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Effect of activated carbon, biochar and compost on the desorption and the biodegradation of low concentrations of phenanthrene sorbed to different soils

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Most regulations and regulatory accepted assessment procedures on soil and sediment contamination are still based on total concentrations. When removal of the contaminant is an expensive exercise and/or there are doubts on the risks posed by the contaminants this often leads to a “wait and see”attitude. Site investigations are often repeated, but no actions are taken to reduce the risks of the contaminants. From a risk-based point of view, contaminations are only a risk if they are or may become (bio)available. This widens the range of management options of contaminated sites and can facilitate more tailor-made solutions for individual sites. In a risk based approach stimulation of biodegradation and/or immobilization and isolation of the contaminant may play a role. In particular bioavailability can be the underlying basis for the description of risks and for determining a solution and can be used to break the infinite circle of new site investigations.
Bioavailability should be more than a concept and including bioavailability in site management asks for methods to measure the bioavailable fraction. Such methods should have an understandable physical base (ISO 17402) and are fortunately available. Using the Tenax method the available and therefor degradable fraction can be measured. Using the different available fractions it is possible to predict the rate of degradation of PAHs and mineral oil and depending on this rate a management plan can be developed. Background and applications will be shown on remediation of heavily and also slightly contaminated soils and sediments.
If contaminants are not biodegradable, the bioavailability can be reduced by immobilization, for instance by adding black carbon or by preventing leaching and physical contact by isolation. Examples will be presented on the management of remote pesticide contaminated areas in Africa using charcoal for immobilization. Natural dune formation and/or stimulation of vegetation to evaporate water thereby preventing leaching have been used for isolation.

EC06A-2
Effect of activated carbon amendments on microbiological communities in PAH contaminated urban soil
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The addition of activated carbon (AC) to contaminated soils is currently being investigated as a cost-effective remediation technique, and an important consideration is the long-term effect of the AC amendments on microbial communities involved in the biodegradation of the organic pollutants. In this work, urban soils impacted by 23±15 mg per kg polycyclic aromatic hydrocarbons were sampled from a remediation field trial, and the long-term effect of 2.0% powder (PAC) or granular (GAC) activated carbon amendments on the microbial community structure and functioning was studied, by using molecular techniques. Denaturing gradient gel electrophoresis (DGGE) analysis showed a statistically significant shift in the predominant microbial community in the soils over time, whereas the effect of PAC or GAC amendments was not statistically significant in an ANOSIM comparison. After three years, the total microbial cell count and soil respiration rates were highest for the GAC amended soils, but cell numbers and respiration rates agreed within a factor three. The sequencing of the predominant DGGE bands, which had similar relative intensity in all soils, revealed the presence of taxa with closest affiliations to known PAH degraders (ie. Rhodococcus jostii RHA-1), or taxa known to harbour PAH degraders (ie. Rhodococcus erythropolis). The potential of the microbial community to degrade PAHs was evaluated by quantifying specific dioxygenase genes, using real-time polymerase chain reaction (PCR) assays. Similar gene copy numbers were measured in unamended, PAC and GAC amended soils. Polyethylene (PE) passive samples batch studies showed a reduction of the PAHs availability with biodegradation when comparing live and sterile soils. The strongest effect of biodegradation on PAH availability was found in unamended soil, with 75% difference between sterile and live soil slurries, while the lowest PAH availability was measured in PAC amended, live soil. The combination of the chemical and microbial studies suggested that microorganisms with the ability to degrade PAHs persist long-term in soils, regardless of the presence of activated carbons amendments which reduce the PAH availability, presumably because they utilized other soil organic matter as their main carbon source.

EC06A-3
Effects of carbon amendments on ecological responses and PCB bioaccumulation in Lumbriculus variegatus
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During the recent years synthetic black carbon products (mainly activated carbons AC, but also biochars), have been under an intense study to be used as a potential stabilization method for contaminated sediments. Results from various studies both in laboratory and pilot scale field studies have supported the high efficiency of AC amendments in sorption, and consequential reduction in bioavailability of HOCs. However, recent studies also indicate that AC amendments may inflict adverse ecological effects on aquatic organisms, e.g. sediment avoidance, inhibition in growth and alteration in sediment ingestion. The direct biological effect of AC on organisms may have an influence for both laboratory-scale bioaccumulation and toxicity testing and field-scale ecological impact assessment. The aim of this study was to test the responses of carbon amendments for remedial purposes in oligochaete Lumbriculus variegatus, a widely used test organism in sediment ecotoxicology. The effects of carbon amendments were tested in PCB contaminated sediments, which do not have acute toxic effect on the test organisms. The measured parameters included PCB bioaccumulation, feeding activity, growth and reproduction.
The AC was more efficient in reducing the bioavailability of PCBs than the tested biochar and the reductions were sediment specific. The results showed a clear AC dose related response in all of the studied ecological parameters. The ecological responses were also sediment dependent. The AC also reduced the biomass of the worms compared to the control; moreover in two sediments out of three the AC addition in the sediment ultimately led the worms to lose weight during the experiment period, whereas in control sediments the worms were gaining weight. The effects of biochar on the biological responses were smaller than that of the AC. The site-specific evaluation is particularly important when remediation measures are designed. Negative effects of carbon amendments to the organisms, such as change in behavior, reduced growth and reduced reproduction needs to be considered, since they are important factors affecting the assessment of toxicity, bioaccumulation and ecological quality of the sediments.

EC06A-4
Effect of activated carbon, biochar and compost on the desorption and the biodegradation of low concentrations of phenanthrene sorbed to different soils
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Polycyclic aromatic hydrocarbons (PAHs) are an important class of soil and groundwater pollutants. Often, a large portion of the PAHs are degraded by soil microorganisms within short times (<100 days), and this is often followed by slower degradation resulting in a non-degradable residual fraction. Such a non-degradable residual fraction is very difficult to remove even by intensive biological and chemical methods. This does imply however, that this non-degradable residual fraction is poorly available to organisms and therefore could perhaps be considered as posing a limited risk.
The addition of PAH sorbing amendments to soil leads to reduced freely dissolved concentrations. On the one hand this limits bioavailability and uptake by organisms leading to reduced toxicity, but on the other hand this might also decrease biodegradation. The aim of this study was to characterize the soil amendments activated charcoal (AC), biochar (charcoal) and compost for their ability to reduce the desorption and biodegradation of phenanthrene as a model PAH in three different sandy loam soils (Outfield, RS, or Olsen).
The extent of abiotic desorption of [9-^{14}C]phenanthrene from suspensions made up of soil (either Outfield, RS, or Olsen) plus amendment (either AC, charcoal, or compost) was investigated over a period of 24 days by desorption into an infinite silicone sink. The extent of desorption was then compared to the extent of mineralization (t = 15 d) of phenanthrene sorbed to the soil plus amendment suspensions by *Sphingomonas sp* (DSM 12247). The total amount of phenanthrene desorbed was 6 to 10% for AC, 38 to 44% for charcoal, 87 to 106% for compost, and 95 to 106% for control without any soil amendments after 24 d. This was more than percentage of initial ^{14}C found in the CO_2-trap at experiment completion, i.e., amount mineralized. These ranged between 3.0 to 5.4% for AC, 10.4 to 14.8% for charcoal, 14.9 to 21.8% for compost, and 25.5 to 31.2% for control.
The amounts of phenanthrene mineralized were slightly lower than the maximum amounts that were abiotically desorbed, and indicate that sorption to the soil amendments had a stronger inhibitory effect on mineralization than abiotic desorption. Nevertheless, desorption into an infinite silicone sink might be useful as a tool to estimate the maximal extent of mineralization (and biodegradation) in soils polluted with PAHs.

EC06A-5
The influence of field aging of activated carbon in sediment on PCB sorption in field trials
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Bioavailability of hydrophobic organic contaminants of concern such as polychlorinated biphenyls (PCBs) in sediments is strongly influenced by the nature of contaminant binding. This observation is at the foundation of utilizing the sorption capacity of activated carbon (AC) to control risks posed by sediment-associated contaminants. Monitoring over several years at pilot-scale application sites at Hunters Point, CA and Grasse River, NY USA has demonstrated that AC amendment reduces contaminant bioavailability by controlling both chemical accessibility and activity. One important question is the long-term sustainability of this remediation strategy under field conditions. To further evaluate the sorption effectiveness of AC after prolonged exposure in the field, sorption of freshly spiked and native PCBs to 1) AC aged for 2-2.5 years under field conditions and 2) fresh AC amendments to untreated sediments were compared for sediments collected from both pilot sites. Pore water concentrations and sorption coefficients (K_{AC}) were determined using passive samplers in batch tests. In a separate study, a mass transfer model simulation of the effectiveness of AC amendment