Batch washing of heavy metals from municipal solid waste (MSW) compost using Na\textsubscript{2}EDTA and a mixture of Na\textsubscript{2}S\textsubscript{2}O\textsubscript{5} and Na\textsubscript{2}EDTA

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Main factor leading to restricted soil conditioner use of compost is its heavy metal content. This paper deals with the removal of heavy metals from municipal solid waste (MSW) compost using Na\textsubscript{2}EDTA and a mixture of Na\textsubscript{2}S\textsubscript{2}O\textsubscript{5} and Na\textsubscript{2}EDTA in the batch mode. At the end of extraction studies, for 3 h at 1:25 solid:liquid ratio by using 0.05 M Na\textsubscript{2}EDTA, 100% removal yields were obtained for all metals studied. Further, heavy metal removal (≥100%) were obtained with 0.01 M Na\textsubscript{2}EDTA and 0.1 M Na\textsubscript{2}S\textsubscript{2}O\textsubscript{5}, at 1:6 solid:liquid ratio, for all heavy metals of this study.

Keywords: Extraction, Heavy metal, Municipal solid waste compost

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Introduction

Compost can be used as a soil conditioner as it contains major plant nutrients (N, P, and K), microplant nutrients (Cu, Fe, and Zn), and organic matter, which improve physical properties in order to have a better soil aeration and water holding capacity\textsuperscript{1}. Presence of heavy metal content is the main factor leading to restricted agricultural use of compost. Effect of compost use on heavy metal levels in the environment varies according to soil type, plant species and compost quality\textsuperscript{2-4}. Based on cumulative research in Europe into the agronomic use of compost, heavy metals tend to accumulate in soil and plants in the following order: Zn> Cu> Pb = Cd > Ni > Cr\textsuperscript{5}. In soil washing techniques, where soil-bound contaminants are transferred to the liquid phase by desorption and solubilization, acid washing and chelator soil washing are two most prevalent removal methods\textsuperscript{6}. A mixture of 0.1 M Na\textsubscript{2}S\textsubscript{2}O\textsubscript{5} and 0.01 M Na\textsubscript{2}EDTA provide an economically optimum solution for Cd and Zn removal\textsuperscript{7}.

The study presents soil-washing techniques using batch mode for removing heavy metals from municipal solid waste (MSW) compost using different concentrations of Na\textsubscript{2}EDTA solutions and different concentrations of mixture of Na\textsubscript{2}S\textsubscript{2}O\textsubscript{5} (reducing reagent) and Na\textsubscript{2}EDTA (chelating reagent).

Materials and Methods

Compost Samples

Compost samples from Istanbul Solid Waste Recycling and Composting Plant in Kisrimandra, Istanbul, were dried at 105°C and ground to yield 0.25 mm-size particles. This sample (1-2 g) was placed into a volumetric flask. Digestion was performed by heating with a 10 ml-mixture of 1:1 (v/v) deionized water and HNO\textsubscript{3}. After cooling, H\textsubscript{2}O\textsubscript{2}, conc. HCl, and deionized water were added to the sample, and heated again. Contents were allowed to cool to room temperature, diluted with deionized water and passed through a 0.45 µm filter, and processed on an atomic absorption spectrometer (UNICAM 929 AA spectrometer) for heavy metal determination\textsuperscript{8}. Metal content in the sample (M) was calculated as mg/kg (dry weight) as

\[ M = (C \times V)/m \]

where, C is metal concentration, mg/l; V is final volume of sample, l; and m is mass of sample, kg. Heavy metals in the compost are: Cu, 348.6; Ni, 521.2; Zn, 903; Pb, 130.9; and Cd, 3.05 mg/kg.

Batch Washing

Dry sample (5 g) was placed into a volumetric flask. Varying volumes and concentrations of washing solution were added into the sample. Sample was shaken horizontally at room temperature for 3 h at 160 rpm. After mixing, aliquot was filtered through a...
0.45-µm membrane filter using vacuum filtration. The pH of washing solution before contact with the compost and pH of filtrate were measured. Following the filtration, filtrate was acidified to pH $\leq 2.0$ with 1:1 HNO$_3$ for heavy metal analysis. Precision was established by preparing a replicate for each test. It was assumed that metal concentration of filtrate represents released matter from the compost. Removal efficiencies were determined by dividing heavy metal release quantities by initial quantity in the compost.

### Results and Discussion

#### Extractions with Na$_2$EDTA

**Determination of Optimum Na$_2$EDTA Concentration**

Dry sample (5 g) was placed into a volumetric flask. Na$_2$EDTA solutions (30 ml) with varying concentrations were added into the sample. These samples were analyzed to determine the optimum Na$_2$EDTA concentration (Table 1, Fig. 1). Increased removal yields for Cu and Zn were obtained with increased molarity of Na$_2$EDTA solution. A similar trend was seen with Cd, but there was no significant difference between 0.05 and 0.1 M Na$_2$EDTA with regard of removal yields. Maximum removal efficiencies for 0.1 M Na$_2$EDTA are: Cu, 59%; Zn, 84%; and Cd, 51%.

#### Determination of Optimum Solid:Liquid Ratio

Optimum ratio was determined by addition of different amounts of 0.05 M Na$_2$EDTA solution (1:2.5, 1:5, 1:12.5, 1:25). Samples were analyzed for heavy metal removal yields from different solid:liquid ratios (Table 2, Fig. 2). Increasing amount of Na$_2$EDTA solution, which necessitates that solid:liquid ratio goes lower, gives higher removal yields for all heavy metals examined. For Cu and Zn, highest yield (100%) is present with 1:12.5, while for Cd, this value becomes 1:25 (Fig. 2).
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Studies Performed with Na$_2$EDTA and Na$_2$S$_2$O$_5$ Mixture

Determination of Optimum Solid:Liquid Ratio

Dry compost (5 g) was mixed with 0.01 M Na$_2$EDTA and 0.1 M Na$_2$S$_2$O$_5$ mixture, with several solid:liquid ratios and the samples were analyzed to determine optimum solid:liquid ratio (Table 3, Fig. 3). Decreasing the solid:liquid ratio increases heavy metal removal ratios. For all metals, highest removal ratios (Cu, 100%; Zn, 100%; Cd, 96.6%) were obtained with 1:6 solid:liquid ratio.

**Table 3**—Heavy metal removal and removal efficiencies at different solid:liquid ratios of compost mixture with Na$_2$EDTA and Na$_2$S$_2$O$_5$

<table>
<thead>
<tr>
<th>Compost mixture with Na$_2$EDTA and Na$_2$S$_2$O$_5$ solid:liquid ratios</th>
<th>Heavy metal removed mg/kg-dry compost</th>
<th>Removal efficiencies %</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/ml</td>
<td>Cu</td>
<td>Zn</td>
</tr>
<tr>
<td>1:2.5</td>
<td>121.44</td>
<td>353.4</td>
</tr>
<tr>
<td>1:5</td>
<td>225.2</td>
<td>689.5</td>
</tr>
<tr>
<td>1:6</td>
<td>348.3</td>
<td>903.9</td>
</tr>
</tbody>
</table>

**Table 4**—Heavy metal removal and removal efficiencies with several concentrations of Na$_2$EDTA and Na$_2$S$_2$O$_5$

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Heavy metal removed mg/kg-dry compost</th>
<th>Removal efficiencies %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
<td>Zn</td>
</tr>
<tr>
<td>Solution 1</td>
<td>33.56</td>
<td>235.6</td>
</tr>
<tr>
<td>Solution 2</td>
<td>100.35</td>
<td>431.7</td>
</tr>
<tr>
<td>Solution 3</td>
<td>348.3</td>
<td>903.9</td>
</tr>
</tbody>
</table>

Solution 1: 0.001 M Na$_2$EDTA and 0.1 M Na$_2$S$_2$O$_5$ mixture; Solution 2: 0.01 M Na$_2$EDTA and 0.05 M Na$_2$S$_2$O$_5$ mixture; Solution 3: 0.01 M Na$_2$EDTA and 0.1 M Na$_2$S$_2$O$_5$ mixture

**Fig. 3**—Heavy metal removal efficiencies for different solid:liquid ratios of compost mixture with Na$_2$EDTA and Na$_2$S$_2$O$_5$

**Fig. 4**—Removal efficiencies from experiments performed with several concentrations of Na$_2$EDTA and Na$_2$S$_2$O$_5$

**Conclusions**

Heavy metal removal efficiencies increase with increasing chelator concentration. Further, as the solid:liquid ratio decreases, higher removal ratios are reached. After agitation for 3 h at 1:25 solid:liquid ratio by using 0.05 M Na$_2$EDTA, 100% removal yields were obtained for all metals studied. Sole chelator usage proves more costly, unless Na$_2$S$_2$O$_5$ is included as the reducing reagent. Therefore, the optimum removal yield was obtained with a mixture of 0.01 M Na$_2$EDTA and 0.1 M Na$_2$S$_2$O$_5$, which provided more efficient removal than sole Na$_2$EDTA usage at 0.05 M, which indicates that the solid:liquid ratio of the former is higher (i.e., less solution volume). Heavy metal removal yields (100%) were obtained with 0.01 M Na$_2$EDTA and 0.1 M Na$_2$S$_2$O$_5$, at 1:6 solid:liquid ratio, for all heavy metals included in this study. It can thus be concluded that the mixture of 0.01 M Na$_2$EDTA and 0.1 M Na$_2$S$_2$O$_5$ mixture can conveniently be used to remove heavy metals from the compost.
Acknowledgements

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References


