

Electrochemical Removal of Sodium Ion from Fermented Food Composts

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Abstract—Fermented food composts, to be recycled into fertilizer and animal feed, require sodium chloride concentrations to be less than 1 wt% due to several toxicities. Electrochemical methods are used to remove sodium ions from fermented food composts. By washing the compost with tap water (with no electric current applied), 48% of the initial sodium ion is removed. With an electric current density of 3 mA/cm² (the distance between the electrodes is 16 cm), the removal efficiency increases to 96% for a 36 h operation. Major factors influencing the efficiency are the treatment time and the electric current density. Removal efficiency increases with energy demand to yield 96% removal at 60 Kwh/m³. Due to the difference in relative ionic mobility, less than 9% of calcium is removed, during the same operation time, which supports the feasibility of this method.

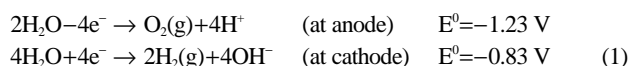
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INTRODUCTION

In Korea, composting is the common choice in the treatment of foodwastes [Kim, 1994]. At present, about 2,500 tons of food-waste is being treated daily in many composting plants in Korea. To recycle composts into fertilizer and/or animal feed, salt stress should be lowered to the level of 1 wt%. Salt stress such as salinity toxicity causes stomatal closure of plants, which reduces the CO₂ to O₂ ratio in leaves and inhibits CO₂ fixation [Lechno et al., 1997]. In animals, direct and indirect salt poisoning occur to lead circulatory inadequacy and autogenous firing of neurons [Trueman and Clague, 1978]. Most investigations of salt damage have focused on the sodium ion because the major salt component of fertilizer and animal feed is sodium chloride. According to the guidelines of the Ministry of Korean Agriculture and Forestry, the sodium chloride level for fertilizer should be lower than 1 wt%. Meanwhile, the calcium ion is the second most abundant metal ion in Korean fermented compost. It is well known that the presence of high calcium ion can increase the transport of nutrients [Martinez and Läuchli, 1993]. Thus, it can be said that the sodium ion content in fermented composts should be reduced, but not the calcium ion content, for effective treatment.

Traditionally, electrochemical treatment has been used to remediate soil contaminated with heavy metals and organic matters [Pamukcu and Wittle, 1992; Hicks and Tondorf, 1994; Acar and Alshwxabekeh, 1996]. This method uses application of direct current, on the order of mA/cm² of electrode area, to remove the contaminants from porous media such as soils. This treatment involves three electrokinetic mechanisms: electrolysis, electroosmosis, and electromigration of ionic and polar species [Pamukcu and Wittle, 1992]. On applying electric current, electrolysis occurs

at the surface of both electrodes. The chemistry concerning electrolysis can be described as follows:



where E^0 indicates the standard reduction electrochemical potential.

The hydroxide ion formed at the cathode is combined with Na⁺ to produce NaOH as a final product. For removal of contaminants, the electrochemical method is based on the assumption that the contaminant is adsorbed on the surface of porous media. Based on this concept, we used, in this study, the electrochemical method to remove sodium ion from fermented food composts for the use of fertilizer and/or animal feed.

EXPERIMENTAL SECTION

Fermented food composts were obtained from the fermented composting plant located in Taejon area, Korea. The composts were well mixed and air-dried at 80 °C for 24 h before treatment. Commercial grade nitric acid (60%) for atomic adsorption analysis was purchased from the Dong Yang Chemical Co. (Korea). The dimensions of the acrylic reactor are as follows: the distance between the cathode and anode was 16 cm and diameter was 8 cm. The electrodes consisted of carbon plates purchased from the Korea Carbon Co. (Korea). The width of the electrodes was 8 mm and several holes were punctured to facilitate the liquid flow. The pore solution used was tap water and was supplied at a constant flow rate of 20 ml/h using a peristaltic pump. Constant electric currents of 0-150 mA were supplied by D.C. power supply. Slurry was made of 150 g of composts and 700 g of tap water (i.e., initial water content was 82%). This slurry was supplied to the acrylic reactor, and all apparatus was set up as shown in Fig. 1. In this system, one sampling was equivalent to one batch run

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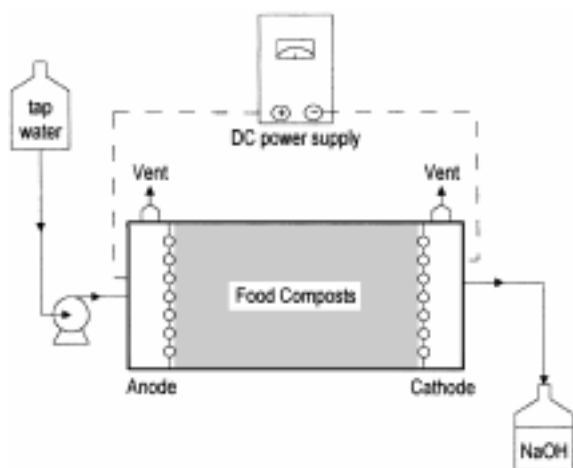


Fig. 1. Schematic of experimental apparatus.

because sampling disturbs the whole experimental conditions. When each experiment was finished, composts in reactor were well mixed and then dried at 80 °C before analysis. During each experiment, concentrated sodium hydroxide solution from the cathode was collected. Initial level of sodium in the composts was measured by using an atomic absorption spectrometer (AAS, Perkin Elmer-3300, USA), and the variation was as much as 2.3 [SE 0.8] wt%. So the initial level of sodium was estimated by summing residual sodium in the composts and sodium in the waste stream.

For the analysis of ions, the dried solid sample should be converted into a liquid sample to perform the analysis of sodium and calcium concentration by AAS. A modified method of Eaton et al. [1995] was established by using a microwave digestion apparatus (CEM-MDS 2100, USA) combined with nitric acid treatment. Detailed procedures are schematically depicted in Fig. 2.

RESULTS AND DISCUSSION

First, sodium removal only by washing with tap water (i.e., with no electric current applied) was carried out to identify the net removal by electric current (Fig. 3). A maximum removal of 48% for a 36 h treatment was achieved. The slow increment of removal efficiency between 12 h and 36 h was probably because

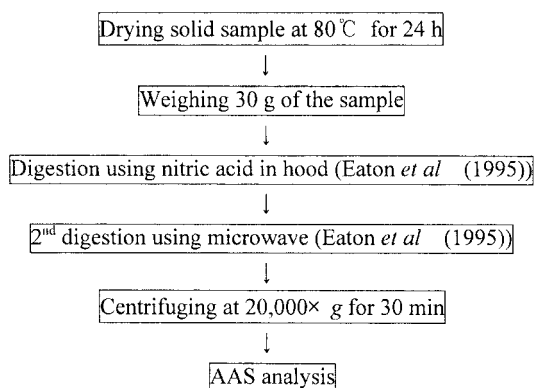


Fig. 2. Pretreatment procedures of solid samples using modified nitric acid method.

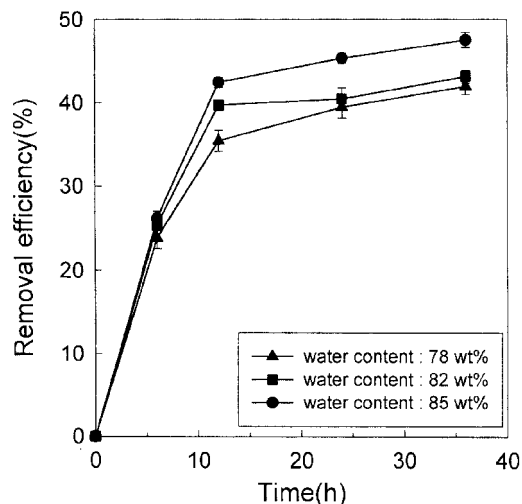


Fig. 3. Removal of sodium ion in fermented food composts by washing with tap water.

a large amount of sodium was located at the external surface of food composts. Additionally, the total amount of calcium ion, very important metal ion in fertilizer, reduced by washing was only 3.9%. The removal efficiency of sodium ion increased with initial water content of the composts. This reflects that the presence of water in composts facilitates ionic mobility. Considering the initial sodium content (3 wt%) of the composts, the removal efficiency by washing alone could not meet the sodium concentration restriction (<1 wt%) for fertilizer. This requires other desalting process such as an electrochemical treatment.

With the electric current density of 3 mA/cm², the removal efficiency of sodium ion increased to 96% for a 36 h operation (Fig. 4). Even while the treatment time and electric current density were increased further, the removal efficiency did not improve beyond 96%. In the case of calcium, a total removal of 9.0% was reached; 3.9% and 5.1% by washing and electrochemical treatment, respectively. The difference in removal efficiency of sodium and calcium is probably due to the difference in the ionic mobility between the two ions [Pamukcu and Wittle, 1992;

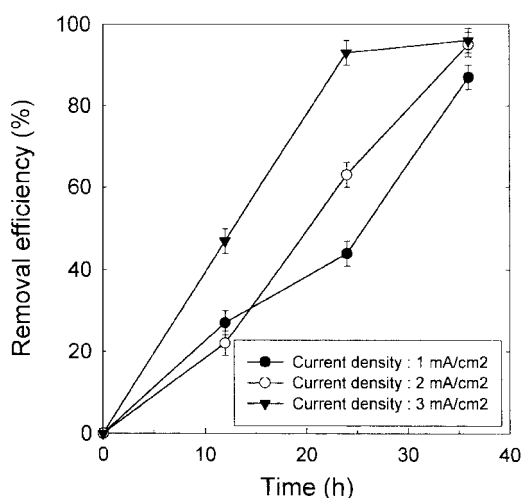


Fig. 4. Removal of sodium ion in fermented food composts by electrochemical method. Initial water content was 82 wt%.

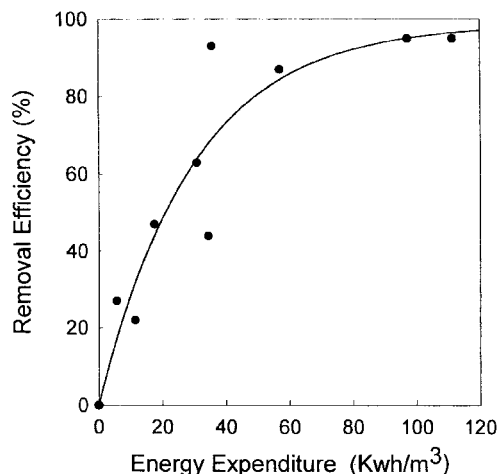


Fig. 5. Effect of energy expenditure on removal efficiency.

Hansen et al., 1997].

As reaction proceeded, a pH gradient across the reactor was caused by the electrolysis and ion transport. This pH difference could be balanced by mixing the composts after the treatment. The final pH of mixed composts reached to 6.7 from the initial value of 8.2, then the treated composts could be used without any post pH adjustment. In removal of sodium chloride, the fate of chloride has usually been ignored. Running the reactor, however, we noticed the blue-green color of chlorine gas near the anode. In this system, the fate of the chloride ion (anode only) can be postulated as follows:



Based on the chemistry, most of free chlorines are supposed to exist as a form of aqueous chlorine and hypochlorous acid (HOCl) due to the high solubility of chlorine gas and low solution pH. Certain volume of solution in this region should be directly removed before the treated composts are mixed because of the toxicity of chlorine gas and HOCl.

Considering the application of this process to the real field, energy expenditure is the most important factor. Energy expenditure per unit volume of composts processed E_u is given as follows:

$$E_u = \frac{E}{V_s} = \frac{1}{V_s} \int V I dt \quad (3)$$

where E =energy (Wh); V_s =volume of composts processed (m^3); V =voltage drop between electrodes (V); and t =time (h).

In constant current condition, the energy expenditure is di-

rectly proportional to the time integral of the voltage drop. The removal efficiency increased with the energy demand to yield 96% removal at 60 kWh/m^3 (Fig. 5). To meet the regulation of sodium level, 75% removal should be sufficient for the fertilizer which results in an energy consumption (or expenditure) of 40 kWh/m^3 .

CONCLUSIONS

Electrochemical treatment has been used to remove sodium chloride in fermented food composts. A cylindrical type acrylic reactor was made and successfully operated. With a current density of 3 mA/cm^2 , 96% of sodium was removed for 36 h operation. Toxic chloride-related byproducts were produced, but they could be simply removed by disposing of a certain volume of composts near cathode. The final pH of treated composts was decreased from 8.2 to 6.7, then the treated composts could be used without post pH adjustment. Considering the energy consumption and the ease of operation, this electrochemical method can be a promising alternative for the removal of sodium chloride from fermented food composts. Optimization of the pilot-scale reactor is in progress and the results will appear elsewhere.

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