J. Elementol. 2008, 13(1): 117–125

DIRECT AND RESIDUAL EFFECT OF MUNICIPAL SOLID WASTE COMPOST ON THE LEAD CONTENT OF SOIL AND PLANTS

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Abstract

The objective of this study was to determine the possibility of using composts obtained from heterogeneous municipal wastes for agricultural purposes. The study involved an analysis of the lead content of plants grown in soil enriched with municipal solid waste compost heap-stored for different periods of time, compost obtained from municipal green waste, and manure. Municipal waste compost was applied at the rates of 10, 20 and 30 $g \cdot kg^{-1}$ soil, while the compost obtained from green waste was administered at a rate of 10 $g \cdot kg^{-1}$ soil. Maize and sunflowers were grown in the first year of the experiment, spring barley and white mustard – in the second year, and *Phacelia tanacetifolia* – in the third year.

It was found that compost produced from municipal green waste had a substantially higher lead content compared to municipal solid waste compost, although both types of composts could be used for agricultural purposes in accordance with the relevant trade standards. The application of bio-waste composts increased the lead content of the green tops of all investigated crops. The accumulation of this element was dependent on plant species, as well as on the type and rate of compost. The highest lead concentrations were recorded in mustard, slightly lower in maize and phacelia, lower in sunflowers and the lowest – in barley. In the case of barley, mustard and phacelia, the highest lead content was reported in pots amended with municipal waste compost heap-stored for 3 months. With respect to maize, such an effect was observed after the application of compost stored for 1 month, whereas in sunflowers – after soil enrichment with compost obtained from urban green waste. At the completion of the experiment, the largest amounts of lead were found in soil amended with municipal solid waste compost heap-stored for 6 months. Soil enriched with compost produced from urban green waste contained on average 14% lead more than soil amended with identical rates of municipal waste compost stored for 6 months.

Key word: lead, municipal compost, plant, soil.

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BEZPOŚREDNI I NASTĘPCZY WPŁYW KOMPOSTÓW Z ODPADÓW KOMUNALNYCH NA ZAWARTOŚĆ OŁOWIU W GLEBIE I ROŚLINACH

Abstract

Oceniano przydatność kompostów z nieselekcjonowanych odpadów komunalnych w rolnictwie. Oceny tej dokonano na podstawie zawartości ołowiu w roślinach nawożonych kompostami z odpadów miejskich o różnym stopniu dojrzałości, kompostem z zieleni miejskiej oraz obornikiem. Komposty z odpadów komunalnych stosowano w dawkach: 10, 20 i 30 $g \cdot kg^{-1}$ gleby, kompost z zieleni miejskiej w dawce 10 $g \cdot kg^{-1}$ gleby. W pierwszym roku doświadczenia uprawiano kukurydzę i słonecznik, w drugim roku jęczmień i gorczycę, w trzecim roku – facelię.

Wykazano, że kompost z zieleni miejskiej zawierał znacznie więcej ołowiu, w porównaniu z kompostami z odpadów miejskich, aczkolwiek oba rodzaje kompostów zgodnie z Normą Branżową kwalifikowały się do rolniczego wykorzystania. Nawożenie kompostami z bioodpadów spowodowało podwyższenie zawartości ołowiu w zielonej masie wszystkich uprawianych roślin. Kumulacja tego pierwiastka zależała od gatunku rośliny, rodzaju kompostu oraz dawki. Najwięcej ołowiu zawierała gorczyca, zbliżone zawartości tego metalu stwierdzono w kukurydzy i facelii, mniej ołowiu zawierał słonecznik, najmniej zaś jęczmień. W jęczmieniu, gorczycy i facelii najwyższą koncentrację ołowiu stwierdzono w obiektach nawożonych 3-miesięcznym kompostem z odpadów komunalnych. W kukurydzy taki efekt zaobserwowano po zastosowaniu kompostu 1-miesięcznego, a w przypadku słonecznika po zastosowaniu kompostu z zieleni miejskiej. Po zakończonym cyklu badawczym najwięcej ołowiu pozostało w glebie użyźnianej 6-miesięcznym kompostem z odpadów komunalnych. Gleba użyźniona kompostem z zieleni miejskiej zawierała średnio o 14% więcej ołowiu, w porównaniu z glebą, do której wprowadzono identyczne dawki półrocznego kompostu z odpadów komunalnych.

S ł o w a k l u c z o w e : ołów, komposty z odpadów komunalnych, roślina, gleba.

INTRODUCTION

Municipal waste contains large amounts of organic matter, which, from the point of view of economy as well as ecology, should be used for environmental purposes (LEKAN, KACPEREK 1990, Drozd et al. 1999). Composts produced from municipal soil waste to be used in agriculture should meet the criteria determined by the standard norm (BN 89/9103-09) which specifies their reaction, content of nutrients and permissible concentrations of heavy metals. Lead is one of the elements which are frequently determined in composts produced from municipal waste. This is a metal which demonstrates extreme toxicity in natural environment (FERGSSON 1990). Excessive amounts of lead in soil not only cause changes in the biological properties of soil but also modify the uptake of macro- and microelements by plants, which affects their growth and development. Lead is relatively less toxic to emerging plants, but in heavily polluted areas such an adverse effect on new plants can be observed (WOŹNY 1995). Lead is often reported to be highly mobile in acidic soils (BRÜMMER 1986, BASTA, TABATABAI 1992).

The objective of the study has been to determine the concentration of lead in aerial parts of crop plants growing in soil fertilised with composts produced from municipal solid and green waste.

MATERIAL AND METHODS

The study consisted of a 3-year pot experiment, in which soil was fertilised with Dano, a compost produced from heterogeneous municipal waste using the MUT biothermal method, or with a compost produced from municipal green waste. The experiment was carried out in a greenhouse at the University of Warmia and Mazury in Olsztyn. For the trials, Kick-Brauckman pots were filled with 10 kg of soil each. A more detailed description of the soil can be found in the previous paper (SĄDEJ et al. 2004). Composts produced from municipal solid waste matured in heaps for 1, 3 and 6 months. They were applied in three rates: 10, 20 and 30 $g \cdot kg^{-1}$, which corresponded to 30, 60 and 90 $t \cdot ha^{-1}$. The compost based on green waste, which matured in a heap for half a year, was administered at 10 $g \cdot kg^{-1}$ of soil (30 $t \cdot ha^{-1}$). The effect of the composts was compared to that generated by a natural fertiliser, FYM, which was applied at the rates balanced in terms of organic carbon with the lowest rates of the composts. All the composts were used in the first year of the trials, when maize and sunflower were grown. These crops were followed by spring barley and white mustard in the second year, and *Phacelia tanacetifolia* in the third year. Maize was harvested at the heading phase, sunflower – at the onset of flowering, spring barley – at the shooting phase, and white mustard and *Phacelia tanacetifolia* were collected at the full flowering phase. The content of lead in the plant material, composts, FYM and soil samples was determined by the atomic emission spectrophotometry with induction activated plasma, using an ICP-AES apparatus (Leeman Labs), in a mixture of HNO_3 and $HClO_4$ acids at a 5 : 4 ratio, in a heating block manufactured by VEL.

RESULTS AND DISCUSSION

It has been found out that the process of composting increased the content of lead by nearly 60% in a six-month old compost compared to the youngest compost (Table 1). It has also been demonstrated that the compost produced from municipal green waste contained nearly twice as much lead as the composts based on solid waste. The content of lead in the soil was within the range accepted as the natural concentration, that is ‘the background’ contamination.

Table 1

Content of lead in composts, FYM and soil used in pot experiment (mg·kg^{-1}d.m.)

Municipal solid waste compost heap-stored for			Green waste compost	FYM	Soil
1 month	3 months	6 months			
121.8	145.2	191.9	281.7	8.40	4.37

Lisk et al. (1992) arrived at contrary results, as they showed that municipal solid waste composts contained more lead than composts produced from green waste. Low concentrations of lead in green waste composts were also implied by Filipek-Mazur and Mazur (2003). The composts produced from municipal solid waste which we analysed contained far less lead that it has been reported by other authors (Rutkowska et al. 2003). Drozd et al. (1996) concluded that the composting process could lead to a four-fold increase in the concentration of this element in a 1-month-old compost compared to fresh compost, but further composting might be accompanied by a gradual decline in the lead concentration.

Studies completed by other researchers (Pinamonti et al. 1997, Kolota et al. 1998, Drozd et al., 1999) suggest that fertilisation of soil with municipal waste composts can produce a varied effect on accumulation of lead in plants. The actual concentration of lead in plants is more strongly correlated with the species of crops rather than the rates of fertilisers.

In our own investigations, fertilisation of soil with municipal waste and green waste composts resulted in raised levels of lead in crops grown immediately after fertilisation treatments as well as those cultivated in the subsequent years. The concentration of lead in plant green matter was to a greater extent modified by the species of a crop rather than the type of compost applied (Figures 1-5).

Maize, which was grown directly after adding the composts to soil, contained the highest levels of lead in the combinations fertilised with the freshest compost. Increasing rates of composts, irrespective of their maturity, raised the content of lead in plants. When green waste compost was used, the concentration of lead was over 9% higher versus the combination with the same rate of six-month old municipal solid waste compost (Figure 1).

Sunflower, which was grown as an aftercrop, contained the highest level of lead in the object fertilised with green waste compost (Figure 2). By increasing the rates of 1- and 6-month-old solid waste composts, a large increment in the lead concentration in sunflower plants was obtained. Higher rates of 3-month-old solid waste compost did not produce such an unambiguous effect. More lead was determined in sunflower grown in soil amended with 10 g of compost per 1 kg^{-1} of soil than in that treated with 20 g·kg^{-1}. Three-month-old compost caused the highest increase in lead in aerial parts of sunflower plants.

Table 2

Total content of lead in the experiment

Object	Rate of compost/FYM ($g \cdot kg^{-1}$ soil)	Application of lead into soil ($mg \cdot pot^{-1}$)	Total uptake of lead by plants ($mg \cdot pot^{-1}$)	Residual amount of lead in soil ($mg \cdot pot^{-1}$)
Control	0	43.70	0.27	43.43
One-month-old municipal solid waste compost				
Compost	10	55.88	0.39	55.49
Compost	20	68.06	0.51	67.55
Compost	30	80.24	0.56	79.68
FYM	15	44.96	0.30	44.66
Three-month-old municipal solid waste compost				
Compost	10	58.22	0.53	57.69
Compost	20	72.74	0.57	72.17
Compost	30	87.26	0.67	86.59
FYM	14	44.88	0.28	44.60
Six-month-old municipal solid waste compost				
Compost	10	62.89	0.38	62.51
Compost	20	82.08	0.35	81.73
Compost	30	101.27	0.41	100.86
FYM	13	44.79	0.29	44.50
Green waste compost	10	71.87	0.37	71.50

Regarding barley, increased rates of 1- and 3-month-old composts caused increased lead levels in plants, with the highest rate of 3-month-old compost raising the concentration of lead over three-fold (Figure 3). The concentration of lead in barley plants fertilised with green waste compost was lower than the control, albeit higher than the levels detected in barley treated with 6-month-old Dano compost applied at 10 $g \cdot kg^{-1}$ soil. Barley plants from the latter object were determined to have only trace amounts of lead. In FYM fertilised barley, the content of lead was similar to that in the control.

White mustard contained the highest concentrations of lead among all the analysed crops. There was one exception, however. White mustard from the control object had only trace amounts of this metal (Figure 4). All the types of composts caused increased levels of lead in white mustard. The sharpest rise in the lead concentration in this plant occurred after fertilisation with the compost heap-stored for 3 months. Increasing

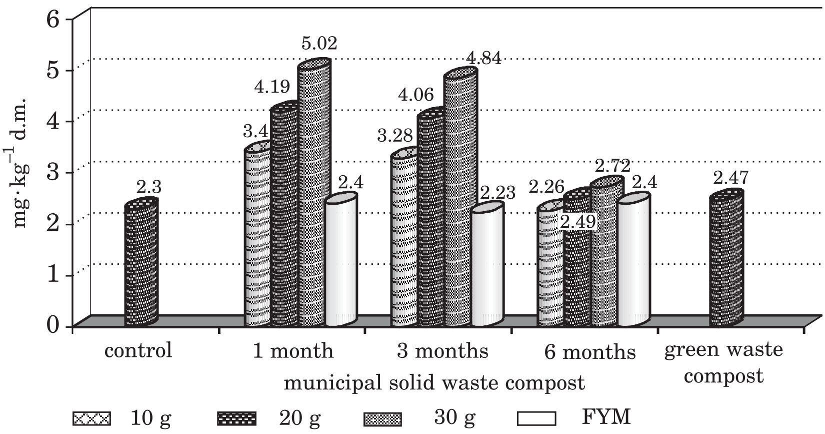

Fig. 1. Content of lead in maize (*Zea mays*)

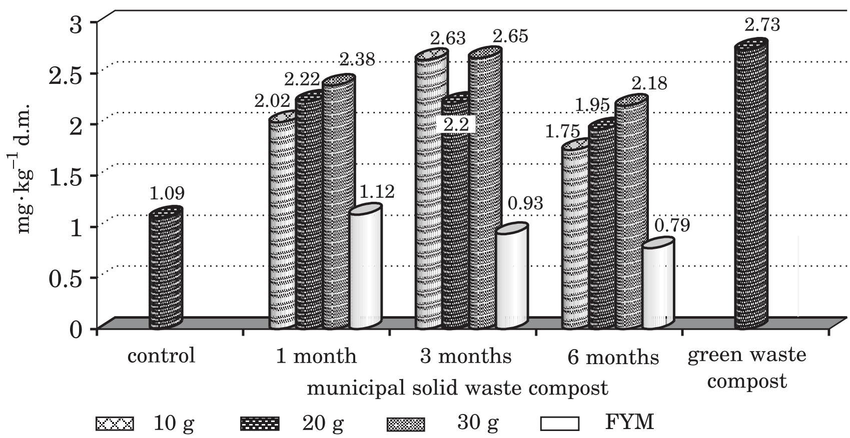

Fig. 2. Content of lead in sunflower (*Helianthus annuus*)

rates of the composts, independent of their maturity, were followed by depressed concentrations of lead in white mustard dry matter. In the plants fertilised with green waste compost, the content of lead was 0.7 mg·kg^{-1} d.m. lower compared to the plants fertilised with 6-month-old compost produced from solid waste.

The concentration of lead in *Phacelia tanacetifolia* ranged between 1.12 and 4.25 mg·kg^{-1}d.m. Analogously to white mustard, fertilization with higher rates of composts resulted in lower lead concentrations in plant tissues. The most severe lead contamination of phacelia was observed after the fertilization treatment involving 3-month-old compost. The content of lead in phacelia fertilized with FYM was only slightly different from the control.

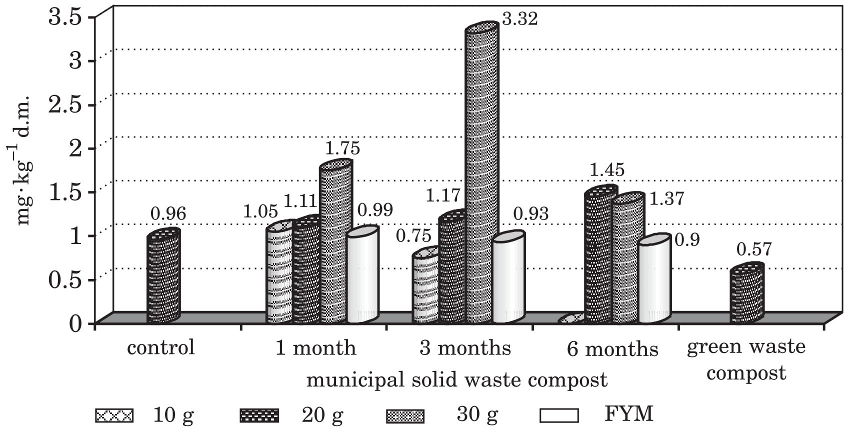

Fig. 3. Content of lead in spring barley (*Hordeum sativum*)

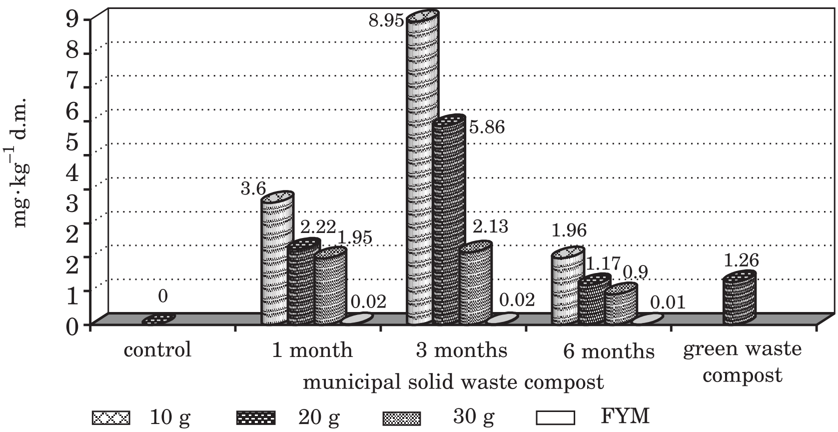

Fig. 4. Content of lead in white mustard (*Sinapis alba*)

JAMROZ et al. (2004) emphasize that when applying municipal waste composts in agriculture special attention should be paid to edible plants due to a possible risk of heavy metal pollution. Their studies proved that, regardless fertilization rates, municipal waste composts increased lead concentrations in green lettuce to such a level that the crop became unsuitable for consumption. Other crops, such as cabbage and celery, were observed to contain elevated levels of lead following fertilization with composts, but in that case the differences were not statistically significant. Our own research clearly shows that it is necessary to take into consideration levels of heavy metals contained in municipal waste composts when designing fertilization rates. A simplified balance of lead we prepared

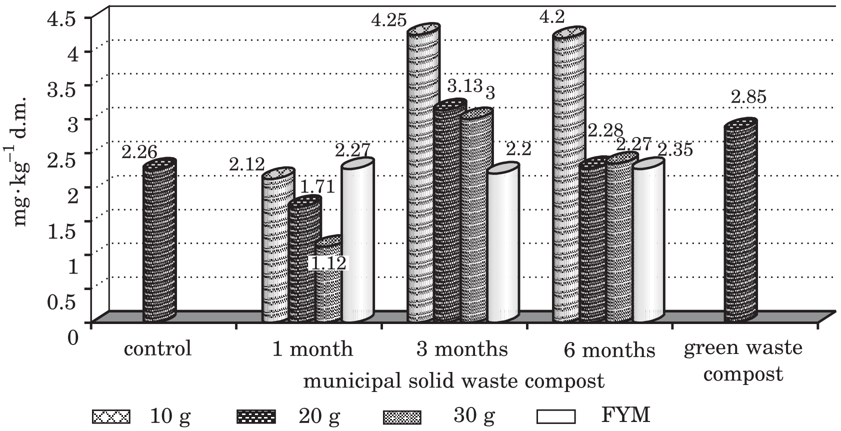

Fig. 5. Content of lead in phacelia (*Phacelia tanacetifolia*)

makes it evident. It shows that increased fertilization rates of composts resulted in increased content of lead in fertilized soil, which persisted for a few years after the fertilization treatments (Figure 2). The highest residual amounts of lead were found in soil fertilized with the oldest compost, which was a consequence of its initial composition (Table 1). The lead balance elaborated for the object treated with municipal green waste compost was similar.

CONCLUSIONS

1. The content of lead in the composts did not exceed permissible concentrations set in the standard norm. The green waste compost contained nearly twice as much lead as the municipal solid waste composts.

2. Fertilization of soils with the composts caused increased levels of lead in the dry matter of crops. The actual accumulation of this element by plants depended on their species, type of compost and fertilization rates.

3. The concentrations of lead were the highest in white mustard, lower in maize, *Phacelia tanacetifolia* or sunflower and the lowest – in barley. Maize grown immediately after fertilization contained the highest levels of lead in the objects treated with 1-month-old compost. In the aftercrops, such results were observed after the application of 3-month-old compost.

4. When the trials had been terminated, the highest concentration of lead in soil was discovered in the soil treated with 6-month-old compost made from municipal solid waste. The soil fertilized with municipal green

waste compost contained on average 14% less lead than the soil which received identical rates of 6-month-old solid waste compost.

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