The sanitation effect of vermicomposting of sewage sludge from a medium-sized WWTP with and without the pre-composting phase – a case study

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Introduction

► A mixture of 1 m^3 of anaerobically stabilized dewatered sludge from a medium-sized WWTP (33 thousand e.p.) and 1.5 m^3 of wood chips was subjected to the vermicomposting process with and without the pre-composting phase. Only composted material was also tested.
► The resulting mixture with a volume of 2.5 m^3 was divided into two parts. One cubic meter of the mixture was placed directly in segment B of a field vermicomposter (***Fig. 1***).
► The second portion of mixture with a volume of 1.5 m^3 was subjected to pre-composting in a covered hall. The pre-composting process was controlled by the oxygen concentration in the bed. The temperature maximum reached 64°C.
► After 4 weeks 1 m^3 from this pre-composted mixture was placed in segment A of the field vermicomposter and the remaining 0.5 m^3 was left in the plastic container in the hall as a control without earthworms.
► Vermicomposting took place in so-called wedge system where earthworms from the inoculum migrate to the new bed horizontally. Vermicomposted sewage sludge mixed with straw from the previous year of the experiment served as the *Eisenia andrei* inoculum (***Fig. 2***).
► Sanitation potential of these processes was tested using specially prepared polyethylene cartridges (***Fig. 3***) containing sterile medium (mixture of vermicompost and sludge) and *E. coli* inoculum of initial concentration (2.7±0.4 x10^6 CFU/g) placed inside the composted and vermicomposted pile. The perforation of the cartridge (PC) allowed the earthworms to move in and out freely.
► To distinguish the effect of earthworm activity and other factors, the same number of cartridges containing polyester fabric (PCF) was added to prevent earthworm from entering . Five parallel samples for each variation (PC and PCF) were taken during each sampling campaign. The same amount of artificially contaminated medium in five parallels for each sampling campaign was left in the closed Petri dishes under laboratory conditions as a control.
► In addition to the test with artificially introduced *E. coli*, the content of hazardous substances and pathogens and other composting parameters focused on nutrient content and biological stability were monitored in the treated mixture.

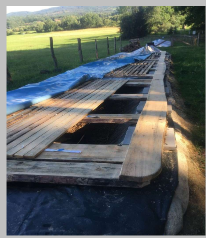

Fig. 1*: Field experiment*

Fig. 2*: Eisenia andrei*

Fig. 3*: Cartridges for measurement of the sanitation potential*

Results & Discussion

► All tested variants met the criteria for the application of treated sludge to agricultural land according to the Czech legislation (Ministry of the environment, 2021) after 6 months of the experiment (***Table 1***). According to agronomic parameters, the result of the process is, in general, quality compost, for all tested variants. However, in the composted sludge (C), a higher value of conductivity and $N\text{-}NH_4^+$ concentration was observed in comparison with both vermicomposts (A and B). The highest biological stability (the lowest AT_4) was observed for variant B. The required range (maximum value 30) was exceeded for the C/N ratio (***Table 2***). This is due to the relatively high proportion of wood chips in the treated material. The ratio of 1: 1.5 (v:v) was based on previous experience with bio-drying of sewage sludge to reach the sufficient temperature profile during the thermophilic phase.

Table 1: *Resulting concentrations of hazardous substances and pathogens in all treatments after 6 months of the experiment (mean and SD of 3 parallels)*

	A (pre-composting + vermicomposting)	B (vermicomposting)	C (composting)	Czech legislation limit
As (mg/kg)	5.9 ± 0.2	6.5 ± 0.1	5.6 ± 1.0	**30**
Cd (mg/kg)	0.8 ± 0.0	0.8 ± 0.0	0.7 ± 0.1	**5**
Cr (mg/kg)	34.7 ± 2.9	37.3 ± 0.9	35.1 ± 3.5	**200**
Cu (mg/kg)	140.4 ± 2.8	154.4 ± 6.0	153.3 ± 17.6	**500**
Hg (mg/kg)	1.2 ± 0.8	0.7 ± 0.1	0.8 ± 0.4	**4**
Ni (mg/kg)	23.9 ± 0.2	26.0 ± 0.2	23.2 ± 4.8	**100**
Pb (mg/kg)	34.1 ± 1.3	37.3 ± 1.2	31.2 ± 3.8	**200**
Mo (mg/kg)	4.7 ± 0.3	4.7 ± 0.1	4.4 ± 0.7	
Zn (mg/kg)	564.2 ± 32.3	561.9 ± 7.8	485.3 ± 71.3	**2,500**
PAHs* (mg/kg)	6.3 ± 6.5	4.5 ± 4.1	5.0 ± 1.9	**10**
PCBs** (mg/kg)	n. d.	n. d.	n. d.	**0.6**
AOX (mg/kg)	n. d.	n. d.	0.6 ± 0.9	**500**
Salmonella sp.	negative in 5 samples	negative in 5 samples	negative in 5 samples	**negative in 5 samples**
E. coli (CFU/g)	negative in 5 samples	negative in 5 samples	negative in 5 samples	**$<10^3$ CFU/g in 4 samples and $<5x10^3$ CFU/g in 1 sample**

*sum of anthracene, benzo(a) anthracene, benzo(b) fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, phenanthrene, fluoranthene, chrysene, indeno(1,2,3-cd)-pyrene, naphthalene and pyrene (mg/kg)
**sum of 7 congeners (28+52+101+118+138+153+180)
n.d.: not detected

Table 2: *Results of measuring agronomic parameters in all treatments after 6 months of the experiment (mean and SD of 3 parallels)*

	A (pre-composting + vermicomposting)	B (vermicomposting)	C (composting)
Ca (mg/kg)	24,500 ± 2,205	24,900 ± 1,134	23,867 ± 3,071
Mg (mg/kg)	4,373 ± 69	4,697 ± 121	4,370 ± 542
K (mg/kg)	8,180 ± 350	8,787 ± 349	8,957 ± 1,149
P_{total} (mg/kg)	23,433 ± 1,634	26,200 ± 572	25,067 ± 3,746
N_{total} (mg/kg)	4,247 ± 120	4,347 ± 131	4,090 ± 468
C/N ratio	77.1 ± 3.9	74.2 ± 3.7	68.0 ± 4.1
$N\text{-}NH_4^+$ (mg/kg)	5.9 ± 1.9	5.1 ± 0.9	11.7 ± 2.6
$N\text{-}NO_3^-$ (mg/kg)	2,593 ± 347	3,193 ± 160	3,140 ± 567
Conductivity (mS/m)	65.7 ± 5.7	68.2 ± 1.7	82.9 ± 5.7
TOC (mg/kg)	271,800 ± 7,746	270,143 ± 29,807	250,113 ± 20,471
AT_4 (mgO_2/g/4days)	4.27 ± 1.72	2.37 ± 0.16	5.12 ± 0.20
pH	6.9 ± 1.5	6.4 ± 0.1	6.2 ± 0.0

► The sanitation effect in cartridges with artificially added *E. coli* measured after the first 4 weeks of the experiment (the duration of pre-composting phase) decreased as follows: composted mixture>vermicomposted mixture with PC >vermicomposted mixture with PCF >control. After 6 months of the experiment, the required sanitation effect (a decrease of 5 orders of magnitude) was achieved in all variants (vermicomposted mixture with PC and PCF in segment B and vermicomposted and pre-composted mixture with PC and PCF in segment A). A slight re-increase of *E.coli* content was observed only for variant C (***Fig. 4***).

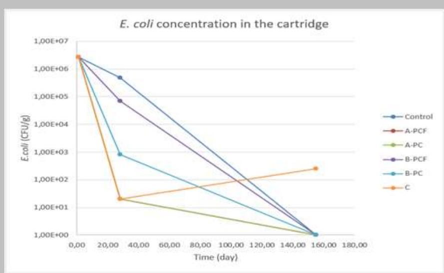

Fig. 4*: Concentration of artificialy added E.coli in cartridges*

Fig. 5*: In the middle of the loading*

Conclusions

► The pre-composting step with the thermophilic phase was not necessary to achieve the sanitation of the sewage sludge during the vermicomposting process.
► Vermicomposted sludge had higher biological stability after 6 months of the process than composted sludge.
► Bio-stabilization of dewatered sewage sludge using earthworms can provide an effective technology for management of this noxious wastewater treatment products.

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