



Is turnover and development of organic matter controlled by mineral composition?



Geertje Johanna Pronk^{a, b, *}, Katja Heister^a, Ingrid Kögel-Knabner^{a, b}

^a Lehrstuhl für Bodenkunde, Technische Universität München, 85350 Freising-Weihenstephan, Germany

^b Institute of Advanced Study, Technische Universität München, Lichtenbergstrasse 2a, D-85748 Garching, Germany

ARTICLE INFO

Article history:

Received 10 May 2013

Received in revised form

1 September 2013

Accepted 8 September 2013

Available online 20 September 2013

Keywords:

Clay mineral

Ferrihydrite

Charcoal

Acid hydrolysis

Organic nitrogen

Artificial soil

ABSTRACT

Interactions between organic matter (OM), minerals and charcoal may play an important role in the development and stabilization of OM in soils. However, these interactions are difficult to characterize in natural soils, which are usually very complex systems with unknown initial conditions. We developed so-called 'artificial soils' with a texture and OM content similar to natural arable soils that were incubated up to 18 months. The aim was to determine the turnover and development of OM with incubation time, and to establish the effect of mineral composition and charcoal presence on organic carbon (OC) and N distribution and properties. Artificial soils were composed of quartz, manure as OM source and a microbial community extracted from a natural arable soil, with 8 different mixtures of montmorillonite, illite, ferrihydrite, boehmite and charcoal. We determined C and N particle size distribution with time and used solid-state ¹³C nuclear magnetic resonance (NMR) spectroscopy and acid hydrolysis to determine the development of OM composition. The CO₂ respiration rate and distribution of OC and N with particle size was similar for all artificial soil compositions. OC and N accumulated in the <20 μm fraction over time and approximately 50% of coarse (>200 μm) particulate OM was lost after 18 months of incubation. ¹³C NMR spectroscopy indicated accumulation of protein-rich OC in the <20 μm fraction, likely in the form of microbially produced substances. Acid hydrolysis showed a higher content of non-hydrolysable N in the mixtures containing clay minerals, indicating that some of the nitrogen present was strongly bound to phyllosilicate surfaces. Ferrihydrite did not have any effect on non-hydrolysable N. From this, it can be concluded that in the artificial soils, clay minerals were more important than metal-oxides for the binding of nitrogen and OC. Overall, the artificial soils developed similarly to incubation experiments with natural soils, and were therefore a valuable model system where the effect of specific components on the development and turnover of soil OM could be determined under simplified conditions.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Recent research indicates that minerals may play an important role in the stabilization of organic matter (OM) and especially nitrogen-containing compounds in soil (e.g. Kleber et al., 2007; Nannipieri and Eldor, 2009; Knicker, 2011). However, it is difficult to determine the effect of mineral composition on soil organic matter (SOM) development in natural soils, which are complex systems where mineral composition is usually not well-defined and initial conditions are generally unknown. Incubation experiments with simplified systems of known composition and initial

conditions can therefore be useful to gain understanding of the factors determining the development of OM over time, and its interactions with minerals. Artificial mixtures have been used in the past to simulate processes taking place in soils. Madhok (1937) already used so-called 'synthetic soils' composed of mineral mixtures to test the decomposition of cellulose in 1937. More recent studies were performed by, for example, Saidy et al. (2012) who incubated clay mineral and oxide mixtures with dissolved organic matter (DOC), and Miltner and Zech (1999) who incubated leaf litter in the presence of different oxides. These studies demonstrated the complex interactions between microbial activity, decomposition of OM and presence of different minerals. To gain further understanding of these interactions, we tried to simulate texture and organic carbon (OC) content of natural arable soils, while focussing on the effect of microbial activity alone under further constant environmental conditions, in a so-called 'artificial

* Corresponding author. Lehrstuhl für Bodenkunde, Technische Universität München, 85350 Freising-Weihenstephan, Germany. Tel.: +49 8161715381.

E-mail address: pronk@wzw.tum.de (G.J. Pronk).

soil' incubation experiment (Pronk et al., 2012). Mixtures of different composition, but the same texture, could so be used to determine the effect of the presence of different mineral surfaces and charcoal on the development of the system. The importance of microbial biomass in the formation of SOM has been highlighted in recent years (e.g. Miltner et al., 2009). The turnover and redistribution of OC and N species in the artificial soils, where microbial activity is the only driving force of OM turnover during incubation, may be used to demonstrate the extent to which microbial communities are able to contribute to SOM, and help to elucidate the characteristics of microbially produced OM in soil.

During degradation, OM is redistributed over the various particle size fractions present in soil as coarse particles are broken up and microbial products are produced. This generally leads to an accumulation of OC and N in the smaller particle size fractions, as has been discussed extensively by e.g. Christensen (1992) and Kleber et al. (2007) for natural soils, and was also observed for incubation experiments (e.g. Grosbellet et al., 2011; Leifeld et al., 2001). The determination of the particle size distribution of OC and N can therefore be a useful tool to monitor the turnover and development of OM during incubation. Solid-state ^{13}C nuclear magnetic resonance (NMR) spectroscopy is often used to characterize OC development and composition, and gives an indication of the type of compounds that are preferentially preserved or decomposed (Kögel-Knabner, 2000; Simpson and Simpson, 2012). Several recent studies have indicated that proteins accumulate in soils over time, and that interaction of organic nitrogen species and microbial residues with minerals may be important for the stabilization of OM in soils (e.g. Kleber et al., 2007; Miltner et al., 2009). Acid hydrolysis is a classic method for the characterization of nitrogen in soils (Stevenson, 1996). It separates the organic nitrogen into protein N (determined as $\alpha\text{-NH}_2$), non-hydrolysable N and unidentified hydrolysable N. Paul et al. (2006) and Silveira et al. (2008) found that acid hydrolysis provided useful information to estimate different SOM pools. Furthermore, Leinweber and Schulten (2000) demonstrated that non-hydrolysable N is not only determined by the chemistry of the organic N species present, but also by strong interaction with mineral surfaces. In an incubation system where the origin of the OM is the same for all treatments, differences in the amount of non-hydrolysable N might therefore be taken as an indication of interaction of nitrogen species with specific minerals.

We performed an incubation experiment with so-called 'artificial soils' composed of mixtures of clean and well-defined model materials, where the development of OM could be followed in a simplified system with known initial conditions. In previous studies, it was found that macroaggregates were quickly formed in the artificial soils and increased until around 12–18 month of incubation, when they started to decrease. OM associated with microaggregates and minerals continued to increase gradually for the entire incubation time (Pronk et al., 2012). This succession of macroaggregation, microaggregation and turnover of microbial debris was in agreement with the aggregate hierarchy model and

current understanding of interplay between aggregation and microbial activity in soils (e.g. Oades, 1984; Six et al., 2004, 2006). The microbial community that developed in the artificial soils depended on charcoal presence and, to a lesser extent, clay mineral type after 3 months of incubation (Ding et al., 2013). After 12 months of incubation, the microbial community composition shifted and metal oxides and clay minerals were the main minerals influencing the microbial community, whereas the effect of charcoal decreased (Babin et al., 2013). However, cumulative CO_2 respiration was similar for all artificial soil compositions, showing no clear effect of these differences in microbial community on respiration (Pronk et al., 2012). It is still an open question whether the differences in artificial soil composition, and the microbial communities following from these compositions, therefore led to differences in OM development within the artificial soils. The objective of this study was to determine the turnover and development of OM with incubation time and to establish the effect of mineral composition and charcoal presence on OC and N distribution and properties.

2. Materials and methods

2.1. Artificial soil incubation

The artificial soils were composed of the model materials quartz, illite, montmorillonite, ferrihydrite, boehmite and charcoal. Air-dried and sterilized manure was used as OM source and the mixtures were inoculated with the water extractable microbial community from a Eutric Cambisol. Manure was added to an equivalent of $15 \pm 2 \text{ mg C g}^{-1}$ and $1.4 \pm 0.2 \text{ mg N g}^{-1}$ in all artificial soils. The mixtures contained 40–42% sand ($>63 \mu\text{m}$), 52–54% coarse and medium silt ($6.3\text{--}63 \mu\text{m}$) and 6% fine silt and clay ($<6.3 \mu\text{m}$). The amount of sand and clay mineral or clay-sized quartz added for each composition (Table 1) was varied slightly to account for differences in the particle size distribution of the model materials. These materials were added in such amounts that the mass of the fraction $<6.3 \mu\text{m}$ always represented 5.6% of the total soil mass. The texture of the illite, montmorillonite and clay-sized quartz was determined by X-ray attenuation (SediGraph 5100/Master Tech 051, Micromeritics GmbH, Mönchengladbach, Germany) and contained 50%, 67% and 74% mass of particles $<2 \mu\text{m}$ respectively. The ferrihydrite, boehmite and charcoal were accounted as part of the $<6.3 \mu\text{m}$ fraction because of their large specific surface area. The model materials, artificial soil composition and incubation were described in detail in Pronk et al. (2012). In total, artificial soils with 8 different compositions (Table 1) were incubated for 3, 6, 12 and 18 months, respectively. Three replicate batches of each composition were sampled at each time point.

The artificial soils were separated into fractions with a size equivalent to coarse and medium sand ($200\text{--}2000 \mu\text{m}$), fine sand ($63\text{--}200 \mu\text{m}$), coarse silt ($20\text{--}63 \mu\text{m}$) and medium + fine silt and clay fraction ($<20 \mu\text{m}$) by wet sieving. The method for aggregate disruption was adapted from Schmidt et al. (1999) and Amelung and Zech (1999). For ultrasonic dispersion, 150 ml of water was

Table 1
Model materials present in the different artificial soil mixtures.

Name	Model component	Soil composition							
		MT	IL	FH	MT + IL	MT + CH	IL + FH	IL + B	IL + FH + CH
MT	Montmorillonite	X			X	X			
IL	Illite		X		X				
QC	Clay-sized quartz			X				X	X
FH	Ferrihydrite			X				X	X
B	Boehmite							X	
CH	Charcoal					X			X

Download English Version:

<https://daneshyari.com/en/article/8365125>

Download Persian Version:

<https://daneshyari.com/article/8365125>

[Daneshyari.com](https://daneshyari.com)