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Nationwide risk assessment of agrochemicals in India and biopesticide solutions

Prexa Shah

prexashah113@gmail.com

Parul University

Research Article

Keywords: agrochemicals, synthetic, food, pollutants, carcinogens

Posted Date: June 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10151719/v1

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Additional Declarations: No competing interests reported.

Abstract

Synthetic agrochemicals are widely used in India to enhance crop yields. However, these penetrate water bodies and soil, causing ecological disasters and endangering humans and the environment.

Aim: To conduct a risk assessment of synthetic agrochemicals in India.

Materials and methods: This experimental study was conducted using soil and water samples collected from across India. Liquid-liquid Extraction (LLE) was used to extract pesticides from aqueous samples, whereas the Soxhlet (solid-liquid) extraction method was used for soil analysis.

Results: Azoxystrobin was detected in 62% of the samples, and β-endosulfan was detected in 28% of the samples. Minor amounts of DDT and dieldrin (10%) were detected using HPLC.

Conclusion: Contamination of soil and water bodies by synthetic agrochemicals poses a significant threat to humans and the environment. Hence, it is important to monitor the levels of these chemicals to raise an alarm regarding their elevated levels in food supplies.

INTRODUCTION

An optimum diet promotes good health. It can be defined as “a complete state of physical, psychological, as well as social well-being, rather than just the absence of any disease. Diet affects both health and the environment. [1] Plant diets are increasingly gaining importance owing to their health benefits and environmental sustainability due to the reduction in the consumption of meat along with an increase in the consumption of fruits, vegetables, whole grains, legumes, and nuts and seeds. [2] Consuming a vegan diet reduces the risk of developing malignancies, cardiac disorders, and mortality. A plant-based diet is ecologically sustainable and resource-efficient during production. [3] However, prolonged exposure to agricultural products contaminated with pesticides has harmful health outcomes. [4] Continued intake of pesticide-containing products results in their accumulation in vital human tissues and organs, leading to the development of chronic disorders. [5] Thus, ensuring food safety by determining pesticide contamination in plant-based food products is challenging. [6]

The unregulated use of herbicides or pesticides on plant produce leads to concentrations of these products exceeding the maximum residue limits, thereby affecting human health. [7] Thus, the implementation of standard guidelines for testing agricultural food products is mandatory. The use of pesticides should be quantified and regulated to reduce their detrimental effects on humans, other fauna, and the environment. An ideal pesticide must be specific to its target and act only on the target pest species without causing unintended harm. However, it is difficult to achieve absolute organism selectivity, as both humans and other species are equally affected. Improper pesticide use results in environmental contamination,including soil, water, air, and vegetation,wildlife. Thus, it is important to

study the toxicity of agrochemical food contaminants to ensure food safety and develop appropriate regulations concerning food safety. [8,9]

Pests andpathogenic organisms cause major losses of agricultural products each year. Excessive use of chemically derived synthetic pesticides and fungicides, along with climate change, has changed pest and pathogen behaviors, resulting in the development of resistance. Microorganisms synthesize secondary metabolites,including antimicrobial peptides, enzymes, volatile products, and toxins. These microorganisms have been utilized as “biopesticides” for controlling phytopathogenic fungi, bacteria, nematodes, and insects. Unlike chemical agents, biopesticides act on pests and pathogenic organisms with no adverse effects on human health or the environment. Microbial-origin biopesticides have been developed using microorganisms such as Trichoderma, Beauveria, Bacillus, Metarhizium, and Pseudomonas spp.. [10]

Hence, this study was undertaken to analyze the risk assessment of synthetic agrochemicals in India by understanding their carcinogenic, mutagenic, and ecotoxicological impacts and providing nano-biopesticide solutions.

MATERIALS AND METHODS

1. Study design and settings: This experimental study was conducted by collecting soil and water samples from different agricultural fields and water bodies in the country.
2. Soil sample collection technique: Surface samples were collected using a stainless steel shovel, trowel, or scoop. To obtain soil samples from intermediate depths (i.e., till approximately seven meters), a hand auger or thin-walled tube sampler was used. A “hand auger” contains a steel pole and a “T” handle with a bladed auger head or a sample collection tube attached. The sample is obtained by twisting it to the desired depth, and then either the auger head is pulled upwards or an attached collection tube is pushed up to the bottom to retrieve the sample. A drill rig was used to obtain soil samples from depths greater than seven meters.
3. Groundwater sample collection technique: Samples from shallow groundwater depths were collected by digging until the water table and then extracting water to obtain surface water samples. The collected water was scooped.
4. Analysis of collected samples: The analytical method used for sample analysis was high-performance liquid chromatography (HPLC).
5. Extraction technique used: Liquid-liquid Extraction (LLE) has been widely used for the extraction of pesticides from aqueous liquid samples, and the Soxhlet (solid-liquid) extraction method was used for soil analysis.

RESULTS AND OBSERVATIONS

Analysis of soil and water samples collected from various regions of India revealed contamination by 22 pesticides, with eight exceeding the maximum residual limit. Azoxystrobin was detected in 62% samples,

while β-endosulfan was detected in 28% samples. Minor amounts of DDT and dieldrin (10%) were also detected using HPLC.

Table 1
Table showing percentages of various agrochemicals discovered in the present study

Name of agrochemical	Percentages
a) Superficial water samples:	
azoxystrobin	23
β-endosulfan	09
ddt	02
dieldrin	02
b) Deep water samples:	
azoxystrobin	29
β-endosulfan	19
ddt	03
dieldrin	01
c) Soil samples	
azoxystrobin	10
β-endosulfan	09
ddt	01

DISCUSSION

The identification of pesticide residues in foods obtained from plants is important for the well-being of bothhumans and the environment. Plant-based diets are generally preferred for their health benefits; however, contamination with a wide variety of pesticides is a major concern.

The present study demonstrated that increased concentrations of azoxystrobin, β-endosulfan, DDT, and dieldrin were detected in the analyzed soil and water samples. Azoxystrobin was found in most of the soil and water samples, whereas β-endosulfan was the second most commonly found pesticide contaminant.

In a study similar to oursours, Ouakhssase et al. (2024) found that eight out of 30 green bean samples contained pesticides. Azoxystrobin was found to be the most frequently detected pesticide. A residue

(0.027 mg/kg) of fipronil was also detected. All collected samples were found to contain pesticide levels at concentrations less than the Minimum Residual Limit. [11]

Ambrus et al. (2023), in their analytical study, reported a maximum residual limit exceeding 1.03%. [12] Gomez et al. (2023) in their study findings reported that 22.1% of the studied samples contained pesticide concentrations greater than 22.3%. Forty different types of pesticides were detected in samples. [13] Balkan et al. (2023) reported pesticide residues in 41.7% of samples, whereas all samples contained pesticide concentrations lower than the minimum residual limit. [14] However, Elgueta et al. (2021) reported that the maximum residual limit was exceeded in 9% of the samples. However, 39% of the samples were free of pesticide residues. [15]

These pesticides have toxicological effects due to inflammatory responses, oxidative stress, and endocrine dysfunction. Risk of spontaneous abortion, especially due to DDT exposure.

Biopesticides include different microorganisms, metabolic products, and plant-origin compounds. These demonstrate various characteristics and activities in different ecosystems. Hence, more research is required to create conditions for transitioning to commercialization. [103]. At the same time, one of the key challenges in the commercialisation of biopesticides is the presence of stringent regulatory requirements that govern their approval and market entry, often slowing down their widespread adoption.[16]

More research is required to ensure the continuous monitoring of pesticide(s) residues in soil, water, and food products, as these are dangerous to human health and the surrounding environment. Further studies are required to evaluate the ecological effects of pesticide residues to develop newer technologies for detecting and taking necessary steps to promote changes in agricultural practices, which might have an adverse effect on the environment.

CONCLUSION

Agrochemical contamination of plant-derived food systems is a pervasive and escalating global concern driven by the intensive application of pesticides, synthetic fertilizers, weedicides, and herbicides. These xenobiotic compounds frequently persist beyond their intended targets, undergoing leaching, runoff, and bioaccumulation within soil matrices and in aquatic ecosystems. The present study elucidates the extent of such contamination within the national context, revealing significant residues in both the edaphic and hydrological compartments. This not only disrupts soil microbiota and biogeochemical cycles but also facilitates trophic transfer through the food chain. Chronic low-dose exposure to these contaminants has been increasingly implicated in endocrine dysregulation, neurotoxicity, and carcinogenesis. These findings underscore the urgent need for stringent regulatory oversight, advanced residue monitoring, and the integration of sustainable agro-ecological practices to mitigate long-term environmental and public health risks.

Declarations

Author Contribution

Dr prexa has prepared the whole article under the guidance of Dr Adishree and Dr sariput

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Figures

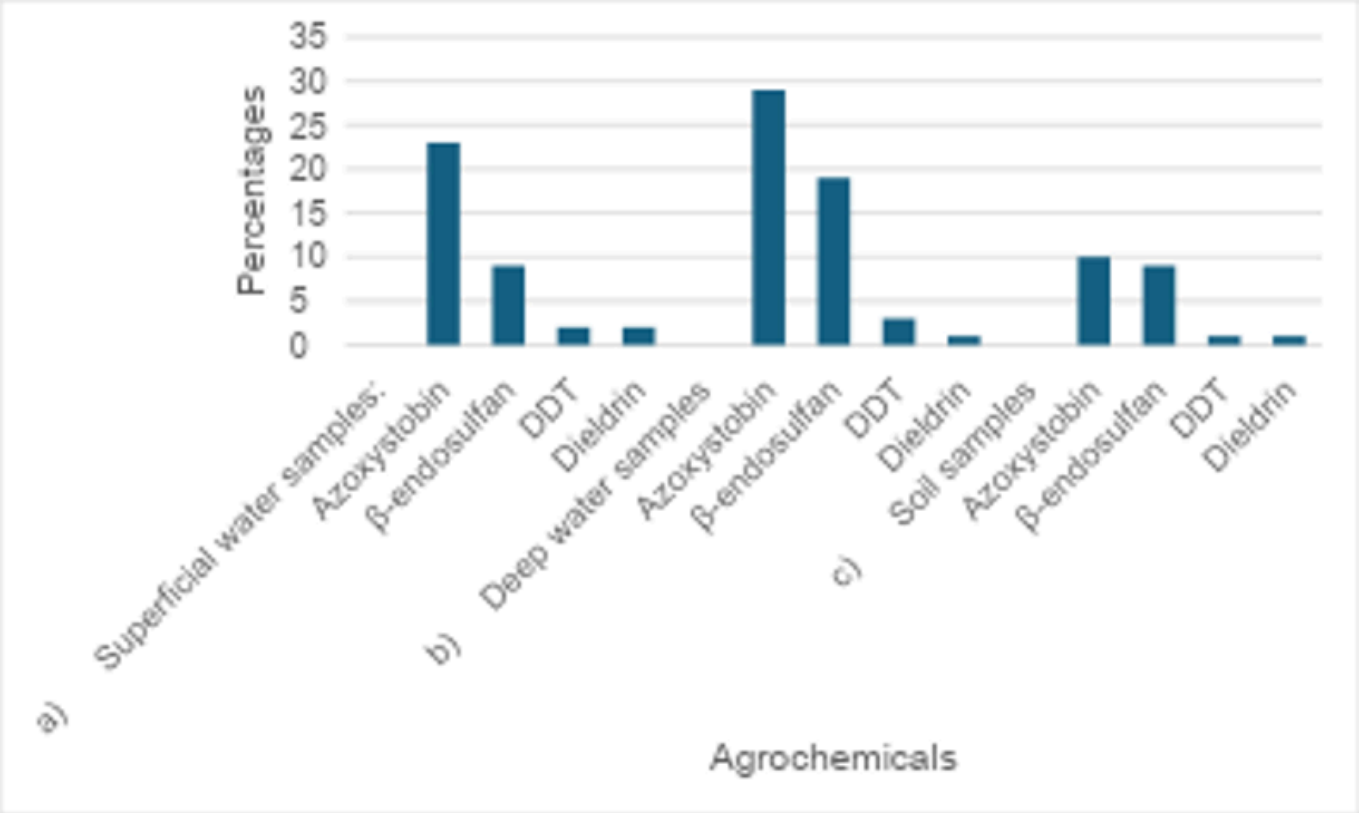


Figure 1

Graph 1: Graph showing percentages of different agrochemicals in the present study