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Bioremediation of Pesticides: A Review

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ABSTRACT

Pesticides at present play an important role in enhancing the yield and provide an economical benefit to our farmers, but the use of pesticides in the agricultural fields is a major concern today. Increase in soil pollution has caused a serious concern. Large numbers of contaminants in which pesticide is one the major concern have pose a serious threat to human health as well as to the natural ecosystem. The available methods (physical or chemical) are either incomplete or costly. Bioremediation provides a novel tool or such process. Bioremediation provides an eco-friendly, economical and efficient method for detoxification of pesticides.

Introduction

Demand for usage of chemical pesticides has increased with the increase in demand for world food production for rapidly growing population. About 45% of annual crop production is lost due to pest attack [1]. One of the best ways to increase productivity is effective pest management by using chemicals like insecticides, herbicides, fungicides, nematicides and rodenticides [2]. Pesticides are the substances or mixture of substances that are used to prevent, destroy, repel or mitigate any organism harmful to living beings [3]. In India, more amount of insecticides are used in comparison to herbicides and fungicides [4]. Crop wise, cotton accounts for the maximum share of pesticide consumption, which is around 37% followed by paddy (20%). The application of chemical pesticides, particularly in agricultural fields, cause harm to the environment, hampers ecological balance and imparts adverse effects on public health. The properties of pesticides like their persistence, mobility, toxicity to non-target species also intensify these damages (Stockholm Convention, 2004). Approximately, 90 percent of agricultural pesticide application never reaches its target organisms but is, instead, dispersed through the air, soil and water. As a result, these pesticides are routinely detected in air, surface and ground water, sediments, soil, vegetables and to some extent in foods. In addition, many soil-applied pesticides for the control of soil borne pests and pathogens are also intentionally introduced into the soil environment which results in the accumulation of their residues and metabolites in soil at unacceptably high levels [5-7]. Over the last decade, an increasing amount of pesticides has been detected in both soils and water [8]. These toxic compounds have been implicated in various disorders and diseases including cancer, adverse reproductive outcomes, peripheral neuropathies, neurobehavioral disorders, impaired immune functions and allergic sensitization reactions particularly of the skin and cumulative inhibition of choline esterase activity because of long-term low doses of exposure [9].

The production of these toxic compounds has forced to implement new technologies to reduce or eliminate them from the environment. Earlier techniques or technologies which were used to eliminate them from environment were landfills, recycling, pyrolysis but these also have adverse effects on the environment and leads to formation of toxic intermediates and secondary metabolites in comparison to bioremediation which is ecofriendly and cost effective [10]. Bioremediation uses biological agents, mainly microorganisms i.e. yeast, fungi or bacteria to clean up contaminated soil and water [11]. This technology relies on promoting the specific microflora or microbial consortia that are indigenous to the contaminated sites and are able to perform desired activities.

Pesticides in the Country

India is an agriculture based country. With over 400 million acres land under cultivation and over 60 percent of the country population dependent on agriculture, the country economy depends on the agricultural sector to a substantial extent. India loses nearly 30 percent of its potential crops to insects, weeds and rodent attacks. The pesticides/agrochemicals industries play a crucial role in protecting crops from damage by weeds, insects and diseases, both before and after harvest. Pesticides constitute the key control strategy for crop pests and disease management and have been making significant contribution towards improving the crop yields per hectare. At present, India is the largest producer of pesticides in Asia. The Indian Pesticide Industry with 82000 MT of production for the year 2005-2006 is ranked second in Asia (behind China) and ranks twelth in the world for the use of pesticides with an annual production of 90,000 tons [12]. Two to three percent of pesticide is actually utilized and the rest persists in soil and water causing environmental pollution leading to toxicity. In India, insecticides account for 52 percent, herbicides 33 percent and fungicides 15 percent of the total consumption of chemical pesticides. The average world consumption comprises 25 percent insecticides, 49 percent herbicides and 22 percent fungicides. As far as the chemical nature of products is concerned, the market comprises 16 percent organochlorines, 50 percent organophosphates, 4 percent carbamates, 19 percent synthetic pyrethroids, 1 percent biopesticides and 10 percent others. The world consumption pattern, on the other hand, is 6 percent organochlorines, 37 percent organophosphates, 23 percent carbamates, 22 percent synthetic pyrethroids and 12 percent others.

Deleterious Effects of Pesticides

Increase in the use of pesticides can lead to different health and environmental problems like poisoning of farmers, cardiopulmonary, neurological and skin disorders, miscarriages, lowering the sperm count of applicators, etc. Due to continuous application of synthetic pesticides the extinction of useful organisms has also take place which are present in the soil. Besides contaminating the environment, especially the soil, useful organisms like earth worms, bees, spiders are also affected by pesticide residues, which otherwise would have contributed towards preventing harmful pests. This negative impact of pesticides is mainly due to the high toxicity, stable nature, less soluble active ingredients of pesticide. Among the various pesticides used, much problematic are organochlorine pesticides. Among these pesticides, chlororganic compounds, aldrin, heptachlor, endosulphan, DDT, are of deep concern, due to their tendency to accumulate [13,14]. A mixture of banned and restricted chemicals like DDT, BHC, aldrin, dieldrin, lindane etc. are also present in the food we eat today which results in functional disorder and disease.

Bioremediation

Bioremediation is an innovative technology which cleans the contaminated soil. It is a process by which organic wastes are biologically degraded under controlled conditions to harmless state. Several naturally occurring bacteria, fungi algae are being used to degrade or detoxify substances precarious to human health or environment. It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances which are hazardous to human health or environment [15]. This technology includes various naturally occurring mitigation processes i.e. natural attenuation, biostimulation, and bioaugmentation. Biodegradation of a compound is generally a result of the actions of multiple organisms. When microorganisms are bringing into a contaminated site to increase degradation, the process is known as bioaugmentation. Living organisms transformed contaminant compounds through reactions that take place as a part of their metabolic processes and thus clean-up of polluted water and land areas. The commonly used biopesticides which are pathogenic for the pest of interest are biofungicides (Trichoderma), bioherbicides (Phytopthora) and bioinsecticides (Bacillus thuringiensis) (Maheshwari et al., 2014).

Influencing Factors of Pesticide Degradation

Three types of factors affecting the microbial processes

(1) physicochemical characteristics of environment or the abiotic factors

(2) biological factors or biotic factors and

(3) climatic conditions

Physicochemical factors include a set of parameters such as redox potential (Eh), pH, ionic strength, solubility, presence or absence of electron acceptors and donors, temperature and age of organometalic ions. Biosorption, a primary step in toxic metal removal by microbes, is a pH-dependent phenomenon whereby pH value influences the isoelectric point in a solution, affecting the net negative charge on the microbial cell surface. Additionally, this change brings changes in ionic state of ligands, e.g., a carboxyl residue,phosphoryl residues, S–H groups and amino acid groups Bioremediation techniques involve reduction of metal ions to insoluble form by the microorganisms from higher to lower oxidation sate (pH dependent) as soluble metal ions can only undergo enzymatic reduction. Higher oxidation states of metals are generally soluble [16]. Solubility plays an important role in degradation of OCs as hydrophobic or sparingly soluble compounds persist in the environment for long lime and are biounavailable [17].

Biological factors are not as such very obvious, however; the importance of these factors is often realized while implementing bioremediation technique. Bacterial chemotaxis is an advantageous behavior of bacteria for the degradation of recalcitrant organic compounds [18]. Microorganisms are vital for the efficient functioning of ecosystems on earth, and factors affecting metabolism, composition and abundance of microbes and microbial communities may disturb the ecosystems [19]. Allelopathic response of terrestrial plants on the microbial community may negatively influence the degradation potential of soil microbes [20].

There is no direct evidence of any likely impacts of climate change on the bioremediation process, however; researches on soil microbes and climate change suggest changes in the physicochemical properties of the microbial niche, which may alter microbial metabolic processes and thereby the bioremediation. Microbial extracellular enzyme production is linked to microbial activity as well as soil physicochemical properties which are influenced by climatic conditions [21-23].

The rate of biodegradation in soil depends on four variables are as follows:

(i) Availability of pesticide to the microorganisms

(ii) Physiological status of the microorganisms

(iii) Survival and proliferation of pesticide degrading microorganisms at contaminated site

(iv) Sustainable population of these microorganisms

Advantages of Bioremediation:

Bioremediation is cost effective, eco friendly, abolish waste permanently and can be used in combination with other physical or chemical treatment methods. Resultant residues from the treatments applied are usually harmless compounds like carbon dioxide and water. The compounds that are harmful can be transformed into non hazardous compounds [24,25].

Conclusion

The use of pesticides and insecticides increases day by day which pollute our air, soil, water and ultimately reach to us through food chain. It is very necessary to degrade these pollutants so that our environment does not degraded and we can live a healthy life in a healthy environment. Bioremediation is the most effective management tool to manage the polluted environment and recover contaminated soil and water. We should use bioremediation to treat contaminated soil and water because it is less harmful, eco friendly, act upon only specific target organism. Moreover, it requires in very small quantity and decompose fast. It avoids the pollution problems. When used as a component of Integrated Pest Management (IPM) programs, biopesticides can contribute greatly. In future we can use genetic engineering to improve the efficacy of microorganisms to reduce the environmental burden of toxic substances.

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