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Phytoremediation of Industrial and Pharmaceutical Pollutants

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Phytoremediation of Industrial and Pharmaceutical Pollutants

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Abstract
Pollution in water bodies and soil is a major and ever-increasing environmental issue nowadays, and most conventional remediation approaches do not provide appropriate solutions. The contamination of soil is a major concern for the environment and needs to be remediated. These pollutants include complex organic compounds, heavy metals released from industries and plants and natural products such as oils from accidental release. Further the nature of pollution will be governed by the source and type of the contaminant, and other inorganic compounds are released into the environment from a number of sources like mining, smelting, electroplating, and farming. Plants can clean up many types of contaminants like metals, pesticides, oils, and explosives. Phytoremediation is emerging as a bio-based and low-cost alternative in the cleanup of heavy metal-contaminated soils.

Keywords: Pollution; Phytoremediation; Environment; Remediation; Contaminant.

1. INTRODUCTION

Environmental pollution has become a promising area which is being extensively explored to reveal the pollutants from natural resources and their harmful effects on our biota. Industrial and pharmaceutical waste products are getting accumulated in soil, air, and water and are causing disastrous effects on plants and develop health issues in humans and animals. The pollutants include organic hydrocarbon wastes, polycyclic aromatic hydrocarbons, heavy-metal contaminants, antibiotics, hormonal wastes, medicines, etc. [1, 2]. Traditionally, certain techniques were developed to remediate these pollutants from natural resources like excavation of soil, its decontamination and refilling, chemical and thermal treatment of soil, acid leaching and electroreclamation, etc. [3, 4]. These techniques were found to have a big disadvantage of being costly, ex situ and can be operated at a small scale only. On the other hand, phytoremediation, the green technology, happens to be a cost effective and an in-situ method for remediation of pollutants.

There exists varying mechanisms through which plants naturally uptake or degrade or decontaminate the pollutants. Few such mechanisms are well known and well studied such as phytoextraction, phytotransformation, phytostabilization, rhizofiltration, etc. as shown in figure. These processes involve the uptake of contaminant from the soil, its degradation or transformation by action of enzymes, decreasing the mobility of heavy metals in the soil through stabilizing agents, thereby minimizing leaching of substances into the soil and filtering the contaminants from waste-water sources.

2. EXPLORATIVE POTENTIAL OF HEAVY METALS, ANTIBIOTICS, HORMONES, AND ANALGESICS

Increased levels of heavy-metal contaminants above nutritional needs can cause extreme imbalance in the ecological system [5]. Moreover, they also cause toxic effects on plants, microbes, and humans like neurotoxicity, carcinogenicity [6], inhibition of plant growth, biochemical and physiological changes, alterations in structures, microbial toxicity [7] via food chain, soil, or water sources. On the other hand, antibiotics, hormonal waste, and analgesics constitute the pharmaceutical waste which gets exposed in the environment in the form of improperly disposed medicines, dumping of unused or expired tablets along with domestic waste, and unmonitored dosage of pills without proper prescription. It poses health issues through entry into food chains via plants as well as uptake through consumption of contaminated water.

2.1. Heavy Metals—Associated Health Concerns and Toxic Effects

Heavy metals are a class of toxic metals which are basically transition metals. Heavy metals are not named so on the basis of their molecular weights but rather on the basis of their specific density which is more than 5 g/cm^3 [3]. Some of the heavy metals are transition species that cause oxidative stresses to the plant and lead to the production of ROS, i.e., reactive-oxygen species. ROS form free radicals that hamper with the protein structures and cause peroxidation of lipids which can lead to alteration in genetic constitution of an organism leading to severe malfunctioning [8]. For example, cadmium toxicity leads to the dysfunctioning of the kidney [9]; likewise nickel can cause allergic reactions [10].

2.2. Pharmaceutical Waste

Most commonly found pharmaceutical wastes like antibiotics, hormones, steroidal medicines, analgesics, and therapeutic agents are an outcome of the improper disposal of pharmaceuticals that are being used to treat humans and animals. These

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Table 1: Heavy metals and their effect on health.

Contaminant	Health concern	Methods of remediation	References
Cd	Nephrotoxic, eventually can lead to renal failure and bone damage, increased cancer risks	Interaction of soil and plant in rhizosphere—phytoremediation by *Helianthus annuus*	[9, 11]
Ni	Allergic reactions, lung and kidney problems	Phytoremediation by *Brassica* species and *Alyssum lesbiacum*	[6, 10, 12, 13]
Zn	Adverse effects on aquatic life, cell death in brain, cytotoxicity in case of oxygen-stress condition	In-situ remediation processes such as chemical stabilization and phytostabilization, soil flushing, vitrification, extraction using plants	[14, 15]
Pb	Toxicity in hepatic and gastrointestinal systems besides oxidative stress		[15, 16]

Table 2: Pharmaceutical wastes, their toxic effects, and remedial measures.

Contaminant	Health concern	Methods of remediation	References
Antibiotics	Aquatic toxicity, harm to fishes	Remediation using microbial action and phytoremediation	[24]
Tetracycline, oxytetracycline	Development of antibiotic-resistance microorganisms and eventually leading to adverse effects on human health	Phytoremediation by *M. aquaticum*, *P. stratiotes, and* hairy root cultures of *Helianthus annuus*	[25]
Hormones	Reproductive health of humans, issues relating to breast cancer, defects in newborns	Membrane-contactor processes	[20, 26]
Estrogen, progestrone			
Analgesics	Chronic exposure leads to toxicity in kidney and liver	Adsorption on activated carbon, treatment with ozone and membrane separation	[27]
NSAIDs (aspirin, ibuprofen), paracetamol			

Table 3: Various plants, contaminants they remove, and the mechanism of action.

S. No	Common name	Botanical name	Contaminant	Mechanism of action	References
1	Thale cress	Arabidoposis thaliana	Zn, Cu, Pb, Mn, P, estrogen	Through cation transporters	[29]
2	Common reed	Phragmite australis	Ibuprofen	Action of antioxidative enzymes	[30]
3	Blackberry night shade	Solanum nigrum	Zn, Cd		[31]
4	Sunflower	Helianthus annus	Zn, Cd, Pb, tetracycline, oxytetracycline	Cd stress reduced by nitric oxide	[32]
5	White lupin	Lupinus albus	Cd and As	Uptake of heavy metal in the root	[33]
6	Alpine pennycress	Thlaspi carulescens	Zn, Cd, Ni, Pb	Phytoextraction	[34]
7	Hemp	Cannabis sativa	Cd		[34]
8	Pigweed	Amaranthus	U		[35]
9	Barley	Hordeum vulgaris	Cr		[36]
10	Sandbar Willow	Salix exigua	Cd, Ni, Pb	Phytoextraction	[37]
11	Chinese Aloe, Indian Aloe, True Aloe, Barbados Aloe	Aloe vera	Zn, Cd, Pb, Fe, Cu, Na, Ca, Mg, P, K		[38]
12	Tiny wild mustard	Thlaspi goesingense	Ni, Zn	Compartmentalizing most of the Ni into the vacuole	[39]
13	Water Fern	Azolla filiculoides	Pb, Cr, Ni, Zn	Vacuolar precipitation of Pb	[40]
14	Brown Mustard	Brassica juncea (Transgenic plant)	Cd, Pb, Se		[41]

contaminants usually come through irrigation, sewage wastes, throwing of expired and unused medicine into domestic drains. Eventually they enter into the ground water and become a part of the food chain [17].

2.2.1. Antibiotic Waste

Certain antibiotics which remain in wastewater even after treatment are tetracycline, oxytetracycline, ibuprofen [17], ciprofloxacin, and norfloxacin [18]. Technology for their cleanup from the environment has to be explored, and certain plants have been reported to perform remediation for it such as Lupinus albus is found to remediate acetaminophen under hydroponic arrangements [19].

2.2.2. Hormonal Waste

It has been reported that wastewater from municipal wastes and urinary waste of humans are the sources of hormones specially steroids in them [20]. These hormones are basically used as contraceptives and therapies. With excreta and household drains, animal waste [21], they become a part of hormonal waste in contaminated water streams. They are known to dismantle endocrine systems in aquatic organisms such as fishes. The most novel way of separation of these contaminants from water resources are ELISA and gas chromatography (GC)/tandem mass spectrometry (MS) [22]. Only very few literatures suggest the role of plants in the removal of hormone contaminants from waste water. Plants called as *Salix exigua* and *Arabidopsis thaliana* have been reported to extract synthetic estrogen and other derivatives from the solutions thus indicative of phytoremediation properties in them [23].

2.2.3. Improper Disposal of Analgesics

Analgesics or painkillers are basically NSAIDs, i.e., nonsteroidal anti-inflammatory drugs or paracetamol. These bioactive compounds and their metabolic products become a part of wastewater streams and river waters even after treatment processes. The unused day-to-day medicines such as aspirin, paracetamol, etc. are disposed off just as domestic waste which causes undesirable effects such as renal toxicity, hepatotoxicity, etc., when they enter into the water table and food chains. Some plants perform remediation for their removal from the environment such as *Phragmites australis* is known for the removal of ibuprofen contamination [19].

3. PLANTS THAT ARE GOOD REMEDIATORS

The conventional processes that usually involve chemical or physical treatment of the pollute sources such as soil, air, and water are very costly and inefficient to be used for large-scale remediation processes [28]. Therefore, the biological method of remediation was thought to be explored as there lays an inherent property of plants to uptake the pollutant material from soil sources [42]. Pollutants are either degraded via action of microbes present in roots of the plants, i.e., rhizospheric activity, or they are modified, i.e., chemically altered by action of root exudates. Therefore, the following table contends potential plants for remediation purposes.

4. CONCLUSION

On the basis of the literature survey that has been summarized in this report, we can say that plants have an excellent potential to be explored in light of the phytoremediative properties they have. These plants uptake contaminants from natural resources like soil and water. Pollutants are directed towards differing mechanisms such as enzyme activity compartmentalization into plant-cell organelles. Heavy metals are such pollutants which are epidemiologically studied and cover a major portion of contaminants through industrial waste. Another category of wastes is the pharmaceutical waste which has extensive harmful effects on human health. They come from improperly disposed antibiotics, hormones, and medicines. The hazardous effects of these contaminants can be interestingly explored to develop remediation against them. The ultimate objective of such study will be to keep up the ecological balance.

Author Contributions

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Conflict of Interest

None.

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