# Effect of Pesticide on Agriculture Soil and their Biodegradation by Soil Bacteria

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**Abstract— Pesticides play a pivotal role in agriculture for the effective production of various crops. The indiscriminate use of pesticides results in the significant bioaccumulation of pesticide residues in vegetables. This situation is beyond the control of consumers and poses a serious health issue for human beings. Occupational exposure to pesticides may occur for farmers, agricultural workers, and industrial producers of pesticides. This occupational exposure primarily causes food and water contamination that gets into humans and environmental pollution. Depending on the toxicity of pesticides, the causes and effects differ in the environment and in human health. The number of criteria used and the method of implementation employed to assess the effect of pesticides on humans and the environment have been increasing, as they may provide characterization of pesticides that are already on the market as well as those that are on the way. The biological control of pests has been increasing nowadays to combat all these effects caused by synthetic pesticides.**

**Keywords— Biodegradation, Pesticide, Agricultural Soil, Soil Bacteria**

## I. INTRODUCTION

Agriculture frequently uses pesticides to control weeds, insect infestations, and diseases. Approximately 1% of the pesticide is applied to target pests; the remaining pesticide enters the soil and encounters several transformations, producing a complex pattern of metabolites. Pesticide residues can persist in the environment for various durations in atmospheric air, groundwater, surface water, soil, and sediments [1]. One of the most commonly used pesticides is an organophosphate, chlorpyrifos (CP) [O, O-diethyl O-(3,5,6-trichloro-2-pyridyl phosphorothioate)]. It has been widely utilised in domestic pest control and agricultural production to detect pesticides in food and the environment. Based on the soil type, climate, and other conditions, the half-life of CP in soil usually ranges from 60 to 120 days but can also be prolonged to over a year. A significant degradation by-product of CP, 3, 5, 6-trichloro-2-pyridinol (TCP) possesses antimicrobial characteristics and inhibits the growth of advantageous soil microbes [2, 3]. TCP adversely affects the diversity of the soil microbiota, reduces soil fertility, and inhibits plant growth, endangering the long-term viability of agricultural soils. It has a half-life of approximately 65–360 days. Diethyl thiophosphoric acid (DETP) is another by-product of CP that plays a crucial role in hormone-disrupting chemicals. In addition, CP and its derivatives can also inhibit beneficial plant growth-promoting microorganisms in the soil. In Thailand, several studies have investigated chlorpyrifos contamination in different environmental media. For example, a study of agricultural soils during winter reported the presence of chlorpyrifos in soil with concentrations of 28.57 ± 18.7 mg/kg.

Another study investigated the presence of chlorpyrifos in water samples from the Chao Phraya River. The study found chlorpyrifos in all water with concentrations ranging from 0.01 to 13.40 µg/L. Numerous reports have described various organophosphate pesticide treatments. Traditional cleaning methods for organophosphate pesticides rely on chemical reactions, recycling, pyrolysis, incineration, and landfill. However, this might result in the production of harmful compounds, which are both expensive and inefficient. On the other hand, the effective detoxification, degradation, and removal of harmful chemicals from polluted soil and water using microbes have emerged as successful methods to clean up polluted sites. Harmful organophosphate pesticides can be decomposed into less harmful derivatives using living organisms such as plants and microbes. In contaminated soil, many genera have been documented to break down organophosphate pesticides, including Achromobacter, Ochrobactrum, as well as Alcaligenes [4, 5].

However, only some bacterial strains that can degrade CP and produce plant growth regulators have been documented. Plant growth-promoting bacteria (PGPB) have attracted attention for encouraging plant growth and degrading environmental pesticides. They exhibit significant plant growthpromoting traits, such as phosphate solubilisation, indole-3-acetic acid (IAA) synthesis, and ammonia production, both in the absence and presence of CP, which are distinctive characteristics of CP degradation and plant growth promotion capabilities. IAA, the main auxin in plants, is an essential plant hormone strongly implicated in plant growth and development. It is a crucial molecule that upregulates numerous genes involved in plant growth and development. It is a multi-functional plant hormone that regulates apical dominance, phototropic and geotropic responses, flower development, fruit ripening, cell division, elongation, and differentiation. Therefore, IAA-producing bacteria have attracted considerable attention in recent years. Bacterial exopolysaccharides (EPS), complex carbohydrates, play important roles in various biological processes, including cell protection, adhesion, and signalling. Some evidence suggests that EPS may have a role in mitigating the harmful effects and enhancing the biodegradation of chlorpyrifos in soil and water. Therefore, IAA and EPS production during chlorpyrifos degradation by microorganisms can be advantageous in multiple ways.

The production of endosulfan (organochlorine) is still being produced by various industries, but endosulfan is a very toxic insecticide for soil application, and it has been banned in many countries, including Korea. It is more toxic and stays longer in the soil system [7]. Lindane (the organochloride) is one of the most widely used insecticides worldwide and is biodegraded by white-rot fungi, including Trametes hirsutus, Bjerkandera adusta, and Pleuotus sp [8,9]. Cyanobacteria in the irrigation water and soil degraded diuron. These encouraging findings suggest that using cyanobacterial mats and other microbial sources to remediate soil and water pollution could be a viable option [10–12]. This review mainly focuses on international reports on insecticide pollution in the agro-ecosystem system and the damage caused by insecticide compounds. The second important role of this review is to show how insecticide pollutants enter the soil system and are then transferred to humans through the food chain. The third goal is to find vital mechanisms to combat insecticide pollution in laboratories and in large-scale studies. In this paper, the authors looked into how entomopathogenic fungi help break down insecticide pollution and how their enzymes help fight pollution in the agroecological system.

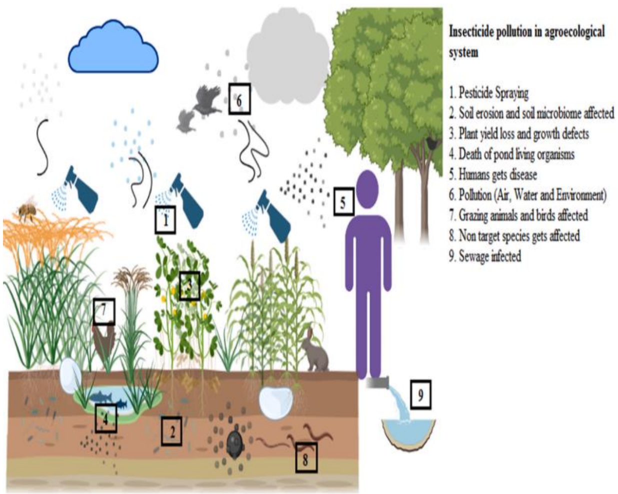


Fig. 1: Insecticide pollution in agro-ecological system and its causes.

## II. BIODEGRADATION AS A STRATEGY TO REDUCE THE NEGATIVE IMPACT OF PESTICIDES

Due to the problems mentioned above, the development of technologies for environmental remediation or waste destruction that guarantees their elimination in a safe, efficient and economical way is important. The mechanisms for the cleanup of pesticides in soil such as chemical treatment, volatilization and incineration have met public opposition because of problems such as the production of large volumes of acids and alkalis that must subsequently be disposed. The potentially toxic emissions and the elevated economic costs are also significant concerns. Overall, most of these physical-chemical cleaning technologies are expensive and inefficient. A methodology for degradation that has gained acceptance is the bioremediation, which is conducted through the biodegradation of these chemical compounds. According to the definition by the International Union of Pure and Applied Chemistry, the term biodegradation is defined as the breakdown of a substance catalyzed by enzymes in vitro or in vivo. Biodegradation may be defined for the purpose of hazard assessment into the following categories:

1. Primary. Alteration of the chemical structure of a substance resulting in loss of a specific property of that substance.
2. Environmentally acceptable. Biodegradation to such an extent as to remove undesirable properties of the compound. This change often corresponds to primary biodegradation but it depends on the circumstances under which the products are discharged into the environment.
3. Ultimate. Complete breakdown of a compound to either fully oxidized or reduced simple molecules (such as carbon dioxide/methane, nitrate/ammonium and water).

It should be noted that the biodegradation products can be more harmful than the substance degraded. The microbial degradation of pesticides in the environment is an important route for the removal of these compounds. The biodegradation of these compounds is often complex and involves biochemical reactions. Although many enzymes efficiently catalyze the biodegradation of pesticides, the full understanding of the biodegradation pathway often requires new investigations. Several pesticide biodegradation studies have shown only the total of degraded pesticide, but have not investigated in depth the new biotransformed products and their fate in the environment. As an efficient, economical and environmentally friendly technique, biodegradation has emerged as a potential alternative to the conventional techniques. However, the biodegradation process of many pesticides has not been fully investigated (Sun et al. 2010). With knowledge of the biodegradation processes, is possible to apply it to improve the bioremediation of sites contaminated with pesticides. Bioremediation enables the destruction of many organic contaminants at a reduced cost, and in recent years, bioremediation technology has progressed for the degradation of a wide range of pollutant compounds. Bioremediation can offer an efficient and cheap option for the decontamination of polluted ecosystems and the destruction of pesticides.

## III. PESTICIDE

Soil pollution is a worldwide problem that draws its origins from anthropologic and natural sources. Urbanization, industrialization, and food-demand increases have required the use of compounds, substances, and chemical agents, which, over the years, have brought on the dispersion and accumulation of pollutants in the environment. The common pollutants present in the soil are heavy metals, polycyclic aromatic hydrocarbons (PAHs), or pesticides [1]. Pesticides are chemical compounds used to eliminate pests. They are chemical or biological agents, that weaken, incapacitate, and kill pests. Based on the types of targeted pests, the pesticides can be divided into several groups, namely insecticides, herbicides, rodenticides, bactericides, fungicides, and larvicides. During the 19th and 20th centuries, the extracts from plants, namely pyrethrins, were used as insecticides, fungicides, and herbicides. The increase in pesticide use happened with synthetic chemistry during the 1930s.

In this period, inorganic chemicals such as arsenic and sulfur compounds were applied for crop protection. The arsenic poison was senic and sulfur compounds were applied for crop protection. The arsenic poison was fatal to insects, while the sulfur was used as a fungicide. At the beginning of the Second World War, numerous pesticides were synthesized, mainly organic chemicals, such as dichlorodiphenyltrichloroethane (DDT), aldrin, and dieldrin used as insecticides, while 2- methyl-4-chlorophenoxyacetic acid (MCPA) and 2,4-dichlorophenoxyacetic acid (2,4-D) were used as herbicides [2]. After 1945, there was a rapid development of the agrochemical field, characterized by the introduction of many insecticides, fungicides, herbicides, and other chemicals, to control pests and ensure the yields of agricultural production. Moreover, pesticides are applied in aquaculture, horticulture, and for various general household applications.

They are also used to control vector-borne diseases (e.g., malaria and dengue) [3]. From 1990 to 2018, there have been registered amounts of used pesticides by all countries in the world, especially in Asia and America. The world average quantity has increased from 1.55 kg·ha−1 in 1990 to 2.63 kg·ha−1 in 2018, as shown in Figure 1.

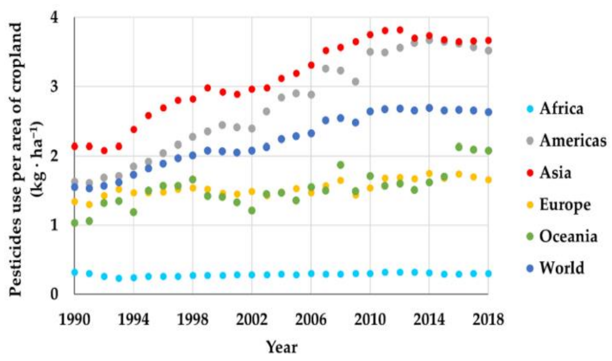


Figure 2: Pesticides use per area of cropland

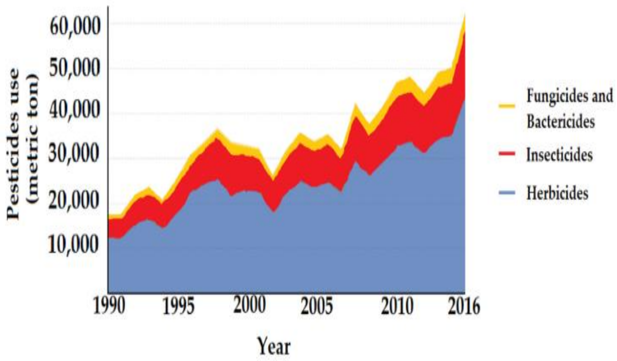


Figure 3: Pesticides use from 1990 to 2016

When pesticides are used, a part of them remains in the soil, and the accumulation affects the microorganisms living there. Human exposure can occur through the ingestion of pesticide-contaminated water and food, the inhalation of pesticide-contaminated air, and directly from occupational, agricultural, and household use. The pesticides can enter the human body by dermal, oral, eye, and respiratory pathways [7]. The toxicity of pesticides depends on the electronic properties and the structure of the molecule, dosage, and exposure times [8, 9]. For these reasons, the residual pesticide concentration present in the soil must be reduced, and effective remediation techniques must be used to do this. An ecofriendly, cost-effective, rather efficient method is bioremediation, which is an alternative to more expensive and toxic approaches, such as chemical and physical methods. In biodegradation, the removal can be achieved by exploiting the microbial activity of microorganisms. The microorganisms, primarily bacteria [10], or fungi [11] transform pesticides into less complex compounds, CO2, water, oxides, or mineral salts, which can be used as carbon, mineral, and energy source. In these reactions, the enzymes have an important role since they act as catalysts [12]. Several techniques are available for the biodegradation of pesticides, which could develop in aerobic or anaerobic conditions based on types of microorganisms. Moreover, the bioremediation techniques can be divided into three categories depending on where the remediation treatment is done, namely in situ, ex situ, or on-site.

## IV. PRINCIPLES OF PESTICIDE BIODEGRADATION

Biodegradation is a process that involves the complete breakdown of an organic compound in its inorganic constituents. The microbial transformation may be driven by energy needs or a need to detoxify the pollutants, or it may be fortuitous in nature (co-metabolism). The ubiquitous nature of microorganisms, their numbers and large biomass relative to other living organisms on earth, their more diverse catalytic mechanisms, and their ability to function even in the absence of oxygen and other extreme conditions are greatly important in the use of microorganisms for the degradation of pesticides. The microbial populations of soil or aquatic environments are composed of diverse, synergistic or antagonistic communities rather than a single strain. In natural environments, biodegradation involves the transfer of substrates and products within a well-coordinated microbial community, a process referred to as metabolic cooperation.

Microorganisms have the ability to interact both chemically and physically with substances, leading to structural changes or the complete degradation of the target molecule. Pesticides interact with soil organisms and their metabolic activities and may alter the physiological and biochemical behavior of soil microbes. Many recent studies have revealed the adverse impacts of pesticides on soil microbial biomass and soil respiration; generally, a decrease in soil respiration reflects the reduction in microbial biomass. Some microbial groups are capable of using applied pesticides as a source of energy and nutrients for their multiplication, whereas the pesticide may be toxic to other organisms. Likewise, sometimes the application of pesticides reduces microbial diversity but increases the functional diversity of microbial communities. Pesticide application may also inhibit or kill certain groups of microorganisms and outnumber other groups by reducing competition. Among the microbial communities, bacteria, fungi and actinomycetes are the main transformers and pesticide degraders. Fungi generally biotransform pesticides and other xenobiotics by introducing minor structural changes to the molecule, rendering it nontoxic. The biotransformed pesticide is released into the environment, where it is susceptible to further degradation by bacteria.

Fungi and bacteria are considered excellent extracellular enzyme-producing microorganisms. Moreover, the ability of fungi to form extended mycelial networks, the low specificity of their catabolic enzymes and their independence from organic chemicals as a growth substrate make fungi well suited for bioremediation processes. Fungi are critical to the biogeochemical cycles and are responsible for the bulk of the degradation of environmental xenobiotics in the biosphere. White rot fungi have been proposed as promising bioremediation agents, especially for compounds that are not readily degraded by bacteria. This ability arises from the production of extracellular enzymes that act on a broad array of organic compounds. Some of these extracellular enzymes are involved in lignin degradation, such as lignin peroxidase, manganese peroxidase, laccase and oxidases. Several bacterial species that degrade pesticides have been isolated, and the list is expanding rapidly. The three main enzyme families implicated in degradation are esterases, glutathione S-transferases (GSTs) and cytochrome P450. Enzymes are central to the biology of many pesticides. Applying enzymes to transform or degrade pesticides is an innovative treatment technique for the removal of these chemicals from polluted environments. Enzyme-catalyzed degradation of a pesticide may be more effective than existing chemical methods.

## V. CONCLUSION

Present study recommends the application of indigenous microorganisms in biodegradation of common agriculture pesticides. Because in stress conditions bacteria could change their genetic profile and easily induce mutant strains, which can adopt in different environmental condition by activating their vast range of biochemical metabolism diversity, hence need to in depth study in this regard. The use of proteomics tools for the purpose of environmental bioremediation gives detailed information of microbial cells protein and composition. Hence it offers a valuable approach to decipher the mechanisms involved in bioremediation at molecular level. Diversity, composition and metabolic potential of soil microbiome are of crucial importance in bioremediation. In addition soil microbial communities also regulate biogeochemical cycling. Hence, detailed analysis of microbial communities at functional and structural level will guide to monitor and assess the effect of pesticides on soil health and their biological status respectively.

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