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UNVEILING THE ECOTOXICOLOGY OF CHLORPYRIFOS: FATE, TRANSPORT, AND ECOSYSTEM DISRUPTION

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ABSTRACT

Excessive and inappropriate use of these pesticides causes significant harm to non-target species, including humans. Their residues persist in the air, soil, and water for long periods, eventually leading to biomagnification through the food chain and inducing pesticide resistance in pests as well as the occurrence of mutations. Pesticides have contributed to dramatic increases in crop yields, as well as in the quantity and variety of food available. They have also aided in the containment of certain diseases. Pesticides, on the other hand, can be harmful to both human health and the environment. These negative health effects include acute and chronic nervous system damage, lung damage, reproductive organ damage, immune and endocrine system dysfunction, birth defects, and cancer. Invertebrates, fish, and amphibians are all extremely poisoned by chlorpyrifos. Death, malformations, and bioaccumulation in tissues can result from even low amounts. In aquatic environments, chlorpyrifos can upset the stability, composition, and structure of microbial communities, impairing their capacity to carry out vital tasks including pollution degradation and nutrient cycling. Plant development and health can be adversely affected by chlorpyrifos, which may lower crop production and have an effect on the food chain. Chlorpyrifos may have an impact on plant health and soil fertility by changing the makeup and role of soil microflora.

Keywords: Chlorpyrifos, flora and fauna, ecosystem, residues

INTRODUCTION

Pesticides are used in 3.5 million tonnes globally each year, with India using 53453 tonnes (FAO, 2019). Pesticides used to prevent or destroy pests have a greater negative impact on our ecological system than their intended action. Pesticides are carried by the wind to other areas, contaminating them. Pesticides also pollute the environment's water, and some pesticides are persistent organic pollutants that contribute to soil contamination (Rockets, 2007).. Pesticides have undoubtedly become an unavoidable component of modern farming. Pesticides have contributed to dramatic increases in crop yields and the quantity and variety of the diet. Also, they have helped to limit the spread of certain diseases. But pesticides have harmful effects; they can cause injury to human health as well as to the environment. The range of these adverse health effects includes acute and persistent injury to the nervous system, lung damage, injury to the reproductive organs, dysfunction of the immune and endocrine systems, birth defects, and cancer (Mansour, 2004). Pesticides will endanger both the environment and living creatures if they are used excessively. Pesticide overuse has a negative impact on sustainable agriculture (Gavrilescu et al., 2015).

Chlorpyrifos, an organophosphate (OP) insecticide has been taken for review on its behavior and ecotoxicology. To have a better understanding of the mechanisms involved and to strengthen the knowledge base on the above, a review of past studies was undertaken and is briefly presented hereunder.

CHLORPYRIFOS AN OP INSECTICIDE

Organophosphorus (OP) compounds are among the most commonly used chemical classes in crop and livestock protection, accounting for an estimated 34% of global insecticide sales (Singh & Walker, 2006). Approximately 150 different OP chemicals have been used to protect crops, livestock, and human health over the last 60 years (Casida & Quistad, 2004).The majority of OPs can be classified as phosphoric acid derivatives. Phosphorothionates are abundant and contain sulfur in their structure, typically in the form of a P=S moiety. Phosphorothionates include parathion, diazinon, and chlorpyrifos. Members of this phosphate subclass are generally more toxic and are typically used as soil or plant systemic insecticides. Pesticides containing OP are neurotoxins that inhibit the action of the neurotransmitter acetylcholine (Ragnarsdottir, 2000). The OP compounds inhibit the enzyme acetylcholinesterase (AChE), which is essential for nerve cell function because it catalyzes the rapid hydrolysis of acetylcholine (Raushel, 2002).

Chlorpyrifos is a chlorinated organophosphate insecticide that is currently in use. It is used to treat fruits, grains, nuts, vegetables, livestock, ornamentals, golf courses, buildings, and wood products. It comes in liquid, granular and flowable concentrates, baits, wettable powders, and dust forms.

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Chlorpyrifos is commonly used in agriculture as a foliar spray or applied directly to the soil and incorporated into it before planting. It is incorporated into the paint as a vector control method. Chlorpyrifos is one of the most widely used insecticides, and it is used in almost every region (Watts, 2012).

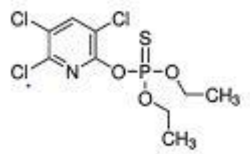
Chlorpyrifos is a well-known halogenated organophosphate pesticide that is widely used to control insects, nematodes, ticks, and mites worldwide. Because of its unpredictable use, the chlorpyrifos pesticide has had an impact on a large number of non-target and beneficial species in the environment, including silkworms, bees, and earthworms. Currently, chlorpyrifos is only used for indoor purposes in developed countries such as the United States, the United Kingdom, and the European Union. Even in developing countries, chlorpyrifos is the most commonly used pesticide for agricultural pest control. In India, chlorpyrifos is the 9th most commonly used pesticide for controlling insect pests in agricultural vegetables (Noore et al., 2021).

Organophosphates (OP), a group of synthetic pesticides developed during the Second World War, are being used as insecticides and nerve agents. Since the removal of organochlorine insecticides from use, organophosphates have become the most widely used pesticides in most nations. Even after withdrawing chlorpyrifos products from indoor/ outdoor domestic, garden, and industrial uses because of toxicity concerns in children, pets, wildlife, and the environment (AgroSciences, 2013),, its production and consumption are drastically increasing every year.

Since the ban on organochlorine insecticides, organophosphates have become the most widely used pesticides in most countries (Cortina-Puig et al., 2010).Even though chlorpyrifos products have been eliminated from indoor/outdoor domestic, garden, and industrial uses due to toxicity concerns in children, pets, wildlife, and the environment, their production and consumption are increasing dramatically every year.

IDENTIFICATION OF CHEMICAL

Common name	Chlorpyrifos	**Physicochemical properties**	
Chemical class	Organophosphate	**State**	Crystalline solid
IUPAC name	O,O-diethyl O-3,5,6-trichloro-2-pyridyl phosphorothioate	**Color**	Colorless to white
CAS no	2921-88-2	**Odor**	Mild mercaptan (thiol) odor
Molecular formula	$C_9H_{11}Cl_3NO_3PS$	**Vapor pressure**	3.35×10^{-3} Pa at 25 $^0C^*$
Relative molecular mass	350.6	**Melting point**	41.5–42.5 ^0C

Trade names	Lorsban, Dursban, Suscon Green, Empire, Chlorpyrifos-ethyl, Detmol UA, Dowco 179, Eradex, Piridane, Scout, Stipend, Tricel, etc.	**Solubility (water)**	0.0014 g L^{-1} at 25^0C^{**}
Structure		**Henry's law constant**	0.478 X m^3 X mol^{-1} *

*EFSA (2005)

**Tomlin (2009)

TOXICOLOGICALLY RELEVANT METABOLITES

3,5,6-trichloro-2-pyridinol (TCP) is the primary degradate of Chlorpyrifosin the environment. It is less destructive than chlorpyrifos. 3,5,6-trichloro-2-methoxypyridine (TMP) is a secondary metabolite. Chlorpyrifos can also be oxidized to produce chlorpyrifosoxon, an active metabolite. In chlorinated water, oxon is rapidly formed but also quickly degrades to TCP. Chlorpyrifosoxon is 12 times more potent than chlorpyrifos (EPA, 2013). After electrochemical degradation of chlorpyrifos in wastewater, six degradation products, including chlorpyrifosoxon, were identified (Robles-Molina et al., 2012).

Metabolite	Importance	Reference
3,5,6-trichloro-2-pyridinol (TCP)	Primary	EFSA (2005)
3,5,6-trichloro-2-methoxypyridine (TMP)	Secondary	EFSA (2005)
O-ethyl-O-(3,5,6-trichloro-2-pyridoyl) Phosphorothioic acid (phosphorothioate)	not stated	EFSA (2005)
Chlorpyrifosoxon	Minor	US EPA (2009)

According to Sardar & Kole (2005), TCP was at its highest on the 30th day after an application to the soil in India and subsequently declined to non-detectable on day 120. TMP, the secondary metabolite, was no longer detectable after day 120. TCP has much lower soil/water partitioning than chlorpyrifos; as a result, significant amounts of TCP are available for runoff for longer periods than chlorpyrifos. According to the US EPA, (2006), the concentrations of TCP in sediment and

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water are likely comparable, and runoff occurs primarily through dissolution in runoff water rather than adsorption to eroding soil.

MECHANISM OF TOXICITY

Cholinesterase (ChE) inhibition is the primary mechanism of toxicity for organophosphorus pesticides such as chlorpyrifos. Acetylcholine esterase (AChE) is a nervous system regulatory enzyme that normally prevents the accumulation of a neurotransmitter, acetylcholine, at the synaptic junction for proper body functions. Organophosphate pesticides cause acute neurotoxicity by suppressing/inhibiting AChE, causing acetylcholine buildup at synaptic junctions. This causes uncontrolled nerve and muscle stimulation, possibly leading to exhaustion and muscle tetany. The metabolic rate, the number of target sites available for chlorpyrifos metabolism to chlorpyrifosoxon, organism surface area, and life stage are all factors that influence chlorpyrifos toxicity across species and groups(El-Merhibi et al., 2004).

MODE OF ACTION AND ITS APPLICATION

Chlorpyrifos is a non-systemic organophosphate pesticide that acts as a cholinesterase inhibitor by contact, ingestion, and inhalation. It affects the neurological system by inhibiting the breakdown of the neurotransmitter acetylcholine in the synaptic cleft by binding to the active site of the cholinesterase enzyme. Overstimulation of neuronal cells results from the buildup of acetylcholine in the synaptic cleft, which leads to neurotoxicity and gradual death.

Chlorpyrifos is used as an insecticide, acaricide, and nematicide in the soil, on foliage, and on animals to control Coleoptera, Diptera, Homoptera, and Lepidopteran insects (WHO, 2009). It's used on nuts, fruits, vegetables, grain, seeds, fodder crops, forestry, nurseries, greenhouses, food processing plants, industrial plants, warehouses, and ships; for disease vector control (mosquito larvicide and adulticide), household pests, fire ants, termites, and pests in animal houses; as a sheep dip for lice, blowfly, and ked control; on golf courses and turf; and for treating poles, fence posts, and other wood structures.

Chlorpyrifos is often used as a foliar spray in agriculture, or it can be administered directly to the soil and integrated before planting. It can also be used on seeds or bark. Aerial spraying, ground boom sprayers, tractor-drawn granular spreaders, airblast sprayers, low and high-pressure hand wands, backpack sprayers, hydraulic hand-held sprayers, shaker cans, belly grinders, push-type spreaders, large tank sprayers, compressed air sprayers, hose-end sprayers, and aerosol sprayers are some of the strategies used to apply it.

PHYSICO-CHEMICAL PROPERTIES

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Chlorpyrifos is a crystalline white solid with a melting point of 41.5 to 42.5 degrees Celsius. In neutral pH and acidic aqueous solutions, it is relatively resistant to hydrolysis. As the pH rises, so does the stability. The hydrolytic stability, together with the 30-day aqueous photolysis half-life and minimal volatilization and degradation under aerobic circumstances, suggests that chlorpyrifos may be persistent in the water columns of some aqueous systems with extended hydrological residence durations.

FACTORS INFLUENCING THE DETOXIFICATION OF CHLORPYRIFOS

According to Cáceres et al.(2002), sorption affects pesticide behavior and fate in the environment. When a pesticide molecule comes into the encounter with soil constituents, it generally forms a pseudo-equilibrium with these elements within hours. The transfer of a solute between a fluid and a solid phase is referred to as sorption. The behavior of both the solute and the solvent must be considered in this procedure. It is known that OP insecticides bind to mineral surfaces or organic materials in soils. Mineral surfaces with a pH-dependent surface charge in aqueous solutions are responsible for the adsorption of solutes such as OP compounds to soil particles(Ragnarsdottir, 2000).

Hydrolysis, which can lead to detoxification, is a crucial step in reducing the persistence of organophosphate pesticides in the environment. The hydrolysis of OP compounds is influenced by both pH and temperature. OP structures are commonly hydrolyzed between pH 7 and 25°C, however this ca,n also happens at pH 5 to 9 in groundwater. In general, for many OP pesticides, the higher the pH, the faster they hydrolyze (Ragnarsdottir, 2000). TCP and O-ethyl-O-(3,5,6-trichloro-2-pyridoyl) phosphorothioate are the major metabolites after hydrolytic breakdown.

In terms of persistence, Chlorpyrifos is persistent in soils under certain situations. Soil persistence half-lives (DT50) have been documented in the literature ranging from a few days to four years, depending on application rate, ecosystem type, and other environmental conditions. Chlorpyrifos persistence on soil, foliage, and fruit has also been observed to vary significantly between formulations including various inert substances, with a microencapsulated formulation being the most persistent(Montemurro et al., 2002).

Under tropical circumstances, chlorpyrifos dissipates faster from the soil; in one study, it was sprayed to a mustard crop and there were negligible levels left after 70 days; half-life was 3.6-9.4 days. Under other investigations, the half-life of chlorpyrifos applied to bare fields in tropical settings ranged from 0.6 to 5.4 days (Chai et al., 2009). Chlorpyrifos, like endosulfan, is characterized by rapid microbial breakdown, photodegradation, and volatilization, and is more durable under temperate circumstances. With a reduction in temperature, a drop in pH, and a drop-in light, it becomes more persistent.

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When some of the factors determining persistence are considered, the dissipative half-life in organic soils is much longer than in mineral soils. In water containing clay minerals, humate, dissolved organic matter, and suspended silt, hydrolysis is slower (Gebremariam et al., 2012). In sterilized soil, adding organic matter in the form of biochar enhanced persistence from 21.3 days to 55.5 days and 158 days. Application rates for termiticides are substantially higher than in agricultural use, and higher application rates result in slower dissipation. The majority of results given are for soil, but it has a stronger affinity for aquatic sediments than soils (Gebremariam et al., 2012). The Australian government evaluation mentions pond tests shows that a 200-day half-life in sediment, exceeding the Stockholm Convention persistence limits.

It was discovered at a concentration of 0.02 g/L in a wastewater treatment plant in Barcelona (Teijón Ávila et al., 2011). Incomplete sentence. In Perth, Australia, chlorpyrifos was found in secondary treated effluent, which is recycled for use as drinking water, but it was not found following reverse osmosis treatment(Rodriguez et al., 2011). In a water/sediment microcosm investigation, Laabs et al. (2007) discovered that chlorpyrifos and endosulfan had identical DTs and were relatively persistent (chlorpyrifos = 36.9 days).

In terms of Chlorpyrifos degradation and partitioning properties, breakdown in seawater is substantially slower than in freshwater. According to one study in California, seawater has a DT_{50} of 49.4 days at 10°C, compared to 18.7 days in freshwater. The DT_{50} for seawater was 15.2 days at 20 degrees Celsius, indicating that temperature has a major impact on seawater degradation (Bondarenko et al., 2004). Chlorpyrifos decomposition is aided by both biotic and abiotic mechanisms. The rate of enzymatic or clay-metal-catalyzed hydrolysis, which increases with pH and temperature, is one of the most important processes. In the presence of sunlight, it also degrades photolytically (Gebremariam et al., 2012). However, aerobic and anaerobic metabolism appears to be the primary pathways for breakdown.

Chlorpyrifos degradation occurs slowly in both aerobic and anaerobic environments. When not exposed to light, the primary metabolite, TCP, persists in soils. Numerous sources prefer different vapor pressure and Henry's Law Constant values, defining it as non-volatile, intermediately volatile, or volatile. However, based on the vapor pressure of 1.43 mPa (25°C) and solubility of chlorpyrifos in distilled water and seawater of 0.39 mg/L and 0.073 mg/L, respectively, volatilization may play a role in the dissipation of chlorpyrifos under some use conditions, especially for open-air uses under tropical conditions(Liu et al., 2001).

Chlorpyrifos has a low water solubility and is somewhat hydrophobic, according to Gebremariam et al.(2012).. Chlorpyrifos is projected to be adsorbed to suspended solids and sediment based on its sorption coefficient (Koc), and it has a stronger affinity for aquatic sediments than soils.

Chlorpyrifos persistence in water and sediment rises with lower temperatures, lower pH, and lower ultraviolet radiation, much as it does in soil. Low temperatures, according to Muir *et al.* (2007), may maintain chlorpyrifos, especially in icecaps and cold, oligotrophic lakes. As a result, it's logical to predict that persistence will be substantially higher in the Arctic's cold and often dark conditions than in tropical or temperate locations, as demonstrated by half-lives determined from such places. Chlorpyrifos residues up to 0.103 g/L were identified in water and up to 238,000 g/kg in sediment from the Kolleru lake wetland in India. In 27 percent samples of water from rice fields and canals in Haryana, Uttar Pradesh, and Uttarkhand, at up to 0.006 g/L (Amaraneni, 2006).

Adsorption reduces the mobility of chlorpyrifos in the soil and improves its persistence by lowering its availability to degradative processes. Chlorpyrifos adsorbs to soil (with a soil adsorption coefficient (Koc) more than 5000), soil particles, organic matter, clay minerals, and sediments to varying degrees, with organic soils adsorbing more than sandy loams (Gebremariam et al., 2012). Parolo et al.(2017) discovered a link between chlorpyrifos sorption coefficient and physicochemical features of soil, which had a strong association with % organic matter. The pH and chemical properties of organic materials, in particular, play a major influence in determining chlorpyrifos sorption behavior. By influencing the rate of certain fate processes such as volatilization, biodegradation, photolysis, and hydrolysis, adsorption and desorption processes have a significant impact on pesticide persistence.

The adsorption behavior of pesticides in the soil is influenced by numerous soil characteristics such as organic matter content, clay type, pH, temperature, and cation exchange capacity, and plays a significant role in determining their mobility (Li et al., 2007). Dow Chemical Company initially registered Chlorpyrifos for use in the United States in 1965 for the control of foliar and soil-borne insect pests. Liquid, gel, granular, soluble, emulsifiable, and flowable concentrates, microencapsulated material, pellets, tablets, impregnated materials, baits, wettable powders, dust, and ready-to-use formulations are all available. Chlorpyrifos has a long persistence time due to its structure and physicochemical properties. Chlorpyrifos has low solubility in water and a high partition from aqueous to organic solvents due to its nonpolar nature. With rising pH, its hydrolytic stability decreases. It is also more durable in the environment due to its low volatilization and breakdown in aerobic conditions.

The half-life of chlorpyrifos in the soil varies widely depending on application rate, ecosystem type, soil microorganisms, and climatic conditions, ranging from a few days to four years. Chlorpyrifos has a stronger persistence at higher concentrations, thus the application level is crucial. A larger application rates, the typical 1–2-month aerobic soil degradation half-lives appear to extend to 6 months to 4 years at regular agricultural rates. Both biotic (microbial) and abiotic (hydrolysis and photolysis) degradation produce dissipation in soil. Various types of pesticides have different impacts on soil bacteria. Many factors influence the effect, including the pesticide's method of action, bioavailability and physicochemical qualities in the soil, ambient circumstances, and the concentration, dose, and frequency with which it is administered.

The principal observed differences include atypical swimming behavioriour (Sharbidre et al., 2011) mortality, paralysis, and histological abnormalities such as loss and shortening of secondary lamellae, as well as mortality, paralysis, and death (De Silva & Samayawardhena, 2002).(Tomlin (2009) found that chlorpyrifos is poisonous to bluegill sunfish and rainbow trout, however, Oruç (2010) found that the LC_{50} in *Oreochromisniloticus* juvenile and adult was 98.67 and 154.01 ppb, respectively, using Dursban (480gL^{-1}Chlorpyrifos). All of these factors point to concern about chlorpyrifos' propensity to harm aquatic life. Chlorpyrifos acute toxic doses for the most vulnerable species vary from 1.0 ng/L for insect larvae to 10 mg/L for freshwater crustaceans (Gebremariam, 2011).

According to John *et al.* (2015) chlorpyrifos has been shown to inhibit the production of hormones such as androgen and estrogen in humans. It causes changes in the thyroid and adrenal glands, lowering the amounts of corresponding hormones in the blood. Children exposed to higher amounts of chlorpyrifos are more likely to have psychomotor and mental development delays, as well as attention issues, attention deficit or hyperactivity disorder, and pervasive developmental disorder issues. Chlorpyrifos exposure has been linked to difficulties with birth weight and length, DNA damage in sperm, and decreased sperm fluid, sperm concentration, sperm motility, cervical fluid, cord blood, meconium, and breast milk in humans (Watts, 2012).

THE BEHAVIOR OF CHLORPYRIFOS IN SOIL AND ITS BIOAVAILABILITY

Soil is a complex mixture of mineral, organic, and faunal substances. The soil fauna, which are the principal consumers and decomposers of the soil ecosystem, have a major role in the management of soil quality, i.e. fertility and functioning of tropical ecosystems (Sumner, 1999).

According to Liang et al.(2011), chlorpyrifos has the highest adsorption affinity, followed by TCP. The half-life (t1/2) of these pollutants in non-sterile soil ranged from 8.40 to 44.34 days, and their degradation followed first-order exponential decay kinetics. The degradation rate was slowed after soil was sterilized, showing that microbes played an important role in the breakdown of these chemicals.

Sardar & Kole, (2005) discovered a substantial drop in available N and P content in soil treated with chlorpyrifos when compared to a control set. The presence of TCP and TMP, rather than chlorpyrifos alone, had an inhibitory effect on available N, and the presence of TCP and TMP had an inhibitory effect on available P, as demonstrated by the stepwise multiple regression techniques. However, by 120 days after incubation, the average N and P status had greatly improved, possibly due to the elimination of the metabolites.

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Soils, according to Lanno et al.(2004), are a highly heterogeneous environmental matrix with differing geographical and temporal gradients of organic carbon, pH, and particle size distribution. The bioavailability of chemicals in soils to earthworms is determined by these soil physical and chemical parameters, which are related to physiology and behavior. Bioavailability can be used in ecological risk assessments as part of the risk analysis process, especially when estimating exposure. Effective concentrations must be produced from laboratory toxicity testing based on exposure estimates using procedures that detect the bioavailable fraction of chemicals in soil, not total chemical concentrations, to be used in site-specific ecological risk assessments of chemicals.

To forecast the dynamic residues in the soil environment, Jang et al.(2015)Jang *et al.* (2015) evaluated the adsorption and removal behaviors of chlorpyrifos in two soils with varying organic matter concentrations. The adsorptive capacity of chlorpyrifos was higher in the soil with high organic matter content than in the other soil, according to the adsorption test.

The biological accessibility of a chemical for assimilation by organisms that could cause toxicity is referred to as bioavailability (Alexander et al., 2006). The nature of the organism, the physicochemical properties of the contaminant, and the type of environmental conditions present all influence bioavailability Soil properties such as pH, the amount and quality of organic matter, and the presence of clay minerals can all affect bioavailability (Van Der Wal et al., 2004). The success of polluted soil treatment employing contaminant-degrading microorganisms, a technique known as bioremediation, is influenced by the degradation rate As a result, knowledge of pesticide sorption and desorption rates is crucial for estimating xenobiotic activity and bioavailability in a specific ecosystem.

BIOAVAILABILITY AND TOXICITY OF CHLORPYRIFOS IN SOIL ORGANISMS (EARTHWORM)

It is now well known that current farming techniques result in biodiversity loss. Traditional biochemical indicators have been employed to detect exposure to organophosphate (OP) pesticides in terrestrial invertebrates, namely earthworms. Earthworms, among other terrestrial invertebrates, are a good bio-indicator of ecosystem health because they have various characteristics that make them ideal for environmental monitoring and soil cleanup (Reinecke & Reinecke, 2004). Earthworms are a reliable model for measuring soil pollution because of their popularity as great bioindicators. There are a variety of biomarkers of harmful substances in earthworm ecotoxicology, including metallothioneins, stress proteins, cholinesterases, detoxifying enzymes, oxidative stress parameters, and others, which vary from the molecular to the organismal level. Biomarker analysis in invertebrates and earthworms gives useful information on both the ecological impact of long-term chemical contamination (diagnostic method) and the conditions of biological repair of damaged ecosystems (predictive approach). Worms play an important role in extending the maturity of soil. They could be used as a bioindicator in ecotoxicological studies of pesticide-induced soil contamination. Worms, *Eudrilus eugeniae*, were exposed to various concentrations of pesticides chlorpyrifos (OP), cypermethrin (a pyrethroid), and their combination for two days using the paper contact harmfulness test. Later openness of the two pesticides and their mix sub-intense convergence of pesticides uncovered worm, *Eudriluse ugeniae,* the sublethal impact of these pesticides caused variety in highlights, such as winding, clitellar expanding, bodily fluid delivery, draining, and body discontinuity in nightcrawlers. When E. eugeniae is exposed to high concentrations of pesticides accumulated in soil, such changes indicate a potential health risk. Pesticides have modified the activity of AChE, oxidative pressure-related chemicals, LPO, GSH content, and GST mobility with morphological modifications, according to Tiwari et al.(2019). This demonstrated that the pesticides toxic potential for the tried organic entity is more noticeable when present in combination than when present individually. Such pesticide-polluted climate changes may have a negative impact on the nightcrawler, an eco-friendly nonobjective organic species.

BIOAVAILABILITY OF CHLORPYRIFOS TO AQUATIC ORGANISMS (*DAPHNIA* SP.)

As a result of pesticide application, pesticides contaminate the aquatic environment and wells in agricultural landscapes, mostly through spray-drift, runoff, and field drainage (Gilliom, 2007). Residues of pesticides have also been discovered in rain and groundwater (Kellogg et al., 2000). Pesticide effects on aquatic systems are frequently investigated using a hydrology transport model to investigate chemical flow and destiny in rivers and streams. Pesticide concentrations in several samples of river water and groundwater above limits allowed for drinking water, according to UK government studies. Water solubility, distance from an application site to a body of water, weather, soil type, presence of a growing crop, and the method used to apply the chemical all affect a pesticide propensity to pollute water. Daphnia magna, a small planktonic crustacean employed in ecotoxicological acute testing and chronic reproduction studies, is a ubiquitous link in the ecological food chain (Rajini et al., 2016).

Females generate diploid eggs that grow into daughters during the parthenogenetic cycle. Diploid asexual eggs that develop into sons can be produced by the same female. Male production is regulated by the environment. Furthermore, a single female can create haploid eggs that must be fertilized by a male. These eggs are then covered in a protective shell and must go through a diapause before producing female offspring. Pesticide use in agriculture has the potential to contaminate surface and ground waterways through drift, runoff, drainage, and leaching (Cerejeira et al., 2003). Insects containing organophosphorus and organochlorine, which caused acute and chronic toxicity in aquatic species (Zalizniak & Nugegoda, 2006). Chlorpyrifos was identified as the most widely used and frequently detected pesticide, with concentrations above the aquatic-life

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benchmark of 0.04 g/L for water in 37 percent of samples collected from water bodies in various land-use scenarios across the United States (Gilliom et al., 2006).

Chlorpyrifos (CPF) has been shown to decrease the swimming behavior of Diamesazernyi larvae, a major species of the macrobenthic community in cold streams, according to Di Nica et al., (2020). The pesticide concentrations reported in high mountain streams, in particular, greatly hindered this organisms swimming activity. Due to the organism reallocating energy reserves to battle significant oxidative stress, locomotor capabilities may be diminished. The behavioral alterations seen in this study have the potential to transmit long-term changes in both population and community levels, posing a real ecological threat to Alpine aquatic habitats where pesticides cannot be avoided (Di Nica et al., 2020).

CONCLUSIONS

Chlorpyrifos had significant effect in the terrestrial and aquatic ecosystems and infact it can be revealed by the bioavailability in earthworms and daphnia respectively. A common insecticide, chlorpyrifos, has a substantial detrimental influence on ecosystems, affecting a range of creatures and ecological processes. It is especially detrimental to aquatic life, producing toxicity in a variety of aquatic species, upsetting microbial populations, and influencing plant growth.

Earthworms and Daphnia sp. are extremely sensitive species and biomarkers in both the terrestrial and aquatic ecosystems; hence additional research is critical. Isolating pesticide- degrading microorganisms can be used to adjust bioremediation using microbes. Investigations on the behavior of chlorpyrifos in various soil types, as well as ecotoxicological studies involving indicator species in soil and water, are rare, according to literature reviews.

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