Soil quality factors related to soil wettability in minesoils reclamation using sewage sludge amendments

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European Geosciences Union
General Assembly 2008
Vienna, Austria, 13 – 18 April 2008

1. Introduction

From the past seventies considerable amount of research has been conducted on the use of sewage sludge for mine land reclamation. It is currently used as organic amendment in topsoil rehabilitation of land degraded by erosion, fire or mining activities, when a rapid and effective soil protection is required. However, this use is limited by the pollutant burden usually present in sludge. In order to improve their quality as organic amendment or fertilizer, composting or thermal drying post-treatments of sludge (previously digested and partially dewatered) has been promoted in order to reduce some harmful effects on soil properties and health hazards that may result from the direct use of digested sludge.

The main objective of this study is to diagnose the effectiveness of composted and thermally-dried sludges using a schematic framework involving soil carbon stock, soil wettability and soil biophysical parameters, in order to quantify the impact of composted and thermally dried municipal sewage sludges produced in different waste water treatment plants.

Figure 1. Location and field experiment.

2. Methods

The experiment was developed at the limestone quarry "Las Cubetas" (Begues municipality, Barcelona, Spain) under field conditions (Figure 1). Reference Soil in this study comes from a skeletic red Mediterranean soil, of a loam texture, low in organic matter (0.47% organic C) but rich in lime (39,3% $CaCO_3$) and coarse fragments (62,0%). This soil was amended with six post-treated sludges produced in different municipal waste water treatment plants from medium towns of Catalonia (NE Spain) (see Table 1), and was sampled one month (S1) and one year (S2) after amendments.

Table 1. Origin, treatments, composition and identification code of the sewage sludges used as organic amendments.

Origin[1] (WWTP)	Type of digestion	Post-treatment	Code	Organic Matter (%)	Stability Degree[2] (%)
Blanes	Anaerobic	Composting	C_{BL}	56.6	29.0
Manresa	Anaerobic	Composting	C_{MR}	55.5	40.6
Vilaseca	Aerobic	Composting	C_{VL}	58.3	35.8
Besós	Physico-chemical	Thermal drying	T_{BS}	72.3	8.6
Mataró	Anaerobic	Thermal drying	T_{MT}	74.0	40.4
Sabadell	Anaerobic	Thermal drying	T_{SB}	62.2	39.5

[1] WWTP: identification of municipal waste water treatment plant. [2] Stability degree: percent of organic matter resistant to acid hydrolysis.

3. Framework to assess the impact of sludge-borne carbon changes on soil wettability and biophysical properties

The model applied compares the values of several soil properties $f(x_i)$ and $f(x_j)$ over a time interval (Δt = 1 year), where $f(x_i)$ correspond to sewage sludge treatments, while $f(x_j)$ to the Reference Soil that did not receive sewage sludge (control). Schematic framework is presented in Figure 2. Impact of sludge on Reference Soil properties was calculated as: $\Phi[f(x_{i,j};\Delta t)] = -[1 - (f(x_i;\Delta t)/f(x_j;\Delta t))]$.

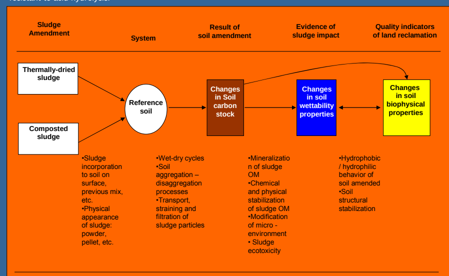

Figure 2. Schematic framework to assess the impact of sewage sludge amendments on soil quality factors related to land reclamation.

4. Results

<u>Soil carbon stock</u>: represented by total organic carbon (TOC), extractable organic carbon (EOC) and extractable carbohydrates (ECH) of Reference Soil, increased by addition of composted and thermally dried sludge amendments, mainly at short term (S1).

<u>Wettability</u>: the process of sewage sludge production and its post-treatment processes (composting or thermal drying) modified the wettability properties (contact angle by capillary rise method: CA_{CRM}; time required to reach zero contact angle: $t_{CA\,=\,0^o}$) when were applied to Reference Soil. Changes in CA_{CRM} indicated modifications in wettability of soil aggregates surface, while changes in $t_{CA\,=\,0^o}$ indicated alterations in soil wettability inside and outside of particles and soil aggregates. These changes were sludge dependent (Figure 3).

<u>Soil biophysical properties</u> (includes microbial biomass carbon: MBC; basal respiration: BR; mean weight diameter obtained by wet sieving: MWD_{wet} and gravimetric water content at wilting point: GWC_{wp}). MBC and BR of the Reference Soil was enhanced, mainly in thermally dried sludge treatments rather than in composted ones (Figure 3). Moreover, soil aggregate stability (MWD_{wet}) and soil water retention (GWC_{wp}) of Reference Soil also was improved in almost all the sludge treatments (Figure 3).

Interactions between wettability properties and biophysical parameters (Figure 3) suggest that soil aggregate stability and water retention were more related to soil surface wettability that were modified by organic matter from composted and thermally dried sludge, whereas soil biological activity was not limited by soil physical protection.

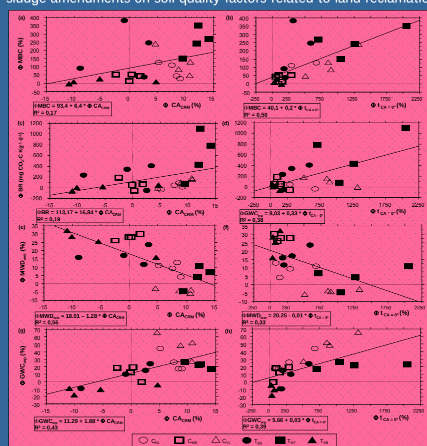

Figure 3. Relationship between sludge impact (Φ) on soil biophysical parameters (MBC: microbial biomass carbon, BR: basal respiration, MWD_{wet}: mean weight diameter by wet sieving, GWD_{wp}: gravimetric water content at wilting point) vs. sludge impact (Φ) on soil wettability properties (CA_{CRM}: contact angle by capillary rise method, $t_{CA\,=\,0^oC}$: time required to reach cero contact angle) of Reference Soil treated with composted sludge from Blanes (CBL), Manresa (CMR) or Vilaseca (CVL), and thermally dried sludge from Besós (TBS), Mataró (TMT) or Sabadell (TSB). All correlations were significant at $p < 0.05$.

5. Conclusions

Composted and thermally dried sludges could be considered as useful organic amendments in land reclamation of minesoils that in some cases can change soil wettability and biological activity properties. However, not all types of sludges seems able to improve soil aggregate stability or to increase soil water retention. The origin of the sludges and the post-treatment processes that it had been submited have an important impact on diverse soil properties when were used as soil amendments.

Acknowledgements: The authors thank to Spanish Ministery of Environment and Catalan Agency of Water to funding RESMINLOD project and all persons and entities participants on it.