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PAHs in soils: Sorption versus degradation - elucidation of rate-limiting processes

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Polycyclic aromatic hydrocarbons (PAHs) belong to the class of persistent organic pollutants, and are of special interest due to their ubiquituous distribution in the environment at relatively high concentrations. Subsequent to their emmission into the environment through incomplete combustion processes of natural and anthropogenic sources (e.g. vulcano eruptions, forest fires, industry, traffic), PAHs can be transported over long distances. Following atmospheric deposition they accumulate in particular in top-soils and have been found to be stable over long periods of time (decades to centuries).
Based on that this study targets on the elucidation of the long-term PAH-fate in top-soils by means of degradation experiments under well-controlled laboratory conditions with well mixed batch experiments at a water to solids ratio 10:1. From a rural site in the Black Forest Mountains, Germany, top-soil samples were taken, which contains approximately 7-8 mg 18 PAHs per kg soil. This soil was sieved through 2 mm to sort out stones, roots- and leaf-parts and homogenised afterwards.
Within the first month of incubation a depletion of native PAHs were observed. However, an exhaustive sequential extraction using accelerated solvent extraction with 3 cycles of acteone and 4 cycles of toluene (100 bar pressure, 10 min static time, 100°C and 150°C respectively) revealed a reduced extractability of PAHs subsequent to incubation. In order to stimulate PAH degradation a second experiment with a higher water to solid ratio (1000:1) was carried out, and phenanthrene was spiked to the water phase of this set up. Results revealed a reduction of phenanthrene concentration more likely to be due to sorption rather than degradation. The set up was changed to aqueous soil solutions without soil in the batch and spiked again with phenanthrene. Degradation of phenanthrene occurred within 10 days in these batches.
The experiments show that the microorganisms present in the Black Forest soil are capable to degrade PAHs. Nevertheless strong sorption and high organic carbon content in this soil prevent these microorganisms from degrading the native PAHs. The results were implemented into a mass balance model considering both, sorption and degradation. The calculations were conducted with first order rate constant taken from the non-soil-containing experiment, and revealed a half-life of phenanthrene up to almost one century.

Keywords: PAH, degradation, sorption