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Release of organic carbon, silica, major and trace elements from degrading plant litter under microbial activity in laboratory experiments

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Quantification of major and trace elements recycling by plants is hampered by the lack of physico-chemical data on chemical elements release from degrading plant litter in soil and model laboratory environments. In this study, we applied a laboratory experimental approach for determining the organic carbon and approx. 30 chemical elements release rates from litter of typical temperate and boreal plants: larch (*Larix gmelinii*), elm (*Ulmus laevis* Pall.), tree fern (*Dicksonia squarrosa*), in 0.01 M NaCl solutions, circumneutral pH and temperature equals to 25°C.

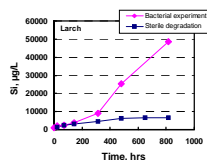
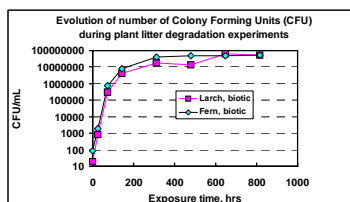
Methods

Open system, mixed-flow reactors equipped with dialysis compartment (1 kDa, or approximately 1 nm pore size) and batch reactors were used. Comparative measurements were performed under sterile and non-sterile conditions with evaluation of the number of active heterotrophic bacteria via counting the number of colony-forming units (CFU) on the agar plates.

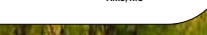
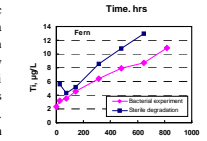
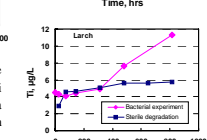
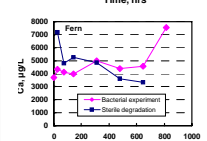
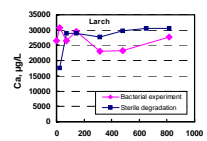
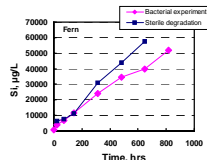
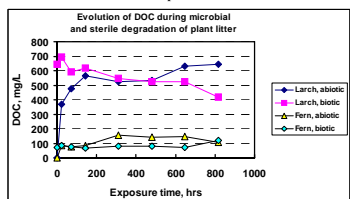
Element release rates from plant litter

Element	Elements release rates in sterilized litter μmol/g _{ppw} /day		
	Elm, pH= 6.5	Larch, pH= 5.8	Fern, pH= 5.9
Li	3.00E-02	2.00E-02	3.00E-02
B	2.00E-02	3.00E-02	2.00E-02
Mg	1.80E-02	4.10E-03	1.07E-01
Si	2.24	1.53	9.49
P	6.00E-02	4.00E-02	6.00E-02
K	1.25E-01	8.50E-02	1.03E-01
Ca	7.60E-01	1.13E-01	3.66E-01
Ti	6.70E-04	4.03E-04	1.05E-03
V	1.03E-04	6.89E-05	8.48E-05
Cr	4.14E-04	3.64E-04	2.73E-04
Mn	8.30E-04	2.21E-04	1.61E-02
Cu	1.62E-03	8.32E-04	1.19E-03
Zn	1.76E-02	1.86E-02	2.05E-02
Rb	3.49E-05	1.69E-05	3.38E-05
Sr	3.69E-03	1.02E-03	1.24E-03
Mo	2.22E-05	1.38E-05	3.69E-05

Litter degradation in batch experiments under microbial activity



Similar concentration of active heterotrophic bacteria for both plant litters



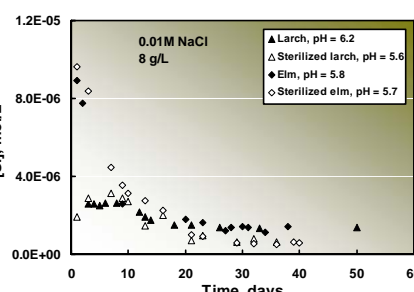
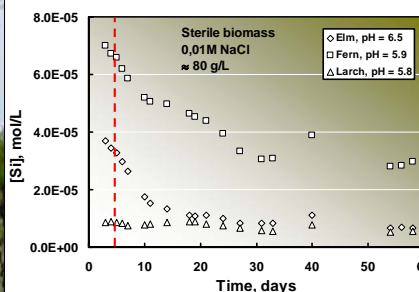
There is five time more of dissolved organic carbon for litter degradation experiments of larch compared to fern. There is a 30-40% decrease of DOC concentration in the course of biotic experiments but gradual increase after 1st day of exposure in sterile runs. This strongly implies the consumption of DOC by bacteria.

The effect of the presence of heterotrophic bacteria on trace element release rate from plant litter is very weak (except for Si and Ti release from the larch). In fact, the presence of bacteria even capable of decreasing the release rate and solution concentrations of Fe, REEs, U, Cs, Sr and other trace elements. Since the concentration of DOC decreases with time in biotic experiments, consumption of DOC and associated TE by bacteria is very likely to occur. Evolution of Al and Fe concentration follows that of the organic carbon, certainly due to the control by Al-Fe-organic colloids and complexation with released organic ligands. Note that the majority of DOC and most trace elements is being released in solution upon the first day of exposure. Exceptions are Si, and Ti which are probably being released from the attached mineral particles being not complexed with DOC.

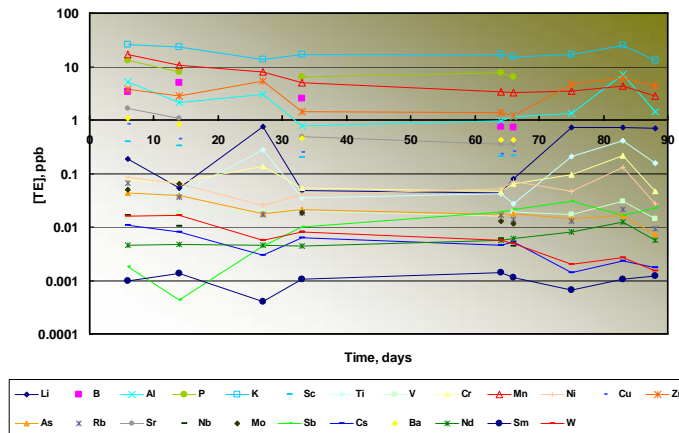
Laboratory litter degradation at 25°C

1/ Open mixed flow experiments with dialysis compartment (1 KDa):

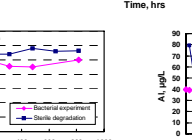
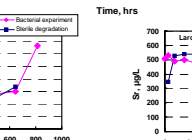
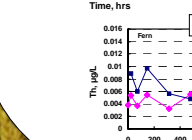
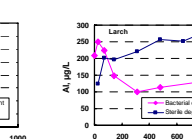
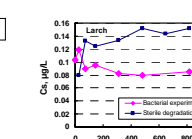
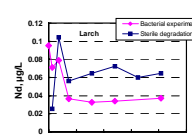
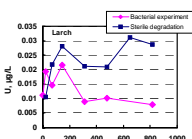
Major elements: Si for example



Trace elements release from sterilized Fern litter



2/ Batch reactor experiments:



Conclusions

Litter degradation results suggest that many chemical elements release rate is independent on dissolved organic carbon release (cellulose hydrolysis). In the open-system mixed flow experiments, most elements are released at the very first stage of litter dissolution. In the closed-system (batch) experiments over 1 month observation time, the sterile biomass of larch needles liberates similar amount of organic carbon and trace metals (Al, Ti, Fe, Mn, Cu, Sr, Y, Zr, Mo, Pb) as in biotic experiment with the presence of soil bacteria. At the same time, Si release rate in sterile condition (0.74 μmol/g/day) is an order of magnitude lower than in the presence of bacteria (6.2 μmol/g/day). The abiotic release rate of TE in experiments with dialysis compartment (< 1 nm) is at least an order of magnitude lower than that in conventional batch experiments (< 0.22 μm) for many trace elements (Al, Fe, Cu, Ni, Zn, Pb...) likely due to colloidal organic matter control onto speciation of these litter-borne trace metals in solution. Elements that are present in the form of free ions or inorganic complexes (Li, B, Na, Mg, Ca, Si, Rb, Sr, Mo, As, Cs...) exhibit similar, by the order of magnitude, release rates in flow-through dialysis compartment and in the batch dialysis-free experiments. The presence of bacteria (100 to 107 colony forming units per L) in the course of biotic plant litter degradation experiment does not significantly modify the release of organic carbon and major (Ca, Mg) and trace elements (Al, Ti, Mn, Fe, Cu, Sr, Pb) both for larch tree and fern biomass.