CO-COMPOSTING AS A TECHNOLOGY FOR THE VALORIZATION OF DREDGED SEDIMENTS AND GREEN WASTE: CZECH EXPERIENCE
“LIFE AGRISED LIFE17 ENV/IT/000269”

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In Europe, dredged river sediments and wood pruning residues are produced and accumulated annually in large quantities, approximately 1 and 13 million tons, respectively. Although European policy and International Conventions encourage the re-use of both, only a part of them is recycled. The AGRISED project aims to demonstrate the suitability of dredged sediments co-composted with green waste to produce an innovative growing media for plant nursery and a reconstituted soil (techno-soil) for degraded soil rehabilitation. The composting process was carried out in the Czech Republic with sediments from a small stream located in an urban area (Čejkovice) and green waste biomass (grass, corn cob, wood chips and dry leaves) from local agriculture. After homogenization, the sediments and green waste biomass were mixed at different ratios (w:w): 3:1 = A, 1:1 = B, and 1:3 = C. The co-composting process was monitored in terms of temperature, humidity, bulk density, organic matter, nutrients, microbial activity, and pollutants for approximately 8 months. The stability and maturity of all co-composts have been demonstrated by the decrease and stabilization of organic matter content, electrical conductivity, microbial activity, and increased humification rate. In addition, the germination index approaching 100% and the reduction of C>12 compared to initial contamination in dredged sediment (42 %, 56% and 57% in piles A, B, and C, respectively) were achieved at the end of composting, showing the process as an effective management strategy, transforming dredged sediments and green waste into suitable substrate that can be used as growing media for plant nursery and soil reconstitution.

Keywords: co-composting, dredged sediments, green waste, waste recycling

Introduction

The production of dredged river sediments and wood pruning residues annually reaches about 1 and 13 million tons, respectively, leading to sustainability concerns. In fact, the presence of high concentrations of contaminants in river sediments (SedNet, 2015) and the variable composition of pruning residues (Giagnoni et al. 2020) limits their applications, thus increasing landfill disposal.

The European waste policy encourages the study and application of the circular economy to waste materials through the production of high-quality resources, to reduce the negative impact on environment and human health (Directive 2008/98/CE). Composting can allow the recycling of both dredged river sediments and pruning residues, creating a reclaimed and fertile product that can be used as an organic amendment and organic substrate for non-food agronomic purposes (Onwosi et al. 2017). However, achieving compost stability and maturity is important for its application in non-food agriculture. Stability is related to microbial activity that decreases with the evolution of organic matter into humic substances, while maturity is mainly related to the effect of compost on plant growth as well as the absence of pathogens and toxic compounds (Cesaro et al. 2015; Guo et al. 2019).

The aim of the AGRISED project is to demonstrate the suitability of co-composting process of dredged sediments and pruning residues as well as the production of suitable growing media for plant nursery and a reconstituted soil (techno-soil) for degraded soil rehabilitation.

Materials and Methods

The co-composting was carried out in the Czech Republic. Sediments derived from a stream located in an urban area (Čejkovice) and green waste biomass (grass, corn cob, wood chips and dry leaves) from local agriculture. Sediments (S) and green waste (GW) biomass were mixed and piled at different ratios (*w:w*) as follows: 3S:1GW = pile A, 1S:1GW = pile B, and 1S:3GW = pile C (Figure 1). The co-composting process was carried out for about 8 months (258 days). The results at the start (day 5), in the middle (day 168) and at the end (day 258) of the process are reported in this work.

Figure 1. Compost pile preparation

Electrical conductivity (EC) was measured in the water extract 1:10 (v:v) of fresh samples, after 30 minutes of stirring, using selective electrode. The total nitrogen (TN) was determined on fresh samples through Kjeldahl method, and the total organic carbon (TOC) was detected on dry and 0.2 mm sieved samples after the oxidation of organic matter, using 2 N potassium dichromate and 96% sulphuric acid (temperature of 160 °C for 10 minutes) and titration with 0.2 N ferrous sulfate. The total humus was detected through extraction with 0.05 M sodium pyrophosphate (pH=9) and titration with 0.5N Mohr salt. The humification rate (HR) was calculated as ratio between total humus and TOC. The determination of hydrocarbons with more than 12 carbon atoms was carried out following the official method ISO 16703: 2004 using a GC-FID Trace 1300 instrument with AS 3000 auto sampler (Thermo Scientific). Butyrate esterase activity was measured as total microbial activity, according to the methods of Marx et al. (2001) and Vepsäläinen et al. (2001), based on the use of fluorogenic methylumbelliferyl (MUF)-substrates and 1 mM butyrate esterase (EC 3.1.1.1). A moist sample (equivalent weight to 1 g oven-dry material) was weighed into a sterile jar and covered with 25 ml of deionized water. A suspension was obtained by treating a sample with UltraTurrax (IKA) homogenizer for 1 minute at 9600 g. Aliquots of 100 µL were withdrawn and dispensed into a 96-well microplate. Finally, 100 µL of substrate solution were added giving a final substrate concentration of 500 µM. Fluorescence (excitation 360 nm; emission 450 nm) was measured, after 0, 30, 60, 120, 180 min of incubation at 30 W C, with an automated fluorimetric plate-reader (Infinite F200 pro TECAN).

The germination test was carried out for ecotoxicological test on water extract (1:5, *v:v*) using *Lepidium sativum* seeds, following Hoekstra et al. (2002) method.

Results and Discussion

Temperature monitoring during co-composting revealed a thermophilic phase above 40 °C in all piles, reaching the maximum temperatures of 43.1 °C in pile A after 4 days, 57.3 °C in pile B and 74.3 °C in pile C after 16 days. Particularly, the recommended temperature (> 55°C) for material sterilization was reached (Bernal et al. 2009; Ownsi et al. 2017) in pile B and C. After the thermophilic phase, the temperature dropped in all the piles (cooling phase) suggesting the reduction of easily decomposable organic materials (Meng et al. 2017) (Figure 2).

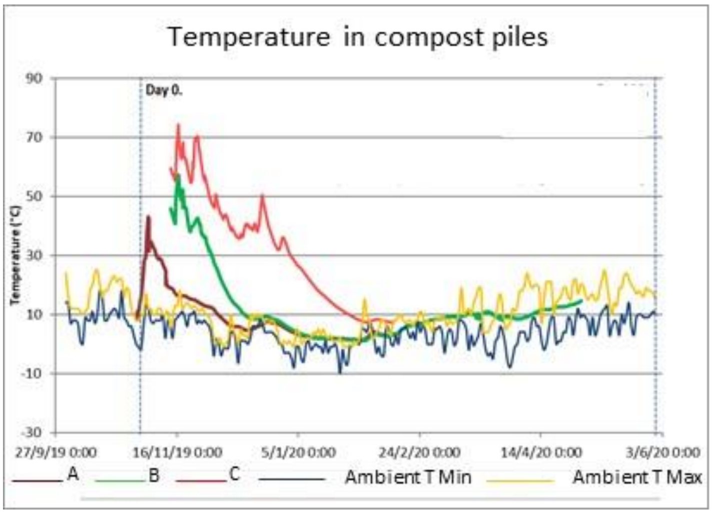

Figure 2. Monitoring of air temperature and temperature inside each co-compost pile during the co-composting process.

The stability and maturity of organic matter was confirmed by TOC, TN, TOC/TN ratio, the humification ratio (HR), electrical conductivity (EC), germination index (GI), and total microbial activity, as reported in table 1.

As expected in a composting process, TOC and TN decreased over time due to degradation of organic substrates. The greater reduction was observed in pile C for the presence of a more easily degradable carbon source (green waste).

The initial TOC/TN values depends on the properties of raw materials (Li et al. 2013) and in our study the piles showed low values of TOC/TN (from 9.9 to 13.1) due to the limited total organic carbon contents in dredged sediments (Jurado et al. 2014; Mattei et al. 2014). However, at the end of the co-composting process, TOC/TN values remained under 20, suggesting suitable compost stability (Gavilanes-Terán et al. 2016).

During the co-composting process, the HR was constant in pile A and increased in the piles with the higher amount of green waste (B and C). The presence of lignin in green waste and its relative degradation products (e.g. phenols) are the main precursors of humic substances during composting. Therefore, such results suggested the efficiency of aerobic composting in the production of humic substances, as well as an evidence of compost maturity (Guo et al. 2019).

The EC reflects the salinity of co-composts and is also used as indicator of compost maturity. The EC decreased in all piles during the compost process, notably reducing of -53%, -34%, and -29%, in piles A, B and C, respectively, compared to the initial values. The final EC values were below the threshold value of 4.0 dS/m, that indicates a harmful salt content (Chhabra, 2004).

The GI confirmed the maturity of the co-composts at the end of the process, in fact GI in all piles reached the limit value of 60%, suggesting the absence of toxic elements (Cesaro et al 2015)

The dynamics of the composting process in terms of decomposition of the organic matter and the evidence of the product stability can be also revealed by the trend of enzymatic activities. The activity of butyrate esterase, an indicator of total microbial activity, decreased over time in all co-composts, suggesting a reduction in overall microbial activity (Wittmann et al. 2004). In fact, the reduction in the availability of organic matter readily available during the process, due to the microbial carbon metabolization, leads to a decrease of microbial activity in the maturation phase (Jurado et al. 2014).

Table 1. Electrical conductivity (EC), organic carbon and total nitrogen ratio (N/C), butyrate esterase activity (but)**,** humification ratio (HR), and germination index (GI) measured in each co-compost pile at start (5 days), middle (168 days) and end (258 days) of co-composting process.

days	co-compost	EC	TOC	TN	C/N	but	HR	GI
		dS/m	%	%		μmol g^{-1} h^{-1}	%	%
5	**A: 3S:1GW**	1.63±0.04	3.41±0.40	0.26±0.02	13.1	2780±310	71.8	73.1±1.6
	B: 1S:1GW	1.52±0.03	4.16±0.10	0.42±0.02	9.9	3716±7	58.2	91.0±1.4
	C: 1S:3GW	1.56±0.04	9.09±0.33	0.85±0.04	10.7	3964±236	55.4	89.9±3.1
168	**A: 3S:1GW**	0.92±0.02	2.91±0.27	0.27±0.03	10.8	1156±30	71.8	121±10
	B: 1S:1GW	0.98±0.02	4.53±0.33	0.35±0.01	12.9	1846±258	69.7	122±16
	C: 1S:3GW	1.25±0.08	8.06±0.63	0.60±0.03	13.4	2317±196	51.3	96.3±9.3
258	**A: 3S:1GW**	0.86±0.02	3.02±0.27	0.26±0.02	11.61	1214±104	69.2	124±9
	B: 1S:1GW	0.78±0.03	3.04±0.15	0.31±0.02	9.8	1531±83	86.1	117±4
	C: 1S:3GW	0.75±0.02	5.04±0.27	0.50±0.02	10.1	2214±24	65.4	108±13

The stability of co-compost was also reached in terms of toxic elements. In fact, at the end of the co-composting processes, the concentration of C>12 decreased of 42%, 56% and 57% in piles A, B, and C, respectively (Figure 3), demonstrating the effectiveness of microbial biomass, in all piles, in the degradation of organic contaminants. Best efficacy of hydrocarbons' reduction observed in pile C has two major causes: 1) the greatest dilution by green waste addition, and 2) the highest co-composting temperature achieved, indicating the greatest microbial activity (including pollutant degraders) and forcing the lighter (lower-C molecules) to volatilization.

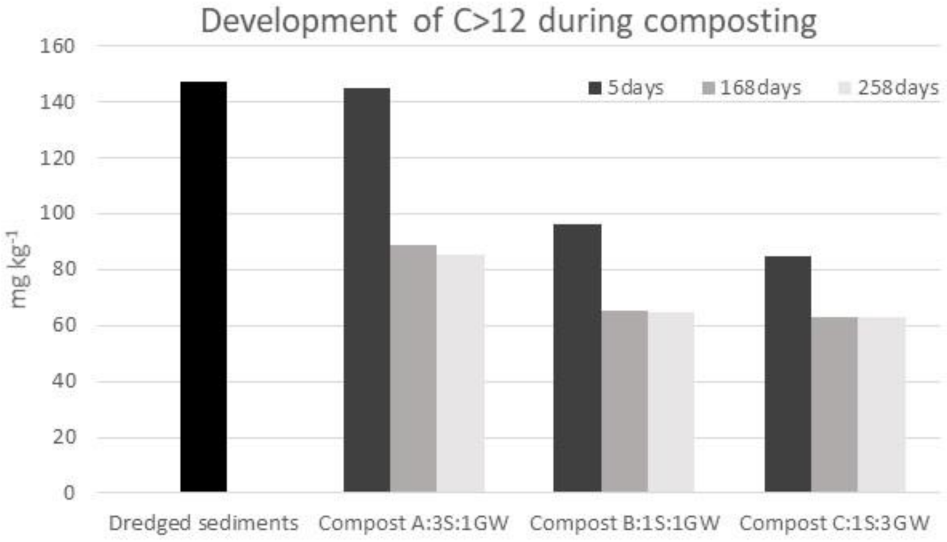

Figure 3. Hydrocarbons (C>12) concentrations detected in dredged sediments and in each co-compost pile at start (5 days), middle (168 days) and end (258 days) of co-composting process.

Conclusion

The dredged sediments co-composted with pruning residues provide a suitable strategy for their management in circular economy perspective. In fact, the stability and maturity of all the co-composts were demonstrated by the decrease and stabilization of organic matter content, electrical conductivity, microbial activity, organic contaminants and by the increase in humification rate and germination index, leading to the production of proper substrate for plant nursery and soil reconstitution for degraded soil rehabilitation.

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