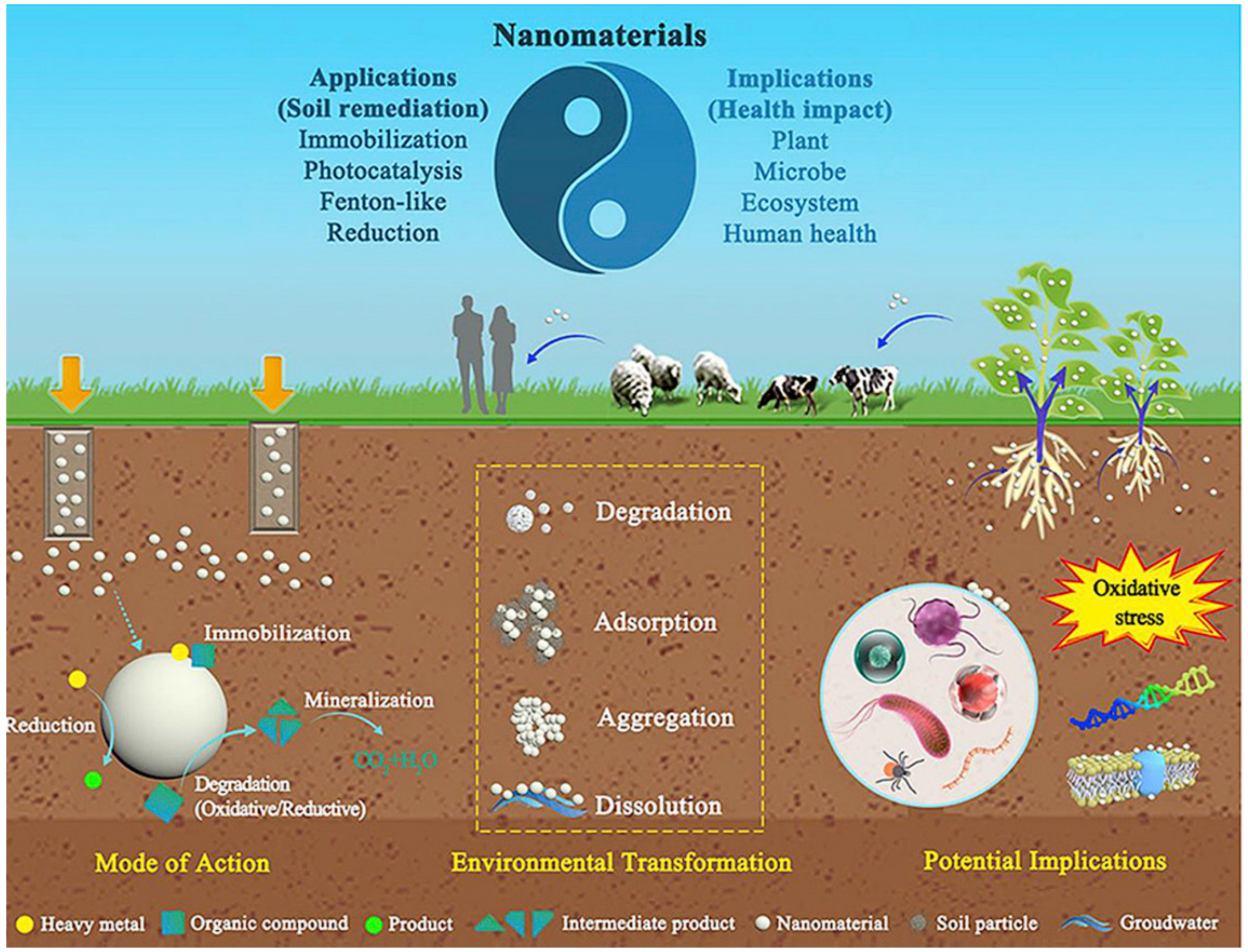
NANO-MATERIALS FOR SOIL-REMEDIATION

Prashant Sharma

INTRODUCTION

WHAT IS SOIL REMEDIATION?

Soil is profoundly affected by environmental pollution, which is often referred to as the "universal sink." Pollutants typically enter soil by sewage, waste, accidental discharge or as byproducts and residues released from the production of various materials. This contamination of soil can lead to undesirable changes in their physical, chemical and biological characteristics, all of which can contribute to alterations in the soil's fertility and productivity levels.



Soil remediation is, therefore, considered to be one of the best approaches to preventing soil pollution.

The primary contaminants targeted by soil remediation techniques include heavy metals such as zinc, lead, arsenic and chromium, organic compounds, including pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons, as well as a wide range of combined contaminants.

TRADITIONAL SOIL REMEDIATION METHODS

The remediation of contaminated soil is typically achieved by one of four approaches, the first of which includes the restricted use of contaminated soil.

Contaminated soil can also undergo an encapsulation process, in which a water-resistant material is incorporated into the material that ultimately gets covered with a clean layer of topsoil.

When ex-situ methods cannot be used, the excavation and disposal of contaminated soil is another type of remediation approach that can be applied. The appropriate soil remediation approach is selected by first determining the type of soil and its physical properties, what contaminant is present and how feasibly it can be isolated and removed from the soil, as well as the handling intensity and related costs.

LIMITATIONS OF SOIL REMEDIATION

Nanotechnology in Space WithNanosurf Atomic Force Microscope Looking for Life on Mars as Part of Phoenix Mars Mission

Agriculture and the Environment - How Nanomaterials and Nanoparticles Can Benefit These Sectors

Soil Nanoparticles Being Used to Assess Soil Viability and Diversity for Appropriate Farming Practice

Unfortunately, the soil-water interface is heterogeneous and complex, causing several technical and economic challenges to arise during the remediation of contaminated soil. More specifically, soil remediation professionals face difficulties in achieving efficient mixing and effective interactions between the target pollutants and remediation agents during in situ monitoring.

In addition to these challenges, many recently developed technologies such as sequestration, immobilization and bioremediation are both time and energy-consuming, economically insufficient and/or environmentally unfriendly, limiting their usefulness in soil remediation applications. Comparatively, engineered nanomaterials (ENMs) and nanotechnology are often associated with small size, high specific surface area and appropriate reactivity and versatility properties.

As a result of the intrinsic advantages of these technologies, researchers have found that the incorporation of ENMs into traditional in situ technologies can allow for the removal of multiple pollutants at once, enhancing the combined soil remediation approach. As a result, ENMs are ideal tools to remove stubborn contaminants from complex environmental media, such as soil.

IMMOBILIZATION BY ENMS

One of the most widely used remedial applications includes the immobilization or adsorption process. Some of the most notable advantages associated with this type of remediation technique are its efficiency, low cost and environmentally friendly method for eliminating metal contaminants from soils.

Some of the different ENMs that have been used for the immobilization of soil contaminants include carbon nanomaterials such as carbon nanotubes (CNTs), metal oxide nanomaterials like ferric oxide (Fe_3O_4) and titanium oxide (TiO_2) and various nanocomposites. Fe_3O_4 nanomaterials, for example, are associated with an exceptional capacity to both absorb and immobilize heavy metals such as cadmium and arsenic from different media samples.

PHOTOCATALYTIC DEGRADATION BY ENMS

During the photocatalytic degradation of soil contaminants, nano-photocatalysts are used in conjunction with an ultraviolet (UV) light source, such as sunlight, to promote the degradation of organic materials, including PAHs, PCBs and pesticides.

The efficiency of this soil remediation method is primarily determined by the intrinsic properties of the contaminated soil samples and its acidity levels, as well as whether any organic matter is present.

One of the most common ENMs to be incorporated into the photocatalytic degradation process is TiO_2, which has been shown to achieve degradation rates of up to 78% within five hours of treatment.

IMPORTANT CONSIDERATIONS

Despite the evident advantages associated with ENMs for soil remediation applications, certain environmental health and safety concerns should be considered.

The introduction of ENMs will inevitably change the indigenous soil ecosystem, and the potential effects of these materials on this natural environment can include alterations in the germination of plant seeds, how plant roots and shoots are developed, soil microorganism growth and metabolism, and even in the lives of individual invertebrate animals residing within the soil, such as snails, earthworms and other insects.

While the potential adverse effects of ENMs must be considered, it should be noted that under certain circumstances, the introduction of ENMs could provide beneficial effects to the soil ecosystem.

Carbon NMs, cellulose NMs and both metal and metal oxide NMs, for example, have all been shown to act as a nutrient stimulant or enhance the delivery of specific nutrients to the soil from seeds, roots and leaves.

As a result, these types of materials can improve crop yields and advance agricultural processes while simultaneously reducing the occurrence of unwanted soil contaminants.