# Chapter 20
# Nano-Bioremediation Technologies for Potential Application in Soil Reclamation

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## ABSTRACT

*Rapid industrialization, urbanization, and use of modern agricultural practices have resulted in the rise in pollutant levels in soil. In this context, nano-bioremediation has emerged as a new tool for controlling soil pollution by the application of nanomaterials with subsequent use of bioremediation. Due to its cost-effectiveness, eco-friendliness, and sustainability, the use of bioremediation in soil reclamation has rapidly gained prominence. Nanomaterials have helped in remediating toxic soil environments, thereby improving microbial activity and bioremediation efficiency. The overall time as well as costs are greatly reduced. The major limitation of this technology is its longer treatment time and its ineffectiveness for a wide range of pollutants. The chapter has an aim to present an overview of the recent advances and applications in the field of nano-bioremediation of various polluted areas of the environment. Different classes of nanomaterials along with their properties as well as application towards removal of soil pollutants will be addressed.*

## INTRODUCTION

Increased anthropogenic activities e.g., industrialization and man-made activities have resulted in unprecedented rise in pollutant levels in the terrestrial environment. Soil has the capacity to degrade the pollutants only up to a specific limit. Excessive levels of pollutants are to some extent stored in the soil and are further transmitted to water bodies or to the biological food chain via the growing plants (Cec-

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chinet al., 2017). The pollutants not only degrade the soil but also the water bodies which in turn has adverse implication to humans and animals. Pollution in soil is mainly caused by indiscriminate use of fertilizers, pesticides, herbicides, insecticides, dumping of organic wastes etc. The major pollutants identified in soil and which have major health implications are inorganic toxic substances like metal ions ($Hg^{2+}$, $Cd^{2+}$, $Pb^{2+}$ etc.), organic wastes like pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), total petroleum hydrocarbon (TPH), nuclear wastes, plastics and sewage etc. Reclamation of soil facilitates recovery of ecosystem, helps to minimize adverse environmental impacts due to soil pollution, creates additional lands for agricultural or forestry uses, and enhances the carbon sequestration.

The different remediation methods adopted for soil reclamation is physico-chemical, thermal remediation, bioremediation, micro-remediation and vermi-remediation. Soil pollutants are converted to less toxic forms via the use of living organisms like plants, fungi, yeast or bacteria (bioremediation), via the use of soil microrganisms (micro-remediation) or via the use microbes like earthworm (vermi-remediation). Different plant species like *Brassica nigra* (Singh et al., 2015), *Helianthus annuus*, *Tithonia diversifolia* (Adesodun et al., 2010) and *Trifolium alexandrinum* (Bhatti et al., 2016) were used for removal of several toxic metal ions from contaminated soil. Some of the various microrganisms used for decontamination of polluted soil by Mani and Kumar (2014) were identified as *Pseudomonas aeruginosa, Chlorella vulgaris, Phormidiumvalderium, Stereumhirsutum, Citrobacter* sp*., Chlorellavulgaris, Ganoderma applanatum, Volvariellavolvacea, Daedaleaquercina* etc. Vermi-remediation technique was used to remove heavy metals and polycyclic aromatic hydrocarbons (Rorat et al., 2017). Petroleum hydrocarbons (Njoku et al., 2017), fly ash (Saxena et al., 1998) and human excreta (Bajsa et al., 2004) was also removed from contaminated soil by vermi-remediation.

Bioremediation, micro-remediation and vermi-remediation are known to be cost-effective and environmentally friendly options for reclamation of soil (Lees and Senior 1995). Other advantages exhibited over physicochemical methods are their high selectivity, specificity, energy efficiency, minimal equipment requirement, etc. As per Azubuike et al. (2016), bioremediation of soil has restricted application in sites which are contaminated with highly toxic and hazardous pollutants. Bioremediation/micro-remediation or vermi-remediation of a contaminated site operates in either of the two ways. In the first process, indigenous microrganisms (microbes inhabiting the site) play a major role in the clean-up process (Shankar et al., 2014); whereas, in the second process, exogenous microbes are added to the site to assist in the degradation of soil pollutants (Mukherjee and Bordoloi, 2011). In both processes, appropriate temperature, pH, nutrients etc. help in the growth of the microbes and thereby enhance the rate of pollutant degradation. The application of bioremediation can be in situ (within the contaminated site). Ex-situ applications require lesser treatment times and are used to treat diverse pollutant types and can be applied to different soil types (Dott et al., 1995). However, such techniques have their own limitation that is, they require longer treatment time for degradation of a toxic pollutant, typically in the range of several months to over a year.

More recently, nano-bioremediation has emerged as more effective, low cost and clean technology for soil reclamation (Otto et al., 2008). Nano-bioremediation technique has fast gained in popularity in the last decade mainly on account of its superiority over bioremediation methods of soil decontamination. It involves the use of reactive nanomaterials for enhancing the bio-catalytic activity and increasing the efficiency of microrganisms during the bioremediation of contaminated soil. The nanomaterials have the potential to transform via chemical reduction or via catalysis so as to minimize or eliminate the toxic pollutants (Otto et al., 2008). The high reactivity of the nanomaterials enables more efficient remediation