

Scientific Report for Exchange Visit to BIOEMCO

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**ESF - Natural molecular structures as drivers and tracers of terrestrial C fluxes
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The host institution was the CNRS - Laboratoire de Biogéochimie et Ecologie des Milieux Continentaux (BIOEMCO) in Grignon (Paris - France) and the supervisor was Dr. Cornelia Rumpel.

1. Purpose of the visit

Fire is a driving factor in soil formation and has a strong impact on soil organic matter (SOM) quantity and quality. Fire severity and frequency are expected to increase in the near future due to global warming.

Lignin is a main component of SOM and an indicator of SOM composition and degradation because it is thought to contribute with its structure to highly recalcitrant fire derived compounds (Knicker, 2011).

Sugars are another major component of SOM and play an important role in the soil environment, being the main source of energy to soil biota and a binding agent in soil aggregates. As one of the most labile fraction of SOM, sugars could be used as an early indicator of changes in SOM quality after a fire (Martin et al., 2009).

The aim of the visit was to examine the changes induced by a high-severity and an extreme-severity wildfires on the quantity and composition of total neutral non-cellulosic sugars and lignin in two forest soils.

2. Description of the work

Before of my exchange visit, I collected several soil samples from two sites that were affected by two wildfires of different severity and from two more sites that were chosen as control areas. The samples were taken from the first layer of the mineral soil (2.5 cm). In the lab the soil samples were air-dried, sieved at 2 mm and finely ground by hand. An aliquot of samples was fractionated using a solution of Sodium polytungstate (NaPT) with a density of 1.8 g cm^{-3} . A first fraction, the free particulate organic matter (fPOM), was isolated simply adding the NaTP solution to the soil and then recovering the floating material after a centrifugation. The second fraction, the occluded particulate organic matter (oPOM) was obtained adding again the NaTP solution to the settled soil, applying an ultrasonic dispersion of aggregates and recovering the floating material after a centrifugation. The remaining sample was consider as mineral associated organic matter (MOM) with a density $> 1.8 \text{ g cm}^{-3}$.

These fractions represent three different pools of SOM with different features regarding the composition and the residence time. In general the lightest fractions are composed by weakly decomposed plant and animal residues with a rapid turnover, whereas the heavy fraction is thought to contain more humified residues with a lower C/N ratio and a lower turnover rate (Glaser et al., 2000).

On these sub-samples I performed the following analysis:

Elemental analysis: Organic Carbon and Nitrogen content were determined by the dry combustion method using a CHN auto-analyser.

Analysis of lignin: Cuo oxidation technique was used to digest and release lignin-derived phenols that were subsequent extracted using C_{18} columns soild-phase extraction system and eluted out by ethyl acetate. The lignin monomers extracted were dissolved in pyridine, derivatised with BSTFA (bis-(trimethylsilyl)-trifluoroacetamide) and finally analysed with GC-FID (gas chromatography-flame ionisation detection). Phenylacetic acid was used as an internal standard for quantification. CuO oxidation yields a suite of phenolic oxidation products of vanillyl- (V), syringil- (S) and coumaryl-tipe (C). The sum of V-, S- and C-type phenols (VSC) is used as an indicator of lignin in soils. The acid to aldehyde ratio of vanillil units $(Ac/al)_v$ and of syringil units $(Ac/Al)_s$ reflect the oxidation state of lignin side chains and thus indicate the degree of microbial alteration of lignin.

Analysis of non-cellulosic polysaccharides: acid hydrolysis of soils was carried out using trifluoroacetic acid (TFA). The monosaccharide units were derivatised by reduction to alditols with sodium borohydride ($NaBH_4$) in dimethylsulfoxide (DMSO) and a subsequent acetylation. Finally, the monosaccharide units were

analysed with a GC-FID. Myo-Inositol was used as an internal standard for quantification. TFA hydrolysis extract all non-cellulosic polysaccharides except fructose whose concentration in soil usually is, however, negligible. The ratio C6/C5 (mannose+galactose)/(xylose+arabinose) has been defined to discriminate between carbohydrates predominantly derived from plants (low ratios, <0.5) and microbial input (high ratios, >2) since it is well known that plant material contains large proportion of pentose sugars and that, in contrast, microbial population synthesises dominantly hexose.

3. Description of the main results obtained

In general, whereas the fire of high severity let the Carbon and Nitrogen content in soil almost unchanged, the fire of extreme severity produced a dramatic loss of SOC. Analysing the C content in the soil density fractions, this loss seemed to be almost totally confined in the fPOM fraction. This result should demonstrate the real importance of soil aggregation in protecting SOC against oxidation during a fire.

After both the fires, non-cellulosic neutral sugars content in soil did not show large change compared to the control sites, although any change in sugar content in soil could have a strong impact on the entire soil ecosystem because of the fundamental role of sugars as energy and as binding agent in soil.

The C6/C5 ratio was high for both sites before the fire, indicating that sugars mainly were synthesised by microorganisms, but only the extreme severe fire burned a large part of pentose sugars. Polysaccharides of microbial origin preferentially act on soil structure and aggregation compared to the sugars derived from plants (Kiem & Kögel-Knabner, 2003) thus a part of hexose sugars formed and, hence, was protected within the aggregates against the fire. In fact, the sugars content in the soil density fractions was particularly low in the fPOM fraction of the burned soil.

Lignin content, expressed as the sum of S, V, and C units, experienced a sharp fire-induced decrease after both the fires, indicating a thermal alteration of lignin polymers. Lignin usually is supposed to be quite resistant to thermal alteration, but in our samples lignin polymers showed a higher susceptibility to fire compared with sugars. Furthermore, differently from the sugars, the fire altered

not only the lignin of fPOM fraction, but also the lignin protected into the aggregates in the oPOM fraction.

Only the acid to aldehyde ratio (Ac/Al) for vanillyl units after the fire of extreme severity had a huge rise. As demonstrated by Kuo et al. (2008), to an increase of burning temperature and duration correspond an increase of the (Ac/Al)_v ratio.

4. Future collaboration with host institution

This collaboration is expected to continue on spectroscopic analysis of soil samples and the quantification of the pyrogenic organic matter in soil.

5. Projected publications / articles

A paper focused on the composition and content of lignin and carbohydrates in forest soils after wildfires of different severity will be write in the following months. Further articles on the evaluation of SOM alteration due to fire at forest sites that experienced fires with a different severity are also in preparation.

References

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