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Research Article

DOES COMPOSTING OF BIODEGRADABLE MUNICIPAL SOLID WASTE ON THE LANDFILL BODY MAKE SENSE?

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ABSTRACT
In this study white mustard (*Sinapis alba*) plants were allowed to grow in earthen pots, treated with municipal solid waste compost (MSWC) to study the effect of MSWC on the plant biomass production. Twenty-one days from the establishment of the experiment sprouts and the number of growing plants occurring in the earthen pots were counted. Plants growing in the earthen pots with the compost samples exhibited an increasing plant biomass while no changes were observed in their appearance; retarded growth or necrotic changes were not recorded. The performed phytotoxicity tests show that the analyzed composts produced in the composting plant situated on the landfill surface achieved high percentages of the germinating capacity of white mustard (*Sinapis alba*) seeds and can be therefore used in the subsequent reclamation of the concerned landfill.

Keywords: waste, household waste recycling, phytotoxicity, *Sinapis alba*, landfill reclamation.

INTRODUCTION

Sanitary landfills, as a method of disposal, are standard practice in today's waste management. The large amounts of municipal solid waste (MSW) generated and the potential for landfills to be a future source of problems indicate that this approach may not be sustainable [Das et al. 2002]. MSW is largely made-up of kitchen and yard waste, and its composting has been adopted by many municipalities [Otten 2001]. Composting of MSW is seen as a method of diverting organic waste materials from landfills while creating a product, at relatively low-cost, that is suitable for agricultural purposes [Eriksen et al. 1999, Wolkowski 2003]. MSW composting has proved to be a safe and effective way to reduce MSW in large quantities and produce a stable humus-like material, beneficially reused as a soil amendment. As an alternate soil amendment, MSW compost is gaining high popularity [Zhao et al. 2012].

This trend may be attributed to economic and environmental factors, such as municipal landfill capacity; costs associated with landfilling and transportation of materials; adoption of legislation to protect the environment; decreasing the use of commercial fertilizers; increasing the capacity for household waste recycling and improved quality of compost products [Otten 2001, He et al. 1992, Hansen et al. 2006, Zhang et al. 2006].

A significant interest towards the use of municipal solid waste compost (MSWC) application for agricultural purposes is getting popular due to the dearth of availability of conventionally used raw materials for compost preparation [Gigliotti et al. 1996, Hargreaves et al. 2008, Karak et al. 2013, Karak et al. 2014, Lakhdar et al. 2010]. On the other hand, the growing interest on MSWC application is associated with an element of concern, which is the presence of considerable amount of heavy metals. MSWC often contains potentially toxic metals that can cause phytotoxicity, soil contamination, and accumulation in plant and animal products [Karak et al. 2013, Topcuoğlu 2005, Zhao, Duo 2015, Carbonell et al. 2011, Jordao et al. 2006, Kabata-Pendias, Pendias 2001, Khan 2001, Laborda et al. 2007, Shanker 2005]

Studies have shown several beneficial effects of MSWC towards better crop management, as it may be considered as a source of different major nutrients and micronutrients to plants [Hargreaves et al. 2008, Hicklenton et al. 2001, Zhou et al. 2013]. Therefore, the advantages or disadvantages of using MSWC as fertilizer and soil amendment should be evaluated with the possible environmental and toxicological impacts together, due to the presence of potentially toxic elements such as heavy metals [Karak et al. 2013].

At present, legislative measures in different countries prohibit the application of MSWC to arable soils and as such, these organic materials have been widely utilized in land reclamation activities. As a matter of fact, the presence of considerable residual concentrations of heavy metals (including Cd, Cr, Cu, Ni, Pb and Zn) in these organic materials is the main problem associated with their application to soil. These heavy metals can be leached through the soil profile, transported in drainage waters, and may pollute groundwater, or they can accumulate in the upper soil layer and can be toxic to plants and soil microbial biomass [Businelli et al. 2009].

The overall objectives of the present study were: (1) to characterize and to evaluate MSWC produced on the landfill body, (2) to investigate the phytotoxicity of the compost and finally, (3) to evaluate the possibility of using this compost to landfill reclamation. The eco-toxicological impact of the compost was evaluated by plant growth tests with white mustard (*Sinapis alba*).

MATERIAL AND METHODS

Site description

The Kuchyňky landfill is situated in a triangular space delimited by main roads connecting the villages of Zdounky, Nětčice and Troubky-Zdislavice at a distance of ca. 1800 m NNW of the church in Zdounky, 750 m NNW of the built-up area limits in Zdounky and 450 m SW of the boundary line of Nětčice (Figure 1). In terms of maintenance, the landfill is classified in the S-category – other waste, sub-category S-OO3. The designed area of the landfill is 70 700 m^2 in five stages with a total volume of 907 000 m^3, i.e. ca. 1 000 000 10^3 kg of waste. Up to now, Stage I of 19 200 m^2 has been constructed together with parts of Stage II (5500 m^2) and Stage III (7500 m^3). Planned service life of the facility is up to year 2018.

The facility receives waste (category of other waste) from a catchments area with the population of ca. 75 000 residents. The annually deposited amount of waste is ca. 40 000 10^3 kg of which 50% are from the communal sphere. The approved landfill sector for waste of sub-category S-OO1 has not been opened yet. The sector will be intended for the disposal of waste (category of other waste) with the low content of organic biologically degradable substances. A sector of the landfill will be intended largely for the disposal of asbestos-containing wastes, gypsum-based waste, stabilized waste, waste with the high sulphur

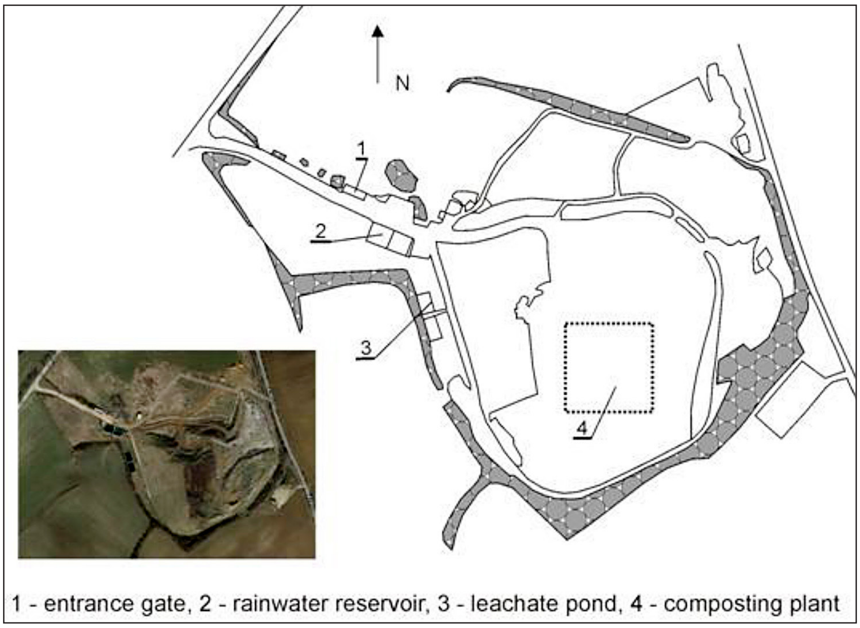

Figure 1. Scheme and aerial photograph (insert) of the landfill site

content and waste with the increased content of metals. Waste with the substantial content of organic biologically degradable substances must not be stored in that sector.

Composting at the landfill body

The composting plot is located on the landfill body surface. Composted materials are biologically degradable wastes (BDW) that are transported from the surrounding towns and villages. They mainly consist of greenery from the maintenance of towns and villages and also of biologically degradable communal waste collected from households in the refuse collection area. The estimated capacity of wastes received by this composting plant is 2.000 10^3 kg/year. The facility is designed for the collection, purchase and exploitation of waste – waste management code R3 pursuant to Annex 3 of the Waste Law as amended.

The composting plant is situated within the II b stage plot of the landfill (Figure 2). On this site, waste disposal had been terminated; the plot was subjected to ground shaping, covered with earth and recycled material, and compacted. The size of the composting plant is 20×35 m. According to conditions (amount of compostable waste), 6–8 compost back fills were established of triangular profile sized 30×1.5 m and a height of 0.8 m (Figure 3).

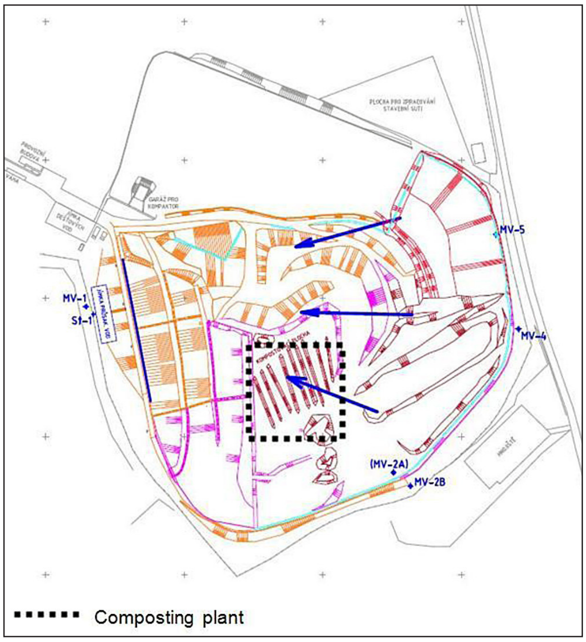

Figure 2. Location of composting plant

Phytotoxicity test

Phytotoxicity of compost (sieved and not sieved) (Figure 4) was investigated by means of a set of biological tests using white mustard (*Sinapis alba*) as the test plant. The possible toxicological effect of compost was assessed according to CSN EN 13432 on the growth of dicotyledonous plants. Reference soil was composed of commercial potting soil and silica sand (8:2) and thoroughly mixed. The medium was commercial potting soil for germination and plant growth and silica sand (8:2), enriched with compost (25%, 50% w/w). Soil without compost was used as a control. Each earthen pots of diameter 11 cm and height 10 cm were loosely filled with 200 g of medium, then 100 seeds were scattered on to the surface, covered with a thin layer of silica sand and the earthen pots were covered with a glass plate (to avoid evaporation). Glass plates were removed when the germinated plants touched them. Plants were grown under controlled conditions for 21 days. Humidity at level of 70–100% of water absorption capacity, low light intensity, and the laboratory temperature were maintained to be constant. Values obtained from two simultaneously conducted experiments were averaged and presented (germination capacity). Photographs were taken to document the establishment of the trial. During the experiment, evaporated water was regularly added as needed.

Plant material

Seeds used as plant material for testing were commercial seeds of white mustard (*Sinapis alba*). Seeds were surface-sterilized by soaking for 2 min in a commercial sodium hypochlorite (2%) solution wit a few drops of Tween-20. Then they were rinsed twice in sterile distilled water.

Figure 3. Composting piles

Figure 4. Samples of sieved and not sieved compost

RESULTS

Compost samples were taken from the composting plant in the Kuchyňky landfill for chemical analyses, which were conducted in the testing laboratory of Laboratoř MORAVA s.r.o. authorized by the Czech Accreditation Institute.

Results from the analyses of compost samples - mixed compost sample (the samples were collected from different compost piles by crap sampling method) and compost - are presented in Table 1 and Table 2.

The compost produced in the given composting plant was sampled. The samples were designated as A-samples (August 2014): A1 – mixed compost sample, A2 – compost, and B-samples (September 2014): B1 – mixed compost sample, B2 – compost. The samples were collected into sterilized plastic containers. Then they were designated and brought to the laboratory at Mendel University in Brno, Department of Applied and Landscape Ecology where they were kept at a temperature of –4 °C until the Phytotoxicity test.

After 14 and 21 days, germinating capacity of seeds and plant growth were assessed for A samples (A1 and A2) and B-samples (B1 and B2). Germinating capacity was evaluated and the course of the experiment was documented photographically. Germinating capacity and growth of white mustard (*Sinapis alba*) are shown in Figure 5. The resulting counts of individual A1 and A2 samples were recorded (Table 3). The same procedure was used also for samples B1 and B2 (Table 4).

The obtained data served for the calculation of values and evaluation of results. The numbers

Table 1. Average results of the analysis of mixed compost sample

Parameter	Result	Unit	Testing method identification	Accr.
As	5.2	mg/kg DM	SOP 02 C (ČSN EN ISO 15586)	A*
Cd	0.64	mg/kg DM	SOP 02 C (ČSN EN ISO 5961)	A
Cr	35.3	mg/kg DM	SOP 23 C (ČSN EN 1233)	A
Cu	40.4	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Hg	0.116	mg/kg DM	SOP 03 (ČSN 465735, ČSN721227)	A
Ni	21.8	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Pb	29.5	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Zn	174	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Humidity	42.38	%	SOP 32 C (ČSN EN 12879)	A
pH	8.39	–	SOP 44 (JPP – ÚKZÚZ, Brno)	A
K	12.6	g/kg DM	SOP 28 B (JPP – ÚKZÚZ, Brno)	A
P	2.77	g/kg DM	SOP 62 A (JPP – ÚKZÚZ, Brno)	A
Combustibles matters	20.5	% in DM	SOP 32 (ČSN EN 12879)	A
N_{total}	1.18	% in DM	SOP 61 A (JPP – ÚKZÚZ, Brno)	A
C:N	9	–	SOP 85 (JPP – ÚKZÚZ, Brno)	N**

Mixed sample – taken from randomly selected places in the compost.
* A – accredited test, ** N – non-accredited test, DM – dry mass.

Table 2. Average results of the analysis of compost sample

Parameter	Result	Unit	Testing method identification	Accr.
As	5.45	mg/kg DM	SOP 02 C (ČSN EN ISO 15586)	A*
Cd	0.67	mg/kg DM	SOP 02 C (ČSN EN ISO 5961)	A
Cr	34.3	mg/kg DM	SOP 23 C (ČSN EN 1233)	A
Cu	40.3	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Hg	0.114	mg/kg DM	SOP 03 (ČSN 465735, ČSN721227)	A
Ni	22.2	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Pb	28.9	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Zn	174	mg/kg DM	SOP 23 C (ČSN ISO 8288)	A
Humidity	42.38	%	SOP 32 C (ČSN EN 12879)	A
pH	8.37	–	SOP 44 (JPP – ÚKZÚZ, Brno)	A
K	15.5	g/kg DM	SOP 28 B (JPP – ÚKZÚZ, Brno)	A
P	6.82	g/kg DM	SOP 62 A (JPP – ÚKZÚZ, Brno)	A
Combustibles matters	28.5	% in DM	SOP 32 (ČSN EN 12879)	A
N_{total}	1.17	% in DM	SOP 61 A (JPP – ÚKZÚZ, Brno)	A
C:N	12	–	SOP 85 (JPP – ÚKZÚZ, Brno)	N**

* A – accredited test, ** N – non-accredited test, DM – dry mass.

Figure 5. Illustration of the germinating capacity of *Sinapis alba* seeds

of sprouts (number of growing plants) were compared for all mixing ratios of compost samples (A and B) and on compost from the blind experiment. Germinating capacity was calculated as a percentage of corresponding values obtained from the compost in the blind experiment.

Tables 5 and 6 show average values calculated from experimental results and include also percentages of germinating capacity for the individual analyzed samples.

The highest germinating capacity (99%) of white mustard (*Sinapis alba*) seeds was recorded after 21 days in sample A2 with 25% of compost, and the highest germinating capacity (91%) after

Table 3. Results of the germinating capacity of *Sinapis alba* (samples A)

Samples – August 2014	Summary – germination test	
25%	14 days	21 days
Blank 1	87	91
Blank 2	80	84
A2 25a	77	79
A2 25b	92	94
A1 25a	72	83
A1 25b	79	78
50%	14 days	21 days
Blank 1	87	91
Blank 2	80	84
A2 50a	77	78
A2 50b	79	81
A1 50a	60	64
A1 50b	73	76

Table 4. Results of the germinating capacity of *Sinapis alba* (B)

Samples – September 2014	Summary – germination test	
25%	14 days	21 days
Blank 1	64	80
Blank 2	60	92
B2 25a	57	84
B2 25b	49	88
B1 25a	53	82
B1 25b	48	82
50%	14 days	21 days
Blank 1	64	80
Blank 2	60	92
B2 50a	56	88
B2 50b	60	86
B1 50a	54	87
B1 50b	58	84

Table 5. Average values and percentages of the germinating capacity of *Sinapis alba* (samples A)

Samples – August 2014 – Mean	Summary – germination test		Percent number of seeds germinated	
25%	14 days	21 days	14 days	21 days
Blank	84	88	–	–
A2 25	85	87	101	99
A1 25	76	81	90	92
50%	14 days	21 days	14 days	21 days
Blank	84	88	–	–
A2 50	78	80	93	91
A1 50	67	70	80	80

Table 6. Average values and percentages of the germinating capacity of *Sinapis alba* (samples B)

Samples – September 2014 – Mean	Summary – germination test		% number of seeds germinated	
25%	14 days	21 days	14 days	21 days
Blank	62	86	–	–
B2 25	53	86	85	100
B1 25	51	82	81	95
50%	14 days	21 days	14 days	21 days
Blank	62	86	–	–
B2 50	58	87	94	101
B1 50	56	86	90	100

21 days was recorded in sample A2 with 50% of compost.

The highest germinating capacity (100%) of white mustard (*Sinapis alba*) seeds was recorded after 21 days in sample B2 with 25% of compost, and the highest germinating capacity (101%) after 21 days was recorded in sample B2 with 50% of compost.

Figure 6 presents percentages of the germinating capacity of white mustard (*Sinapis alba*) seeds (25%, 50% of compost A1 and A2) after 14 days from the beginning of the experiment and after 21 days (end of the experiment).

The highest germinating capacity of seeds was achieved in sample A2 25 both after 14 days (101%) and after 21 days (99%). The second and third highest values of seed germinating capacity were nearly identical for sample A1 25 and sample A2 25 with the germinating capacity of seeds ranging from 90–93%. Sample A1 50 exhibited the lowest germinating capacity of seeds both after 14 days (80%) and after 21 days (80%) from the establishment of the trial. Pursuant to the standard, values below 90% are considered slightly toxic.

Figure 7 presents percentages of the germinating capacity of white mustard (*Sinapis alba*) seeds (25% and 50% of compost in B1 and B2) after 14 days from the beginning of the experiment and after 21 days (end of the experiment).

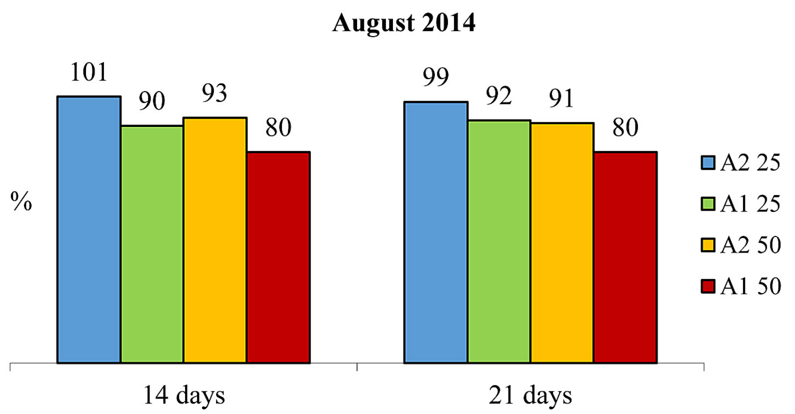

Figure 6. Comparison of the germinating capacity of seeds in A compost samples

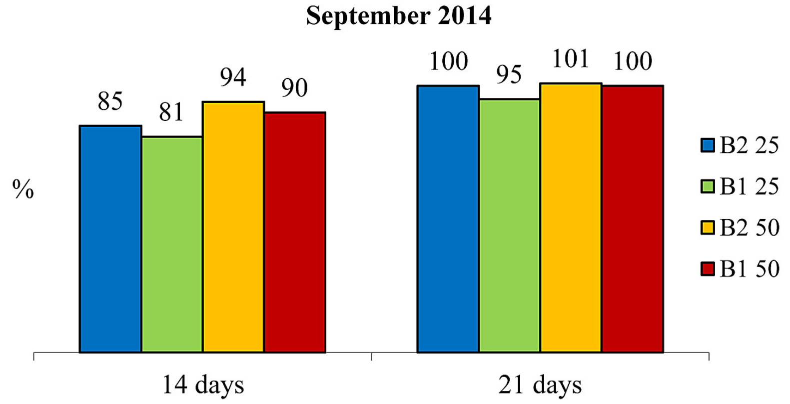

Figure 7. Comparison of the germinating capacity of seeds in B compost samples

The highest germinating capacity of seeds was achieved in sample B2 50 both after 14 days (94%) and after 21 days (101%). The second highest value of seed germinating capacity was found in sample B1 both after 14 days (90%) and after 21 days (100%). Sample B2 25 exhibited the third highest values (14 days – 85%, 21 days – 100%). Sample B1 25 exhibited the lowest germinating capacity of seeds both after 14 days (81%) and after 21 days (95%) from the establishment of the trial.

CONCLUSIONS

The two performed phytotoxicity tests show that the analyzed composts produced in the composting plant situated on the landfill surface achieved high percentages of the germinating capacity of white mustard (*Sinapis alba*) seeds and can be therefore used in the subsequent reclamation of the concerned landfill.

Standard CSN EN 13432 states that the analyzed compost does not exhibit phytotoxicity if the indicator of germinated seeds is not lower than 90%, as compared with plants growing in the control sample. Sample A1 50 exhibited the seed germinating capacity of 80% in both cases. Values below 90% are considered slightly phytotoxic according to the standard. Values below 90% were further found in samples B2 25 (85%) and B1 25 (81%) after 14 days from the beginning of the experiment. However, after 21 days (at the end of the experiment), both samples exhibited values higher than 90% (B2 25 – 100%, B1 25 – 95%). Thus, the samples were not toxic for the plants at the end of the test.

Advantages of composting on the landfill body consist in the full exploitation of landfill space, in landfill security and in the used technology. Biologically degradable waste is not stored in the landfill, which is the main objective of European regulations concerning the management of biologically degradable waste, but its material is exploited (landfill reclamation). This method brings benefits of both economic (transportation costs, building of composting plant, technical support) and environmental character (emissions during transport and handling, fuel consumption, dustiness, noise etc.).

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