Magnetic susceptibility and trace element distribution in compost

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Abstract
Magnetic susceptibility can be used for assessing anthropogenic pollution in solid matrices, including soils and composts. The objective of this work was studying the distribution of trace element concentrations and magnetic susceptibility in the different size fractions of six composts. Magnetic susceptibility decreased with increasing particle size in all composts, and the same was true for most trace element concentrations. Significant correlations of magnetic susceptibility with Cu, Zn, Pb, Cr and Ni concentrations were found, which prove the relationship between the presence of ferric particles and trace element contamination in compost. Our results also suggest that the association of trace elements and magnetic susceptibility is a characteristic feature in municipal solid waste composts, and opens the possibility to use magnetic separators to reduce metal contamination, particularly that associated with the fine particles of compost.

Introduction
Municipal solid waste (MSW) compost is often contaminated by heavy metals mainly due to inadequate separation of biodegradable fractions from non-degradable or inert materials [1]. These composts may present high concentrations of potentially toxic trace elements such as Cu, Zn or Cr, especially when mechanically-sorted organic fraction is used for their production, instead of the separately collected waste [2]. When excessive accumulation in soil exists, heavy metals may have adverse effects on the growth and development of plants and can also enter the food chain thus affecting animal and human health. Therefore, the content in heavy metals is one of the main restrictions to the agronomic use of MSW compost and considerable efforts are currently devoted to the study of their concentrations and distribution.
Magnetic susceptibility measurements are a simple technique that has been reported as an useful tool for assessing anthropogenic pollution in solid matrices, including soils and composts [3-6]. It can be used to evaluate heavy metal contamination and to determine the origin of heavy metals in compost. In a previous work [7], we have found significant positive correlations between magnetic susceptibility and total Cd, Zn, Pb, Cr and Ni concentrations in composts from different origin. The relationship between ferric particles and trace elements was demonstrated when the application of a magnet reduced simultaneously the magnetic susceptibility and the trace element contents of the composts. The objective of this work is to further explore this link by studying the distribution of trace element concentrations and magnetic susceptibility in the different size fractions of six composts.

Material and Methods
The composition of five municipal solid waste composts and a manure vermicompost was studied. They were the following: MSWC1 is a compost obtained by anaerobic fermentation of the biodegradable fraction of municipal solid waste (MSW), separated before collection, followed by an aerobic composting step, to stabilize the incompletely digested residue. MSWC2 and MSWC3 are aerobic MSW composts obtained from source separated biodegradable fraction of MSW; all MSW composts were provided by industrial composting facilities located in A Coruña (Spain). MSGW is a commercial compost obtained from source separated biodegradable fraction of MSW mixed with green waste, and MGSS is compost from municipal garden trimmings mixed with sewage sludge; they both were supplied by an industrial composting facility located in Catalunya (Spain). MV is a mixed manure vermicompost supplied by a local producer in Galicia (Spain). For their analysis, the Spanish version of the European methods for the characterization of soil amendments and substrates [8-10] was followed. Four size fractions were separated after sieving 400 g of air-dried compost through the

following meshes: 0.5, 2, and 5 mm. Each fraction was weighed, ground in an agate mortar (<500 μm), and analysed for total Fe, Cu, Zn, Pb, Cr and Ni after wet digestion with aqua regia [11]. The specific mass magnetic susceptibility of the fractions was measured using a magnetic susceptibility meter MS2 linked to a MS2B dual frequency sensor (Bartington Instruments Ltd.); the measures were performed at low frequency.

Results

The general properties of the composts are shown in Table 1. All the composts presented alkaline pH values (7.3-9.2), and TOC contents within the same range (217-298 g kg^{-1}), whereas salinity was the highest for the three composts produced from MSW only (MSWC1-MSWC3).

Table 1. Properties of the composts. EC: electric conductivity; TOC: total organic carbon.

	pH	EC (dS m^{-1})	TOC (g kg^{-1})	C/N
MSWC1	8.4	2.3	280	17
MSWC2	8.2	2.4	230	15
MSWC3	8.7	5.1	220	12
MSGW	9.2	1.2	248	14
MGSS	7.3	1.4	298	15
MV	7.9	0.7	217	21

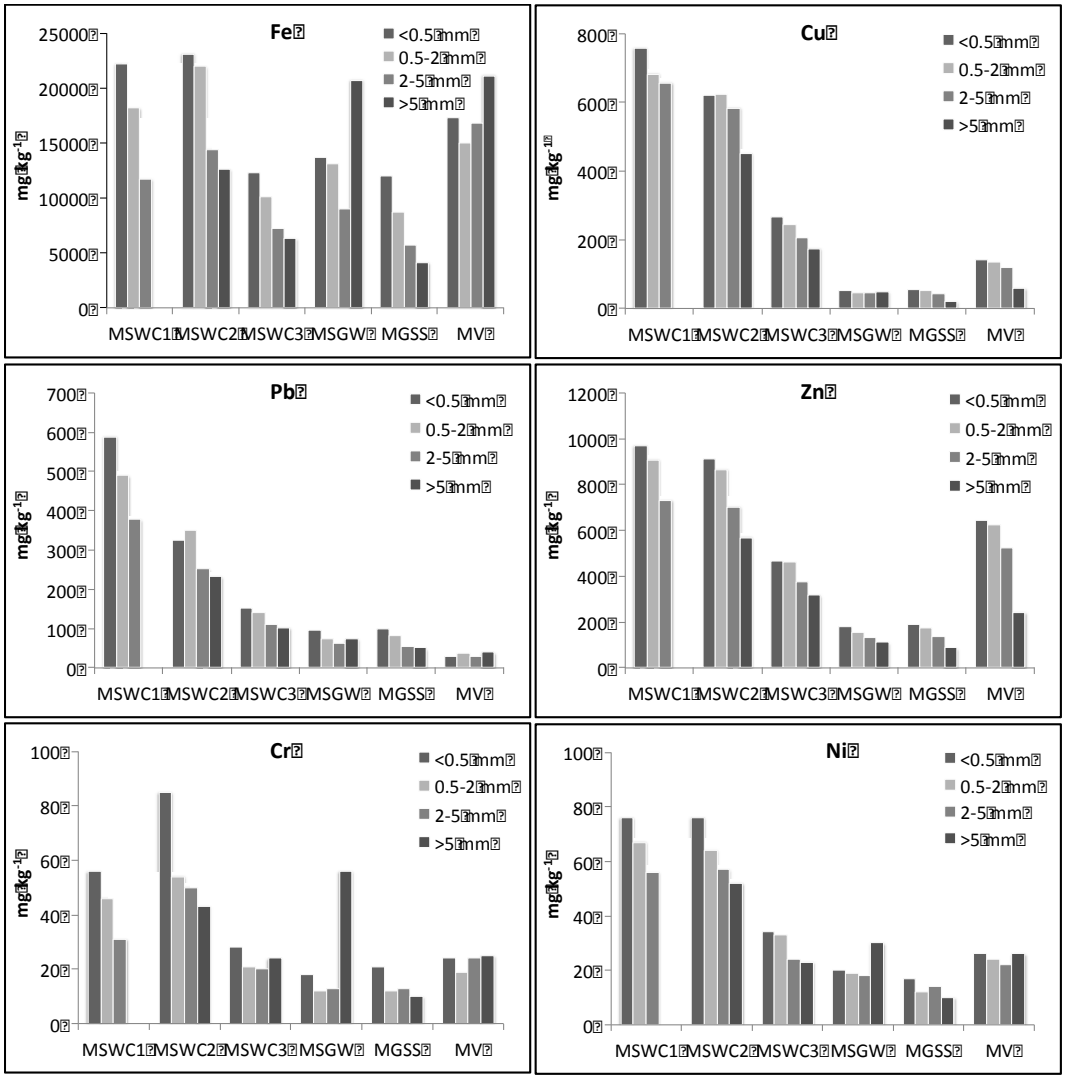

Figure 1. Trace elements contents in the composts' size fractions.

As shown in Figure 1, trace elements were unevenly distributed among the composts particle size fractions. The highest concentrations of Fe appeared in the finer fractions (< 2 mm) for MSWC1, MSWC2, MSWC3 and MGSS, whereas MV and MSGW had the highest concentrations in the > 5 mm fraction. Regarding Cu, its concentrations remained fairly constant in the fractions of the compost MSGW, but increased in the finer fractions of the other composts. All the composts showed a consistent trend of increasing Zn concentration with decreasing particle size. The concentrations of Pb showed less clear trends than Zn, but in general the fractions under 2 mm were richer than the fractions over 2 mm, with the exception of the compost MV, for which no differences existed. The distribution for Cr was similar to that of Fe, whereas Ni was overall evenly distributed in the different size fractions for all the composts.

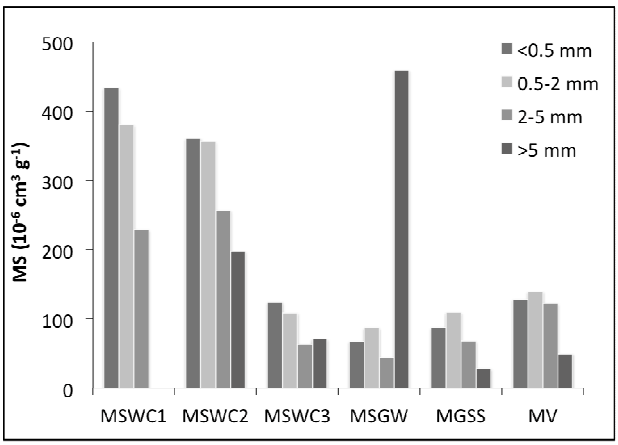

Figure 2. Magnetic susceptibility (MS) of the composts' size fractions.

In general, magnetic susceptibility decreased with increasing particle size, as shown in Figure 2 (it must be noted that there is an abnormal enrichment of the 5 mm fraction in the compost MGSS, probably an iron particle pollution, as confirmed by the high Fe, Ni and Cr contents of this fraction). This trend was very clear for the MSW composts, and less clear for the compost MGSS and MSGW (which include green waste in their composition), whereas no differences were observed in the manure compost. This suggests that the association of trace elements and magnetic susceptibility is a characteristic feature in municipal solid waste composts.

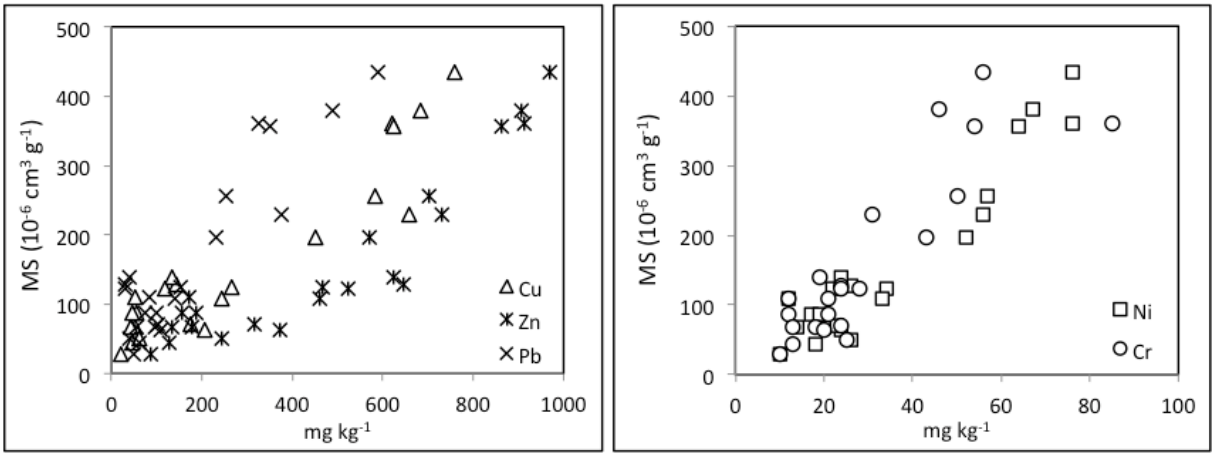

Figure 3. Relationships between trace element contents and magnetic susceptibility (MS) in the composts' size fractions.

Although the correlation of magnetic susceptibility with Fe was good (not shown), this property was better correlated with Cu, Zn, Pb, Cr and Ni (Figure 3). These relationships were clearer for those samples with the highest trace element contents, i.,e., at concentrations above 200 mg kg^{-1} for Cu, Pb and Zn, and above 30 mg kg^{-1} for Cr and Ni. The existence of a correlation between trace element concentrations and magnetic susceptibility does not demonstrate that heavy metals in composts are

exclusively associated to ferric particles (except for Cr and Ni, which could be mostly present in Fe alloys, as confirmed by their low solubility in the composts [12]), but rather that metallic particles are their main origin and source. These elements enter the compost pile at the beginning of composting associated to ferric particles and/or oxides, and afterwards some of them (Cu, Pb, Zn) can migrate due to changes in the physicochemical conditions during the composting process, in particular into the organic fraction, therefore changing their distribution within the compost fractions. In consequence, in the finished composts, the fraction associated to metallic particles could be lower that at the beginning of the process, even though high correlations with magnetic susceptibility remain, showing their common origin.

Conclusion and perspectives

Magnetic susceptibility and trace element concentrations decreased with increasing particle size in six composts produced from different feedstocks, mainly urban wastes. The significant correlations found between trace element contents and magnetic susceptibility demonstrate a relationship between the presence of ferric particles and trace element contamination in compost. Comparison of the results among composts with different compositions suggested that the association of trace elements and magnetic susceptibility is characteristic to municipal solid waste composts.

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