of organic wastes in MFCs often results in the conversion of the waste materials into environmentally friendly safer forms.

3 Health and Wellbeing Promotion (SDG 3)

The insanitary management of wastewater creates enabling environments for the spread of diseases including malaria. Stagnant water in particular promotes the growth of Anopheles mosquitoes that are responsible for malaria. Also, when fecal sludge is not treated before discharge, several bacterial, fungi, protozoan, and viral diseases can be spread leading to an incapacitated population and by extension, economy. MFCs have proved to be capable of treating high-strength wastewater [5] thus can reduce the incidences of pollution often resulting from poor handling of industrial wastewater.

Also, poor wastewater handling reduces the esthetic quality of the environment aside the fact that the environment is polluted and ecosystems are disturbed. A clean environment promotes wellbeing. Sereneness promotes emotional balance and inner peace [21] and these are important factors for an individual's wellbeing. Also, the presence of a clean environment and clean air for breathing reduces the chances of one falling ill. Clean environments are known to help convalescence recover quickly from ill-health [55]. Moreover, MFCs can help reduce pollution resulting from the use of fossil fuels. The release of CO_X, $NO_{X,}$ and SO_X from fossil fuel use can lead to disease conditions associated with cardiovascular disorders. Unfortunately, these gases can be transported further away from polluting sources and cause harm to all forms of biota. MFCs provide renewable energy with no external carbon emission [20]. It is therefore beneficial for use in the construction of safe and sustainable infrastructures (planned settlements, hospitals, recreation centers) that are necessary for our wellbeing.

4 Water and Sanitation for All (SDG 6)

Conventional water treatment facilities are high-energy consumers. In the USA, for example, they account for an approximated 116.07–145.08 out of the 2,901.67 USD/MWh costs of electricity production using a 10% discount on "levelised" cost of electricity generation [28]. This high-energy consumption of conventional water treatment plants increases their carbon footprints and also, may limit their profit margins. Suitable alternative energy sources are thus needed to reduce the reliance on fossil fuel-based ones. The MFC technology is one promising choice, especially because it supports cyclic economy by converting waste into energy and other resources (ie, manure). MFCs may be used as a standalone source or supplementary energy source for conventional wastewater treatment plants. Some researchers have recorded high COD and BOD reductions (see subsequent sections) that make this technology a candidate for wastewater reuse and thus can promote environmental sanitation. Across the world, large volumes of domestic wastewater are generated and discharged, sometimes without any form of treatment. For instance, in Ghana, less than 8% of domestic wastewater generated are treated [64]. Meanwhile, treated domestic wastewater can at least be used for irrigation purposes or discharged into wetlands to support the biodiversity of wetlands.

Also, groundwater resources are abundant in many parts of the world and are relatively safer to use compared to surface waters. They usually require no treatment at all, especially in less industrial and agricultural environments. However, because of the need for energy to pump groundwater for use, their availability in remote areas in the developing world is limited. MFCs have the potential to overcome the "energy-need barrier" of electric powered boreholes. It is relatively easier to assemble and detach. Fully functional MFCs can serve as sustainable batteries for electric powered boreholes in remote areas not connected to national grids. With reduced energy cost, the availability of clean water for the observation of good sanitary practices (cleaning and maintenance) will most likely increase and thus reduce the incidences of disease outbreaks related to poor sanitation. MFCs can also be used to treat fecal sludge and therefore contribute to the safe management of human waste.

5 Affordable, Reliable, Sustainable, Modern Energy for All (SDG 7)

The energy produced from MFCs is from the chemical energy stored in the organic fraction of solid waste and wastewater. Thus, the energy from MFCs can comparably be more affordable than fossil and thermal-based sources. The initial cost of constructing MFCs can be high but considering the fact that the source of energy is from waste, it has a long-term benefit including the improvement of environmental quality. Biohydrogen can also be produced from MFCs [20]. Hydrogen is a cleaner source of energy (no carbon emissions) that can be made more affordable with the use of MFCs. Since MFCs are comparably easier to assemble, they can be set up in remote areas for biohydrogen production to support electricity generation and thus reducing the need for connection to national grids. The high cost of extending electricity from the national grid to remote areas is one of the main reasons why a number of remote communities live without electricity in the developing world. When cheaper, simple, and more efficient electrode materials, membranes, and catholytes are developed, MFCs will have the additional advantage of being easy to operate and maintain and thus be a more sustainable source of energy. So far as humans exist, organic waste will be produced. This presents some assurance of the continuous availability of sources of raw materials for the running of MFCs for affordable energy. Also, MFCs with microalgae as terminal electron (O_2) producers in the cathode chamber have the additional benefits of producing algal biomass, which can be used for biodiesel production [30]. Biodiesel can be used as an alternative to natural gas and diesel for the running of engines.

6 Resilient Infrastructure, Sustainable Industrialization, and Innovation (SDG 9)

MFCs have several applications including use for nutrient recovery [65], heavy metal reduction [59], biohygrogen production [33], and as biosensors [14]. It is a technology that allows for innovation in many aspects of science and technology. It occupies a relatively small space, thus is appropriate in this era and for the future as land space is continuously becoming a limited resource. Wastewater treatment plants such as stabilization ponds occupy large areas of land but traditionally perform one function (wastewater treatment). Meanwhile, MFCs per their designs will occupy relatively small areas of land and besides wastewater treatment, produce electricity, and several other products including biohydrogen and algal biomass. Currently, industrial development is on the trajectory of efficiency and low carbon footprints. Industries that are interested in clean and affordable energy will find MFCs as ideal alternatives or supplementary energy sources to promote the eco-friendliness of their business through cuts in carbon emissions.

7 Usefulness of MFCs for Achieving SDGs 12, 13, 14, and 15

This section discusses three SDGs together because of the cross-cutting nature of the usefulness of the MFC technology to these goals.

7.1 MFC as Biosensors to Monitor Pollution

Generally, a sensor is a device that measures physical variables such as temperature, pressure, mass, light, humidity, and strain. It then converts the measured variable into an accessible signal, usually an electric signal, by a transducer. The electric signal generated is transferred to a microprocessor that translates it into a meaningful reading to be displayed [68]. Sensors require power for their functionality. Many sensors have a battery as their main power source. Power is needed for data processing and communication. Sensors use a communication system as they can be in a remote area or at a non-accessible location of the equipment. Data transmission can be costly in terms of energy consumption, the energy required depends on the specific sensor category. Gas sensors require a higher amount of energy compared to image, temperature, and pressure sensors [45].

Battery-powered sensors come with their limitations as the batteries have to be replaced or recharged. Self-powered sensors can help overcome this challenge as they can harvest the needed power for sensing, computing, storage, and communication. The power needed can be harvested from the signal being sensed or from other energy sources like solar energy and ambient vibrations. This provides a reliable and sustainable means of monitoring and assessment [47]. An MFC-based biosensor is a self-powered device that can run for a long period. The device is user-friendly, cost-friendly, easy to install, and reusable [40]. MFC-based biosensors can be used for various applications like water quality monitoring (such as biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), microbial activity, and heavy metals monitoring in wastewater and monitoring of air quality. These are all parameters that are useful in assessing how far SDGs 12, 13, 14, and 15 have been achieved. The operational mechanism of an MFC-based biosensor is such that it measures the analyte of interest and gives a corresponding response to its output electrical current, without the need for a transducer. The sensing step is integrated with the electrical signal transition step. This gives it a fast response time [53]. With this technology, proper environmental monitoring can be done for example concerning industrial water effluents. This will ensure effluents released into the environment are meeting the required standards and are not affecting life under water directly or indirectly (SDG 14). With MFC-based biosensors being self-powered, monitoring can be done in remote areas (e.g., Benthic regions) and for long periods. This can help check and ensure responsible behavioral practices from producers and end-users (SDG 12). Sediment microbial fuel cell (SMFC) is a proven application of MFC-based biosensor. Under appropriate working conditions, SMFCs generate electrical energy by oxidizing organic matter [34]. This technology has been used in the aquatic environment for the monitoring of temperature [70], dissolved oxygen concentrations [51], and water quality including pH, electrical conductivity, Cl^-, K^+, NO_3^-, and SO_4^{2-} [57] in remote areas. With SMFC, monitoring of seawater/ocean floor can be done (SDG 14).

7.2 MFC for Bioremediation

The application of MFCs for the remediation of various organic and inorganic environmental pollutants is an area of interest as it can help many manufacturing and processing industries manage waste generated from their processes [35] (SDG 12). Studies show that MFCs can be used for the effective degradation of antibiotics (e.g., chloramphenicol, sulphamethoxazole, acetaminophen), phenolic compounds (e.g., 2,4-dichlorophenol, p-nitrophenol, 4-chlorophenol), synthetic dye (e.g., azo dye, methyl orange, monoazo dye, congo red), nitrogen-based compounds (e.g., pyridine, ammonium), organic solvents (e.g., ethyl acetate, toluene), polycyclic aromatic hydrocarbons, pesticide, perchlorate, sulfur, emerging contaminants (e.g., bisphenol A, estrone, sulfamethazine, triclocarban), and trace organic compounds (e.g., atenolol, trimethoprim, naproxen, ibuprofen, caffeine, dilantin, norfluoxetine, diclofenac, cimetidine) [35]. With the wide application of this technology, responsible and environmentally friendly management of waste by industries including food processing, textile, pharmaceutical, plastic, petrochemical, refinery, printing, leather, detergent manufacturing, and mining industries can be achieved. The production and use of fossil fuels come with a lot of environmental threats that need to be addressed. One of such threats that cannot be overlooked is oil spillage. MFC technology can be utilized for the biodegradation of hydrocarbons (Oils spills). It has been used in the biodegradation of hydrocarbon-contaminated sediments [39], phenanthrene, and benzene in aqueous systems [4] (SDG 14) and petroleum hydrocarbons in saline soils [32]. As such, MFCs can be explored as a technology for oil spill cleanup either in combination with other methods or independently. This offers effective cleanup while reducing the risk of secondary pollution. Also, an added benefit of using MFC for oil spill cleanup can be the use of power generated from MFC for powering power-consuming cleanup activities.

8 MFC for the Production of Renewable Energy

8.1 Power Generation from Wastewater Using MFC

Currently, fossil fuels are a major source of energy [41]. With fossil fuels being non-renewable, the world is burdened with possible exhaustion of this resource and environmental pollution challenges that come with the use of fossil fuels. The combustion of fossil fuels to generate electricity contributes to about 40% of global CO_2 emissions, which is a major contributing factor to global warming [2]. The effects of global warming go beyond an increase in average temperature. Plants' and animals' extinction, rise in global sea levels and ocean acidification, and attack on food and water security among others are all threats facing our world. Climate change today is a pressing challenge and a collective effort is thus required to help reduce emissions of CO_2 and other greenhouse gases from human activities. To ensure a responsible development, there is a need for us to move towards sustainable ways of producing energy. Already, renewable energy sources such as wind energy, solar energy, geothermal power, and biomass energy are currently being explored and are fast-growing [19]. According to the International Energy Agency (IEA) [27], 29% of electricity generated globally was from renewables. Similarly, the microbial fuel cell technology is an alternative technology for energy production as it can convert the chemical energy of organic compounds into electrical energy, while reducing carbon footprint and environmental pollution (SDG 13). The power generation process of MFC is clean, reliable, and efficient as it utilizes renewable methods and does not generate any toxic by-products [15]. The MFC technology can be applied to a wide range of waste sources, including solid waste and wastewater, from domestic and various manufacturing and processing industries such as agriculture, food processing, oil, and mining. With waste sources being readily available, power can be generated all year-round and at a relatively low cost (SDG 12). Considering the benefits of MFC as a power generation alternative, there is the need to explore this technology and commercialize it [15].

8.2 Power Generation from Methane Using MFC

Over the years, several technologies have been used to produce electricity from methane [22]. Fortunately, methane can be available in large quantities and there is the need to explore ways of capturing, storing, and safer ways of generating power from it. This will provide sustainable means of generating power, while mitigating the environmental threat methane poses. Globally, methane emissions from natural sources and human activities are estimated to be in hundreds of million tonnes [26]. Agriculture is considered the main source of methane emissions followed by the energy sector. Other sources include stationary and mobile waste combustion. Methane is a more potent greenhouse gas compared to CO_2 and also affects air quality making it a dangerous air pollutant [26]. The main difficulty with the biological conversion of methane to electricity has been finding suitable microbes for effective anaerobic CH_4 oxidation. Though biological conversion of methane to power with MFC technology has its challenges, conventional technologies such as gas-turbine generators and conversion of methane to liquid fuel are capital intensive [31]. Previous studies have shown that a sustainable and considerable amount of electricity can be generated in MFCs using specific microbes and a combination of selected microbes [31]. The use of external electron carriers and increasing acid concentrations proved to increase current generation and power density. Moreover, MFC technology offers flexibility in operations and provides the ability to integrate with other processes. A two-staged system, where methane is initially converted to liquid fuel, like methanol, and then followed by electricity generation, using methanol as substrate in an MFC has proven to generate maximum power density [31]. MFC has a promising future concerning energy production from methane (SDG 13). Also, with methane being available in large quantities all year-round, it can serve as a sustainable source of energy that supports the MFC technology to perform better. This will help meet the growing global energy demands with a more responsible approach.

8.3 MFC for Biohydrogen Production

Biohydrogen can be produced from microbial electrolysis cells coupled with MFC (MEC–MFC). This technology offers a sustainable and clean way of producing hydrogen. Currently, the majority of global industrial hydrogen production is based on fossil fuels like oil, natural gas, and coal [10]. MEC–MFC accomplishes the production of biohydrogen by combining electrolysis and MFC technology for the conversion of organic materials from biodegradable wastes to high-purity hydrogen [54]. Electrolysis is performed in the MEC, whereas electricity for the electrolysis is supplied by the MFC. Conventional methods for hydrogen production that employ the use of electrolysis have relatively high electricity demand [54]. However, with improved technology in MEC–MFC-coupled systems, hydrogen can be extracted from substrates without extra electricity supply [54] (SDG 12). Hydrogen is extensively used by many industries for a variety of applications. It is mainly used in petroleum refinery processes such as for desulfurization and cracking of oil [22]. Hydrogen is used as a raw material or for the synthesis of chemicals such as methanol, dimethyl ether, cyclohexane, and ammonia [10]. Other industrial uses include astronautics, aeronautics, metallurgy, plastics, steel, electronics and semiconductors, food, and edible oil processing. As the world seeks to move towards clean and renewable energy resources, the use of hydrogen as an energy carrier in fuel cells for generating electricity and as an alternative fuel for vehicles is being heavily explored [10] (SDG 12). Compared to fossil-based fuels, hydrogen has higher mass energy [60]. Moreover, it does not contain any traces of carbon making it environmentally friendly [1]. This would help solve the problem of greenhouse gase emissions from vehicles (SDG

13). The Intergovernmental Panel on Climate Change (IPCC) [25] report on mitigation of climate change estimated that 23% of total energy-related CO_2 emissions were produced from the transport sector. Studies carried out to explore the feasibility of hydrogen as a potential replacement for fossil fuels showed that hydrogen fuel offers economic savings compared to conventional fuels [50]. Fuel cells convert chemical energy from fuels into electrical energy through electrochemical reactions [38]. Thus, a hydrogen-powered fuel cell will serve as a sustainable technology for powering vehicles. This will help the world's agenda of phasing out fossil-fuel cars to mitigate global warming and climate change (SDG 13).

8.4 MFC for Water Recycling

Water is a major resource for most human activities [43]. These include the use of water for domestic, agricultural, commercial, and industrial purposes. The overall demand for water keeps increasing, contributing to an increased generation of wastewater. Therefore, there is a need to explore new technologies for the treatment and reuse of wastewater. These technologies should not just aim at treating wastewater for its safe disposal into the environment but also maximizing the recovery of resources from the treatment process. Wastewater is a source of contaminants, such as nutrients, hydrocarbons, heavy metals, endocrine disruptors, microbes, and organic matter, which can have adverse effects on humans and the environment. It can also serve as a breeding ground for disease-causing pathogenic microorganisms such as bacteria, fungi, protozoa, and viruses [7]. Available methods for the treatment of wastewater involve physical, biological, chemical, and mechanical processes such as filtration, precipitation, sedimentation, coagulation/flocculation, oxidation, biodegradation, adsorption, and ion exchange. These processes are costly as they consume a lot of energy and chemicals. The treatment process also generates excess sludge that needs to be disposed of after the treatment. Therefore, there is the need to move towards cheaper and more effective treatment methods [17].

The application of MFCs for treating wastewater offers a more sustainable treatment option and utilization of wastewater as compared to traditional wastewater treatment systems that focus on meeting discharge standards and stabilization of sludge. It has been reported that wastewater has an energy content of 3–10 times higher than the energy required to treat it [23]. With MFC technology, intrinsic energy locked in wastewater in the form of chemicals (such as organic matter and nutritional elements such as nitrogen and phosphorus) and thermal energy can be harvested [23]. Other processes involved in the treatment process that requires electricity can be powered by internally generated energy using this technology. This makes the treatment process energy self-sufficient [23]. Agriculture alone contributes to about 70% of the total freshwater use in the world [3]. Exploring alternative sources of water for the agriculture sector is important as it will reduce the demand for freshwater. Burek et al. [12] projected an annual demand of up to 5,500–6,000 km^3, which translates into about a 20–30% increment above the current water demand level, by the year 2050, due to rising demands in the industrial and domestic sectors. With wastewater treatment systems providing an alternate source for irrigation water, the stress levels on the demand for freshwater could be reduced. Growth in the agriculture sector would not only ensure food security but would also help mitigate poverty globally. As the production of wastewater is continuous, reclaimed water provides a reliable water source [16]. Using reclaimed water from wastewater treatment for irrigation can help alleviate water scarcity and promote food security. Besides proving an alternative water source for irrigation, reclaimed water can serve as sources of nitrogen and phosphorus needed by plants [16]. Also, it can be a source of plant micronutrients such as iron, manganese, zinc, copper, boron, nickel, and molybdenum. This will help reduce fertilizer needs in crop production [16].

8.5 Energy Production to Reduce Deforestation (SDG 15)

About 2 billion individuals rely on forest goods like natural products, game meat, fibres, and fuelwood to meet basic needs [36]. Fuelwood is a major source of energy for most rural populations across the world. Fuelwood harvesting in developing nations is so significant to the point that it rivals other sources of modern energy like electricity but this is mainly among needy individuals in rustic regions [37].

The utilization of fuelwood, in general, has been identified with deforestation, land debasement, loss of biodiversity, and environmental change [49]. Firewood represents more than 54% of all worldwide gathers per annum which brings about a huge volumes of forest loss [63]. Wood fuels are made of firewood, charcoal, black liquor, and wood waste [18]. It is mostly collected from the forest, often as branches or twigs. The forest constitutes the world's largest and most important terrestrial environment and has the biggest supply of plants and other creatures on land [37]. The demand for sustainable energy is urgent because of the depletion of forest resources, increasing energy consumption, and environmental pollution due to the burning of wood to produce charcoal [48]. Deforestation is the second most significant ozone emissions activity in the world [58]. With the emergence of the MFC technology to produce energy, we can move away from the use of wood fuel and charcoal, which destroy biodiversity.

9 Conclusion

In this chapter, we have discussed the potential benefits of the microbial fuel cell technology to sustainable development through the technology's relevance for the achievement of nine (9) SDGs. The key benefits of the MFC technology identified were wastewater treatment and reuse, energy production, resource recovery, and the prevention of environmental pollution. The MFC technology however requires further research to bring it up to the level of commercialization.

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