USING BIOCHAR FROM SEWAGE SLUDGE AND OTHER FEEDSTOCKS IN EUROPEAN AGROFORESTRY: OPPORTUNITIES AND CHALLENGES

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Abstract

Forty to fifty percent of the nutrient-rich sewage sludge (SS) from wastewater treatment plants is used as a soil amendment in Europe and the USA. When applied in excess of crop requirements, this sludge can cause environmental problems due to loss of nutrients to adjacent water bodies. Conversion of SS to biochar likely leads to more stable form of nutrients, decreasing their loss through runoff or leaching, while converting carbon to a more stable phase. A biochar developed from SS and plant residues such as pruned materials from agroforestry systems would result in an interesting soil amendment with properties less detrimental to the environment. Compared with SS biochar, such tailored biochars could be lower in nutrient content and at the same time remove bulky "waste products" from agroforestry systems that would normally have to be moved off-site.

Keywords: anaerobic digestion; animal-based feedstocks; extractable phosphorus; nutrients; plant-based feedstocks

Introduction

Agroforestry systems on arable lands could have the woody components distributed in even or uneven configurations. In Europe, the common practices involve woody components as boundary plantings (along field boundaries) and as hedgerows around field plots. Substantial amounts of woody materials and other biomass products are obtained when these woody components are pruned periodically, which is an essential aspect of their management. These woody materials can be used to produce bioenergy or composted and used as a soil amendment or as a nutrient source. Because of their low nutrient contents and wide carbon: nitrogen (C:N) ratios, however, they by themselves have only limited value as nutrient sources. Combining these materials with other farm residues such as nutrient-rich sewage sludge (SS) – [illegible]ation could be [illegible] this seemingly win-win situation in European agroforestry within the bioeconomy framework.

Sewage sludge from wastewater treatment plants often ends in landfills all over the world. European regulations promote its use as compost, manure, or after anaerobic digestion; but still quite a major proportion goes to landfills. This poses a problem since natural decomposition of the sludge would result in the generation of gases, primarily methane, a greenhouse gas. Moreover, the landfills are getting filled at a rapid rate and creating social problems as most people do not like to have landfills in their vicinity. Further, nutrients such as phosphorus and nitrogen from SS could move out from the landfill and cause eutrophication of nearby water bodies. The high nutrient content of the SS makes it a very valuable fertilizer, but its repeated application could likely result in soil phosphorus (P) saturation and eventual loss of nutrients from the soil (Mosquera-Losada et al. 2010a; 2010b; Ferreiro-Domínguez et al. 2016).

Converting the SS into biochar may lead to more firm retention and less release of nutrients, while converting carbon to a more stable phase. A white paper by the International Biochar Initiative states: “Pyrolysis and gasification—a continuum of thermochemical conversion processes—have been shown to minimize harmful air emissions, while producing energy and biochar, a carbon-rich solid material with beneficial soil health properties.” The paper also pointed out that over 7 million dry tons of stabilized SS was produced per year in the US, of which 49% was used for agricultural land application (IBI 2013).

Sewage sludge application in Europe

The production of SS in Europe has increased in the last century due to the implementation of Directive 91/271/CEE (EU 1991), which makes it mandatory to treat wastewaters in all cities with more than 2000 inhabitants. Over 10 million tons of SS are produced every year in Europe with a projected production of 13 million tons in 2020 (EU 2008). In 2010, about 42% of Europe’s municipal SS was treated and used on farmlands, 27% incinerated, 14% sent to landfills and about 17% disposed off in other ways (EUROSTAT 2018).

Biochar from sewage sludge and other feedstocks

Comparative data on nutrient contents of SS produced by anaerobic processes and their corresponding biochars in Spain and from a US facility (Table 1) can be used to evaluate the potential for using the material as a nutrient source in agricultural and agroforestry systems. All biosolids were converted to biochar using the same process at the University of Florida for the Spain and US samples to minimize differences arising from analyses in different laboratories. We also determined nutrients in biochar prepared from other animal- and plant-based feedstocks (Table 1) including commercial biochar products using the same procedure.

Table 1: Properties of sewage sludge (SS) and their corresponding biochars from i) Spain and USA and ii) non-sewage sludge feedstocks including commercially available products

Material	**Total P**	**TKN**	**M3-P**	**M3-K**
	mg kg^{-1}			
Anaerobic SS (Spain)	19 500	32 960	2 010	910
Anaerobic SS – Biochar (Spain)	21 100	16 400	1 920	720
Anaerobic-composted SS (Spain)	22 600	21 700	2 460	3 080
Anaerobic-composted SS – Biochar (Spain)	39 400	13 900	2 130	2 880
Anaerobic-pelletized SS (Spain)	21 300	32 200	1 560	810
Anaerobic-pelletized SS – Biochar (Spain)	41 300	18 100	2 440	840
Anaerobic SS (USA)	32 500	54 200	10 960	2 220
Anaerobic SS – Biochar (USA)	67 300	50 700	7 060	500
Non-SS feedstocks				
Poultry litter biochar	32 460	34 900	22 370	64 900
Hardwood biochar	870	10	90	4 340
Maple biochar	730	3 050	100	4 140
Pine biochar	410	0	70	450
Commercial products				
Earth Activated biochar (USA)†	12 080	7 230	2 730	3 340
EarthSpring biochar (USA)†	1 560	7 470	300	4 290
BCX biochar (India)‡	710	1 940	60	960

TKN = Total kjeldahl nitrogen; M3-P = Mehlich 3-P; M3-K = Mehlich 3-K

† EarthSpring (50% mixture of hardwood biochar and organic compost) and Earth Activated biochar (obtained from the supplier): http://earthspringbiochar.com/

‡ BCX biochar (from wood chips with microorganisms added; Chatterjee N, personal communication)

A general trend of increases in total P concentrations when SS is converted to biochar is evident from Table 1, but not for extractable P (Mehlich 3-P). Total P and extractable P content of the SS vary substantially depending on the source of material. Many of the differences in releasable P upon conversion to biochar could be related to the biochar source, the biochar-conversion process and the form in which P is held in the biochar. This suggests that the mineral composition of the final product is likely dependent on the origin and process of the SS production. Total nitrogen (TKN) is generally lower in biochar compared to the corresponding SS. Biochar production facilities range from large- to mid-scale in the US and Europe, while small- and micro- scale kilns are used by smallholder farmers to convert agricultural residues to biochar, particularly in Africa and Asia. It is important to follow standardized procedures for conversion of biochar from SS and other feedstocks to ensure a final product of similar quality—a major challenge, irrespective of whether it is produced in local facilities or large commercial biochar plants.

Dari et al. (2016), using an x-ray diffraction procedure identified whitlockite, a sparingly soluble Ca (or Ca-Mg) P form in poultry litter biochar that could behave as a slow release P fertilizer. Similar associations were not found in the biochars from SS in this study. Additional biochar samples from different processes need to be evaluated to determine process-specific benefits of biochar production from SS.

Heavy metal concentrations do not differ much in these samples upon conversion of SS to biochar; mean values obtained in this study were: Cd = 0 mg kg^{-1}; Zn = 240 mg kg^{-1} for the Spain samples and 60 mg kg^{-1} for the USA sample; Pb <18 mg kg^{-1} and Cu < 60 mg kg^{-1} for all samples.

Use of biochar from mixed feedstocks vs. sewage sludge

The differences in biochar properties between animal- and plant-based sources suggest that SS biochar could be combined with biochar from locally available woody materials to create a mix for land application. These tailored biochars could reduce excess nutrients in the SS biochar and at the same time remove “waste products” from agroforestry systems that would normally have to be moved off-site or disposed of otherwise. Commercially available biochar, such as those analyzed in this study, often use combinations of such materials. Addition of biochar while composting is another potential applicability in agroforestry systems.

Other benefits and challenges

Conversion of feedstock to biochar brings about a substantial reduction in the volume of the materials (up to 90% http://earthsystems.com.au/wp-content/uploads/2014/09/Conversion-of-Waste-Wood-to-Biochar.pdf). This makes storage and transportation of biochar easier and cheaper, compared to the raw materials. Nair et al. (2017) have discussed several other desirable properties of biochar in the context of land-application, including increases in nutrient retention, soil carbon sequestration, water-holding capacity and soil microbial activity, and decrease of soil bulk density. Further, conversion of agricultural wastes to biochar could reduce greenhouse gas emission from feedstocks during natural decomposition or burning of the waste material.

Several other issues are important in the context of practical applications of biochar. The price of biochar products varies from country to country: US$ 0.09 kg^{-1} in the Philippines and US$ 8.85 in the US in 2003. Although a viable alternative to chemical fertilizers, the behavior of biochar prepared from varying feedstocks including SS is unpredictable and depends on the soil type where the material is applied (Dari et al. 2016). For example, the rate and frequency of biochar application cannot be the same for a sandy soil where P is readily lost from a soil vs. a high P retentive soil. Adequate information is not available on the impact of adding biochar from varying feedstocks in different agro-ecological settings such as the humid tropics, arid, and semi-arid regions. In brief, it is a challenge to find the ideal rate of application of biochar derived from SS or mixed feedstocks for specific conditions and objectives in agroforestry and other land-use systems. Nevertheless, on-site conversion of locally available waste materials to biochar could be a win-win situation in terms of combined benefits of waste disposal, increased farm outputs, and environmental advantages.

References

Dari B, Nair VD, Harris WG, Nair PKR, Sollenberger L, Mylavarapu R (2016) Relative influence of soil- vs. biochar properties on soil phosphorus retention. Geoderma 280: 82–87.

EU (European Union) (1991) Council Directive of 21 May 1991concerning urban waste water treatment. http://eurlex.europa.eu/legalcontent/EN/TXT/?uri=celex%3A31991L0271 (accessed 25/01/2018).

EU (European Union) (2008) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098 (accessed 25/01/2018).

EUROSTAT (Statistical Office of the European Union) (2018) Sewage Sludge and Disposal. http://ec.europa.eu/eurostat/web/products-datasets/product?code=env_ww_spd (accessed 07/02/2018).

Ferreiro-Domínguez N, Nair VD, Freese D (2016) Phosphorus dynamics in poplar silvopastoral systems fertilised with sewage sludge. Agr Ecosyst Environ 22: 87–98.

IBI White Paper: Pyrolysis and gasification of biosolids to produce biochar. 2013. http://www.biochar-international.org/sites/default/files/IBI_white_paper_biosolids_biochar_final.pdf (accessed 25/01/2018).

Mosquera-Losada MR, Ferreiro-Domínguez N, Rigueiro-Rodríguez A (2010 a) Fertilization in pastoral and Pinus radiata D. Don silvopastoral systems developed in forest and agronomic soils of Northwest Spain. Agr Ecosyst Environ 139: 618–628

Mosquera-Losada MR, Muñoz-Ferreiro N, Rigueiro-Rodríguez A (2010 b) Agronomic characterization of different types of sewage sludge: policy implications. Waste Manage 30: 492–503.

Nair VD, Nair PKR, Dari B, Andressa, AM, Chatterjee, N, Pinheiro, FM. (2017) Biochar in the Agroecosystem–Climate-Change–Sustainability Nexus (2017) Front Plant Sci 8. 2051 doi: 10.3389/fpls.2017.02051