Biogeochemistry (2011) 106:1–4
DOI 10.1007/s10533-011-9586-y

EDITORIAL

# From land to water, an overview of organic matter research in France—proceedings of the Sainte-Maxime 2009 symposium organized by the French network on organic matter research

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Received: 17 February 2011 / Accepted: 20 February 2011 / Published online: 12 March 2011


A Research Network focusing on organic matter (Réseau MO) was established in 2004 in France. Its overall goal was to encourage discussions between French speaking scientists originating from a wide range of disciplines (soil science, hydrology, oceanography, sedimentology, cosmochemistry, waste management, etc.) studying the same subject: organic matter (OM). The various scientific communities working on OM often ignore each other. However, they focus on the same issues regarding sources, transformations and interactions of OM with other compounds. They use similar techniques and methodologies to address these issues, and face similar limitations regarding the understanding of this complex matrix. In order to improve scientific synergy between the various OM approaches, the "Réseau MO" intends to stimulate interactions between scientists from all communities working on OM. Workshops, summer schools and conferences are organised regularly to facilitate the sharing of recent analytical tools, to present emerging methods, to relate the latest scientific findings, to identify crosscutting and uniting themes, and to stimulate creativity.

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This special issue of Biogeochemistry presents a selection of the results from the Second Conference organised by this network, which took place on 25–28 January, 2009 at Sainte Maxime, in the south of France. The conference was attended by 140 delegates and focused on the impact of human activities on OM dynamics. Five sessions were held during the Conference, four of them dedicated to a research theme and the last one specifically focusing on methodological advances for OM study. Presentations and debates addressed the storage of carbon in soils and wetlands, the impact of anthropogenic activities on this storage, the sources of OM in aquatic systems, and the affinity of dissolved organic matter for hazardous compounds. Outcomes of these topics are summarised below.

## Storage of carbon in soils and wetlands: contribution of plant versus microbial OM

Terrestrial ecosystems, if properly managed, are expected to sequester a part of the increased atmospheric carbon originating from anthropogenic activities. Consequently, it has become increasingly important to understand which processes generate stable OM and what may impact the efficiency of the preservation in the current context of global change.

OM in terrestrial environments is mainly derived from plant input and is progressively transformed and mineralised due to the activity of decomposers. This continuous and repeated processing of OM has opposing effects on the storage of C. It releases carbon dioxide into the atmosphere but also generates microbial products suspected to exhibit a high potential for long-term storage (Gleixner et al. 1999). Identification of the degree of decomposition and microbial processing of plant-derived OM is the first step forwards in the understanding of mechanisms ruling OM sequestration. Various techniques have been developed for this purpose.

Measurement of the amount of hydrocarbonaceous and oxygenated compounds by Rock–Eval pyrolysis is commonly used in petroleum chemistry to determine the degree of maturation of oils. It has been successfully applied to sediments, peatlands and soils so as to identify the plant or microbial nature of OM (Delarue et al. 2011; Disnar et al. 2003; Gogo et al. 2011; Jacob et al. 2004).

Natural abundance of $^{13}C$ and $^{15}N$ isotopes also increasingly serves as a tool for inferring sources of soil organic matter (SOM). Indeed, numerous observations showed that plant compounds are slightly depleted in $^{13}C$ and $^{15}N$ compared to bulk SOM. Lerch et al. (2011) tested the assumption according to which fractionation accompanying microbial metabolism may be at the origin of this enrichment of SOM (Balesdent and Mariotti 1996; Bird et al. 2003; Dijkstra et al. 2006). They quantified $^{13}C$ and $^{15}N$ fractionation factors between soil and microbial biomass and confirmed that microbial isotopic fractionation leads to the enrichment of SOM in heavy isotopes. However, they showed that disturbances associated with experimental set-up may impact the dynamics of the microbial communities and induce variations in the isotopic composition of microbial biomass.

Specific organic molecules can be used as markers of sources too. The relative contributions of their main functional groups to OM can be evaluated by spectroscopic techniques such as NMR, FTIR. Such biomarkers can also be quantified by chromatographic techniques after chemical degradation or pyrolysis. For example, neutral sugars are commonly used as specific markers of phyto-inheritance or in situ microbial synthesis (Comont et al. 2006; Delarue et al. 2011; Gogo et al. 2011; Jia et al. 2008). In this issue, Mendez-Millan et al. (2011) investigated the potential of cutin and suberin constitutive monomers as a robust indicator of shoot and root origin. They showed that mid-chain hydroxy carboxylic acids are mainly found in shoots, while $\alpha,\omega$-alkanedioic acids are specific to roots. In addition, the differences in isotopic composition of these monomers in wheat and maize plants are large enough to be used to quantify their mean residence time in soil after a $C_3$–$C_4$ plant conversion.

The research presented in the contributions to this special issue illustrates how important it is to apply and confront multiple techniques to investigate the complex chemical composition of OM, as some techniques tend to under/overestimate some moieties. The inclusion of information using one technique or another, may serve not only as a support for each, but also as a complement.

## Impacts of anthropogenic activities on carbon storage in soil

A major matter of concern today is that anthropogenic activities may strongly impact the processes of OM decay and transformation in continental ecosystems and then decrease their potential as a sink of atmospheric carbon. Regarding this issue, Delarue et al. (2011) examined how climate change towards dryer conditions would affect the OM dynamics in peatlands. Their study revealed that highly oxygenated compounds, typical of fresh plant material, are particularly sensitive to the moisture content in peat and decay faster under dry conditions. The nutrient requirements of microbes may be satisfied thanks to OM mineralization in such dry areas whereas the intermittent flow of nutrients in drained wet areas could meet microbial needs (Gogo et al. 2011).

High level of nitrogen deposition is also of concern. In peatlands, it stimulates the growth of vascular invading species, which causes the decline of *Sphagnum* species (Tomassen et al. 2004) and affects OM dynamics. The litter of invading species indeed exhibits higher degradability and higher nutrient contents in comparison with *Sphagnum*, which promote the decay of OM (Gogo et al. 2011). Moreover colonisation of the *Sphagnum*-dominated peatland by roots of the vascular invading plants may also enhance the decomposition of deep OM through the injection of labile exudates stimulating dormant microbial communities (Fontaine et al. 2007).

## Continental and anthropogenic sources of OM in aquatic ecosystems

OM accumulated and preserved in soils is eventually remobilised and exported towards rivers. The paper by Bardy et al. (2011) explored the contribution of surface and deep horizons to the OM of the water-table of the Rio Negro basin. They showed that the water soluble OM extracted from soil exhibits contrasting features depending on the horizon and the degree of podzolization. Comparison of water-extractable OM with the groundwater draining a well-developed podzol revealed that in the Rio Negro basin, both the surface and the deep Bh horizons contribute to the exportation of OM towards the river.

In addition to natural processes, human activities also introduce large amounts of OM into natural water: streaming from street runoff, OM released in rivers after waste-water treatment, or leaching from composts applied in agrosystems. These anthropogenic inputs modify the nature of dissolved organic matter (DOM). For example, OM in the treated effluent of waste-water displays a strong proteinaceous nature, which is interpreted as a result of the intense microbial activity during urban water treatment (Pernet-Coudrier et al. 2011). Moreover, it has been shown that when compost is added to a soil, the hydrophobic compounds remain selectively on solid surfaces whereas more hydrophilic compounds are exported in solution (Jardine et al. 1989, Kaiser et al. 1996).

## Contribution of human activities to the affinity of DOM for potentially hazardous compounds

The enhancement of the hydrophilic nature of DOM by the anthropogenic input into natural water also increases DOM affinity for potentially hazardous compounds like metals or organic pollutants. Quantification of the affinity of OM for contaminants is the first step in the assessment of the risk of pollutants in surface water and to develop the adequate treatments for producing safe drinking water.

A well-known method to measure complexing properties of OM is the use of its fluorescence properties since the presence of a complexing cation or anion modifies the fluorescence intensity of the DOM (Canabiss 1992; Coble 1996). The DOM is observed by measuring the excitation and emission matrix of fluorescence and locating peaks of fluorescence. Usual treatment consists of analysing a few excitation/emission peaks referenced as humic-like, fulvic-like or protein moieties. In this issue Mounier et al. (2011) illustrate that all of the information contained in the excitation-emission fluorescence matrix can be successfully treated by a statistical method, parallel factor analysis and provides a robust estimate of the complexing parameters of DOM for copper in black water from Rio Negro in Brazil.

The transport of pollutants in water not only depends on their sorption to DOM, but also on the competition between DOM and pollutants for the solid phase. This latter mechanism may play an important role in the desorption of pollutants as evidenced by Barriuso et al. (2011). They propose to model the behaviour of pesticide in a three phase interaction system (solid-DOM-liquid) so as to better assess the real risk of water pollution.

## Synopsis of the Network activities

During its first years of activity, the French Research Network on organic matter has already proven the great power—and pleasure—that exists in gathering and networking the various scientific communities investigating OM. The active transfer of methodologies and techniques between communities is one important outcome of this Network. The connection of communities studying OM at different time-scales or studying OM in spatially related reservoirs, like soil science and aquatic science societies is another, and this has been especially fruitful regarding issues related to sources and transformation of OM. We hope that ideas sparked from this knowledge sharing will soon lead to great advances in the understanding of the multiple processes affecting organic matter on Earth. The "Réseau MO" wants to act as an incentive to foster the emergence of new and innovative research projects dedicated to OM at the national and the European level, and it is fully open to other European initiatives in similar directions.

**Acknowledgements** The members of the scientific committee of the Network (Pierre Benoit, Laetitia Bernard, Jérôme Cortet, Pierre Faure, Jérémy Jacob, Cécile Miège, Edith Parlanti, Claude Geffroy-Rodier and Christian Bechemin) deserve high praise for organising the many activities of the Network, especially the second Conference, and for spending a lot of time in producing this special issue. We also acknowledge the numerous reviewers for their expertise and Ayrene Dialogo and Kate Lajtha for their help and kind advice. Thanks also to French Research Organizations (INRA, INSU-CNRS, ADEME, CEMAGREF and IRD) and to the MicroHumus company that supported the Conference. Finally, the "Réseau MO" is particularly thankful to the Environment & Agronomy (EA) and Ecology of Forests, Grasslands & Freshwaters (EFPA) Divisions of INRA for initiating and financing the network.

## References

Balesdent J, Mariotti A (1996) Measurement of soil organic matter turnover using 13C natural abundance. In: Boutton TW, Yamasaki S (eds) Mass Spectrometry of Soils. Marcel Dekker, Inc., New York, pp 83–111

Bardy M, Derenne S, Allard T, Benedetti M, Fritsch E (2011) Podzolisation and exportation of organic matter in black waters of the Rio Negro (upper Amazon basin, Brazil). Biogeochemistry. doi:10.1007/s10533-010-9564-9

Barriuso E, Andrades M-S, Benoit P, Houot S (2011) Pesticide desorption from soils facilitated by dissolved organic matter coming from composts: experimental data and modelling approach. Biogeochemistry. doi:10.1007/s10533-010-9481-y

Bird MI, Kracht O, Derrien D, Zhou Y (2003) The effect of soil texture and roots on the stable carbon isotope composition of soil organic carbon. Aust J Soil Research 41:77–94

Canabiss SE (1992) Synchrotronous fluorescence spectra of metal-fulvic acid complexes. Environ Sci Technol 6:1133–1139

Coble PG (1996) Characterization of marine and terrestrial DOM in sea water using excitation-emission matrix spectroscopy. Mar Chem 51:325–346

Comont L, Laggoun-Défarge F, Disnar J-R (2006) Evolution of organic matter indicators in response to major environmental changes: the case of a formerly cut-over peatbog (Le Russey, Jura Mountains, France). Org Geochem 37:1736–1751

Delarue F, Laggoun-Défarge F, Disnar J, Lottier N, Gogo S (2011) Organic matter sources and decay assessment in a Sphagnum-dominated peatland (Le Forbonnet, Jura Mountains, France): impact of moisture conditions. Biogeochemistry. doi:10.1007/s10533-010-9410-0

Dijkstra P, Ishizu A, Doucett R, Hart SC, Schwartz E, Menyailo OV, Hungate BA (2006) C-13 and N-15 natural abundances of the soil microbial biomass. Soil Biol Biochem 38:3257–3266

Disnar J-R, Guillet B, Keravis D et al (2003) Soil organic matter (SOM) characterization by Rock-Eval pyrolysis: scope and limitations. Org Geochem 34:327–343

Fontaine S, Barot S, Barré P, Bdioui N, Mary B, Rumpel C (2007) Stability of organic carbon in deep soil layers controlled by fresh carbon supply. Nature 450:277–280

Gleixner G, Poss R, Balesdent J (1999) Molecular insight into soil carbon turnover. Rapid Commun Mass Spectrom 13:1278–1283

Gogo S, Laggoun-Défarge F, Delarue F, Lottier N (2011) Invasion of a Sphagnum-peatland by Betula spp and *Molinia caerulea* impacts organic matter biochemistry. Implications for carbon and nutrient cycling. Biogeochemistry. doi:10.1007/s10533-010-9433-6

Jacob J, Disnar J-R, Boussafir M et al (2004) Major environmental changes recorded by lacustrine sedimentary organic matter since the last glacial maximum near the equator (Lagao do Caço, NE, Brazil). Palaeogeogr Palaeoclim Palaeoecol 205:183–197

Jardine PM, Weber NL, McCarthy JF (1989) Mechanisms of dissolved organic-carbon adsorption on soil. Soil Sci Soc Am J 53:1378–1385

Jia GD, Dungait JAJ, Bingham EM, Valiranta M, Korhola A, Evershed RP (2008) Neutral monosaccharides as biomarker proxies for bog-forming plants for application to palaeovegetation reconstruction in ombrotrophic peat deposits. Org Geochem 39:1790–1799

Kaiser K, Guggenberger G, Zech W (1996) Sorption of DOM and DOM fractions to forest soils. Geoderma 74:281–303

Lerch T, Nunan N, Dignac MF, Chenu C, Mariotti A (2011) Variations in microbial isotopic fractionation during soil organic matter decomposition. Biogeochemistry. doi:10.1007/s10533-010-9432-7

Mendez-Millan M, Dignac M-F, Rumpel C, Derenne S (2011) Can cutin and suberin biomarkers be used to trace shoot and root-derived organic matter? A molecular and isotopic approach. Biogeochemistry. doi:10.1007/s10533-010-9407-8

Mounier S, Zhao H, Garnier C, Redon R (2011) Copper complexing properties of dissolved organic matter: PARAFAC treatment of fluorescence quenching. Biogeochemistry. doi:10.1007/s10533-010-9486-6

Pernet-Coudrier B, Varrault G, Saad M, Croue J, Dignac MF, Mouchel JM (2011) Characterisation of dissolved organic matter in Parisian urban aquatic systems: predominance of hydrophilic and proteinaceous structures. Biogeochemistry. doi:10.1007/s10533-010-9480-z

Tomassen HBM, Smolders AJP, Limpens J, Lamers LPM, Roelofs JGM (2004) Expansion of invasive species on ombrotrophic bogs: desiccation or high N deposition? J Appl Ecol 41:139–150