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Natural and Synthetic Pesticides and Their Effects on Life

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Abstract

Natural and synthetic pesticides both play roles in pest control but differ significantly in their impact on life and the environment. Natural pesticides, often derived from plants and microorganisms, are biodegradable, eco-friendly, and generally exhibit lower toxicity to non-target organisms and humans. Synthetic pesticides, while highly effective in pest control and used extensively in conventional agriculture, tend to have greater toxicity, persist longer in the environment, and pose more significant health risks such as acute poisoning and chronic diseases, including cancer and neurobehavioral disorders. They also disrupt ecosystems by affecting non-target species and contributing to biodiversity loss and pollution. Integrated pest management practices increasingly prioritize natural and biological pesticides to reduce these adverse effects and promote environmental and human health safety. Natural Pesticides are derived from plants and microorganisms. Natural pesticides include compounds like terpenes, alkaloids, and polyphenols that control pests through various ecological activities, such as repellency and toxicity specific to pests. They are less persistent in the environment, reducing contamination risks and adverse effects on non-target organisms. Their biodegradability and specificity make them more sustainable alternatives to synthetic chemicals for pest management. Synthetic pesticides are chemically produced and widely used for their high potency. They have major ecological impacts, including disruption of soil microbial communities, harm to non-target arthropods and aquatic life, and accumulation leading to long-term environmental contamination. Human exposure, both acute and chronic, is associated with symptoms ranging from irritation and poisoning to serious health conditions like cancer and endocrine disruption.

Keywords: Natural pesticides, synthetic pesticides, toxicity, health risks, biodegradability, specificity

INTRODUCTION

Natural pesticides have been an integral part of human civilization for centuries. Early farmers and communities relied on naturally occurring substances derived from plants, animals, and minerals to protect their crops from pests and diseases. These natural compounds were considered safer for humans and the environment because they are biodegradable and do not persist in soil or water for long periods. Unlike synthetic chemicals, natural pesticides generally pose minimal health risks to humans and non-target organisms, as they are obtained from renewable biological sources such as neem, pyrethrum, nicotine, and certain essential oils extracted from plants and animals.

With the onset of the modern industrial era, synthetic pesticides were developed and rapidly adopted due to their high effectiveness, quick action, and ability to control a wide range of pests. However, the widespread and indiscriminate use of these chemical pesticides in agriculture, forestry, and household pest control has led to serious

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concerns. Many synthetic pesticides have been found to cause harmful effects on human health, such as neurological disorders, hormonal imbalances, and even cancer. Additionally, they have contributed to soil degradation, water contamination, and loss of biodiversity by affecting beneficial insects, birds, and aquatic life. Because of these adverse impacts, several synthetic pesticides have been restricted or banned in many countries.

This study provides a comprehensive overview of natural pesticides, their classification, advantages, and limitations, along with a comparative discussion on synthetic pesticides. It also highlights the environmental and health impacts of chemical pesticides, presents a list of banned pesticides, and explains the reasons behind their prohibition and their previous uses. Through this discussion, the study aims to emphasize the importance of adopting safer, sustainable, and eco-friendly pest control methods for future agricultural practices [1].

COMMON TYPES OF NATURAL PESTICIDES

- *Neem oil and extracts:* Derived from the neem tree, these are potent bioinsecticides effective against nearly 400 insect species and also help control fungal infections. Neem oil disrupts the reproductive systems of insects and is used widely in organic gardening.
- *Plant essential oils:* Oils from plants like rosemary, thyme, peppermint, and clove act as insect repellents, affecting pests through their scent or toxicity.
- *Hot pepper and garlic sprays:* Solutions made from hot peppers or garlic serve as general repellents and are effective against caterpillars, ants, aphids, beetles, and more.
- *Diatomaceous earth:* This fine, powdery substance made from fossilized algae physically damages and dehydrates crawling insects such as snails and slugs.
- *Tobacco and nicotine preparations:* Made from tobacco plants, these are effective against some crop insects but must be used with caution due to their high toxicity.
- *Rotenone and sabadilla:* Plant-derived insecticides with efficacy against a range of insects, though some (like rotenone) have restricted use due to toxicity concerns.
- *Wood ash:* Sprinkling wood ash around plants repels surface-feeding insects and slugs through dehydration [2].

Benefits and Application

- Natural pesticides are often biodegradable and less harmful to humans, pets, and beneficial insects when used as directed, making them suitable for organic farming and household gardens.
- Application methods include foliar sprays, dusting, or soil treatments, and they often require repeat applications after rain or irrigation. These pesticides typically work by disrupting pest life [3].

SYNTHETIC PESTICIDES

Synthetic pesticides are chemically manufactured substances specifically formulated to control or eliminate pests such as insects, weeds, fungi, rodents, and other harmful organisms that threaten crops, livestock, and human health. Unlike natural pesticides, which are obtained from biological or mineral sources, synthetic pesticides are produced through industrial chemical processes designed to achieve rapid, targeted, and long-lasting pest control. These compounds are engineered to interfere with the biological systems of pests, often by disrupting their nervous system, growth, reproduction, or metabolic functions.

The introduction of synthetic pesticides revolutionized modern agriculture by significantly increasing crop yields, reducing pest-related losses, and ensuring food security on a large scale. Common examples include organochlorines (such as DDT), organophosphates, carbamates, and pyrethroids, each developed to target specific pest types with varying levels of toxicity and persistence. However, despite their initial success and efficiency, the excessive and improper use of these chemicals has led to several unintended consequences. Over time, pests have developed resistance to many synthetic formulations,

leading to the need for higher doses or newer chemicals. Furthermore, residues of these pesticides often persist in soil, water, and food chains, posing serious threats to human health and environmental balance.

Studies have linked prolonged exposure to certain synthetic pesticides with neurological disorders, reproductive problems, hormonal disruptions, and carcinogenic effects in humans. In ecosystems, they contribute to the decline of pollinators, soil microbial imbalance, and bioaccumulation in aquatic organisms. Due to these hazards, many countries have implemented strict regulations and have banned or restricted the use of several synthetic pesticides known to be toxic or environmentally persistent [4].

Characteristics of Synthetic Pesticides

- Synthetic pesticides include a broad range of chemicals classified into categories like insecticides, herbicides, fungicides, rodenticides, and others, depending on the target pest type.
- They typically exhibit high potency and persistent activity, allowing long-lasting protection with fewer applications compared to some natural alternatives.
- Common examples include Malathion and DDT (insecticides), 2,4-D (herbicide), and Thiram (fungicide) [5].

Environmental and Health Impacts

- Synthetic pesticides often have significant ecological impacts, such as disrupting beneficial soil bacteria, altering prey-predator balances, contributing to pesticide resistance, and causing pollution in soil and water [6].
- Acute exposure symptoms in humans can include vomiting, eye irritation, headaches, and convulsions, while chronic exposure has been linked to asthma, immunotoxicity, reproductive issues, neurobehavioral disorders, cancer, and endocrine disruption.
- Due to these risks, synthetic pesticides are strictly regulated by authorities worldwide to ensure safe usage [7].

Regulation and Usage

- Regulatory agencies like the US EPA perform rigorous testing before approval and regularly reassess pesticides for safety and effectiveness.
- Many synthetic pesticides have restrictions or bans based on their toxicity profiles, with ongoing efforts to reduce use and promote safer alternatives.
- Despite risks, synthetic pesticides remain integral to modern agriculture due to their effectiveness and cost efficiency [8].

List of Banned Pesticides and their use

A comprehensive list of banned pesticides in India includes substances prohibited for manufacture, import, or use due to health and environmental concerns, as well as some that are restricted or only permitted for export [9]. These chemicals were formerly used across agriculture for pest control, herbicide, and fungicide purposes, but many are now banned due to toxicity, persistence, and export restrictions (Table 1). Their use spanned major crops such as rice, vegetables, fruits, pulses, and oilseeds before regulation [10].

Banned pesticides negatively affect human health through acute and chronic exposure, showing a wide range of harmful effects. Acute exposure can cause symptoms like headaches, irritation, vomiting, sneezing, skin rashes, and respiratory issues (Figure 1). Chronic or long-term exposure, often through consumption of contaminated food or water or occupational contact, leads to severe health problems such as cancer (especially breast cancer and leukemia), neurological impairments (including Parkinson's disease), reproductive disorders, immune system dysfunction, respiratory diseases (asthma, reduced lung function), and endocrine system disruption. These pesticides can accumulate in the body, causing persistent toxic effects and systemic damage [11].

Table 1. List of banned pesticides and their use.

Toxic pesticides	Uses	Toxic effects
Aldrin	Used to Control Soil Insects and termites in maize, Sugarcane, etc.	Highly toxic to humans and animals.
DDT (Dichloro-Diphenyl Trichloroethane)	Used to control mosquitoes and crop pests.	It causes bioaccumulations and environmental persistence.
Endrin	Used on control and grains.	It causes neurological damage and high toxicity.
Lindane (Gamma BHC)	Used against lice and agricultural pests.	Linked to cancer and reproductive harm.
Carbofuran	Used for pest control in rice and sugar.	Extremely toxic to birds and mammals.
Pentachlorophenol	Used for weed control	Highly toxic and environmentally persistent.
Heptachlor	Used for termites and soil insects.	Persistent, bioaccumulative, and toxic.
Toxaphene	Used for controlling insects in cotton.	Persistent organic pollutants (POP)

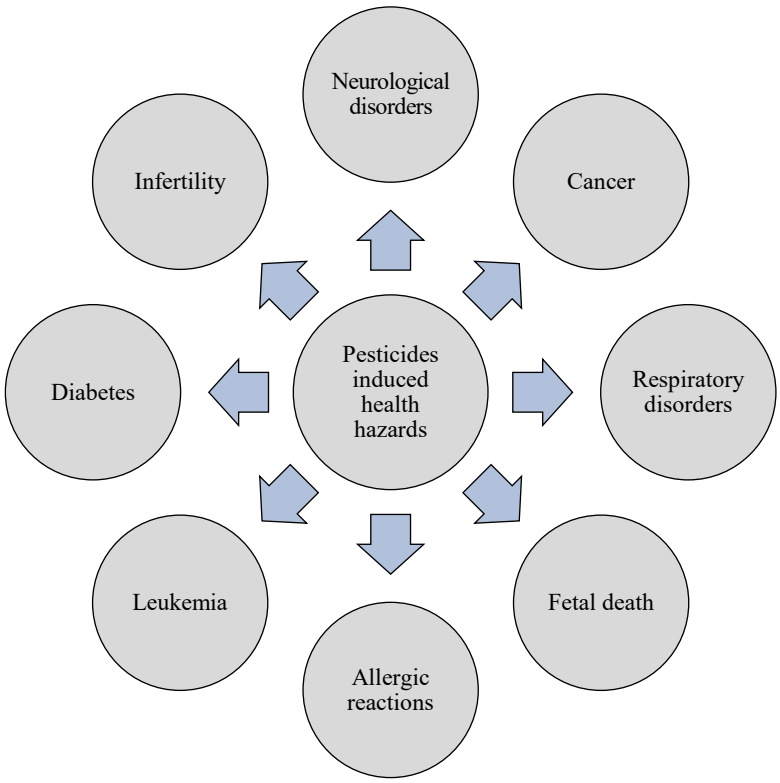

Figure 1. Diagram illustrating the health hazards induced by pesticide exposure: infertility, diabetes, leukemia, neurological disorders, allergic reactions, respiratory disorders, fetal death, and cancer.

Specific banned pesticides such as organochlorines (e.g., DDT), organophosphates (e.g., malathion, parathion), and paraquat have been linked to cancer, neurotoxicity, hormonal imbalances, and birth defects. Their modes of action often involve mimicking or antagonizing natural hormones, inhibiting critical enzymes like acetylcholinesterase, or causing oxidative stress, which leads to cellular and genetic damage. Exposure to banned pesticides has been implicated in increased risks of asthma, allergies, developmental delays in children, cardiovascular disease, diabetes, mental health disorders, and even fetal death.

Overall, banned pesticides persist in the environment and the food chain, continuing to pose significant human health risks long after their use has been discontinued (Figure 2), making regulatory controls and avoidance crucial for public health safety [12].

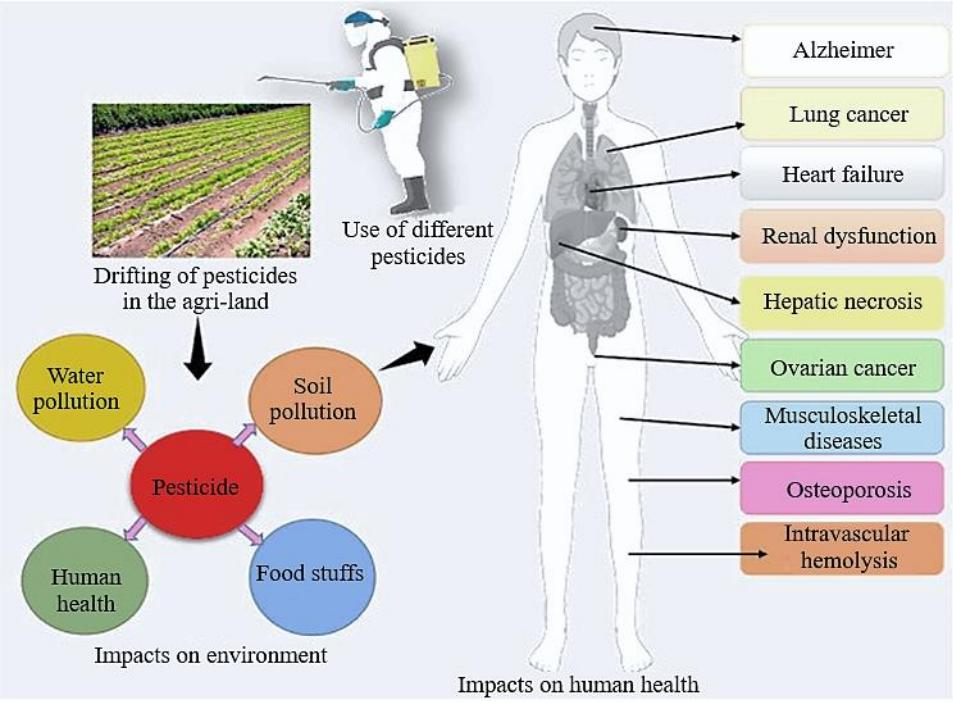

Figure 2. Diagram showing pesticide application, environmental pathways (soil, water, food), and associated human-health outcomes (e.g., Alzheimer's disease, lung cancer, renal dysfunction, hepatic necrosis, ovarian cancer, osteoporosis, intravascular hemolysis).

CONCLUSION

The conclusion of the document on natural and synthetic pesticides and their effects on life is as follows. Natural pesticides, derived from plants, minerals, and microbes, have been used for centuries and are generally less harmful to humans, animals, and the environment. They are biodegradable and suitable for organic farming and household gardening. Synthetic pesticides, introduced in the modern era, are chemically manufactured for fast, targeted pest control but have significant negative impacts on the environment and human health, including toxicity, persistence, and causing diseases like cancer, neurological, and reproductive disorders. Many synthetic pesticides have been banned due to their harmful effects and persistence in the environment. Banned pesticides continue to pose risks through contamination and accumulation, making regulatory control and avoiding their use vital for public health safety.

This document emphasizes understanding the types, benefits, disadvantages, and toxic behaviors of pesticides to ensure safer pest

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