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Research paper

Role of Phosphorous Solubilizing Microbes and their Interaction with Microbial Fuel Cell for the Reduction of Phosphorous in Eutrophic Aquatic Ecosystem

R. Caroline Jeba [a] *, **M. Aakash Reddy** [a]

[a] *Department of Biotechnology, Dr. M.G.R Educational and Research Institute, Maduravoyal, Chennai, India*

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ABSTRACT

Phosphorous (P) is one of the major cause for the eutrophication process in all the water bodies. It can be derived from agricultural runoff or from domestic and industrial wastes. The phosphorous concentration content reduction in the sediment and the water was attempted with the help of microbial fuel cell. A comprehensive study was done with the phosphate rich water along with a control. The study involved a 30-day treatment of oxidation catalysis of organic matter by bacteria called Microbial Fuel Cell (MFC) technology that has been conducted to reduce the contamination of phosphorous in the water. The initial parameter measurements of the phosphorous concentration content were found to be reduced by the end of the study when compared with the control. Electricity was also produced as a byproduct as the result of the microbial activity. However, the reduction in the phosphorous concentration content was accomplished with the help of Phosphate Solubilising Microbes such as *Actinomyces*, *Streptomyces. B. mycoides*, *B. polymyxa*, *B. coagulans*, *Anabena* sp., *Calothrix braunii*, *Nostoc* sp., *Scytonema* sp., etc. These microorganisms are extracted from the sludge present their natural aquatic environments such as ponds and lakes. Such microbes are allowed to grow in the anode of the MFC which breakdown both the organic and inorganic phosphates present in the water bodies. These phosphate solubilizing microorganisms with the help of Microbial Fuel Cell (MFC) could be a promising approach for reducing the phosphate concentration in the eutrophic water bodies.

1. Introduction

Phosphorus (P) concentrations in soil and freshwater systems have increased by at least 75 % during the last decades, and the estimated flow of P from the total land area to the ocean has risen to 22 million tons per year [1]. This amount exceeds the world's annual consumption of P fertilizer, estimated around 15 million tons [1,2]. While much of the P accumulated in terrestrial systems would eventually be available for plant growth, there is no practical way to recover P lost to aquatic systems. In aquatic systems too much Pond nitrogen result in eutrophication, which promotes excessive algal and aquatic plant growth along with undesirable impacts on biodiversity (the destruction of communities and elimination of the less competitive), water quality (production of cyanotoxins), fish stocks and the recreational value of the environment. Algal

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*Corresponding author: R. Caroline Jeba
Email: janeshjeba@gmail.com

bloomscan include species that release toxins harmful to humans or animals, while decomposition of algae can lower dissolved oxygen levels, causing mass mortality among fish [3].

Eutrophication of surface waters bodies results mainly from anthropogenic activities occurring in watersheds—extensive fertilization and domestic or industrial sewage discharges without removal of nutrients (especially P)—and is one of the most significant and unresolved problems with respect to water resource protection [3,4,5]. Many of the world largest freshwater lakes are eutrophic, including Lake Erie (United States), Lake Victoria (Tanzania/ Uganda/Kenya), and Tai Lake (China) [4].Moreover, all 217 lakes included in the International Lake Environment Committee survey showed an increase in the level of eutrophication over the past 50 years [4,5]. Eutrophication of European lakes and reservoirs is a severe problem and isthemainreasonwhy thestatus ofthesebodiesof water is deemed unsatisfactory under the rules of the Water Framework Directive [5,6]. Thus, finding a solution to the problem of eutrophication in developing countries is urgent because, as time passes, stopping eutrophication becomes more difficult and expensive every year [6,7]. As an example, the estimated costs of the damage caused by freshwater eutrophication in the UK werearound85–130million euros peryear plus61 million euros per year of costs incurred in designing of measurestocombateutrophication [7,8,9].

Evidence of naturally occurring rhizospheric phosphorus solubilizing microorganism (PSM) dates back to 1903 [10,11]. Bacteria are more effective in phosphorus solubilization than fungi [11]. Among the whole microbial population in soil, PSB constitute 1 to 50 %, while phosphorus solubilizing fungi (PSF) are only 0.1 to 0.5 % in P solubilization potential [10,11]. Number of PSB among total PSM in north Iranian soil was around 88 % [11]. Microorganisms involved in phosphorus acquisition include mycorrhizal fungi and PSMs [11]. Among the soil bacterial communities, ectorhizospheric strains from Pseudomonas and Bacilli, and endosymbiotic rhizobia have been described as effective phosphate solubilizers [12]. Strains from bacterial genera Pseudomonas, Bacillus, Rhizobium and Enterobacter along with Penicillium and Aspergillus fungi are the most powerful P solubilizers [12]. Bacillus megaterium, B. circulans, B. subtilis, B. polymyxa, B. sircalmous, Pseudomonas striata, and Enterobacter could be referred as the most important strains[12,13]. A nemato fungus *Arthrobo trysoligospora* also has the ability to solubilize the phosphate rocks [13].

2. Materials and Methods

2.1 Water and Sediment

Media used in this study were water and sediments from Kolavailake. Sediments were taken using Eickman Grab as much as 40 litres of water from the location approximately 10–13 metres below the surface, and then stored in sterile plastic jar with airtight lid. Water was taken from the water column at the same location with sediments [8,9]. Water samples were taken in the amount of 30 litres, which was then collected in sterile jerry cans. Water and sediment samples were stored in a cool box during the trip, and kept at refrigerator under the temperature of 10°C to slow down the metabolism of microorganisms and also to avoid any unexpected chemical reactions until the experiment was conducted.

2.2 Microbial Fuel Cell Circuit

The MFC series was made in three consecutive stages: preparation of the electrode, the setting up of tank, and the setting up for aeration. Rod-shaped carbon electrode was used with its dimension of 6×1.5×1 cm3 [9]. Prior to the application, carbon electrodes were neutralised using soaking treatment in succession with 1N NaOH after initial soaking in 1N HCl solution for 24 hours each respectively. The electrodes were then rinsed at each soaking treatment with distilled water and dried via air. Electrodes were soaked in distilled water until the experiments. Shortly before the experiment began, neutralised electrodes were wounded with copper wire. An electrode made of carbon (anode) was placed on the sediments and covered by 2-cm thick sediments. The tank was then filled with water sample and stored in room temperature for 24 hours to precipitate the particles of sediments. On the next day, a carbon electrode (cathode) was placed 1 cm above the sediment surface and kept surfacing on the water column. Cables from the anode and the cathode were connected to the resistor (820 Ω ± 5%) to form a closed circuit. Water loss due to evaporation during the measurement of electric current was replaced with sterilised distilled water demineralization [9,11]. Cathode chamber was filled with water sample at full volume, as well as the anode chamber, filled with sediments in the other vessel. Carbon electrode was stored on each of the cathode and anode. Cathode chamber was then coupled with aeration to provide oxygen for the treatment using aeration.

3. Results

Table 1 Initial readings of the fresh water sample

S.No.	Test Parameters	Unit	Result	Average
01	pH at 25°C	Nil	6.7	6-7
02	Biological oxygen demand (BOD) at 27°C for 3 days	mg/L	96	Unpolluted: <1; Moderately polluted: 2 - 8; Untreated sewage: 9 -500
03	Total Phosphate	mg/L	8.1	0.05 - 1
04	Total Nitrogen	mg/L	1.43	<1

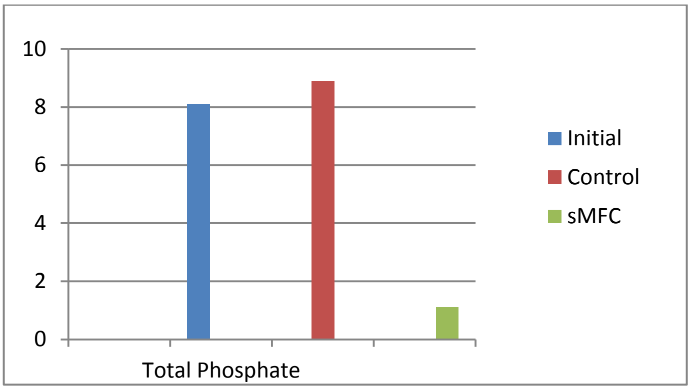

Fig. 2 Graphical representation of Total Phosphate

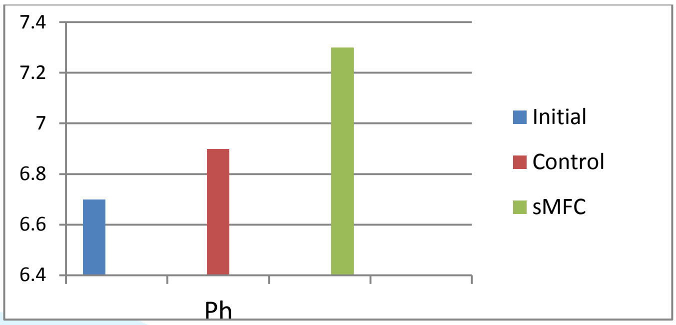

Fig. 3 Graphical representation of pH levels

Table 2 Comparison of results

Test Parameters	Unit	Initial Result (Fresh sample)	Control Result (without MFC)	sMFC Result
pH at 25°C	Nil	6.7	6.9	7.3
BOD at 27°C for 3 days	mg/L	96	110	60
Total Phosphate	mg/L	8.1	8.9	1.1
Total Nitrogen	mg/L	1.43	Nil	Nil

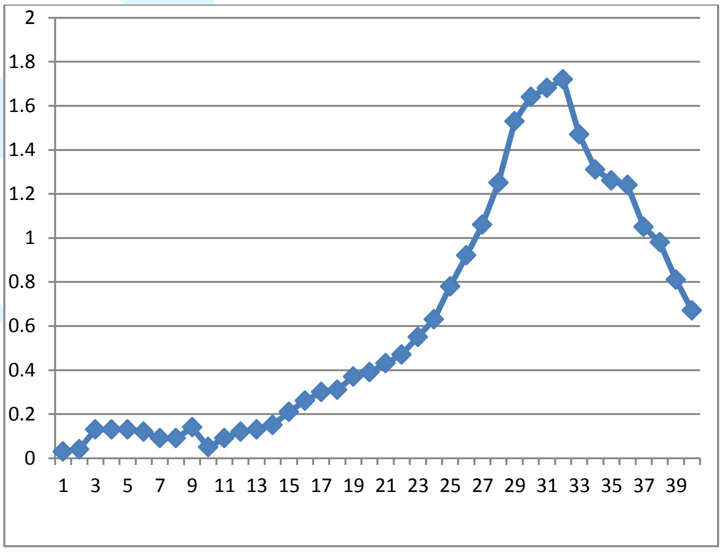

Fig. 4 Graphical representation of power generation in MFC for 40 days

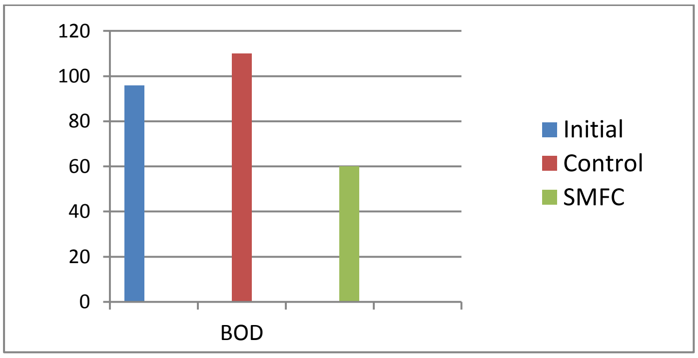

Fig. 1 Graphical representation of BOD levels

- The sediment MFC containing pond water shows very less concentration of phosphate and BOD as compared to the control and the fresh water sample.
- The pH of the water is converted from acidic to neutral.
- The microbes present in sMFC has absorbed all the phosphates in the water and has increased the oxygen levels in the water as a result of lower BOD rates.

- As a result, the MFC has generated power for an average of 40 days with 0.69 mV daily.

4. Conclusion

It is an innovative and sustainable approach towards the production of bio energy from the excess organic nutrients present in our ecosystem .The interaction between phosphate solubilising microorganisms and microbial fuel cells are the futuristic means of bioremediation in agriculture and inland aquatic ecosystems. The phosphate solubilising microorganisms are easily compatible with bio devices and provide a solution to many environmental problems.

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