



## Green and Sustainable Remediation for Enhancing Crop Productivity and Soil Health

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### INTRODUCTION

Environmental pollution has long been recognized as a major global issue. Various anthropogenic activities like industrial activities, agricultural activities, mismanagement of waste, *etc.* are the main causes of environmental pollution. The contaminated areas often pose multi-faceted health and environmental problems. Therefore, there is an urgent need to take significant steps for the remediation of these contaminated sites.

The conventional approaches towards the remediation of contaminated sites were focused on identifying the contaminants of concern and reducing the contaminant levels at low cost and time with the ease of implementation. These approaches do not account the broader environmental impacts. To address this, a focus on green and sustainable remediation approach has begun to emerge. Green and sustainable remediation is a holistic approach with a broader perspective involving environmental, social and economic benefits. It is defined as the site-specific employment of products, processes, technologies and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and net environmental effects (ITRC, 2011).

### General principles

- **Going beyond the site boundary:** The decision making in conventional methods for remediation of contaminated soils focuses on site itself. However, green and sustainable remediation extends beyond the site boundary overcoming the conventional spatial barrier allows for more comprehensive decision-making and greater consideration of societal requirements.

- **Looking beyond the contemporary time horizon:** The decision making in green and sustainable remediation takes into account the effects on present as well as on future generations.
- **Expanding to social and economic sustainability:** Green remediation approach focuses on environmental impact of the remediation process only. However, green and sustainable remediation is a holistic approach which focuses on environmental, social and economic impacts.
- **Fostering resilience to environmental and social changes:** Green and sustainable remediation takes into account the changing climatic conditions and has the ability to fulfil evolving human health and environmental standards.
- **Embracing nature-based solutions:** The adoption of nature-based solutions involves a number of environmental, social and economic benefits from reduced energy use and improved material efficiency to the development of resilience to environmental and social changes.

### **Green and sustainable remediation for enhancing crop productivity and soil health**

Green and sustainable remediation mainly focuses on the use of green soil amendments such as biochar, industrial waste-based materials, natural minerals, metal oxides, nanomaterials, *etc* and nature-based solution such as phytoremediation, microbial based bioremediation and stabilization used green materials to obtain overall sustainability in the remediation process. Pal and Maiti (2019) investigated the effectiveness of biochar produced from used tea waste for cadmium immobilization in sediment. The results showed that sediment treated with 10 per cent tea biochar led to the reduction of exchangeable fraction of cadmium in soil thus reducing its bioavailability. Das *et al.* (2018)

reported that the application of green silver nanoparticles significantly improved the pod yield and crude protein content in common bean as compared to conventionally synthesized silver nanoparticles. They also showed increment in the values of water holding capacity of soil, organic carbon, available N, available P, cation exchange capacity and urease activity as compared to conventionally synthesized silver nanoparticles.

### **Implementation of green and sustainable remediation**

The implementation of green and sustainable remediation approach is based on the site evaluation. Possible remedial alternatives are then listed according to the site characteristics which are further evaluated by different green and sustainable remediation tools such as Greener cleanup Matric (developed by Illinois EPA), Toolkit for greener practices (developed by Minnesota pollution control agency), GREM, Waste Reduction Model (WARM), SRT, SiteWise and Life cycle assessment tool, *etc*. These tools aid in the selection of technically suitable and sustainable remediation technology out of several different potential remedial alternatives. The selected remediation method is then implemented and monitored for its secondary and tertiary impacts.

### **Challenges and opportunities**

The implementation of green and sustainable remediation approach involves several challenges and opportunities. Some of them include the absence of stakeholder's knowledge and training, validated evaluation tools and well-documented case studies involving eco-friendly and sustainable solutions.

### **CONCLUSIONS**

Remediation of contaminated sites is a significant step in the protection of environment. Conventional remediation technologies only focused upon the removal of contaminants without any consideration of the side effects. Green and sustainable remediation

is a holistic approach with a broader perspective (environmental, social and economic benefits). To maximize the long-term advantages of remediation, more research studies must be conducted to increase awareness among stakeholders and establish validated methodologies for analyzing the environmental, economic, and social impacts.

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