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ESTIMATING MATURITY OF COMPOSTS FROM SUGAR-INDUSTRY ANAEROBIC SEWAGE SLUDGE ON BASIS OF ELECTRIC CONDUCTIVITY MEASUREMENT

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Abstract. The relationship between the Na^+, K^+, Ca^{2+} and Mg^{2+} concentration in water extracts from composts made of anaerobic sewage sludge from the sugar industry and the electric conductivity of the extracts was investigated for the purposes of estimating the maturity of composts. The conductivity values proved to be correlated with the concentration of the cations. The determination coefficients were statistically significant ($p = 0.05$) for composts with an addition of structure-forming materials (straw, farmyard manure). This means that the measurement of conductivity can be used to estimate the degree of mineralisation of composted materials.

Key words: anaerobic sewage sludge, electric conductivity, electrolytes, ions

INTRODUCTION

The biodegradation of wastes involves various physicochemical changes occurring in their components due to the different degrees of mineralisation of those complex organic compounds. The rate of the process of organic matter mineralisation can be estimated by measuring the changes in the concentration of organic compounds in water extracts. When some chemical elements in water extracts are present in ionic form, the changes in their solubility, and thus in the solubility of the substances, may be quantified by measuring conductivity. Conductivity measurements have a wide application in the analyses of multi-component systems, among them food products (e.g. milk, meat, wine vinegar, honey), in the control of water quality for household and industrial purposes, in sewage-processing systems, etc.

The water extracts from composts can be treated as water solutions of electrolytes constituting a specific kind of conductors. Besides temperature and ion mobility, the

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concentration of a solution is one of the most important parameters influencing electric conductivity. Since ions are electric-charge carriers in water solutions of electrolytes, a solution makes the better conductor, the more ions it contains, i.e. conductivity increases with a rise in solution concentration. This holds only for low concentrations of solutions. At high concentrations, the dissociation point decreases and not all particles introduced into the solution ionise. In addition, with an increase in the concentration of ions in the solution their energy increases, as does the energy of interactions between the particles. That is why conductivity increases with the rise in concentration only to a certain limited value, and then begins to fall. When measuring conductivity, it should therefore be considered that each kind of ions in a solution makes a different contribution to its conductivity, e.g. the conductivity of some salts dissolved in water (100 $mg \cdot dm^{-3}$) at a temperature of 25 °C is as follows: for KNO_3 – 120 $\mu S \cdot cm^{-1}$, for KCl – 170 $\mu S \cdot cm^{-1}$, and for $CaCl_2$ – 220 $\mu S \cdot cm^{-1}$ [Harada and Inoko 1980]. Because both the mobility of ions and the dissociation point of particles change with temperature, it is very important to take measurements at the same temperature (20 or 25 °C) or to use the electrode with temperature compensation [Brinton et al. 1995].

The research was aimed at examining the relationship between the concentration of ions in water extracts from composted anaerobic sewage sludge of sugar-industry origin and the electric conductivity of the extracts to determine whether the two measurements (conductivity and ion concentration) can be used for estimating the degree of mineralisation of composted materials.

MATERIAL AND METHODS

The compost heaps had the following weight composition (on dry matter basis):
– Heap I: anaerobic sewage sludge (209 kg) + farmyard manure (143.4 kg);
– Heap II: anaerobic sewage sludge (209 kg) + straw (6.9 kg);
– Heap III: anaerobic sewage sludge (209 kg).

The weight ratios of the components were calculated on the basis of the amounts of carbon and nitrogen that each component brought into the compost volume.

The heaps were covered with a special hydrophobic porous material which was air-permeable to maintain the compost humidity at the same level. The initial moisture content of composts ranged from 57 to 65%. Any water losses caused by evaporation (albeit limited due to the hydrophobic cover of composts) were made up for every 10 days based on the determination of dry matter and the observation of the internal structure of composts. The material was mixed during the composting process and was aerated on day 10 and 20 of the process.

The samples were taken 9 times from each compost heap: on the day of heap formation and on days 10, 20, 30, 45, 60, 90, 120 and 180.

In order to determine the intensity of the mineralisation process by measuring conductivity, water extracts of composts (1 : 10 v/v) were prepared in the course of biodegradation using re-distilled water with a conductivity of 0.1 $\mu S \cdot cm^{-1}$. The conductivity of the extracts was measured with a conductometer type OK-102/1 (Radelkis, Budapest) [Korol and Korol 1992]. The water extracts were prepared from the composts containing straw or manure

as an additive. The course of the changes that took place in each of the composts was monitored for 180 days on the basis of the results obtained at the nine sampling dates.

The magnesium concentration in the water extracts from composts was determined by flame atomic absorption spectrometry with deuterium BC (SpectrAA 250 Plus, Varian). The calcium, potassium and sodium concentrations in the organic matter and the water extracts from composts were determined by flame spectrometry (spectrometer Flapho 40).

The sum of cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) was correlated to the conductivity of water extracts from composts, and the determination coefficients (R^2) were calculated and analysed for statistical significance.

The statistical evaluation of the data was performed using analysis of variance, Levene's test, Kruskall-Wallis' test, LSD test and Tukey's test. The calculations were made using Statistica 5.0 software.

RESULTS AND DISCUSSION

Changes in the concentration of K^+, Na^+, Ca^{2+} and Mg^{2+} ions as related to the duration of composting

As shown by the pattern of changes in the concentrations of K^+, Na^+, Mg^{2+} and Ca^{2+} cations in the water extracts from composts of anaerobic sewage sludge (Fig. 1), the composting process caused an increase in the quantities of soluble forms of potassium, sodium, magnesium and calcium in the materials. The cation concentration changes were most pronounced for the compost to which farmyard manure was added as a structure-forming organic material (Fig. 1a). The increase in concentration was statistically significant ($p < 0.01$) for all the cations examined. At the end of the composting process, the highest concentration, 1.43 $g \cdot dm^{-3}$, was recorded for calcium (a 100% rise compared to the beginning of the experiment); the other values were as follows: Mg^{2+} – 0.09 $g \cdot dm^{-3}$, K^+ – 0.43 $g \cdot dm^{-3}$, and Na^+ – 0.1 $g \cdot dm^{-3}$. The changes in the concentrations of the cations in the anaerobic sewage sludge + farmyard manure compost were most intensive during the first 30 days of the composting process, and afterwards they slowed down.

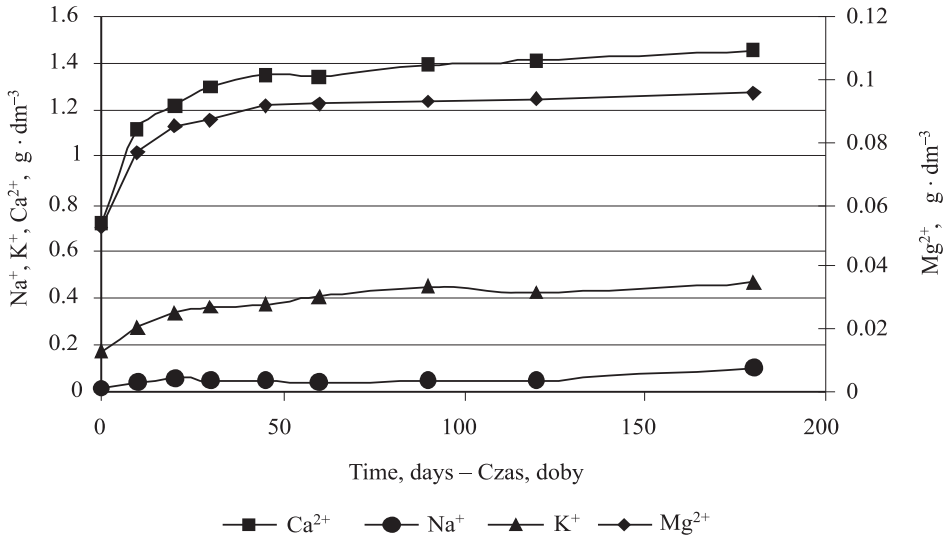
As shown by the concentration changes of K^+, Na^+, Mg^{2+} and Ca^{2+} in the water extracts from composts, the mineralisation processes taking place in the anaerobic sewage sludge + + straw compost were also intensive although slower than those observed in the compost supplemented with farmyard manure. Similarly, the changes in cation concentration were biggest during the first 30 days of composting (Fig. 1b). The final concentrations of K^+, Ca^{2+} and Mg^{2+} were 20% lower than those determined for the compost comprising farmyard manure.

No statistically significant ($p > 0.05$) increase in the concentration of the cations was observed in the compost of anaerobic sewage sludge without additives (Fig. 1c).

Increased levels of soluble forms of potassium, calcium and magnesium due to the composting of farmyard manure supplemented with wheat straw were reported by Blanco and Almendros [1995, 1997]: after 60 days of the composting process, they recorded an 80–90% rise in the cation concentration. Gonzales-Vila et al. [1999], studying composts made on the basis of solid municipal wastes, observed changes in the total Mg and Ca concentration of the composts stored in spring. Besides, they noted that the changes (by

80–90%) in the levels of soluble forms of the two elements in this period were biggest than for composts stored at the end of summer and the beginning of autumn. On the other hand, the latter researchers failed to find significant changes in the levels of soluble forms of K and Na after 50 days of the process in either period of storage. The experiments conducted by Michel and Reddy [1998] on municipal wastes composted at a constant temperature of 50 °C in a reactor with three different air flows (0.1, 1 and 10 mg $O_2 \cdot min^{-1}$) demonstrated that larger changes in the soluble forms of K, Na, Mg and Ca (increase by about 70–80%) occurred in the systems with stronger aeration.

a



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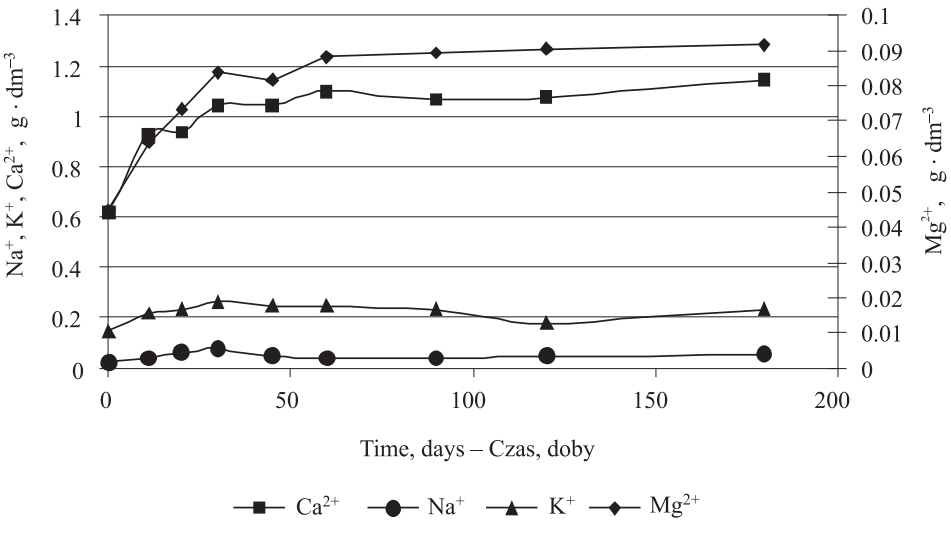

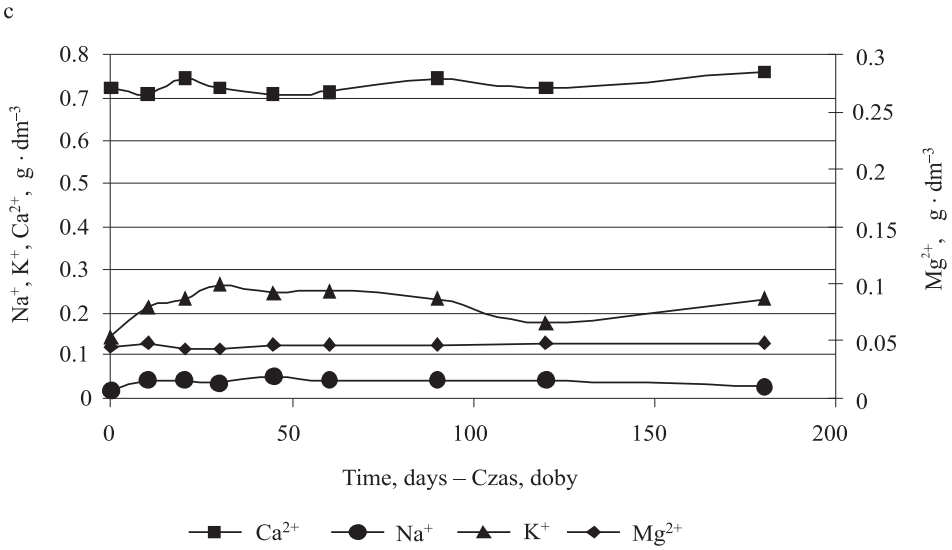

Fig. 1. Changes in concentrations of potassium, sodium, calcium and magnesium ions in water extracts from composts of anaerobic sewage sludge with or without additives as dependent on duration of composting; a – sludge + manure, b – sludge + straw, c – sludge

Rys. 1. Zmiany zawartości jonów potasu, sodu, wapnia i magnezu w wyciągach wodnych z kompostów beztlenowego osadu ściekowego z dodatkami i bez dodatków w zależności od czasu kompostowania; a – osad + obornik, b – osad + słoma, c – osad

Changes in the electric conductivity of water extracts from composts as related to the duration of composting

The conductivity of the water extracts from composts of anaerobic sewage sludge increased with time, the most so for the compost supplemented with farmyard manure (from 4 $mS \cdot cm^{-1}$ at the start to over 9.7 $mS \cdot cm^{-1}$ at the end of experiment; Fig. 2). In the case of this compost, the maximum value was reached on the 120th day of the composting process. For the compost supplemented with straw, the process of conductivity changes was slower and lasted until the 90th day of composting (Fig. 2). No statistically significant ($p > 0.05$) changes in conductivity were observed in the anaerobic sewage sludge composted without additives (Fig. 2).

Conductivity changes were also noted by Hartz and Giannini [1998] who studied the composting of municipal wastes in a heap system with hot air aeration. The heap kept at a higher temperature showed a larger increase in conductivity than the heap with more frequent aeration and a lower temperature (from 11.0 to 16.9 $mS \cdot cm^{-1}$ vs. 16.0 $mS \cdot cm^{-1}$ on the 105th day of composting; later on, until the end of the process on the 120th day, the conductivity of both heaps tended to decrease). As reported by Negro et al. [1999], composting communal sewage sludge with an addition of farmyard manure increased the conductivity of these materials (from 0.27 to 6.96 $mS \cdot cm^{-1}$ after 150 days), which indicates that the organic substances in the heaps underwent intense mineralisation processes. By contrast, after 96 days of composting farmyard manure with ash and wood chips in 10

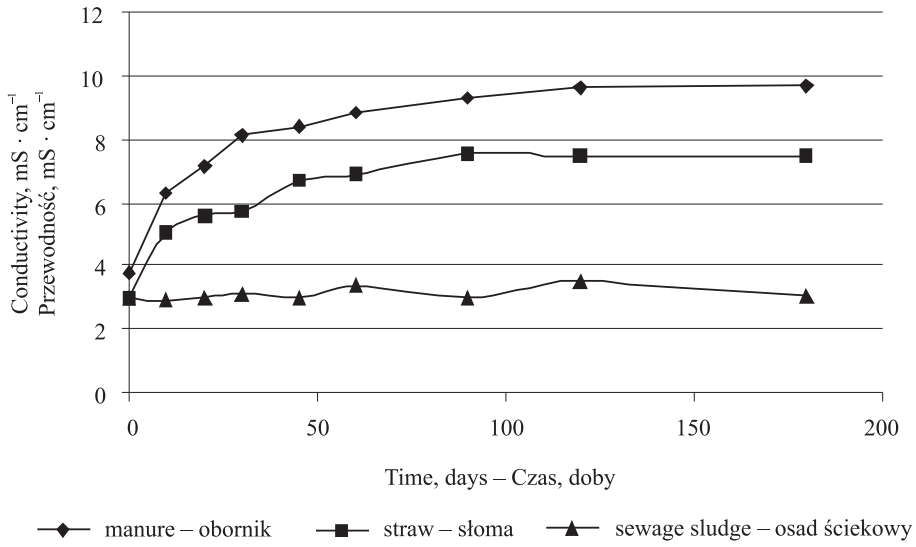

Fig. 2. Changes in conductivity of water extracts from composts of anaerobic sewage sludge as dependent on duration of composting

Rys. 2. Zmiany przewodności wyciągów wodnych z kompostów beztlenowego osadu ściekowego w zależności od czasu kompostowania

experimental heaps, Fauci et al. [1999] failed to record statistically significant changes in the conductivity of compost. No increase in conductivity after 360 days of the process was also observed by Ozores-Hampton et al. [1999] in their experiments with composting solid municipal wastes in a heap system. Hakett et al. [1999] who investigated the composting of ground newspaper material in two variants of compost heaps reported even a decline in conductivity (from 16.0 to 1.4 $mS \cdot cm^{-1}$ after 120 days of composting) for both heaps.

Correlation between the sum of cations and the electric conductivity of water extracts from composts

The sum of cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) in the water extracts from anaerobic sewage sludge composted with additives was found to be correlated to the conductivity of the compost extracts both for the addition of straw ($R^2 = 0.95$) and farmyard manure ($R^2 = 0.87$; Fig. 3).

The concentrations of individual cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) showed correlation to the conductivity of the extracts for the two kinds of sewage sludge composts with additives (straw or manure) in which mineralisation of organic matter was observed. All the determination coefficients were statistically significant ($p = 0.05$). The correlation was the most significant for the cations whose concentrations in the water extracts from composts were highest, i.e. for calcium and magnesium (Fig. 4).

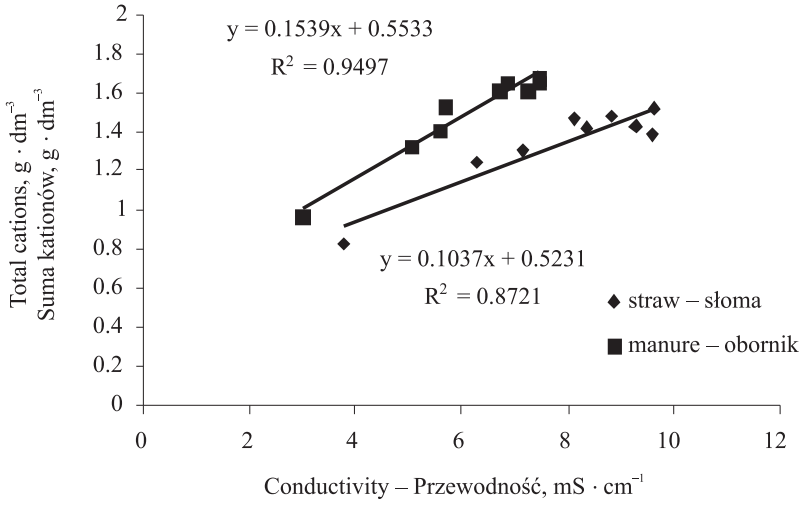

Fig. 3. Correlations between sum of cations (Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}) in water extracts from composts of anaerobic sewage sludge with manure and straw and conductivity of extracts

Rys. 3. Krzywe korelacji między sumą kationów (Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}) w wyciągach wodnych z kompostów beztlenowego osadu ściekowego z dodatkiem obornika i słomy a przewodnością wyciągów

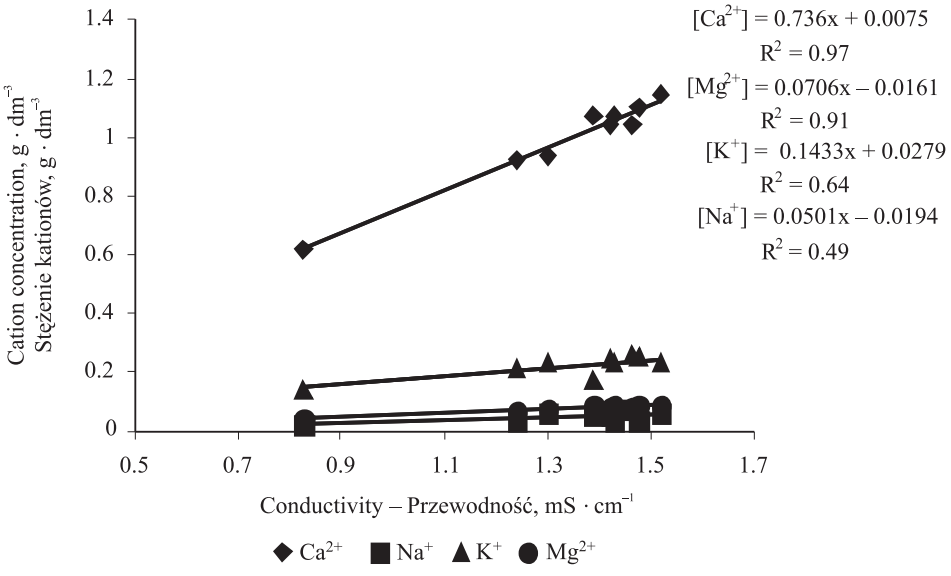

Fig. 4a. Correlations between concentrations of individual cations in water extracts from composts of anaerobic sewage sludge with additives and conductivity of extracts – sludge + straw

Rys. 4a. Krzywe korelacji między zawartością poszczególnych kationów w wyciągach wodnych z kompostów beztlenowego osadu ściekowego z dodatkami a przewodnością wyciągów – osad + słoma

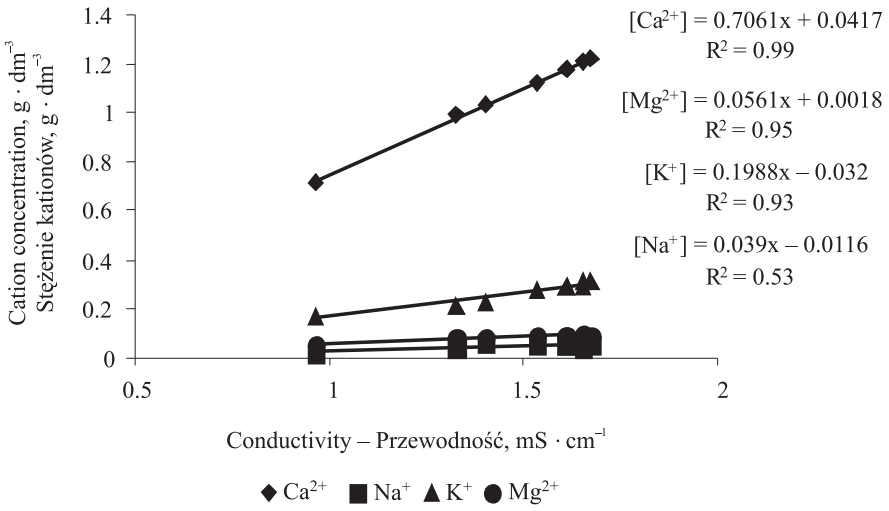

Fig. 4b. Correlations between concentrations of individual cations in water extracts from composts of anaerobic sewage sludge with additives and conductivity of extracts – sludge + manure

Rys. 4b. Krzywe korelacji między zawartością poszczególnych kationów w wyciągach wodnych z kompostów beztlenowego osadu ściekowego z dodatkami a przewodnością wyciągów – osad + obornik

CONCLUSIONS

The mineralisation processes taking place in composts made of anaerobic sewage sludge with/without straw or farmyard manure were more intensive during the first 20 days of composting when the heaps were aerated.

There was a correlation between the concentration of cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) in the water extracts from composts and the electric conductivity of the extracts. All the determination coefficients were statistically significant ($p = 0.05$) for the composts supplemented with straw or manure, which suggests that the measurement of conductivity can be used to estimate the degree of mineralisation of composted materials.

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OCENA DOJRZAŁOŚCI KOMPOSTU Z CUKROWNICZEGO BEZTLENOWEGO OSADU ŚCIEKOWEGO NA PODSTAWIE POMIARU PRZEWODNOŚCI ELEKTRYCZNEJ

Streszczenie. Badano zależność między stężeniem Na^+, K^+, Ca^{2+} i Mg^{2+} w wyciągach wodnych kompostów z beztlenowego osadu ściekowego z przemysłu cukrowniczego a przewodnością wyciągów w celu określania dojrzałości kompostów. Stwierdzono, że wartość przewodności elektrycznej wyciągów jest skorelowana ze stężeniem badanych kationów. Wyznaczone współczynniki determinacji były statystycznie istotne ($p = 0,05$) dla kompostów z dodatkiem materiałów strukturotwórczych (słomy i obornika). Oznacza to, że pomiar przewodności można wykorzystać do oceny stopnia mineralizacji kompostowanych materiałów.

Słowa kluczowe: beztlenowy osad ściekowy, przewodność elektryczna właściwa, elektrolity, jony

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