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Microbial adaption to a pesticide in agricultural soils: Accelerated degradation of 14C-atrazine in field soils from Brazil and Belgium

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An increasing demand for food, feed and bioenergy, and simultaneously a decline of arable land will require an intensive agricultural production including the use of pesticides. With an increasing use of pesticides the occurrence of an accelerated degradation potential has to be assessed.

Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] is one of the most widely used herbicides in the world. Even though its use was banned in several countries it is still widely used throughout America and the Asia-Pacific region. Atrazine is the most widely used herbicide in maize plantations in Brazil and the US. The use of atrazine in Belgium and all EU member states was banned in September 2004, with the permission to consume existing stocks until October 2005.

Atrazine and its residues are still regularly detected in soil, ground and surface waters even years after its prohibition. Its persistence in soil and in association with organic particles might become crucial in terms of erosion due to climate and environmental changes. Due to its potential microbiological accessibility, the microbial mineralization of atrazine competes with chemical/physical interaction such as sorption and binding processes of the chemical molecule in the soil matrix. Binding or intrusion of the chemical on soil components results in a decrease of its accessibility for soil microbes, which does not necessarily exclude the molecule from environmental interactions.

In the present study the accelerated atrazine degradation in agriculturally used soils was examined. Soil samples were collected from a Rhodic Ferralsol, Campinas do Sul, South Brazil, and Geric Ferralsol, Correntina, Northeastern Brazil. The sampling site of the Rhodic Ferralsol soil has been under crop rotation (soybean/wheat/maize/oat) since 1990. The Geric Ferralsol site has alternately been cultivated with maize and soybean since 2000. Both areas have been treated biennially with atrazine at recommended doses of 1.5 – 3.0 kg ha^{-1}. Additionally, samples were taken from a Belgian field which was used for corn-plantations and which was regularly treated with atrazine for the last 30 years in varying doses of 0.5 – 3.0 kg ha^{-1}.

The experiment was performed using ^{14}C-labelled and unlabelled atrazine in accordance to a field application dose of 3 mg kg^{-1} for the Brazilian soils, and 1 mg kg^{-1} for the Belgian soil, equaling approximately 3.0 and 1.0 kg ha^{-1}, respectively.

All soils with atrazine application history showed a high extent of atrazine mineralization, indicating a highly adapted microbial community being able to mineralize this pesticide.

After 15 days of incubation, about 75 % of the initially applied ^{14}C-atrazine was mineralized in the Rhodic Ferralsol, while in the Geric Ferralsol it did not exceed 15 % of the total applied ^{14}C-activity. After a total incubation time of 85 days, the amount mineralized reached 82 % in the Rhodic Ferralsol and 74 % in the Geric Ferralsol.

In the Belgian soil, after a total incubation time of 92 days, the mineralized amount of atrazine reached 83% of the initially applied ^{14}C-activity in the atrazine treated soil for the slurry setup. A maximum of atrazine mineralization was observed in the treated field soil between 6 and 7 days of incubation for both, 50% WHC_{max} and slurry setups. The total ^{14}C-atrazine mineralization was equally high for 50% WHC_{max} in the atrazine treated soil, totaling 81%.

The formation of desorbable metabolites as well as the formation of unextractable, bound atrazine residues during the incubation process was monitored by desorption and accelerated solvent extraction, and successive LC-MSMS and LSC analyses, subsequent to sample oxidation. With increasing incubation time the presence of atrazine metabolites increased in the extracts, with hydroxyl-atrazine as the main metabolite.