European Commission

Science for Environment Policy

Microbes and enzymes: the future for bioremediation of PAH-contaminated soils?

Microbes and biocatalytic enzymes could offer useful tools for cleaning soils polluted with polycyclic aromatic hydrocarbons (PAHs), suggests a new review of remediation approaches. However, risk assessments and further work are needed before their use can be extended beyond the lab to real-world situations. This comprehensive overview of available and novel methods indicates their constraints and potential for future development and research.

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PAHs are a large group of extremely toxic contaminants, which includes many carcinogens. Burning fossil fuels is the chief source of PAH pollution, with estimates showing that global concentrations of PAHs in soils have doubled since 1980. In the EU, eight types of carcinogenic PAH are regulated by the REACH regulation[1].

Reviewing studies published since 1990, the researchers describe commonly used, established technologies for dealing with PAHs in soil, including incineration, in-situ thermal desorption (ISTD), soil washing and chemical oxidation. While these are all effective, they have various drawbacks; for example, incineration requires heat, which is energy intensive, while soil washing relies on surfactants and oils to flush out PAHs, which then require disposal or further treatment.

The researchers highlight that the efficacy of soil washing can be improved by using the natural surfactant humic acid, which has the added benefit of promoting microbial activity. Microbes are vital to natural degradation of PAHs, breaking them down into less toxic chemicals, and many bioremediation processes are based on this mechanism.

Bioremediation (biological remediation) techniques have gained wide approval as safe and eco-friendly, but are often insufficient in isolation. For example, soil tillage, which promotes microbial break-down of PAHs, is a cheap but slow option and only works on the top 35 cm of soil. Similarly, composting approaches use fresh organic matter or sewage sludge to promote microbial degradation, while fast-growing plants can take up contaminants and also encourage useful soil microbes (phytoremediation).

The speed of composting and phytoremediation is influenced by the weather, for example slowing down in cold temperatures. Removing soil for treatment in a bioreactor allows better control over conditions and results in fast removal of PAHs by bacteria, but incurs additional cost and energy.

Combining processes, for example using tillage followed by phytoremediation, plus adding PAH-degrading bacteria, increases efficiency. However, in highly contaminated soils (>10 000 mg per kg), the researchers note that pre-treating with a more effective thermal or chemical process is currently necessary — a drawback of bioremediation. Pre-treating the soil with biosurfactants (produced from bacteria and fungi) could improve the success rate of bioremediation by increasing the bioavailability of PAHs, but, to make this feasible, work is needed to produce biosurfactants cost-effectively.

An emerging technology, enzyme-mediated bioremediation, offers a greener, more efficient approach than established chemical treatments. The process uses microbial enzymes that transform PAHs into less toxic substances in the soil. One major benefit is that these enzymes can work at relatively low temperatures and in a wide pH range. One enzyme of particular interest is a fungus extract, laccase, though this is, at present, costly.

1. http://ec.europa.eu/environment/chemicals/reach/reach_en.htm

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Microbes and enzymes: the future for bioremediation of PAH-contaminated soils? *(continued)*

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Vermiremediation is also the subject of recent studies. In fine soils, earthworms can play an important role by enlarging soil 'pores' (space between particles) so that microbes can reach PAHs. Worms also digest PAHs, which transforms some types into harmless substances, though some are bioaccumulated. Worms can reproduce rapidly and the process requires little to no energy, making it very economical. However, it is only suited to low-to-medium-grade contaminated sites which worms can tolerate, limiting its application.

Recent work has also indicated the potential of microbial consortia, in particular combinations of algae and bacteria, specifically designed to target contaminants and to work in adverse conditions. For instance, microalgae can supply oxygen to aerobic bacteria, which enhances their ability to degrade contaminants. Future research could focus on developing strains intended to work on PAHs, and on overcoming the problem of competition with existing populations of soil microbes, which can suppress PAH-degrading microbes, although risk assessment would be required before applying these in the environment.

Another avenue being explored is green nanoremediation. For example, nanofertilisers and nanominerals could be developed which promote microbial degradation in deeper soil levels, due to the small size of particles employed. Again, this approach would require risk assessment before being used in the environment.

While a number of promising new technologies are at the prototype stage, the review highlights that in many cases, cost is a barrier to application. For example, cost-effective ways of producing biosurfactants and microbial enzymes are required. However, the researchers note that one barrier to commercial interest is a lack of marketable by-product. Nevertheless, recent work on microbe and enzyme-based remediation shows that, given attention, they could be the future of remediation on PAH-contaminated soils.