Food and Agriculture Organization of the United Nations

HOW TO CLEAN UP PESTICIDE CONTAMINATED SOILS

PROMISING OPTION: BIO- AND PHYTO-REMEDIATION TECHNOLOGIES

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SOURCE OF POPS PESTICIDE CONTAMINATED SOILS

It is estimated that around half the obsolete pesticides in the world can be found in the former Soviet Union, with a large portion in Central Asia. These hazardous chemicals are often stored in deteriorated containers or buried in landfills, where leakages contaminate the soil and water and pose a high risk for the environment, biodiversity and human health.

Organochlorine pesticides such as DDT only very slowly degrade in the environment and belong to a group of chemicals called Persistent Organic Pollutants (POPs). Despite not being used since the 1970s, they are still found in hazardous levels in the soil.

The danger of POPs pesticides lies in their resistance to natural degradation, global mobility across food chains, and ability to accumulate in living organisms, leading to bio-accumulation in fatty tissue and causing mutagenic, teratogenic, and carcinogenic effects.

Safe removal and disposal of obsolete pesticides is a technically complex and costly activity. Due to past substantial use of POPs pesticides in the Central Asia region, agricultural soil remains contaminated until today, which jeopardizes safe food production. Hence, there is an urgent need of cleaning up soil in Central Asia, however, significant challenges are the sheer volumes and large affected areas.

Therefore, remediating the large volumes of contaminated agricultural soil in Central Asia needs cost-effective, simple and also environmentally safe approaches to have a realistic chance to be implemented.

BEST SOLUTION TO ADDRESS

A global overview shows that biological remediation of pesticide contaminated soils comes forward as a viable and applicable solution. Biological remediation technology is a very cost-effective method for restoring contaminated soils compared to physical or chemical remediation methods. It can be mainly applied for low-contaminated soils where a longer remediation time is not important. It can be implemented worldwide, especially when it relies on locally existing microorganisms.

Biological remediation encompasses a set of methods for treating soil and water by leveraging the biochemical potential of microorganisms, algae, and higher plants.

BIOLOGICAL REMEDIATION COMBINATION OF BIO- AND PHYTO-REMEDIATION

Bioremediation, which involves microorganisms, and phytoremediation, which uses plants, are two key techniques within biological remediation.

Bioremediation involves stimulating the natural microbial degradation of pollutants in the environment by providing nutrients as carbon sources or electron donors. Various microorganisms are successfully used for neutralization of toxic organic substances. This can be achieved using local microorganisms, which are obviously thriving in the contaminated conditions, or specific cultures capable of efficiently metabolizing contaminants. There are some patented microorganisms in bioremediation and they are often tailored to local environmental conditions and may not exhibit the same efficacy when applied elsewhere. Bioremediation can be conducted ex situ or in situ, without generating secondary waste and at a lower cost compared to other remediation methods, though taking more time than other more costly methods.

While microorganisms are ineffective in removing heavy metals and radioactive isotopes from soil and water, green plants offer a viable solution. Phytoremediation involves using different plant species to clean up a great variety of polluted environments and restore degraded ecosystems. Phytoremediation is a cost-effective method too, requires minimal equipment and specialized personnel, which makes it suitable for a wide range of environmental pollutants.

FAO TRIALS IN KAZAKHSTAN

Since 2023, research has started in Kazakhstan in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the Ministry of Ecology and Natural Resources of Kazakhstan within the Global Environment Facility (GEF)-funded and FAO-managed project **"Lifecycle Management of Pesticides and Disposal of POPs Pesticides in Central Asian countries and Türkiye"**.

The aim is to define and test the most efficient method for cleaning up pesticide contaminated soils around obsolete pesticide stocks, and based on the results develop an approach, which can be applied in other regions of Kazakhstan.

THE TOXIC CHEMICALS FOUND IN THE SOIL IN THE TRIALS

The soil used in the experiment was sampled from the territory of a former obsolete pesticide store located in Saimasay village, Yenbekshi-Kazakh district, Almaty region. The soil contains 24 different types of organochlorine pesticides including POP pesticides: DDT and its metabolites, HCH isomers, eldrin, chlordane, dieldrin, heptachlor, etc., as well as various heavy metals, mainly Ni, Cd, Zn. Of all organochlorine pesticides, DDT has the greatest persistence in the environment.

BIO-REMEDIATION STAGE IN THE TRIALS

At the first stage of the bioremediation trials, the composition of the microbial community in the pesticide-contaminated soil was evaluated. Then, promising strains were selected and their destructive capacity was evaluated by chromatographic analysis.

The results of chromatographic analysis revealed that the destructive capacity of thirteen isolates on HCH isomers ranged from 50.2 to 96.4 percent compared to a control sample; and with respect to DDT and its metabolites, twelve strains had destruction levels from 24.1 to 67.8 percent.

PHYTO-REMEDIATION STAGE IN THE TRIALS

After successful implementation of bioremediation techniques leading to a considerable reduction of initial contamination levels, phytoremediation can then be used as a second stage for further cleaning and restoration of contaminated soils. For developing phytoremediation, first the natural flora in and around the territory of the former obsolete pesticide store site was studied. Sixteen dominant plant species were identified, of which fourteen species inhabit the pilot site. Subsequently, a collection of seeds of these dominant native plant species was collected during the flowering season. The phytoremediation potential of six plant species (Xanthium strumarium, Lolium multiflorum, Medicago sativa, Amaranthus retrofluxus, Paulownia tomentosa and Rosa canina), which were cultivated on soil samples from the pilot and the control site, was evaluated under greenhouse and field conditions. Based on chromatographic and statistical analysis, the most effective plant species for remediation of contaminated soils around the store area were defined.

In a next step, the project will plant phytoremediant plants with phytostabilization ability for soil purification on the territory of the former obsolete pesticide store. This will help to avoid spreading contamination of terrestrial biomass and reduce the risks of migration of accumulated xenobiotics through the food chain.

PROS VS CONS

There is a wide range of soil remediation options, each having some advantages as well as limitations. The context of a remediation project defines the best applicable option. Defining conditions can be time or budget available, type and concentration of contaminants, or the future use of a site. The bio- and phyto-remediation trials under the project is key to test technologies in local settings. However, scaling-up these technologies to large areas will be a next challenge. Therefore, a comprehensive perspective should be adapted to overcome limitations.

	FOR BIO-REMEDIATION	FOR PHYTO-REMEDIATION
PROS	• Microorganisms metabolize a large number of different organic substances • Easy to implement • Environmentally friendly • Low cost and rather low tech • Do not lead to significant changes in key soil indicators	• Successful removal of a wide range of organic and inorganic compounds down to low contamination levels • Easy to implement • Environmentally friendly • Low cost
CONS	• Often slow rate of biodegradation of toxicant • Destruction processes possible only under certain conditions such as pH values, temperature, water availability, relatively low levels of contaminants, etc. • Despite its relative affordability, bioremediation still requires significant investment and specialized equipment mainly for analysis of soil contamination levels, limiting it swidespread application.	• Dependence on soil type and microbiota, climatic, hydrological and biogeochemical soil parameters. • Lengthy remediation period. • Production of contaminated biomass as waste • Risk of invasiveness of the selected species • Applicable to low to moderately contaminated sites, as plants will not germinate in heavily contaminated soils • There is a potential for negative impacts on the food chain

CONTACT

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https://www.fao.org/in-action/pesticides-central-asia/en

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