Impact of Agrochemicals on Human Health: A Review

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Abstract— *The widespread use of agrochemicals, including fertilizers, pesticides, herbicides, and plant growth regulators, has greatly enhanced agricultural productivity worldwide. However, their long-term impact on human health and the environment has become a major concern. This paper investigates the health risks associated with agrochemical exposure, such as neurological disorders, cancer, endocrine disruptions, and cardiovascular diseases. It also explores exposure pathways, bioaccumulation, and biomagnification. Case studies, including the Endosulfan tragedy in India and the link between glyphosate and cancer risk, underscore the urgent need for stricter regulations and safer farming practices. The study highlights the importance of sustainable agriculture, organic alternatives, and increased awareness among farmers and consumers to reduce health risks while ensuring food security.*

Keywords— Agrochemicals, Pesticide exposure, Human health risks, Bioaccumulation, Sustainable agriculture.

I. INTRODUCTION

For centuries, agriculture has been fundamental to human civilization, providing food security and economic stability. To enhance crop production and counter natural challenges, farmers increasingly relied on agrochemicals—chemical agents used to promote plant growth and control pests. The Green Revolution of the 1960s marked a major shift, introducing synthetic fertilizers, pesticides, and herbicides that significantly boosted food production (Pal *et al.,* 2006). However, while these chemicals contributed to higher yields, their long-term impact on human health and the environment has become a growing concern.

India, a major agricultural nation with 176.5 million hectares of farmland, depends heavily on agrochemicals to sustain its food supply (Wikipedia, 2024). Nearly half of the country's workforce is engaged in agriculture, with 59% of the rural population relying directly on farming for their livelihood (Statista, 2024). However, agricultural exports have declined from USD 55 billion in 2022 to USD 51 billion in 2023, partly due to quality control issues and contamination from excessive pesticide use (The Hindu Business Line, 2024).

Despite their advantages, agrochemicals have been linked to severe health risks, including neurological disorders, cancers, and endocrine system disruptions (Onder & Dursun, 2011). Farmworkers face regular exposure through direct handling, while consumers may ingest residues through contaminated food and water. Addressing these challenges is crucial for sustainable agriculture, ensuring both food security and public health.

II. TYPES OF AGROCHEMICALS AND THEIR EFFECTS ON HUMAN HEALTH

2.1 Fertilizers and Their Health Effects:

Fertilizers replenish essential soil nutrients, enhancing plant growth and agricultural productivity. However, excessive use can lead to adverse health and environmental consequences.

- **Nitrate Contamination:** Overapplication of nitrogen-based fertilizers causes nitrate leaching into groundwater. Elevated nitrate levels in drinking water have been linked to methemoglobinemia (blue baby syndrome) and gastrointestinal disorders (Bahadur *et al.,* 2015).

- **Heavy Metal Accumulation:** Some fertilizers contain trace amounts of toxic metals like cadmium, arsenic, and lead, which can accumulate in human tissues, increasing the risk of kidney damage, neurological disorders, and cancer (Gupta & Gupta, 2020).

2.2 Pesticides and Their Health Effects:

Pesticides are used to control agricultural pests, but their residues persist in food and the environment, posing significant health risks.

- **Insecticides:** Organophosphates and carbamates inhibit acetylcholinesterase, an enzyme essential for nerve function. Chronic exposure has been linked to cognitive decline, memory loss, and, in severe cases, paralysis (Sunkara, 2023).
- **Herbicides:** Glyphosate, one of the most widely used herbicides, has been classified as a probable human carcinogen (De Roos *et al.*, 2005). Long-term exposure has been associated with an increased risk of non-Hodgkin's lymphoma.
- **Fungicides:** These chemicals can disrupt endocrine functions, leading to hormonal imbalances and reproductive disorders (Serrano-Medina *et al.*, 2019).

2.3 Plant Growth Regulators and Their Health Effects:

Plant growth regulators (PGRs) help control plant growth and enhance crop yields. However, synthetic PGRs can interfere with hormonal balance in humans, potentially affecting fertility and fetal development (Srivastava & Kesavachandran, 2019).

2.3.1 Exposure Pathways and Bioaccumulation:

- **Routes of Exposure**

  Humans come into contact with agrochemicals through multiple pathways:

  - **Occupational Exposure:** Farmers, agricultural workers, and pesticide applicators face direct exposure through handling and inhalation.
  - **Dietary Exposure:** Residues of pesticides and fertilizers in food serve as a primary source of indirect exposure.
  - **Environmental Exposure:** Agrochemicals contaminate air, water, and soil, affecting entire communities, particularly those in agricultural regions (UNEP, 2021).

- **Bioaccumulation and Biomagnification**

  Certain agrochemicals, especially persistent organic pollutants (POPs), do not degrade easily and tend to accumulate in body fat over time (bioaccumulation). As they move up the food chain, their concentration increases, leading to higher toxicity in humans (Katagi & Tanaka, 2016; Wang *et al.*, 2019).

2.4 Health Impacts of Agrochemical Exposure:

The extensive use of agrochemicals, particularly pesticides, has raised serious concerns about their effects on human health. While these chemicals play a crucial role in modern agriculture, prolonged exposure has been linked to severe health issues, including neurological disorders, cancer, hormonal imbalances, and cardiovascular diseases.

- **Neurological Disorders:** Long-term pesticide exposure has been associated with neurodegenerative diseases such as Parkinson's and Alzheimer's (Buralli *et al.*, 2019). These conditions develop gradually as pesticides damage brain cells, leading to memory loss, cognitive decline, and motor dysfunction (Brown *et al.*, 2005). Studies suggest that both genetic predisposition and environmental factors contribute to these disorders, with pesticides playing a role through mechanisms such as oxidative stress and mitochondrial dysfunction (Sherer *et al.*, 2001; Tanner *et al.*, 2011). Even at low doses, certain farming chemicals can subtly impair brain function, increasing the likelihood of dementia-related diseases later in life (Baldi *et al.*, 2003; Hayden *et al.*, 2010).
- **Cancer Risks:** Research has linked pesticide exposure to cancers such as non-Hodgkin's lymphoma, leukemia, and prostate cancer (McDuffie *et al.*, 2001; Pluth *et al.*, 2019). While lifestyle factors like smoking and poor diet are well-known contributors to cancer, involuntary pesticide exposure is an emerging concern (Anand *et al.*, 2008; Stewart, 2012). Some insecticides, including organophosphates and pyrethroids, have demonstrated carcinogenic properties,

particularly with prolonged exposure (Alavanja *et al.,* 2013; George & Shukla, 2011). These chemicals may interact with other environmental toxins or an individual's genetic makeup, increasing cancer susceptibility (Soffritti *et al.,* 2008). Alarmingly, many people are unknowingly exposed to these hazardous substances, unaware of their long-term health risks.

- **Endocrine and Reproductive Disruptions:** Pesticides have been shown to interfere with hormonal balance, affecting fertility in both men and women (Dwivedi *et al.,* 2022). In agricultural regions such as Alto Valle del Río Negro, Argentina, studies indicate that pregnant women living near farms using organophosphate pesticides experience hormonal imbalances, placental complications, and fetal development issues (Bulgaroni *et al.,* 2013; Cecchi *et al.,* 2012). Some pesticides mimic natural hormones, disrupting endocrine functions, while others block essential enzymes required for reproductive health (Usmani *et al.,* 2003; Hernández *et al.,* 2013). Additionally, certain carbamate pesticides have been found to impact thyroid function and interfere with progesterone production (Abreu-Villaça & Levin, 2017). These disruptions can have long-term consequences on fertility, pregnancy outcomes, and overall reproductive well-being.
- **Respiratory and Cardiovascular Diseases:** Inhalation of pesticide aerosols—whether in agricultural fields, manufacturing plants, or contaminated air—can contribute to chronic respiratory conditions and cardiovascular diseases (Berg *et al.,* 2019). Prolonged exposure induces oxidative stress, which can lead to metabolic disorders such as high cholesterol and, ultimately, cardiovascular disease (Reichard *et al.,* 2006; Adeyemi *et al.,* 2021). Studies indicate that workers in pesticide manufacturing industries have a higher prevalence of circulatory system diseases and coronary heart disease (Berg *et al.,* 2019). Scientific findings suggest that pesticide toxicity triggers inflammation and metabolic imbalances, both of which are major contributors to heart disease (Montaigne *et al.,* 2021; Wang & Chen, 2021).

III. CASE STUDIES

- **The Endosulfan Tragedy in India (**Dileep Kumar & Jayakumar, 2019**)**

  Background: Endosulfan, a hazardous pesticide, was used in Kerala's Kasaragod district despite early warnings from 1979.

  Key Events:

  1970s–2001: Aerial spraying by the state-owned Plantation Corporation of Kerala caused widespread health issues (congenital disabilities, cancers).

  2001: A lower court halted the spraying.

  2011: The Supreme Court banned endosulfan nationwide based on the precautionary principle and Article 21 (right to life and health).

  2017: Compensation was awarded to affected victims.

  Impact: The case highlights the critical role of judicial intervention and preventive action in protecting public health and environmental justice.

- **Impact of Glyphosate on Cancer Risk (**Andreotti *et al.,* 2018**)**

  Overview: Glyphosate, a widely used herbicide, was evaluated in a large prospective cohort of 54,251 pesticide applicators from Iowa and North Carolina.

  Exposure & Methods: Exposure was measured as lifetime days and intensity-weighted lifetime days (using self-reported and imputed data). Cancer incidence was tracked through state registries over approximately 15–20 years.

  Key Findings: Overall cancer risk was not increased among glyphosate users. However, applicators in the highest exposure group showed a suggestive (though not consistently statistically significant) increased risk of acute myeloid leukemia (AML), with an observed rate ratio around 2.44.

  Implications: While reassuring for overall cancer incidence, the potential AML risk in high-exposure subgroups calls for continued research and improved exposure controls for applicators.

IV. CONCLUSION

The extensive use of agrochemicals has undeniably boosted agricultural productivity, but the associated health risks are deeply concerning. Incidents such as endosulfan poisoning in India and glyphosate-related lawsuits in the United States highlight the severe consequences of unregulated agrochemical use. The impact extends beyond affected individuals, placing a significant burden on healthcare systems, reducing productivity, and contributing to environmental degradation.

Striking a balance between food security and human health is essential. If the current reliance on agrochemicals continues unchecked, the long-term health repercussions could be devastating. Therefore, immediate action is required to promote sustainable farming practices, enforce stricter regulations, and enhance awareness among both farmers and consumers.

RECOMMENDATIONS

- **Stronger Regulations:** Governments must implement stricter policies to control pesticide and fertilizer use, ensuring that residue levels remain within safe limits.
- **Promotion of Organic Farming:** Encouraging sustainable and organic farming practices can help minimize reliance on harmful agrochemicals.
- **Farmer Education Programs:** Providing farmers with training on safe handling, proper disposal, and eco-friendly pest control methods is essential.
- **Research on Safer Alternatives:** Increased investment in biological pest control, organic fertilizers, and genetically modified pest-resistant crops is crucial for reducing chemical dependency.

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