S J SCIENTARA JOURNAL
Journal of Agricultural, Environmental and Life Sciences

SCIENTARA JOURNAL

Journal of Agricultural, Environmental and Life Sciences

ARTICLE TYPE	VOLUME / ISSUE	ACCEPTED / PUBLISHED
Review Article	Vol. 1, Issue 1	20-08-2026/03-09-2026

A Comprehensive Study on Pesticides and Public Health: A Global Perspective on Risks and Preventive Measures

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ABSTRACT

Synthetic and natural pesticides are extensively utilized in agriculture for managing pests, but their large-scale application has far-reaching public health and environmental concerns. A complete review of exposure to pesticides and its ill effects is here put forth, particularly in developing nations where the regulation is less than ideal. Pesticide residues contaminate soil, water, air, and food, resulting in acute and chronic health impacts such as oxidative stress, respiratory disease, neurological impairment, and cancers. Case studies in Nigeria, India, Brazil, and Germany indicate the real impact, pointing towards increased mortality rates, cancer cases, and environmental deterioration. Systematic monitoring, risk assessment, and policy implementation are still lacking despite global awareness of these risks. Farmers' improper use of pesticides, lack of protective equipment, and ineffective regulatory enforcement increase health hazards. The WHO Mortality Database reports a reduction in pesticide-related fatalities but that accidental poisonings are a major issue, especially among low- and middle-income countries. This research stresses the necessity of strict regulation, more safety measures, and encouraging the utilization of sustainable methods such as integrated pest management (IPM). There is a pressing need for global action to balance farm productivity with environmental conservation and public health, ensuring long-term sustainable pest management practices.

Keywords: Pesticides Exposure; Environmental Risks; Sustainable Agriculture; Public Health

How to cite: Kumar, A., & Gautam, G. (2026). A comprehensive study on pesticides and public health: A global perspective on risks and preventive measures. *Scientara Journal, 1*(1), 1–8.

1. INTRODUCTION

Pesticides are artificial or natural chemicals applied to limit, control, and kill weeds, insects, and other organisms that hamper plant growth. They are classified according to their chemical composition, use, hazards and mode of action (Ayaz Ahamad, Jitendra Kumar, 2023). Primarily due to commercial farming, the demand for pesticides has grown tremendously and increasingly worldwide since the mid-1940s (Reddicherla Umapathi, et al., 2022). Pesticide residues occur in soil, water, air, fruits and vegetables and processed food. In developing countries in particular, exposure to agricultural pesticides through diet and their acute and chronic adverse health effects represent significant public health hazards. Chemical pesticides are potentially mutagenic, cytotoxic, and carcinogenic to human beings (Ling Fang, et al., 2020). Due to their non-species-specific mode of action, pesticides may kill or harm other organisms apart from pests, including humans. Overuse of pesticides led to waterway, agricultural, and environment pollution, as well as food contamination (Ramona Cech, et al., 2023). According to the World Health Organization (WHO) and The United Nations Environment Programme (UNEP), pesticide exposure leads to 200,000 deaths and three million poisonings worldwide, mostly in developing countries (Md Faruque Ahmad a, et al., 2024). Pesticides induce the formation of reactive oxygen species, which decreases the level of antioxidants and decreases their ability to defend cells against oxidative stress. Nucleic acids, proteins, and lipids are also affected by the disruption of

cellular signaling pathways. Oxidative stress and reactive oxygen species are the causes of long-term health problems. Farmers' use of pesticides is the main cause of their problems. Pesticides are commonly used

carelessly, which has a variety of negative health effects on people, ranging from acute intoxication to chronic illnesses like bladder, colon, prostate, breast, and brain cancer (Lata Rani, et al., 2021). " Even though it is commonly known that agrochemicals can boost agricultural output, the production and development of environmentally friendly pesticides in a variety of formulations, including powder, solution, and emulsifiable concentrates, has significantly increased in the developed world (Hazra, Dipak Kumar, et al., 2017). However, the use of pesticides must be balanced with health and environmental concerns, and to guarantee sustainable and successful pest control methods, responsible pesticide practices like integrated pest management should be encouraged. The number of pesticides used in agriculture worldwide is rising daily as a result of all these losses. Fig. 1 shows that the number of pesticides used in agriculture worldwide has increased between 1990 and 2020 (Statista Research Department 2024).

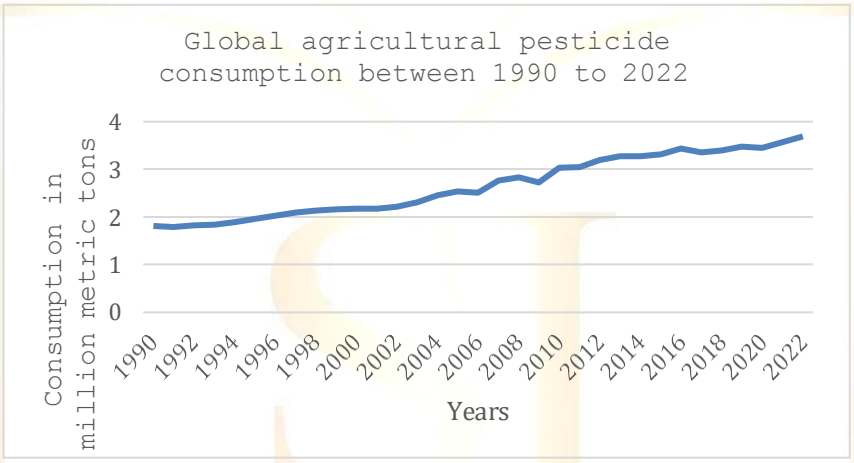


Fig.1. Global agricultural pesticide consumption between 1990 to 2022

2. BACKGROUND

2.1 CASE STUDY- 01

A case study in Nigeria, Health impaired by exposure, farmers' reports of pesticide poisoning symptoms by Adekunle, C, et al., (2017). This study asked farmers if they had any health weaknesses (discomfort) as a result of using chemical pesticides on a daily basis. It then relied only on their self-assessed/reported health effects. Whether the farmer sprayed pesticides or not determined the primary exposure status with regard to pesticides. 78.3% of the 120 farmers who participated in the interview said they personally sprayed pesticides. Other agricultural tasks, such as weeding, replanting, watering, etc., occupied the remaining 21.6% of "non-sprayers" (Adekunle, C. et al., 2017). Additionally, 95% of respondents said that they or a family member had experienced health symptoms linked to pesticides during or after pesticide application. This is typically the case in the majority of developing nations, where farmers occasionally report hospitalizations and other health issues after applying pesticides (Wilson, Clevo & Tisdell, Clem, 2001). However, the sprayers were questioned about whether they had encountered these symptoms during or right after applying pesticides. Among the more frequent signs and symptoms of the use of pesticides were burning or chest discomfort (82.5%), redness of the skin or white spots (68.33%), coughing or difficulty breathing (64.17%), hypersalivation (60%) and burning, stinging, or watery eyes (57.5%). However, these symptoms were believed to be normal and were attributed to fatigue and lassitude from working in the fields. They all concurred, though, when questioned whether they believed pesticides could be bad for the environment and for human health. The farmers' actions suggested that they did not strictly follow the usage instructions, despite their obvious awareness of the potential health risks associated with pesticide use (Stephanie Williamson, et al., 2008).

2.2. CASE STUDY- 02

Some case studies from India, there is just one train, which differs from others. This lightless train leaves the Bathinda station in Punjab at night at 9:30 PM, carrying nearly 300 passengers, mostly suffering from cancer, and headed for Acharya Tulsi Regional Cancer Hospital at Bikaner, Rajasthan. The tickets to the patients are free while discount tickets are given for attendants. But in case of interstate migration, the reason is only the cost of cancer treatment. Already, most of the hospitals of Bikaner city have been included under Mukh Mantri Punjab Cancer Raahat Kosh Scheme, in which patients are given financial assistance up to 1,500,000 INR, which is almost $1,787, but it is difficult for patients in Punjab to access the scheme. The distance is approximately 325 km and the traveling time is about 6 hours, but the patients usually get delayed. Patients go to Bikaner for low-cost treatment because the native hospitals of Punjab are not available easily for financial aid. Punjab has a high rate of cancer because of environmental issues and India is called the cancer capital of the world. Cancer cases in the country have risen to a record high as public officials last reported that there were 1,496,972 cases recorded in 2023. Comparatively, this number shoots to 1,461,427 in 2022. Between 2017 and 2018, it had surged 300 percent. Studies report that by 2020, The number of cancer patients in India is 1.4 million. By 2025, the number of cases may rise to 1.57 million. This can be because the consumption patterns with food changes, genetic disposition increased toward this disease, as well as negligence toward their initial condition of cancer (Punjab's 'Cancer Train, 2024). Punjab is the country's largest fertilizer consumer and has phosphates, potash, and nitrogen. The province is using an average of around 223 kg per hectare where the national average is only 90 kg per hectare. Shivraj Chouhan informed the Rajya Sabha that Punjab's total chemical pesticide use went up from 5,130 MT in 2022–2023 to 5,270 MT in 2023–2024 (66 kg per hectare). With significantly larger cultivated areas of 2.41 crore hectares and 2.05 crore hectares, respectively, Uttar Pradesh 11,828 MT and Maharashtra 8,718 MT, Punjab is currently the third in the nation for chemical pesticide consumption. The use of pesticides in Punjab accounts for 9.52% of the entire consumed throughout the nation. Urea requirement went up from 28.30 lakh MT in the year 2020–21 to 29.25 lakh MT in the year 2022–2023, and NPK requirements went up from 0.76 lakh MT to 1.70 lakh MT. The demand for DAP, however, went down from 8.25 lakh MT to 7.25 lakh MT. The state itself consumes only 193 MT each year, making it 11th in the country for adopting biopesticides (the new Indian express, (2024).

It all started in the 1960s when Punjab and Haryana were two major recipients of the "Green Revolution" that was an answer to India's food security problem. The most common effect of the farm and scientific revolution was increasing crop yield. However, the change mostly occurred due to a higher use of fertilizers and pesticides (Ann Raeboline, et al., 2019). The primary cause of cancer cases in Punjab and Haryana is known to be the overuse of pesticides of the 33,318 deaths from cancer, 14,682 occurred in the Malwa region. One of the factors that have been associated with the unusually high prevalence, especially in the cotton-producing areas of south-western Punjab, is pesticide use by cotton farmers. Malwa uses 75% of the state's pesticides, as per the State Council for Science and Technology's 2007 State of Environment Report. Multiple factors, including pesticide use, are responsible for cancer cases in Talwandi Sabo, according to a 2005 report on high rates of cancer among PGIMER Chandigarh's farming community (Chitleen K Sethi & Navrajdeep Singh, 2015). Whereas normal cells eventually die, cancer develops when a cell continues to grow and divide uncontrollably. Humans are biochemically protected from cancer naturally by tumor-suppressor genes. Tumor-suppressor genes can be turned off by certain chemicals causing them to mutate. Prolonged exposure to pesticides can thus increase an individual's chances of developing cancer. Punjab, the biggest per capita consumer and third-largest consumer in the country, has an incredible annual consumption of 5,270 metric tonnes of pesticides. Because of this extensive use, pesticides end up in food, drinking water, and groundwater. The human body then absorbs these pollutants. In Haryana, recent studies discovered pesticide residues in nursing mothers' breast milk (Mehta, R, et al., 2020). Hexachlorocyclohexane, endosulfan, cypermethrin, cyhalothrin, permethrin, chlorpyrifos, ethion and pronephros were some of the toxic pesticides which were in excess in 6.9% of Ludhiana, Punjab cow milk samples as revealed by another research as per described in fig.2 (Gill, J.P.S. et al., 2020).

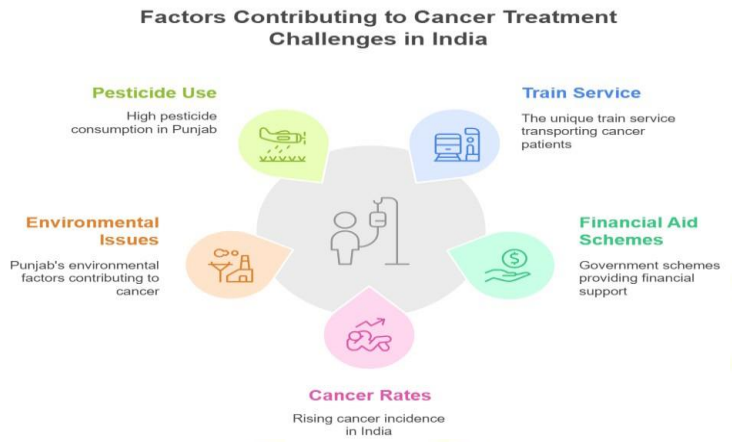


Fig. 2. Rising Cancer Cases in India

2.3. CASE STUDY- 03

Case studies in Brazil, Glyphosate contamination from contiguous soybean and corn fields has resulted in severe health issues for the Avá-Guarani people in Brazil, prompting international human rights complaints against Bayer (EHN Curators, 2024). In the far west of the state of Paraná, there are approximately 4,000 Avá-Guarani Indigenous people who could be contaminated by glyphosate. Significant health risks are associated with glyphosate exposure, which also exacerbates chronic illnesses and environmental degradation, bringing up concerns about human rights and agricultural regulations in Brazil. It is the active component of Roundup, the most popular pesticide in the world for getting rid of weeds from public areas and even crops. In the past few years, Ava-Guarani has come to expect headaches, light headedness, skin rashes, and illnesses like cancer. "Many individuals are plagued by headaches and frequent trips to the health centre when spraying poison. Each time they make use of the poison; we have a spectrum of health challenges. Some others ended up suffering from cancer eventually. Avá-Guarani people were poisoned with glyphosate by the biochem company Bayer, which was accused by the organization for economic cooperation and development (OECD) of causing harm to both human health and the environment. The complaint was submitted to the National Contact Point (NCP) in Germany, the location of Bayer's headquarters, along with three additional cases from Latin America, including the Avá-Guarani. The agency is in charge of handling cases through non-judicial complaint mechanisms and promoting the OECD guidelines for multinational corporations as per described in fig.3 (Ana Paula Rocha, 2024).



Fig. 3. Glyphosate Contamination and Human Rights Issues

2.4. CASE STUDY- 04

Certain German case studies, the increasing application of pesticides is the leading cause of environmental damage globally, as indicated in a recent German environmental groups' report. Susan Haffmans, agricultural engineer at Pesticide Action Network Germany and key contributor to the Pesticide Atlas report, said, "When you work with agriculture, health, species extinction, and water contamination, you're facing the problem everywhere." "There is one major cross-cutting problem." A new study published in the journal Public Health asserts that 385 million farmers fall ill yearly due to acute pesticide poisoning. Following poisoning, farmers and farm workers report symptoms ranging from headaches and weakness to fainting, vomiting, diarrhea, skin rashes, and nervous system problems. The heart, lungs, or kidneys fail in extreme situations. The study did not include pesticide-related suicide deaths, but estimated 11,000 individuals in agriculture are killed every year due to acute poisoning. Agricultural workers and small farmers from the Global South are particularly susceptible to pesticide poisoning. It estimated there are about 12.3 million cases of acute pesticide poisoning in Latin America, 116 million in Africa, and 256 million in Asia. At 1.6 million, it is far less in Europe. According to Haffmans, 44% of all workers globally experience at least one poisoning annually, and in some nations, the number is significantly higher. For instance, 83% of agricultural laborers in Burkina Faso experience at least one pesticide-related illness. The Atlas identifies a number of causes for the Global South's noticeably higher poisoning rate. First of all, numerous harmful pesticides—some of which are prohibited in Europe- are sprayed there. Furthermore, a large number of small farmers there lack safety clothing and lack knowledge of the risks (Gero Rueter, 2022). In even more contaminated places, pesticides have also been linked to allergies, asthma, endocrine gland problems, obesity, deformities, and miscarriages. "Research also indicates a connection to Type II diabetes, Parkinson's disease, or specific types of cancer," the Haffmans said. and "Even if we don't live on the field's edge, we come into contact with pesticides everywhere.

3. KNOWLEDGE GAPS

There are still a lot of unanswered questions despite the large number of peer-reviewed scientific studies that have helped us comprehend the harmful effects of fertilizers and pesticides around the world. These gaps need to be filled and investigated further. Initially, the study identifies deficiencies in systematic reviews, environmental risk assessments, and continuing monitoring initiatives pertaining to pesticides' effects on the environment. Our comprehension of the actual environmental impact of these substances is limited by the absence of thorough data. Second, there are a number of important knowledge gaps regarding the effects on human health. These include the requirement for more comprehensive toxicological analyses of formulated products and co-formulants, as well as assessments of the intricate health consequences of pesticide exposure. A lack of disaggregated data for vulnerable groups, like female farmers and agricultural workers, is another issue. The dangers of combined exposure to multiple active substances are also not well understood.

Furthermore, no international review that thoroughly examines the substance and application of pest or pesticide management policies is currently available. This impairs our capacity to decide on sustainable methods of managing pests and vectors. The monitoring of fertilizers' negative effects is also frequently neglected by governments, despite their desire to improve public health and welfare. The information that is currently available is not broken down by gender, age, or type of fertilizer (organic vs. inorganic), which results in substantial data gaps about the effects of fertilizers on the environment and human health. Furthermore, little is known about national, regional, and international fertilizer policy conditions (United Nations Environment Programme, 2022).

4. METHODS

Data collected, filtered, and processed, which is based on scientific research published in Scopus-indexed journals, Science Direct, Digital Library at Uttaranchal University and Google Scholar that covered pesticide application, human impact, and environmental impact are presented in the "Materials and Methods" section.

To source data, suitable studies were identified using keywords, topics, and areas on toxicity, pesticide impact, and geographical trends. Major emphasis was placed on the peer-reviewed articles that emerged within a certain time scale. Inclusion was based on the criterion that they relate to the study's goals; low-quality or outdated studies were excluded. The extraction process during the synthesis entailed categorizing the information into cases related to health, environment, and region-related issues.

5. WHO MORTALITY DATABASE

The WHO Mortality Database is a comprehensive series of mortality data, including causes of death for member countries since 1950. The database plays a central role in the analysis of health trends as well as policy making. In pesticide exposure, it offers vital statistics on mortality from unintentional poisonings. Over the last 20 years, overall mortality rate due to unintentional poisonings has declined, according to World Health Statistics 2024. It dropped to 1.1 deaths per 100,000 by 2019 from about 1.5 deaths per 100,000 in 2000. Over the same period, female fatalities dropped from 1.1 to 0.8 per 100,000 population and male fatalities dropped from 2.0 to 1.4 as per described in fig.4. Higher incidence rates in these countries are caused by a number of factors, including poor regulatory frameworks, limited information on proper handling procedures, and restricted access to healthcare. The WHO Mortality Database is an essential tool for tracking such trends, targeted interventions, and encouraging safer farming practices in an effort to curtail the adverse effects of pesticide exposure on human health.

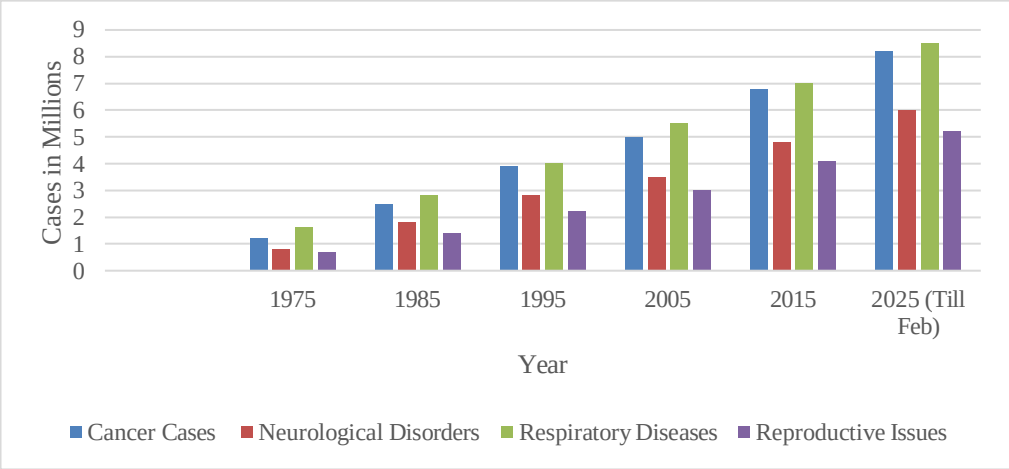


Fig. 4. Impact of pesticides on health hazards.

6. RECOMMENDATION

To ensure public health, it is highly advised to reduce pesticide use as much as possible, emphasize Integrated Pest Management (IPM) practices, follow label directions to the letter when using pesticides, use proper protective equipment, store pesticides properly, and dispose of them correctly, particularly given the increased susceptibility of children and pregnant women to pesticide exposure; also, advocate policies encouraging safer alternatives to pesticides and regulation of their use.

Key recommendations:

I. Minimize pesticide use: Use non-chemical pest management techniques such as biological controls or cultural practices where possible.
II. Integrated pest management (IPM): Implement IPM strategies that involve the use of a mix of pest control methods, including monitoring pest populations to minimize the use of pesticides when necessary.
III. Read and follow label instructions: Always read and carefully follow all label instructions on pesticides for application rates, personal protective equipment, and disposal methods.
IV. Protective clothing: Wear the proper personal protective equipment (PPE), when handling pesticides such as gloves, long sleeves, respirators and pants.

V. Storage: It is recommended that pesticides be kept in their original containers in a locked cabinet away from food supplies, kids and pets.
VI. Disposal: Never pour leftover pesticides or empty containers on the ground or down drains; instead, dispose of them as directed on the label.
VII. Public awareness: Publicize the need for safe handling practices and the potential health risks associated with pesticide exposure.
VIII. Policy support: Encourage the creation and use of safer alternatives to pesticides, limit the use of pesticides in sensitive areas, and enforce strict laws regarding the registration and use of pesticides.

7. CONCLUSION

The global impact of pesticide uses on the health of the public and the environment remains a concern. Case studies in Nigeria, India, Brazil, and Germany detail the catastrophic health consequences of pesticide exposure, from acute poisoning to chronic illness such as cancer. The impact is most severe in poor countries where control and protective measures are absent. Overuse and misuses of pesticides are among the reasons for environmental degradation, contaminating water, land, and foodstuffs. The use of pesticides continues to expand despite known risks, as the agricultural productivity gap generates demands that the past must meet. Alternative strategies to sustainability such as integrated pest management and ecologically acceptable pesticides are promising weapons of risk reduction. To provide adequate policies, gaps in knowledge must be filled by ongoing environmental risk assessment, toxicological studies, and greater information collection for the vulnerable. The WHO Mortality Database documents the continuing public health risk of pesticide exposure, particularly in low- and middle-income nations. While unintentional pesticide poisoning deaths decreased worldwide, major obstacles remain to providing safe pesticide practice. In the future, a strategy of balance will be required encouraging prudent use of pesticides while giving highest priority to public health and environmental sustainability. Strengthening regulations, increasing public awareness, and investment in safer alternatives will be the key to minimizing the long-term impact of pesticide exposure worldwide.

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