Suppression of phosphorous release from sediment in agricultural drainages flowing into Lake Kojima by using biochar-amended sediment microbial fuel cells

*Gamamada Liyanage Erandi Priyangika Perera[1], Morihiro Maeda[1]

1. Graduate School of Environmental and Life Science, Okayama University

Polluted sediment in watersheds tends to act as an internal source of phosphorous due to metabolism of iron reducing bacteria (IRB) under depleted dissolved oxygen concentrations at benthic layer, despite the mitigating measures taken to control external P loadings. Iron bound P repositories releases P into overlying water bodies when iron hydroxides in sediment are dissolved by anaerobic digestion, causing enhancement of trophic states in surface waters. Sediment Microbial Fuel Cell (SMFC) is an electrochemical system that produces bioelectricity using the electrons released by electroactive microorganisms while improving P immobilization of sediment. Biochar has found as an electron shuttle and electron acceptor which promotes the mass transportation in freshwater sediments and support microbial redox transformations. Recently, the fishery industry and agricultural activities in Kojima lake are substantially affected due to degraded surface water quality. As a result of recent remedial measures though N and COD concentrations are reducing, P concentration is recorded as twice of the water quality standards. Agricultural drainages are the prime P donors of Lake Kojima. Although a number of studies have been conducted on microbial fuel cells, the effectiveness of SMFCs in irrigated water is not sufficiently addressed. Thus, initiation of SMFCs in agricultural drainages and investigating on biochar and nano-biochar amendment in SMFCs will denote a novel platform to maintain the water quality within the thresholds.

Sediment samples (130g were used in each cell) were collected from agricultural drainage which flows into Kurashiki river (N= 34.5, E = 133.9). pH, electrical conductivity (1:10) and the moisture content of the sediment were measured to identify the raw sediment characteristics. Four laboratory scale dual chambered SMFC models were constructed using fiber glass cylindrical columns (dia. =45mm, height =440mm). Wooden (Cedar) biochar and nano biochar samples were prepared and sediment was mixed with 2% of biochar and nano biochar. Biochar was produced by pyrolyzing the wood chips at 800^{o}C for 1 hour and nano-biochar was produced by pyrolyzing the wood chip at 800^{0}C for 1 hour after treating in a $Fe(NO_3)_3{\bullet}9H_2O$ solution. Pure water was used as overlying water and the brim was covered with a silicon plug. Cathode chamber was executed with 100 ml of 0.2 mol KCl filled glass beaker and connected with a salt bridge. Carbon rods (10cm long and 5mm dia. with 3cm, 3cm carbon cloth) were used as electrodes while platinum electrode was used as the reference electrode. External circuit consist of 1000Ω resistor and titanium wires was used to connect the electrodes. The experiment was conducted in a 25^{0}C dark room for 7 days. Data acquisition system was used to record the generating current and voltage. Physicochemical characteristics of sediment and biochar were determined after the SMFC operation to evaluate the alteration of sediment and microbial characteristics. Eh measurements were measured and nutrient analysis was conducted for both sediment and overlying water using Auto-analyzer.

Nano biochar circuit showed the highest current density while biochar circuit shows the second best bioelectricity production. The lowest voltage was observed in the control treatment. This is probably due to the enhanced iron mobility and low internal resistivity resulted due to the biochar amelioration. High graphite compound of nanobiochar improves the electrical conductivity. Highest effectiveness of PO_4^{3-}

suppression is recorded in nanobiochar while biochar and control systems fall to second and third. This results can be explained with the high adsorption capability of nanobiochar due to high specific surface area compared to biochar and added Fe(III) during the nano biochar production may enhance the metal bound P adsorption. High redox potential at the anode of nanobiochar and biochar treatments proves the enhancing oxidative condition of sediment layer.

This study suggests that the power productivity and P adsorption can be intensify in freshwater sediments of agricultural drainages by the nanobiochar amelioration in SMFCs. High graphite compound and high specific surface area of nanobiochar demonstrate its suitability as an amendment in freshwater SMFCs for a sustainable aquatic ecosystem management. However, the results may depend upon the properties of raw materials used to produce nanobiochar and biochar.

Keywords: Sediment microbial fuel cell (SMFC), Nano biochar, Phosphorus adsorption, Kojima lake, Bio-electricity, Biochar