

**PESTICIDES: PHYSIOLOGICAL EFFECTS ON SOIL MICROFLORA**

**Adegboyega, D. A<sup>1</sup>., Akala, A. O<sup>2</sup>., Akanni, F.O<sup>2</sup> Ademuwagun, A.A<sup>3</sup>, Olatunji, A.O<sup>4</sup> and Eniola. O<sup>5</sup>**

<sup>1</sup>Pathology Section, Department of Forest Conservation and Protection

<sup>2</sup>Biotechnology Section, Bioscience Department, Forestry Research Institute of Nigeria, Ibadan

<sup>3</sup>Federal College of Forestry Mechanization, Afaka, Kaduna.

<sup>4</sup>Soils and Tree Nutrition Department

<sup>5</sup>Agricultural Extension and Management Department, Federal College of Forestry, Ibadan

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**ABSTRACT**

The extensive and inappropriate use of pesticides for increased crop yields due to their local formulation and easy availability can be a significant source of surface water, groundwater, air, and soil contamination which adversely affect soil microbial community. This work review on the possible effects of pesticides on the soil microflora.

**Keywords:** Pesticides, Soil, Contamination, Microflora.

**1. INTRODUCTION**

The problem of environmental contamination by pesticides goes beyond the locality where it is used. The agricultural pesticides that are exhaustively applied to the land surface travel long distances and can move downward until reaching the water table at detectable concentrations, reaching aquatic environments at significantly longer distances

Therefore, the fate of pesticides is often uncertain; they can contaminate other areas that are distant from where they were originally used. Thus, decontaminating pesticide-polluted areas is a very complex task (Gavrilescu, 2005).

About 30% of agricultural produce is lost due to pests. Hence, the use of pesticides has become indispensable in agriculture. The abusive use of pesticides for pest control has been widely used in agriculture. However, the indiscriminate use of pesticides has inflicted serious harm and problems to humans as well as to the biodiversity (Gavrilescu, 2005; Hussain *et al.*, 2009).

Decontamination of pesticide-infested environments is a difficult matter and can be very costly. In fact, the damages from pesticides in the environment are practically irreparable. Any measure used to decrease the effects of pesticides in the environment will always be a palliative solution and never definitive for the problems caused. Regrettably, there is always irreparable damage to the organisms and the environment, as for instance, the extinction of bird species and microorganisms in the world. The biological methods are advantageous to decontaminate areas that have been polluted by pesticides. These methods consider the thousands of microorganisms in the environment that in order to survive seek for alternatives to eliminate the pesticides that

were sprayed. Many native microorganisms develop complex and effective metabolic pathways that permit the biodegradation of toxic substances that are released into the environment. Although the metabolic process is lengthy, it is a more viable alternative for removing the sources of xenobiotic compounds and pollution (Diaz, 2004; Schoefs *et al.*, 2004; Finley *et al.*, 2010).

On account of the grave risks synthetic pesticides pose to the organisms, there is an incessant search for pesticide safety and for the development of sustainable agriculture. The biological pesticides are based on natural compounds that effectively control the infestation of pests in agriculture. The advantage is that, contrary to synthetic pesticides, they are efficient and do not cause collateral damage (Fravel, 2005; Gerhardson, 2002; Raaijmakers *et al.*, 2002).

### **Degradation of Pesticides in Soil**

Pesticides in the soil environment are subject to a variety of degradative processes. The overall degradation of a pesticide from soil results from a combination of loss mechanisms. The degree to which each mechanism will contribute to the overall loss of the pesticide is in turn dependent on the physico-chemical properties of the pesticides, characteristics of the soils, environmental conditions and management practices. The studies in respect of the salient factors that determine the degradation of pesticides are presented.

### **Concentration**

Concentration of pesticide application is an important parameter in determining the rate of biodegradation. The degradation kinetics of many pesticides approaches first order; the rate of degradation decreases roughly in proportion with the residual pesticide concentration (Topp *et al.*, 1997). Gupta and Gajbhiye (2002) reported that the half-life of flufenacet in three Indian soils, viz., inceptisol, vertisol and ultisol, varied from 10.1 to 31.0 days at low rate (1.0  $\mu\text{g g}^{-1}$  soil) compared to 13.0 to 29.2 days at high rate (10.0  $\mu\text{g g}^{-1}$  soil) of application. Prakash and Suseela Devi (2000) reported the reduced degradation rate of butachlor at higher initial concentrations, which could be attributed to limitation in the number of reaction sites in soil and toxic effect on microorganisms or enzyme inhibition. Yu *et al.* (2003) reported that the half-lives of butachlor in non-rhizosphere, wheat rhizosphere and inoculated rhizosphere soils ranged from (6.3 to 18.0) days at 1.0  $\text{mg kg}^{-1}$ , (2.9 to 19.9) days at 10.0  $\text{mg kg}^{-1}$  and (10.8 to 23.2) days at 100.0  $\text{mg kg}^{-1}$  indicating the degradation of butachlor to be dependent on application rate and soil type.

### **Solubility**

Pesticides with low water solubility tend to be more resistant to microbial degradation than compounds of higher water solubility. Microorganisms can use only the dissolved fraction of the compound in soil solution. Therefore, the rate of dissolution of pesticides would govern the rate of their biodegradation (Cork and Krueger, 1991).

### **Soil Types**

Soil properties like organic matter, clay content, pH etc. affect the degradation of pesticides in soil (Gupta and Gajbhiye, 2002). The role of the soil in pesticide biodegradation is critical because it provides the environment for degradative microorganisms. Soil particles

can sorb pesticides, regulating their bioavailability and influencing their persistence. Both content and type of clay and organic matter are important soil parameters, which influence the activity of pesticide degrading microorganisms. Therefore, it is important to study the effect of soil types in pesticide degradation. Gold *et al.* (1996) reported that soil pH and clay content greatly affected the persistence of bifenthrin, chlorpyrifos, cypermethrin, fenvalerate, permethrin and isofenphos under field conditions. The half-lives of rim sulfuron under field conditions varied within a wider range of 5.6 days in a sandy clay loam soil in the United States (Schneiders *et al.*, 1993) and of 120 days in a light sandy soil in Denmark (Reinke *et al.*, 1991). Jones and Ananyeva (2001) reported that the degradation of metalaxyl and propachlor occurred at different rates in different soils. The half-lives in pasture, arable and pine forest soils were 10, 19 and 36 days for metalaxyl and 2.6, 6.1 and 8.2 days for propachlor. Gupta and Gajbhiye (2002) stated that the degradation of flufenacet was greatly influenced by soil types and the half-life values varied from 10.1 to 22.3 days in an inceptisol, 10.5 to 24.1 days in a ultisol and 29.2 to 31.0 days in a vertisol. Hafez and Thiemann (2003) mentioned that the degradations of imidacloprid and diazinon were faster in the silty loam soil followed by sandy loam and sandy soil. Degradation of pencycuron was soil dependent (Pal *et al.*, 2005b). Pencycuron degraded faster in coastal saline soil than alluvial soil and in soil amended with decomposed cow manure whereas microbial mediated degradation of pencycuron was more in alluvial soil than in coastal saline soil.

### **Moisture**

Water acts as solvent for pesticides movement and diffusion and is essential for microbial functioning. Pesticide degradation is slow in dry soils. The rate of pesticide transformation generally increases with water content. In very wet soils such as rice paddies, the rate of diffusion of atmospheric oxygen into the soil is limited and anaerobic pesticide transformation can prevail over aerobic degradation. Poor oxygen transfer at high moisture content can, however, accelerate or retard the degradation of pesticides. Phorate was more persistent in flooded soil than in nonflooded soil (Walter-Echols and Liechtenstein, 1978). The herbicides atrazine and trifluralin disappeared more rapidly under anaerobic conditions than under aerobic conditions. The insecticide  $\gamma$ -BHC persists for several years in aerobic soils, but it is biodegraded partly in submerged soils and a high content of organic matter hastens the biodegradation (Ponnamperuma, 1972). DDT is fairly stable in aerobic soils, but is degraded rapidly to DDD in submerged soils (Topp *et al.*, 1997). The alteration in the oxidation state is important in microbes-pesticides interaction because the oxidized or reduced forms of pesticides often determine their toxicity in the environment through adsorption, solubility etc. (Hicks *et al.*, 1990) and also the microbial activity under submerged condition. Thus, the transformation of pesticides in the submerged soils is different from that of the soils in field moist state. In contrast, Baskaran *et al.* (1999) reported that soil moisture content had no effect on the degradation of imidacloprid and bifenthrin. Racke *et al.* (1994) also found similar type of behaviour while studying the degradation of chlorpyrifos. Schneiders *et al.* (1993) reported that the half-lives of rimsulfuron were 24.5 and 22.5 days under anaerobic and aerobic conditions respectively in a sandy loam soil. Pencycuron degraded rapidly in aerobic soil compared the submerged soil (Pal *et al.*, 2005b).

**Structure**

The structure of a pesticide molecule determines its physical and chemical properties and inherent biodegradability. The introduction of substituents on a benzene ring influences its degradation. Minor alterations in structure frequently cause a drastic change in the susceptibility of a compound to biotransformations. Introduction of polar groups such as OH, COOH and NH<sub>2</sub> may provide the microbial system, a site of attack. Halogen or alkyl substituents tend to make the molecule more resistant to biodegradation (Cork and Krueger, 1991). Chlorinated hydrocarbons such as DDT, pentachloro and dieldrin are insoluble in water, sorb tightly to soil and are thus relatively unavailable for biodegradation. The insecticide carbofuran and the herbicide 2,4-D, which are of different molecular structure, can be degraded in a matter of few days in field soils. Minor differences in the position or nature of substituents in pesticides of the same class can influence the rate of degradation (Topp *et al.*, 1997)

**Temperature**

The effect of temperature on pesticide degradation depends on the molecular structure of the pesticide. Temperature affects adsorption by altering the solubility and hydrolysis of pesticides in soil (Burns, 1975, Racke *et al.*, 1997). As adsorption processes are exothermic and desorption processes are endothermic, it is expected that adsorption will reduce with increase in temperature with a corresponding increase in pesticide solubility. Vischetti *et al.* (1995) found that the half-lives of rimsulfuron ranged from 14.8 days at 10°C to 3.5 days at 25°C in a clay loam soil incubated at 75% humidity. Microbial activity is stimulated by increase in temperature and some ecological groups tend to dominate within certain temperature ranges. Perucci *et al.* (1999) studied the effect of rimsulfuron on the growth and activity of microbial biomass under laboratory conditions at varying conditions of temperature in a silty clay loam soil. The onset and magnitude of the effects were temperature dependent and generally slight and transitory. Rimsulfuron hydrolyses rapidly in soil under conditions of high temperature (Vischetti *et al.*, 2000). The maximum growth and activity of microorganisms in soils occur at 25-35°C (Alexander, 1977) and the pesticide degradation is optimal at mesophilic temperature range of around 25-40°C (Topp *et al.*, 1997). Jitender *et al.* (1993) conducted laboratory experiments with thiobencarb and butachlor incubated at 25 and 35°C for 90 days and observed a direct relationship between temperature and pesticide concentration-lower temperature and higher concentration resulted in greater persistence. Getzin (1981) observed that the half-lives of chlorpyrifos ranged from >20 to 1 day over the temperature range of 5 to 45°C, respectively. Zhu *et al.* (2004) reported faster degradation of fipronil at 35°C than at 25°C in non sterile clay loam soil.

**pH**

Soil pH may affect pesticide adsorption, abiotic and biotic degradation processes (Burns, 1975). It influences the sorptive behavior of pesticide molecules on clay and organic surfaces and thus, the chemical speciation, mobility and bioavailability (Hicks *et al.*, 1990). For instance, the sorption of prometryn to clay montmorillonite is more at pH 3 than at pH 7

(Topp *et al.*, 1997). The effect of soil pH on degradation of a given pesticide depends greatly on whether a compound is susceptible to alkaline or acid catalyzed hydrolysis (Rackeet *et al.*, 1997). Rimsulfuron hydrolyses rapidly in soil under conditions of high temperature (Vischetti *et al.*, 2000).

### **Salinity**

Limited information is available on the degradation of pesticides in saline soils although salinity is a severe problem in many arid, semiarid and coastal regions. Parathion was degraded faster in nonsaline soil than in saline soils and its stability increased with increasing electrical conductivity (Reddy and Sethunathan, 1985). However, reports on the stability of pesticides in estuarine and seawater of varying degrees of salinity are available. A high salt content in seawater may be innocuous (Walker, 1976) or inhibitory to degradation (Weber, 1976; Kodama and Kuwatsuka, 1980). Degradation of pencycuron was less in the coastal saline soil compared to the alluvial soil (Pal *et al.*, 2005b).

### **Physiological Effects of Pesticides on soil microbes**

The effect of pesticides varied greatly with the type, rate, and time after application of pesticides. Efforts must be made to determine the proper type and dosage of pesticide for agricultural crops in order to prevent their adverse effect on the environment in general and on useful soil organisms in particular. When pesticides are applied, the possibilities exist that these chemicals may exert certain effects on nontarget organisms, including soil microorganisms (Zhao *et al.*, 2013).

The microbes play an important role in the soil ecosystem (Khan *et al.*, 2010), and their functions (Khan *et al.*, 2007) are very crucial in nutrient cycling and decomposition (Lorenzo *et al.*, 2001). The study of pesticide effects on non-target populations is an accepted strategy to evaluate its associated potential environmental risks. Among non-target populations, soil microorganisms are extremely important, since they play an essential role in nutrient turnover (Aneja, 2004), maintaining generative capacity in agro-ecosystems (Bohlen, 2002). The processes of ecological succession are, among other factors, mediated by microorganisms and depend on a fine balance of their population dynamics (Kennedy, 1999). Under these circumstances, the impact inflicted on soil microbial populations caused by a specific pesticide is a potential indicator of the toxicity level of this product, and may represent a component of a broad study aiming to evaluate its potential impact on the environment (Kent, 2002).

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