IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 10, December 2014.
www.ijiset.com
ISSN 2348 – 7968

# Phytoremediation: Proficient to Prevent Pesticide Pollution

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**Abstract -** Phytoremediation techniques are impending gradually its potency as a valued sustainable advance for the remediation of environmental pollutions, especially pesticides contaminations. Phytoremediation is a general term including several processes among which phytoextraction and phytostabilisation are the most reliable for pesticides pollutions and helps the healthy growth of plants. This cost-effective and innovative technology employs plants to clear wide-ranging organic and inorganic wastes. This study has been conducted to give an overview on the role of this green technology which is drawing attention to eliminate the further contamination, may obtain from through appliance of pesticides, sewage sludge, fertilizers and manure. Considering several reports, it is concluded that phytoremediation a cheap plan, takes advantage of the plant's ability to remove pollutants from the environment or to make them harmless or less dangerous.

**Key Words:** Green technology, Pesticides, Phytoremediation, Pollution, Transgenic plants,

## I. INTRODUCTION

Data flourished in literature that validates the information that environmental degradation, outcomes from pollutants generation. The pollution generation has been traced to anthropogenic sources in the expedition for exploiting nature as a source of means of livelihood. Misuse has lead to depletion of various natural resources to an extent that today half of our natural wealth is at the edge of depletion [1]. Global urbanization raises new disputes, especially in the field of environmental reinforcement. The demand for industrial development outweighs the demand for a safe, pure and natural environment; therefore, it is the industrial, economic and agricultural developments that are often linked to polluting environment.

Recently researchers have found the focus of phytoremediation as biological interventions of biodiversity for mitigation of the noxious effects caused by environmental pollutants in a given site. The traditional physico-chemical processes for treatment involve high energy and large capital investment, whereas aquatic plant based cost effective technologies can be adopted by developing countries for treatment of waste water, especially contaminated by pesticides, heavy metals. The important aspects of phytoremediation have been summarized in several comprehensive reviews [2-6].

The word phytoremediation comes from Greek word phyto which means plant and Latin word remediation which means to remove, which refers to a diverse collection of plants based technologies that use either physically going on, or genetically engineered set to clean contaminants. It is a clean, efficient, inexpensive and environment friendly technology. It is a non-invasive alternative technology for engineering-based remediation methods. The primary motivation behind the development of phytoremediation technologies is the potential for low-cost remediation [7,8].

## II. PHYTOREMEDIATION

The perception of using plants to fresh and renovate soil and wastewater has been employed for over 300 years. Frequent bench-scale studies have been carried out to establish plant toxicities and contaminant uptake capabilities. In order for phytoremediation to achieve acceptance as a remedial method, field-scale applications need

ISSN 2348 – 7968

to be executed and filed. To demonstrate their ability to remediate contamination, build up wetlands and vegetative covers have been widely applied in the field and their data has been fine documented [9]. More recently, field-scale studies of groundwater and soil plantations have been done to evaluate their effectuality in remediating contamination. In this section, the information will be useful in assessing the feasibility of phytoremediation as a remedial technology for a site.

In order to contain, degrade contaminants or extract from soil and groundwater, phytoremediation is the use of undergrowth and its associated microorganisms, enzymes and water consumption. Both organic and inorganic contaminants can be successfully contained or degraded using phytoremediation in a variety of media (i.e. soil, sediment, sludge, groundwater, and air).

**Phytoremediation technology**

Phytoremediation techniques have been momentarily described in various literatures. The nonspecific term “phytoremediation” consists of the Greek prefix phyto (plant), attached to the Latin root remedium (to correct or remove an evil). Generally, according to the researchers, phytoremediation is defined as a rising technology via selected plants to clear out the contaminated environment from hazardous contaminant to look up the environment class. For organics, it involves phytostabilization, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatilization. These machineries related to organic contaminant possessions are not competent to be engrossed into the plant tissue.

The root plants exudates to alleviate disband and combine the contaminants in the soil medium, in that way plummeting their bioavailability. These all are called as phytostabilization way. To immobilize contaminants in ground water and in soil through accretion and absorption by roots, adsorption onto roots, or precipitation within the root zone, certain plant species have used. This process is for organics and metals contaminants in soils, sediments, and sludge medium. The go down of contaminants in the soil from beginning to end microbial activity that is improved by the presence of the root zone is called rhizodegradation. This procedure uses microorganisms to consume and digest organic substances for nutrition and energy. Natural substances unconstrained by the plant roots, sugars, and alcohols, contain natural carbon that provides food for soil microorganisms and set up a dense root mass that takes up large quantities of water. This process is for organic material contaminants in soil medium [10, 11].

Metal accumulating plant species can concentrate heavy metals like Cd, Zn, Co, Mn, Ni, and Pb those taken up by nonaccumulator (excluder) plants. In most cases, microorganisms like, bacteria and fungi, living in the rhizosphere closely connected with plants, may add to drum up metal ions, growing the bio-available fraction. Their role in removing organic contaminants is even more significant than that in case of inorganic compounds [12]. Heavy metal uptake by plant through phytoremediation technologies is using these mechanisms of phytoextraction, phytostabilisation, rhizofiltration, and phytovolatilization as shown in Fig. 1.

***Phytoextraction:*** The uptake and translocation of contaminants by plant roots into the above ground portions of the plants that can be harvested and burned gaining energy and recycling the metal from the ash.

***Phytostabilisation:*** Use of certain plant species to bring to a standstill the contaminants in the soil and groundwater through absorption and accumulation in plant tissues, adsorption onto roots, or precipitation within the root zone preventing their movement by erosion and deflation.

***Rhizofiltration:*** The adsorption or precipitation onto plant roots or absorption into and sequesterization in the roots of contaminants that are in

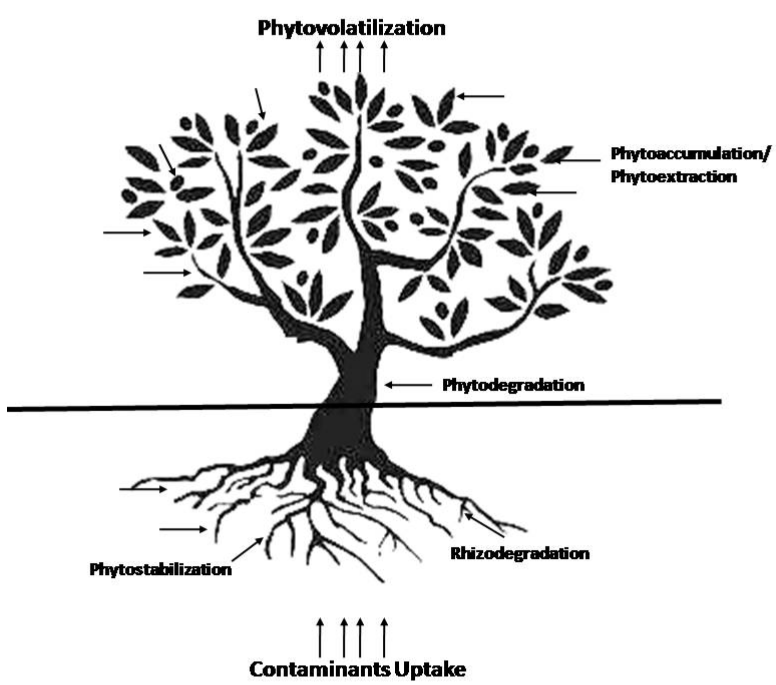


**Figure 1:** Schematic representation of different phytoremediation technologies involving removal and containment of contaminants.

solution surrounding the root zone by constructed wetland for cleaning up communal wastewater

***Phytovolatilization:*** The uptake and transpiration of a contaminant by a plant, with release of the contaminant or a modified form of the contaminant to the atmosphere from the plant. Phytovolatilization crops up as upward trees and other plants take up water along with the contaminants. Some of these contaminants can pass through the plants to the leaves and volatilize into the atmosphere at comparatively low concentrations.

Plants also execute an imperative secondary role in physically stabilizing the soil with their root system, preventing erosion, protecting the soil surface, and dipping the impact of rain. At the same time, plant roots discharge nutrients that sustain a rich microbial community in the rhizosphere. Bacterial community composition in the rhizosphere is affected by complex interactions between soil type, plant species, and root region locality. Microbial populations are normally higher in the rhizosphere than in the root-free soil. This is due to a symbiotic relationship between soil microorganisms and plants. This symbiotic relationship can enhance some bioremediation progression. Plant roots also may offer surfaces for sorption or precipitation of metal contaminants. In phytoremediation, the root zone is of special attention. The contaminants can be absorbed by the root to be afterward stored or metabolised by the plant. Degradation of contaminants in the soil by plant enzymes exuded from the roots is another phytoremediation mechanism. For many contaminants, passive uptake via micropores in the root cell walls may be a major route into the root, where degradation can take place [12].

## III. PHYTOREMEDIATION ON PESTICIDES POLUTION

Currently, a significant amount of research has been conducted on the interaction between microorganisms and plants in the rhizosphere and the potential to apply this for the remediation of pesticide-contaminated media. According to groundwork studies, improved degradation of atrazine, metolachlor and trifluralin have been observed in contaminated soils where plants of the *Kochia* sp. have been planted. The increased degradation occurs in the rhizosphere of this herbicide-tolerant plant, suggesting that rhizosphere interactions between the plant and microorganisms have lead to the amplified degradation of the pesticides present [13]. Additional studies using the *Kochia* sp. have been conducted by these researchers and also show assure for the phytoremediation of pesticide-contaminated soils and groundwater.

Phytoremediation mainly refers to the use of plants and associated soil microbes to reduce the concentrations or toxic effects of contaminants in the environment. Also, this technology has partial function where the concentrations of contaminants are toxic to plants. Phytoremediation technologies are available for various environments and types of contaminants. These engross different processes such as in situ stabilization or degradation and removal (i.e., volatilization or extraction) of contaminants (Fig. 1; Table 1).

Table 1: Comparison between phytoremediation technologies

| Technology | Action on Contaminants | Main Type of Contaminants | Vegetation |
|---|---|---|---|
| Phytostabilization | Retained in situ | Organics and metals | Cover maintained |
| Phytodegradation | Attenuated in situ | Organics | Cover maintained |
| Phytovolatilization | Removed | Organics and metals | Cover maintained |
| Phytoextraction | Removed | Metals | Harvested repeatedly |

In laboratory studies, the quick-growing and deep-rooted poplar tree has been shown to be successful in the remediation of groundwater. Its speedy growth necessitates high volumes of water that are pulled from the saturated region. Contaminated groundwater is absorbed by the plant and the pollutants are subsequently transformed into organic molecules for plant growth. This technique has already proven successful for the remediation of atrazine-contaminated soil and groundwater. Hybrid poplars are being used in the remediation of a farm chemical site with high levels of nitrate, atrazine and arochlor in the groundwater (14). Approximately 1.5 acres are being treated and results to date show reduction of both the nitrates and herbicides in the groundwater [12, 14].

**Transgenic plants expressing pesticides degrading enzymes**

Plants show evidence of an intrinsic ability to detoxify some xenobiotic compounds; but they generally require catabolic pathways to execute degradation/mineralization. Therefore, the transfer of genes involved in catabolism of xenobiotics from microbes or other eukaryotes to plants will further augment their potential for remediation [15]. An extracellular fungal enzyme, the laccase of *Coriolus versicolor*, into tobacco plants, the transgenic plant was able to remove pentachlorophenol by bringing into being laccase and secreting into the rhizosphere. Similarly, for the decontamination of organophosphorus pesticide, a bacterial organophosphorus hydrolase (OPH) gene in tobacco plants has been executed. The transgenic plants degraded more than 99% of methylparathion after 14 days of growth. A multiplicity of plant enzymes, including peroxygenases, cytochrome P450, peroxidase, glutathione-*S*-transferases, carboxylesterases, *N*-, *O*glucosyltransferases and *N*-, *O*-malonyltransferases, are involved in the phytotransformation of xenobiotics in plant cells [16]. Glutathione *S*-transferases are a multigene family of detoxifying enzymes for herbicides. The gene *gstI–6His* from maize, which predetermines for 6His-tagged GST I, was utilized for the creation of a binary vector appropriate for genetic engineering of tobacco plants (*Nicotiana tabacum*). The transgenic plants illustrated a considerably higher tolerance to alachlor, suggesting their role in phytoremediation of herbicide-contaminated agriculutural fields. Resembling other plant enzymes, the arylamine *N*-acetyltransferases (NAT) are xenobiotic-metabolizing enzymes that catalyze transmit of an acetyl group from acetyl CoA (AcCoA) to the nitrogen or oxygen atom of arylamine based xenobiotics and their hydroxylated metabolites. They play an significant function in the detoxification of many xenobiotics and pesticides and have been reported to happen in soil bactria such as *Pseudomonas* sp. NAT isoforms have been recognized in several species from bacteria to mammals, but viewing of complete and incomplete genomes has identified no NAT enzymes in plants. In recent times, due to symbiosis with *Mesorhizobium loti*, it has been established the occurrence of the NAT-dependent pathway in leguminous plants.

In a separate study, Inui et al. [17] urbanized transgenic potato plants expressing human CYP1A1/yeast NADPH–cytochrome P450 reductase (YR)-fused enzyme generated from *Agrobacterium* transformation system. They reported that P450-dependent monooxygenase activity of the transgenic potato plants was 3.5 to 4.2 times higher in 7-ethoxycoumarin 0- deethylation in vitro and 5.3 to 6.4 times in chlortoluron metabolism in vivo than those of the control plants. The manifestation of deisopropylated deethylated metabolite, a non-phytotoxic metabolite of atrazine, was more distinct in transgenic plants than the control. The transgenic plants demonstrated tolerance toward both atrazine and pyriminobac-methyl, while the control died by treatment with both herbicides.

These plants demonstrated cross forbearance on the way to the herbicides acetochlor, atrazine, chlortoluron, methabenzthiazuron, metolachlor, norflurazon, and pyributicarb, and established a privileged activity in the metabolism of each of chlortoluron, atrazine, pyributicarb, and methoxychlor than non-transgenic control plants. These transgenic plants completely mineralized pyributicarb to m-tert-butylphenol (BP), Odemethylated PC (DMPC), hydroxylated BP (BPOH), and some unknown metabolites. However, methoxychlor was rapidly metabolized in T1977 through O-demethylation to yield mono-demethylated and di-demethylated metabolites, which were deposited as glucosides in the plants [17]. From these findings, they concluded that three P450 species expressed in T1977 coordinately functioned and actively metabolized the herbicides and the insecticide, and, thus, they could be used for the development of transgenic plants for phytoremediation of pesticide-contaminated soil environment. Table 2 shows some recent work related to transgenic plant species investigated for enhanced phytodegradation of pesticides.

Table 2: Some specific enzymes introduced in plant cells to accelerate phytoremediation

| Pesticide | Plant species | Source of gene | Enzyme |
|---|---|---|---|
| Alachlor | Tobacco | Maize (Zea mays) | GST I |
| Atrazine | Tobacco | Homo sapiens sapiens | P450[#] (CYP1A1, CYP1A2) |
| Metamitron | Tobacco | Homo sapiens sapiens | P450[#] (CYP1A1, CYP1A2) |
| Acetochlor, metolachlor, triazine | Arabidopsis seedling | Arabidopsis | GlutathioneStransferases (GSTs) AtGSTF2, AtGSTU1, AtGSTU24 |
| Organophosphates | Tobacco | P. pseudoalcaligenes | Hydrolase |
| Herbicides | Rice | Pig (Sus scrofa) | CYP2B22 and CYP2C49 |
| Herbicides | Rice | Homo sapiens sapiens | P450[#] (CYP1A1, CYP2B6, and CYP2C19) |

[#]P450: Cytochrome P450 is a family of powerful detoxifying enzymes with hundreds of genetic variations present in plants and mammalian cells. CYP1A1 is a type of the human cytochrome P4501A1 gene that produces an aryl hydrocarbon hydroxylase involved in the metabolism of endogenous compounds and xenobiotics. CYP1A2 are monooxygenases that catalyze many reactions involved in the metabolism of many xenobiotics, like pesticides and synthesis of cholesterol, steroids, and other lipids. CYP2C9 is mephenytoin 4-hydroxylase involved in the metabolism of endogenous compounds and xenobiotics. CYP2C19 and CYP2B6 are human cytochrome P450, while CYP2C49 and CYP2B22 are pig cytochrome P450 involved in the metabolism of endogenous compounds and xenobiotics. tfdA is widely reported among soil bacteria. The tfdA gene encodes 2,4-dichlorophenoxyacetic acid (2,4-D)/a-ketoglutarate dioxygenase. It is uniquely associated with 2,4-D degradation.

**Transgenic plants expressing antibodies for detoxification of pesticides**

The phytoremediation capabilities of plants could also be extended to pesticides by generating transgenic plants expressing antibodies specific to a particular group of pesticides. Transgenic plants have been used to produce full-length immunoglobulin G (IgG) antibody, multimeric secretory antibody and a wide range of functional antibody fragments used a model system of hydroponic tobacco plant cultures expressing the murine monoclonal antibody Guy's 13 to demonstrate the feasibility of using antibody-expressing plants for phytoremediation purposes. Guy's 13, a neutralizing antibody, recognizes a 185 kDa cell surface protein (SA I/II) of *Streptococcus* mutants. To determine whether secreted antibody would bind SA I/II in the aqueous environment surrounding the roots, functional full-length antibody was developed and secreted from the roots into the surrounding nutrient medium in a one type of transgenic plants. In the second plant type (i.e., mIgG plants), antibody was expressed and retained in the plant cell plasma membrane due to the presence of a transmembrane sequence. In the first plant type, functional antibody was rhizosecreted and shown to bind with antigen in the surrounding medium to form an immune complex [18]. In the second, a transmembrane sequence retained monoclonal antibody in the plants on the plasma membrane. Antigen added to the nutrient medium around the roots of mIgG plants was transported within 24 h to the topmost leaves of the plant, where it was sequestered as an immune complex by binding to antibody on the cell membrane [18] (Drake et al., 2002). Concentration of immune complex in the leaf tissue remained constant over a 72 h period after removal of antigen from nutrient medium. Moreover, Drake et al. [19] demonstrated the secretion of a functional, full-length monoclonal antibody complex from transgenic *Nicotiana tabacum* roots. Initially, seeds were germinated on nitrocellulose membranes and antibody secretion detected from the developing roots. Plants were then established in hydroponic culture and secretion into the growth medium measured over 25 days. Western blotting indicated that full-length antibody was present in the medium along with other fragments. Secreted antibody was shown to be functional by binding to antigen in enzyme-linked immunosorbent assay (ELISA) studies. In contrast, no antibody could be detected from transgenic *Nicotiana* in which the same antibody was expressed as a membrane protein in the plasmalemma. According to the results obtained, antibody accumulation in the growth medium is genuinely caused by rhizosecretion and not cell damage. The addition of gelatin to plant growth medium markedly increased antibody accumulation. These results strongly acknowledge that such rhizosecretion of antibodies in transgenic plants may prove a novel approach for removal or neutralization of environmental pollutants. According to these results, two strategies of rhizosecretion-mediated binding and sequestration in leaf tissue could potentially be used in the phytoremediation of pollutants such as pesticides, for which it is possible to generate a monoclonal antibody. To date, no authentic laboratory results are available regarding this aspect of phytoremediation of pesticide-contaminated soil and water environments, but in the near future this strategy may receive an increasing amount of attention [20].

## IV. CONCLUSION

Developed nations have the capacity to find alternatives and treatments for the harmful pollutants and to gift a suitable environment. Remediation projects have been conducted at numerous pesticide-contaminated sites. Plants using phytoremediation technology, appears to be a wealthy approach to remediate pesticides polluted environment. It has some compensation compared with other normally used unadventurous equipments. Numerous factors must be well thought-out in order to achieve a high presentation of remediation result. The most important factor is a suitable plant species which can be used to uptake the contaminant. Even the phytoremediation technique seems to be one of the best alternatives, it also has some limitations. Prolong research needs to be conducted to minimize this limitation in order to apply this technique effectively. However, Phytoremediation using "green plants" has potential benefits in restoring a balance in stressed surroundings. It is an promising low cost tools, non-intrusive, and aesthetically pleasurable using the outstanding capability of green plants to metabolize diverse essentials and compounds from the atmosphere.

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