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Environmental inventory modelling of the use of compost and peat in growth media preparation

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ABSTRACT

Compost produced from biological treatment of organic waste has a potential for substituting peat in growth media preparation. The life-cycle-inventories (LCIs) of the two alternatives were compared using LCA-modelling (EASEWASTE) considering a 100-year period and a volumetric substitution ratio of 1:1. For the compost alternative, the composting process, growth media use, and offsetting of mineral fertilizers were considered. For the peat alternative, peatland preparation, excavation, transportation, and growth media use were considered. It was assumed that for compost 14% of the initial carbon was left in the soil after 100 years, while all carbon in peat was mineralized. With respect to greenhouse gas emissions, the former is considered a saving, while the later is considered an emission, because peat in a peatland is considered stored biogenic carbon. The leaching during the growth media use was assessed by means of batch leaching tests involving 4 compost samples and 7 peat samples. The compost leached 3–20 times more heavy metals and other compounds than the peat. The life-cycle-assessment showed that compost performs better regarding global warming (savings in the range of 70–150 kg CO_2-eq. Mg^{-1}) and nutrient enrichment (savings in the range of 1.7–6.8 kg NO_3 Mg^{-1} compost), while peat performs better in some toxic categories, because of the lower content of heavy metals.

1. Introduction

Growth media is used in horticulture, in professional gardening and landscaping, and in private gardens for lawns, pots and plant beds. Growth media typically consists of an organic component, fertilizer, and sand or sandy soil. The organic component is often peat excavated from natural bogs or fens. Peat is plant debris that in its natural setting is degrading very slowly and thus peat can be considered bound biogenic carbon. However, excavated peat used in a growth media will degrade over a few decades and emit the bound carbon as CO_2. Thus CO_2 released by degradation of peat should be counted as a greenhouse gas (GHG). This is an issue that must be addressed since almost 80% of growth media used in Europe is constituted of peat materials (IPS, 2007).

Compost produced from organic waste from residential areas could be an alternative to the use of peat in growth media. The organic residential waste, in terms of kitchen organics and garden waste, originates from relative short-term crops and vegetation and thus CO_2 released from its degradation can be considered neutral with respect to GHG (Christensen et al., 2009).

However, comparison of the use of compost and peat in growth media production should also pay attention – in addition to differences in carbon releases – to differences in the need of transport, the fertilizer content, the content of contaminants, and the leaching of nutrients and contaminants into the subsoil. To our knowledge no comprehensive dataset exists to support such a comparison.

This study presents life-cycle-inventories for compost and peat used in growth media. The inventories include exchanges with the environment from the production, transportation and utilization for a total period of 100 years. Leaching of substances to groundwater was assessed by means of batch leaching tests. The provided inventories can be used in comparison of alternative management scenarios for residential organic waste involving composting and substitution of peat in growth media preparation. As an illustrative example, the life-cycle-inventories (LCIs) provided were used in a life-cycle-assessment (LCA) of alternative management of residential organic waste in order to illustrate the importance of detailed LCIs for compost and peat use in growth media production.

1.1. Peat

Peat is an accumulation of organic detritus that forms in anoxic, waterlogged and acidic conditions of bogs and fens. Peat can be

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Abbreviations: EU, European Union; GHG, greenhouse gases; GWC, garden waste compost; GWP, global warming potential; KWC, kitchen waste compost; LCA, life-cycle-assessment; LCI, life-cycle-inventory; PE, polyethylene.

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excavated and used either as a fuel or as a soil amendment in the plant production industry. In 1999, about 100 million cubic metres of peat were produced worldwide (Joosten and Clarke, 2002), of which 65% was used for energy purposes and 35% in the horticultural sector. The majority of peat is produced in temperate northern countries, i.e. the countries of the former USSR, Canada, USA, Scandinavia and Finland. In 2000, Canada produced around 1.3×10^6 Mg of peat, being the largest producer of peat for horticultural purposes in the world (Cleary et al., 2005).

Peatlands are significant reservoirs of carbon. Carbon in peat in boreal and temperate regions is estimated to be around one third of the carbon stored in the world's soils (Gorham, 1991) or 500 Pg (IPCC, 2003). Carbon accumulation in the form of peat occurs over a long period of time as a result of degradation of plant material under anaerobic conditions and could play a major role in the global carbon cycle. According to Joosten and Clarke (2002), about 5–10% of the biomass (and thus carbon) produced annually in the peatland area ends up in the peat stock.

The impact of peatlands on climate change is determined by the net emissions of CO_2, CH_4 and N_2O, depending on the environmental (e.g. deepness of the bog) and geographic conditions, type and age of the peatland and land-use (Lappalainen, 1996). For example, fens (a type of wetland), which receive groundwater and are dominated by vascular plant vegetation, emit more CH_4 than bogs dominated by Sphagnum moss (Lappalainen, 1996).

Extraction of peat disturbs the natural cycle of carbon in peatlands. Lowering of the water table due to drainage increases the depth of the aerobic layer and therefore CO_2 emissions are increased. CH_4 emissions generally cease following drainage. The removal of plant cover in areas converted to peat production also terminates the accumulation of plant debris and hence the CO_2 sequestration (Lappi and Byrne, 2004). Degradation of dewatered peat (into carbon containing gases including CO_2) could result in emissions in the order of at least 7.4 Mg CO_2-eq. ha^{-1} $year^{-1}$ (Reijnders and Huijbregts, 2003).

Transportation and biological decomposition of excavated peat are also contributing to GHGs emissions during the peat life cycle. Being mainly produced in northern areas of the world, peat is often transported very far by different means of transportation. Regarding decomposition, both Smith et al. (2001) and Cleary et al. (2005) report that within 100 years all peat used outdoor is completely degraded and all carbon contained is consequently released to the atmosphere, primarily as CO_2. Release of this CO_2 is accounted as a GHG in this study, because of the long natural cycle (i.e. centuries to millennia) of carbon in peatlands.

Table 1
Compost and peat samples.

Material	Producer	Country	Collection
Compost			
Kitchen waste (KWC)	Solum A/S	DK	Composting plant
Garden waste (GWC)	Solum A/S	DK	Composting plant
	Århus Affaldscenter	DK	Composting plant
	RGS90	DK	Composting plant
Peat			
Sphagnum	Unimuld	DK	Commercial
Sphagnum	Sphagnum BG	SE	Commercial
Peat	Scan Muld	SE	Commercial
Sphagnum	Moss Peat	LT	Commercial
Peat	Bord Na Mona	IE	Production site
White Peat	Vapo	FI	Production site
Brown Peat	Vapo	FI	Production site

DK: Denmark, SE: Sweden, LT: Lithuania, IE: Ireland, FI: Finland.

1.2. Compost

Various technologies exist to produce compost from residential biowaste such as kitchen organics and garden waste. Composts and compost-containing products are already widely used in different areas, e.g. for agricultural purposes, landscaping, soil reclamation, organic farming, private gardening, erosion control, roadside projects and nurseries. In the European Union (EU) 70–80% of compost is used for agriculture, landscaping, nurseries, etc. while the remaining 20–30% is used by residential garden owners. Compost is locally produced and thus transportation of the compost is short before use. Beside organic matter, compost also contains nutrients and, depending on its origin, a certain content of contaminants, in particular heavy metals. Nutrients as well as metals may leach into the subsoil when compost is used on land.

2. Materials and methods

For the development of the life-cycle-inventories, data were collected from the literature and supplemented with experimental data regarding the composition of peat and the potential leaching from peat as well as from compost.

2.1. Samples

Four samples of compost were collected at composting facilities in Denmark, and seven samples of peat were collected either at production sites or at commercial sites where peat materials were sold as growth media. Details are presented in Table 1. Both peat and compost were stored shortly in tight plastic barrels before being tested.

Dry matter content of all samples was measured by heating 80–200 g of sample at 55 °C until water evaporation was completed (at least 24 h). Afterwards, samples were sent to a certified external lab (former Analytica AB, now ALS Scandinavia AB, Luleå, Sweden) for chemical and physical characterisation (Table 2).

2.2. Leaching tests

Leaching tests (on wet material) were performed in 2 l polyethylene (PE) bottles, where 200–300 g of test material and water were mixed at a liquid-to-solid ratio (L/S) of 10 l/kg dry material. The bottles were rotated for approximately 24 h. Liquid and solids were separated through several steps. A first coarse filtration was done with a nylon filter, followed by centrifugation for 8 min at 2500 rpm. Finally, filtrations with a GF/C filter and a 0.45 μm filter were performed. Filtrations through the nylon and GF/C filters were enhanced by suction with a vacuum pump. Three samples were taken from the remaining liquid: one 40 ml sample for heavy metals analysis (conserved as 2‰ nitric acid) and two 50 ml samples for organic carbon and anion analysis (conserved in freezer to stop any biological activity). To avoid heavy metals contamination, all equipment used was initially acid washed in a 3 M nitric acid solution and washed again with 1 ml-HNO_3/500 ml water between one sample and the next.

The organic carbon in the leachate was measured as Non-Purgeable Organic Carbon (NPOC). The analysis was performed on a Shimadzu TOC 5000A with auto sampler ASI-5000. Dilution was necessary to measure concentrations within the detection range. Anions measured in the samples comprised chloride, bromide, nitrate and sulphate. The analysis was performed on a Dionex DX-120 Ion Chromatograph. Heavy metal content, both in solids and leachate, was analysed by a certified external lab (ALS Scandinavia AB, Luleå, Sweden).