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# 3. Ecological Impact of Agricultural Chemicals

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***Abstract:***

*This study delves into the world of agrochemicals, exploring their various types—including insecticides, herbicides, fungicides, and weedicides—and their roles in enhancing agricultural productivity. While highlighting the positive aspects of agrochemicals in plant development, this research also brings to light their adverse effects.*

*The World Health Organization (WHO) has noted that three million cases of pesticide poisoning occur annually in underprivileged nations.*

*The extended and intensive application of these chemicals has detrimental impacts on soil biodiversity, the sustainability of agriculture, and the safety of food supplies, leading to persistent adverse consequences on the health of humans and animals, as well as on food security. This chapter not only discusses the pros and cons of agrochemical use but also concentrates on their ecological impacts and operational mechanisms. It includes an examination of the risks associated with agrochemical usage and potential mitigation strategies. The paper concludes with a call for future research, particularly in the molecular analysis of agrochemical mechanisms.*

***Keywords:***

*Agrochemicals, pesticides, detrimental effect, environment, climate-change.*

## 3.1 Introduction:

Role of agrochemicals in modern agriculture, primarily focusing on pesticides like insecticides, herbicides, fungicides, and others, as well as fertilizers, soil conditioners, and plant growth regulators. These chemicals, integral to industrial farming, aim to boost crop yields and reduce losses from pests. Their use surged following the Green Revolution in the 1960s, particularly with the increased application of nitrogen, phosphorus, and potassium-based inorganic fertilizers and pesticides. This boost in agrochemical uses significantly contributed to meeting the food demands of the growing global population. The history of pesticide usage spans three distinct phases. Initially, before the 1870s, natural compounds were used for pest control. Between 1870 and 1945, the use of synthetic inorganic materials began, marked by the use of copper and sulphur compounds in Sweden to combat fungal infections in fruits and potatoes. Post-1945 saw the advent of synthetic pesticides, with the discovery of DDT and other chemicals marking a new era in pest control (Pal et al., 2006).

Pesticides have since become a fundamental aspect of agriculture, enabling farmers to produce high-quality, safe food at reasonable prices. Without them, pests, diseases, and weeds could potentially destroy over half of our crops. Despite their benefits, these chemicals are costly and contribute to pollution. Recent statistics show varying levels of pesticide usage globally, with the highest recorded in Taiwan and relatively lower usage in India compared to the world average. As of October 2022, India registered 318 pesticides for agricultural use, covering a significant portion of its cultivated area (Bahadur et al., 2015). Looking at the broader market, the global agrochemicals and pesticides sector was valued at approximately 278,428.78 million USD in 2023 and is projected to reach around 320,916.55 million USD by 2028, growing at a CAGR of 2.4% (Anonymous, 2023).

Pesticides are chemical compounds designed to eradicate or deter living organisms deemed harmful. Depending on their application and characteristics, they can be categorized into several classes, such as bactericides, algicides, herbicides and more. (Ahirwar NK et al., 2023) Excessive and improper application of agrochemicals and pesticides has led to significant health issues, economic losses, and a range of environmental problems, impacting soil microorganisms and ecosystems at large (Onder et al., 2011). This overuse contributes to various forms of pollution, including contamination of air, water, and soil, disrupting the ecological balance and leading to the pollution of water bodies. In agriculture, weeds and insects are major biotic factors that lower crop yields, productivity, and the efficiency of resource use (Oliveira et al., 2014). Enhancing grain yield in crops under adverse environmental conditions hinges on pinpointing specific target traits relevant to the reproductive stage and unravelling how crop reproductive tissues, whether these stresses occur alone or in combination with agrochemicals (Narendra Kumar Ahirwar, 2023). On the other hand, synthetic fertilizers and pesticides have played a role in boosting agricultural output by protecting crops from disease pathogens and pests. However, the impact of pesticides on microorganisms is influenced by several factors, including the chemical dosage, soil properties, and various environmental conditions.

## 3.2 Agrochemicals and Their Effects:

The excessive and negligent application of agrochemicals has led to a multitude of problems, including soil fertility degradation, pest resurgence, the decline of pollinators and natural predators, development of pesticide resistance, emergence of drug-resistant plant pathogens, and various health risks to humans and animals. These issues extend to limb disorders and diseases in humans, damage to native plants and animals, concerns about bioaccumulation and biomagnification, exacerbating climate change, and overall environmental pollution. This situation presents a grave threat to both life and health. Overuse of these chemicals not only disrupts nutrient balance and reduces the crop's yield potential but also leaves harmful residues. Significant concern with bacteria developing resistance to pesticides, leading to adverse effects on aquatic life, including fish deaths in various water bodies.

## A. Effect on Environments:

A healthy environment is crucial for human well-being, yet contamination of soil and water due to human, industrial, and agrochemical waste is a widespread and acknowledged issue, particularly in developing countries. The detrimental environmental impacts of agrochemicals stem from their chemical composition, which adversely affects humans, animals, and nature as a whole. The uncontrolled disposal of domestic and industrial waste in both urban and rural areas, coupled with pollution of water bodies from agrochemical and pesticide runoff, is a growing concern. This situation is exacerbated by deforestation and subsequent soil erosion. One of the primary sources of pollution in drinkable water sources, reservoirs, and watersheds is the misuse of agrochemicals. This is largely due to the careless practices of farmers and agrochemical vendors, as well as sizeable government subsidies for fertilizers that promote excessive use.

These practices are entirely preventable, as noted by (Wimalawansa and Wimalawansa 2014). Ultimately, these pollutants persist in the environment for a long time, leading to ongoing environmental pollution.

## B. Effect of Agrochemicals on Soil:

The excessive application of synthetic fertilizers and pesticides has led to a reduction in organic matter, soil microbiota, and microbial enzymes (Kalia and Gosal, 2011).

Additionally, herbicide use has been shown to affect the rhizobium-legume symbiosis (Drew et al., 2007), and fungicide application has been linked to a decline in soil fungal populations (Kalia and Gosal, 2011). Furthermore, these agrochemicals may also eliminate beneficial soil microorganisms, elevate soil nitrate levels, modify soil pH, and diminish soil quality due to increased residual effects and toxicity.

### a. Impact of Agrochemicals on Soil Microbes:

Soil microflora is essential for decomposing organic matter, particularly carbamates. The effects of pesticides on the growth, activity, and enzyme levels of soil microflora can adversely impact soil fertility and health. Research by (Ghoshal and Hati 2019) found that the use of Rynaxypyr, cartap hydrochloride, fipronil, and chlorpyrifos did not significantly harm the collembolan population.

However, applying carbofuran and phorate in a rice-maize cropping system led to population reductions of 27.65% and 13.47%, respectively. Soil pollution, often a result of xenobiotic (human-made) chemicals or other changes in the natural soil environment, can be attributed to industrial activities, agricultural chemicals, or improper waste disposal, all contributing to land degradation (Pangos et al., 2013).

### b. Impact of Agrochemicals on the Metabolic Processes of Soil Microbes:

Agrochemicals disrupt the metabolic processes of soil microbes and alter the activity of soil enzymes. These chemicals are partially broken down by soil enzymes, which play a pivotal role in sustaining soil health and fertility, making enzymatic activity a crucial indicator of soil health (Mandal et al., 2020). Specific herbicides, such as atrazine and metolachlor, detrimentally affect the functioning of invertase and dehydrogenase enzymes. Fungicides like benomyl, mancozeb, thiram, and tridemorph impede the activities of enzymes such as phosphatase, urease, and dehydrogenase. Additionally, while agrochemicals, especially pesticides, are designed to eliminate specific soil microorganisms, they can inadvertently lead to the rapid proliferation and dominance of non-target microorganisms.

### C. Impact of Agrochemicals on Water:

Agrochemicals enter water bodies through processes like runoff, drift, and leaching through soil, or they may be directly applied to surface water for controlling aquatic pests or mosquitoes. These substances, particularly insecticides and herbicides, can impact fish and invertebrates, altering the species composition in aquatic environments.

This occurs when these chemicals mix with surface water through spray drift or runoff. According to the IUCN in 2020, about 41% of all amphibian species are under threat, and as per their 2009 report, a third of the 6000 amphibian species globally face extinction risks.

In addition to threats like habitat loss, overexploitation, and invasive species, amphibians are increasingly impacted by the pollution of surface waters with fertilizers and pesticides (Praween and Jan 2020). In addition, both the energy intensive industrial processes for the production of fertilizers, and the runoff or leaching of soluble nutrients from the applied agrochemicals into the aquatic systems, are sources of environmental contamination. (Narendra et al., 2019). The presence of agrochemicals in water not only makes it unfit for consumption but also promotes algal growth, leading to eutrophication due to the excessive use of chemical fertilizers. Aquatic animals encounter agrochemicals or pesticides in three primary ways: through breathing (uptake via gills), dermally (absorption through the skin), and orally (ingesting contaminated water).

This exposure can reduce dissolved oxygen in the water and cause physiological and behavioral changes in fish populations. A study in India found that 58% of drinking water samples, collected from various hand pumps and wells around Bhopal, contained organochlorine pesticides.

## D. Impact of Agrochemicals on Air:

Air quality is determined by the concentration of pollutants in our atmosphere, encompassing both indoor and outdoor environments. Agrochemicals, especially pesticides used in agricultural and urban areas, can contribute to air contamination, impacting the health of humans, animals, and plants. Some pesticide components have a brief atmospheric lifespan, while others persist longer. Agrochemicals released into the air can settle to the ground, undergo decomposition through sunlight and water in the atmosphere, or mix with air, altering their chemical structure. The presence of agrochemical residues and particles can contribute to air pollution. Pesticide drift occurs when air currents transport agrochemical particles from one area to another, and the amount of spray evaporation can increase with lower humidity and higher temperatures. This can lead to respiratory illnesses in nearby living organisms due to the inhalation of air polluted by agrochemical use.

## E. Impact of Agrochemicals on Non-Target Flora:

Herbicides significantly affect plant diversity, as observed by Gove et al. (2007), with young plants being more susceptible to their effects. Boutin et al. (2014) found that exposure to high concentrations of herbicides can adversely affect the reproductive systems of plants.

From the second year of exposure onwards, the drift of agrochemical sprays begins to alter the balance of species and disrupts the diversity of plant life. Fungicides and insecticides negatively affect non-target plant species. Petit et al. (2008) noted that plant photosynthesis is influenced by fungicide application, while Saladin et al. (2003) reported impacts on the metabolism of carbon and nitrogen. The effectiveness of pollination is also compromised due to a reduction in floral visits and alterations in the community of floral visitors, as highlighted by Cahill et al. (2008). Jennings et al. (2012) further stated that pesticides can affect plant growth and germination.

## F. Impact of Agrochemicals on Vertebrates:

Organophosphates and carbamates hinder the ability of vertebrates to regulate their body temperature, consume nutrients, forage, reproduce, and perform other essential metabolic functions, as outlined by Story and Cox (2001).

These chemicals also disrupt thyroid functions in a variety of species, including rodents, birds, amphibians, and fish, as observed by Brucker-Davis (1998).

Additionally, insecticides, herbicides, and fungicides impact the immune system, as noted by Sanchez-Bayo (2012) and also found that terrestrial vertebrates are generally more resistant to pesticides derived from plant or fungal toxins compared to birds and mammals.

## G. Impact of Agrochemicals on Snails and Slugs:

Snails and slugs have been found to accumulate insecticides, particularly organophosphates and carbamates, in their bodies. Recent research indicates that these organisms have high levels of diazinon, phorate, and carbofuran, likely due to the water solubility of these substances.

While insecticide use may not adversely affect the targeted pests, it poses a significant threat to predatory bird species that feed on these snails and slugs.

The consumption of these contaminated organisms puts these birds at a high risk of mortality due to insecticide exposure. This situation underscores the broader impacts of chemical pesticides, plant growth regulators, fertilizers, soil conditioners, and chemicals used in animal husbandry.

## H. Link Between Agrochemical Use and Climate Change:

The escalation of agrochemical use is a direct response to the increased incidence of pests and diseases, a consequence of climate change induced by rising temperatures. Additionally, the production and application of these agrochemicals contribute to climate issues. The creation of nitrogen-based fertilizers, for instance, involves burning fossil fuels, a process that demands significant energy. When farmers apply these synthetic fertilizers, it leads to a series of chemical reactions that emit nitrous oxide (N2O), a potent greenhouse gas. N2O's global warming potential is 265 times greater than that of carbon dioxide and methane.

## 3.3 Minimizing the Impact of Agrochemicals through Effective Management Strategies:

To mitigate the adverse effects of agrochemicals, it is imperative to prioritize the adoption of safe technologies and implement sound working practices. Effective management strategies include:

- **Seek Expert Advice:** Users of agrochemicals should consistently seek advice and guidance from experts, such as agricultural extension services, agronomists, or certified crop advisors, when making decisions related to agrochemical usage. Their expertise can help in choosing the right products and application methods.
- **Prioritize Low Toxicity:** When selecting pesticides, prioritize those with the lowest toxicity to humans, mammals, fish, birds, and other invertebrates. This approach minimizes the potential harm to non-target species and reduces the environmental impact.
- Minimize Runoff Risk: Prefer liquid applications over granular formulations for agrochemicals to reduce runoff potential. Liquid formulations are less likely to be carried away by rainwater, which can contaminate nearby water bodies.
- **Select Appropriate Spray Equipment:** While there are various types of spray equipment available, prioritize those designed with safety in mind. Equipment designed for safety ensures precise and controlled application, reducing the risk of exposure.
- **Adopt Science-Based Environmental Management:** Implement science-based holistic approaches to environmental management. These strategies aim to reduce the likelihood of pesticides and other chemicals, as well as sediment, from moving off treated areas and into nearby water bodies.
- **Control Application Variables:** Use recommended agrochemical doses and exercise control over application variables. This includes regulating the rate, method, timing,

and type of chemicals being applied, ensuring that they align with established guidelines and best practices.

- **Integrated Pest Management (IPM):** Implement Integrated Pest Management practices that emphasize a holistic approach to pest control. IPM incorporates various strategies, including biological control, crop rotation, and cultural practices, to reduce the reliance on agrochemicals and minimize their adverse effects.
- **Proper Storage and Handling:** Store agrochemicals in secure and well-ventilated areas, away from food, water sources, and livestock. Follow strict handling procedures, wear appropriate personal protective equipment (PPE), and adhere to safety guidelines to prevent accidents and exposure.
- **Calibration and Precision Application:** Calibrate equipment accurately to ensure the precise application of agrochemicals. This prevents overuse and minimizes the risk of contamination.
- **Restricted-Entry Intervals (REIs):** Adhere to the recommended REIs, which specify the amount of time that must pass before workers can safely re-enter treated areas. This safeguards against direct exposure to agrochemical residues.
- **Record Keeping:** Maintain detailed records of agrochemical usage, including product names, application rates, dates, and locations. This information helps track the history of applications and facilitates responsible decision-making.
- **Education and Training:** Provide comprehensive training and education to farmers and workers involved in agrochemical application. Ensure they are aware of the potential risks, safety measures, and emergency procedures.
- **Environmental Monitoring:** Regularly monitor the environmental impact of agrochemical use, including water quality, soil health, and biodiversity. Adjust practices as needed to minimize adverse effects on ecosystems.
- **Transition to Sustainable Alternatives:** Explore and transition to sustainable and eco-friendly alternatives, such as organic farming practices, biopesticides, and reduced chemical inputs, to reduce the reliance on conventional agrochemicals.

By embracing these management strategies, agricultural stakeholders can promote safer and more sustainable agrochemical use, ultimately minimizing their negative effects on human health and the environment.

### 3.4 Conclusion:

Agrochemicals have often been seen as a powerful tool, akin to a "magic bullet," in developing nations, with the potential to increase agricultural productivity and improve critical public health indicators. However, it is increasingly evident that the use of agrochemicals carries significant risks. Pesticides, in particular, can have adverse effects on ecosystems, and their impact on plant growth is not without consequences. In summary, while agrochemicals offer benefits in terms of agricultural productivity and public health improvement, their negative ecological and environmental impacts cannot be ignored. To address these challenges, it is imperative to consider a multifaceted approach that includes the exploration of biological techniques and a thorough investigation of the molecular-level mechanisms of agrochemicals. This balanced approach can help optimize agricultural practices for both increased yields and environmental sustainability.

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