Department of Defense

Phytoremediation to Clear Heavy Metal Contaminants

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Office of the Under Secretary of Defense
for Acquisition and Sustainment

The estimated cost of this report or study for the Department of Defense is approximately $9,400 for the 2020 Fiscal Year. This includes $6,000 in expenses and $3,400 in DoD labor.

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I. INTRODUCTION

House Report 116-120, page 114, accompanying the National Defense Authorization Act for Fiscal Year 2020 (Public Law 116-92), requests the Office of the Secretary of Defense to submit a report "on the use of plants that have hyperaccumulatory and phytoremediation capabilities to clear contaminants from or related to heavy metal contamination, including but not limited to arsenic, lead, mercury, copper, chromium, and nickel, and other related toxic areas, including for contaminants in soil, water, and air."

II. BACKGROUND

Phytoremediation uses plants, some genetically engineered, to remove, degrade, or contain contaminants for the cleanup of groundwater, surface water, soil, sediments, and sludges.[1] Phytotechnology mechanisms, called "phytomechanisms," are selected based on the type of contaminant, the media affected, and the cleanup goals.[2] Typical phytoremediation cleanup goals include containing contaminated groundwater; reducing contamination levels to meet regulatory standards; absorbing and degrading contaminants within plant tissues; and decomposing contaminants.[3] A project team will also select plant species for phytoremediation using detailed information about the site conditions, and operation and maintenance, budgetary, and regulatory requirements to achieve the cleanup goals.

III. DOD'S USE OF PHYTOREMEDIATION CAPABILITIES TO ADDRESS HEAVY METALS

One such phytomechanism combines soil washing with phytoremediation to clean lead-contaminated soil from small arms firing ranges. Contaminated soil from the range is removed, sifted, and washed to remove larger lead particles from the soil. Then hyperaccumulating plants, such as Indian Mustard, are planted, harvested, and either composted to recycle the metals or incinerated. The ash resulting from the incineration is disposed of in a hazardous waste landfill to further reduce lead levels.[4]

From 2000 to 2002, the U.S. Army RangeSafe Technology Demonstration Initiative funded a demonstration and validation study at Fort Dix, New Jersey. The demonstration's goal was to reduce lead concentrations in the soil to comply with the New Jersey Department of Environmental Protection (NJDEP) residential soil standard. The U.S. Army first removed lead fragments from the sandy soil and then excavated and placed the soil in a lined treatment area. The lined treatment area was planted with three successive crops of Indian Mustard, Sunflower,

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[1] Interstate Technology & Regulatory Council (ITRC), *Phytotechnology Technical and Regulatory Guidance and Decision Trees, Revised*, 2009. Copies may be obtained at https://www.itrcweb.org/GuidanceDocuments/PHYTO-3.pdf

[2] *Ibid.*

[3] *Ibid.*

[4] DoD, *Ensuring Readiness Through Environmental Restoration*, 2001. Copies may be obtained at https://www.denix.osd.mil/arc/previous-years/eqfy2001/unassigned/ensuring-readiness-through-environmental-restoration/

and a Rye and Barley mixture. These plants successfully removed lead in soils up to 12 inches deep, with a final post-harvest soil lead concentration below the NJDEP residential soil standard.[5]

IV. DOD'S PHYTOREMEDIATION RESEARCH AND DEVELOPMENT

The Department primarily researches and develops new cleanup technologies through two key programs — the Strategic Environmental Research and Development Program (SERDP), which focuses on basic and applied research, and the Environmental Security Technology Certification Program (ESTCP), which focuses on validating more mature technologies to transition them to widespread use. SERDP's and ESTCP's mission is to address high priority environmental challenges.

SERDP and ESTCP have funded a small number of projects focused on phytoremediation. The most extensive studies were initiated in 2006 under SERDP to develop phytoremediation technologies that could be used on testing and training ranges to mitigate munitions constituents transport, particularly RDX. These studies have since matured with a successful demonstration in the field under ESTCP. In addition, a current project is focused on developing a combined phyto/microbial remediation technology for treatment of groundwater impacted by 1,4-dioxane. This effort is currently ongoing under SERDP after successfully passing the proof-of-concept stage and will be complete by 2021.

SERDP and ESTCP have not funded other phytoremediation projects related to heavy metals because in general phytoremediation is not a viable cleanup method at sediment sites (e.g., harbors, rivers, groundwater) where DoD has the biggest issues with heavy metals. Heavy metals are also found at munitions sites, but in general, the Department has found that other cleanup methods are more cost effective.

V. ADVANTAGES AND CHALLENGES

Phytoremediation has some advantages. Generally, phytoremediation requires little if any hardware or operational facilities and has low installation and maintenance costs. Plants used for phytoremediation also create sustainable green spaces, provide visual screening, reduce noise, have minimal air emissions, water discharge, and secondary waste generation, and require little human interaction and energy to install and operate in the long term.[6] Phytoremediation has the potential to "improve air quality and sequester greenhouse gases."

However, phytoremediation has some limitations as well which has limited the Department's use at its cleanup sites. Phytoremediation requires several favorable conditions for plant growth. The length of time available for cleanup, local seasonal conditions, soil conditions, and the depth, type, and concentrations of contaminants can impact the success rate of phytoremediation. Additionally, the extent of contamination at a site impacts how well

[5] U.S. Environmental Protection Agency, *Phytotechnology Project Profiles*, 2016. Project profiles may be obtained at https://clu-in.org/products/phyto/
[6] ITRC, *Phytoremediation*, 2009.

phytoremediation works because phytoremediation is not effective at sites with high levels of contamination.[7] Therefore, phytoremediation does not work for all contaminated sites.

Phytoremediation can take significantly longer than other remedial technologies to achieve cleanup goals because the plants must first establish well-developed root systems to be effective. Phytoremediation is also only effective while the plants are actively growing and most plant species are susceptible to seasonal and daily weather patterns. Plant dependence on seasonal growth will limit the application of phytoremediation at a site.[8]

The condition, type, and consistency of the contaminated soil at a site can limit using phytoremediation and have a large impact on a phytoremediation project's success.[9] Typically, industrial sites use highly compacted soils to meet military construction requirements. Plants have a difficult time establishing roots in compacted soils. At these sites, DoD would have to invest significant time and money to alter the soil to sustain plant growth. Phytoremediation of soils is further limited by the depth of the plant roots. While local soil conditions ultimately dictate the root's depth, most plant roots reach a maximum of two feet deep, though some can reach 15 feet. Trees typically have roots down to 10 or 15 feet, and a maximum of 25 feet.[10] Phytoremediation isn't a viable solution if contaminants are found much deeper than the roots of suitable plants.

Additionally, many regulators have concerns about phytoremediation because in some cases the process transfers the contaminants from one medium to another, which may pose a risk to human health. For example, while removing contaminants from soil some plants may release chemical vapors into the air or groundwater posing a risk to human health.[11] These consequences may prevent regulators from agreeing to use phytoremediation in field settings.

VI. CONCLUSION

DoD does not regularly use phytoremediation to cleanup heavy metal contaminants in soil and water because phytoremediation requires specific soil conditions for plant growth, does not work for all contaminants and contaminant levels, relies on seasonal conditions for success, does not guarantee meeting regulatory goals, and the process may pose risks to human health and the environment. The Department's priority for its environmental program is continuing to ensure the protection of human health and the environment.

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[7] U.S. Environmental Protection Agency, *Phytoremediation Resource Guide*, 1999. Copies may be obtained from https://www.epa.gov/sites/production/files/2015-04/documents/phytoresgude.pdf
[8] ITRC, *Phytoremediation,* 2009.
[9] *Ibid.*
[10] *Ibid.*
[11] *Ibid.*