**Persistent Poisons: Mapping the Health and Environmental Impacts of Pesticide Use in India**

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ABSTRACT

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| This review examined major pesticide-related incidents across India, highlighting their root causes, impacts and the recurring themes of corporate negligence, policy failure and grassroots resistance. A troubling legacy of acute disasters, chronic exposures, and systemic regulatory shortcomings has shaped India's relationship with pesticides. From the catastrophic Bhopal gas tragedy in 1984 to the recurring pesticide-related suicides and ecological degradation, the country has endured profound public health, environmental, and socio-economic consequences due to unregulated chemical use. The tragedies span a wide spectrum: industrial disasters such as the Bhopal gas leak and the pesticide poisoning in Yavatmal; long-term public health emergencies like the Endosulfan tragedy in Kerala; and the emergence of a pesticide-induced cancer belt in Punjab. These incidents underscore critical regulatory failures, including poor enforcement of the Insecticides Act (1968), continued use of banned or highly hazardous chemicals, lack of oversight on pesticide approval and inadequate safety measures for farmers and agricultural workers. Despite these failures, many affected Communities, particularly women, have led movements demanding accountability, justice, and safer alternatives. As India observed 40 years since Bhopal, these case studies stood as stark reminders of preventable harm. They also served as an urgent call to reimagine agriculture rooted in agroecology, farmer safety, biodiversity and environmental justice-towards a healthier and more sustainable future. |

*Keywords:* ***Pesticide Poisoning, Environmental Pollution, Regulatory Failure, Public Health Crisis, Agrochemical Resistance, Occupational Hazards and Sustainable Agriculture.***

1. Introduction

Pesticide exposure has been linked to numerous chronic health effects, including congenital malformations, prenatal deaths, poisoning and endocrine disruption. Alarming levels of pesticide residues-such as DDT, Endosulfan and profenofos- have been found above the Maximum Residue Limits (MRLs) in various food items and consumables, including khat, red pepper, coffee, rice, sorghum, millet, poultry feeds and even drinking water (Gedefaw et al., 2022). According to the same study, 31% of farmers reported feeling unwell after pesticide application, with 14.2% acknowledging incidents of poisoning. Notably, 22% of registered pesticides are classified as highly hazardous, yet 85% of farmers had never received formal training on safe pesticide use. Alarmingly, women account for 51% of all pesticide poisoning cases reported (Gedefaw *et al*., 2022).

Globally, the scale of pesticide-related health issues is stark-over 4 million people are poisoned by pesticides each year, leading to approximately 350,000 unintentional deaths, as per World Health Organization estimates. Since the 1950s, the use of synthetic pesticides has surged 50-fold, with toxicity increasing by 10 to 100 times. Environmental consequences are equally severe. In a single incident in Oregon, the neonicotinoid insecticide dinotefuran was responsible for the death of 50,000 bumblebees. Moreover, pesticide poisoning contributes to the death of an estimated 67 million birds annually, either through bait exposure or direct contact (Hashimi *et al*., 2020).

* 1. **Problems Associated with the Use of Pesticides**

**1.1.1 Environmental Pollution and Ecotoxicity**

Pesticide use contributes significantly to environmental pollution. Residual chemicals may leach into groundwater or drinking water sources, leading to contamination. Furthermore, the drift of pesticides through wind, runoff and soil erosion often results in widespread ecological damage. This environmental burden includes adverse effects on non-target plant species and the bioaccumulation of toxic residues in the ecosystem, (Devi *et al.,* 2022; Khan *et al*., 2023).

**1.1.2 Non-Target Effects on Beneficial Organisms**

Pesticides are known to affect non-target organisms, including beneficial soil microorganisms, enzymes, algae and aquatic fauna. These disruptions alter the ecological balance and reduce biodiversity, potentially affecting soil fertility and water health, (Pathak *et al*., 2022; Mata *et al*., 2024).

**1.1.3 Development of Resistance**

Frequent and indiscriminate pesticide usage has led to the evolution of resistance in target pests. This includes both direct resistance and cross-resistance to other active compounds, often requiring the development of stronger chemical agents and exacerbating the pest problem over time.

**1.1.4Suppression of Alternative Methods**

Excessive dependence on chemical control has discouraged farmers from adopting more sustainable practices such as organic farming, crop rotation and biopesticides. This over-reliance limits innovation and resilience in pest management systems, (Barathi *et al*., 2024).

**1.1.5 Contamination from Poor Application Practices**

Pesticide misuse, including over-application and incorrect timing, results in excessive residue levels on crops and within the environment. Such misuse is often due to poor understanding of application technologies and lack of training, particularly among smallholder farmers in developing regions, (Dhuldhaj *et al*., 2023; Upadhayay *et al*., 2020).

**1.1.6 Weak Regulatory Frameworks**

In many developing countries, government intervention in pesticide regulation is minimal due to a lack of legislative expertise, insufficient staff, limited infrastructure, inadequate laboratory facilities and poor budget allocations. This contributes to uncontrolled and potentially hazardous use of pesticides.

**1.1.7 Health Risks and Safety Gaps**

Inadequate use of personal protective equipment (PPE) during pesticide application poses serious health risks. Many farmers, especially in rural areas, lack awareness about safety protocols, increasing incidences of poisoning and long-term health complications, (Kaur *et al.,* 2024).

**1.1.8 Poor Extension Services**

The inefficiency of agricultural extension services hinders proper pesticide usage education. Limited mobility, inadequate training, lack of incentives, and poor engagement with farmers often leave them dependent on unqualified pesticide vendors for guidance. This results in misuse, including improper dosage, incorrect identification of pests, inappropriate mixing of chemicals and neglect of waiting periods for pesticide degradation, (Abubakar, et al., 2020).

1. **BHOPAL GAS TRAGEDY (1984)**

December 2024 marks 40 years since the Bhopal gas tragedy-widely regarded as the world’s worst industrial disaster that occurred in Bhopal, Madhya Pradesh, involving the release of methyl isocyanate (MIC), a toxic chemical used in the production of the pesticide Carbaryl (commercially known as Sevin). On the night of December 2-3, 1984, toxic methyl isocyanate gas leaked from the Union Carbide pesticide factory in Bhopal, India. The disaster resulted in over 15,000 deaths-according to both official and unofficial estimates-and caused long-term respiratory, reproductive and neurological disorders in thousands of affected individuals. Dhara and Dhara, (2002). Though often remembered as a past event, Bhopal remains an ongoing humanitarian and environmental crisis. After the disaster, Union Carbide abandoned the site without safely disposing of the remaining toxic chemicals. In 2001, the company merged with Dow Chemical, which has also refused to take responsibility for the contamination. Over the past four decades, toxic waste has leached into the soil and groundwater, affecting generations of people in nearby working-class neighborhoods. Children continue to be born with health complications and residents suffer from chronic exposure. Amid this long-standing injustice, women from affected communities have emerged as leaders. Through sustained grassroots activism, they have drawn global attention to the crisis and secured clean drinking water for many bases. Their fight, rooted in lived experience and collective action, is a testament to resilience, dignity and the pursuit of environmental justice, (Dhingra and Dutta, 2024).

1. **ENDOSULFAN DISASTER IN KERALA (1976-2001)**

Endosulfan, a widely used organochlorine insecticide, was introduced in the 1950s during the Green Revolution. Known for its affordability, high efficacy and chemical stability, it has gained popularity across global agricultural sectors and remained in use for over 3 decades, despite being part of the restricted OC class. However, over time, numerous cases of endosulfan poisoning began to surface worldwide, raising serious health and environmental concerns. The most devastating and widely recognized instance occurred in Kasaragod, Kerala, India, where its use over a 25-year period resulted in severe public health and ecological consequences, (Sreekumar and Prathapan, 2021). This disaster was a chronic environmental and health crisis that unfolded, due to the extensive use of Endosulfan, an organochlorine pesticide. Prolonged exposure to this chemical led to hundreds of cases of birth defects, neurological disorders and cancers among the local population. In response to mounting health concerns and public outcry, India officially banned the use of Endosulfan in 2011 following a Supreme Court intervention.This incident remains a pivotal case in environmental justice and agrochemical regulation, (James and Emmanuel, 2021).

**4. BIHAR MID-DAY MEAL TRAGEDY (2013)**

The **Bihar Mid-Day Meal tragedy** remains one of the most alarming examples of **point-source foodborne poisoning** in recent Indian public health history. On **July 16, 2013**, in a government primary school in **Gandaman village, Mashrak block, Saran district**, 23 children lost their lives, and 22 were hospitalized after consuming a pesticide-contaminated Mid-Day Meal. The case fatality ratio (CFR) was calculated at **51.11%** and the attack rate was **45%**, both extremely high indices for any epidemic.

Investigations revealed the presence of **Monocrotophos**, a highly toxic **organophosphorus pesticide**, in the oil used for preparing the meal. Forensic Science Laboratory (FSL) reports confirmed pesticide contamination in samples of cooking oil, food remains and serving utensils. Monocrotophos is known for its **high human toxicity** and is often banned or heavily restricted in many countries, (Oirdi *et al.*, 2024).

The incident underlines **severe gaps in food surveillance** and **public health preparedness**, especially at the primary level. The primary health center lacked necessary emergency care facilities and there was no rapid transport to advanced medical centers. This event sparked widespread demands for policy overhaul, including raising the **cost per unit meal**, reinforcing **food safety,** and strengthening **nutritional surveillance**, (Samal, 2014).

**5. PERAMBALUR PESTICIDE POISONING (2018) -TAMIL NADU**

In **2018**, at least **five farm workers** died in **Perambalur and Ariyalur districts** of Tamil Nadu due to **direct exposure to pesticides** used in cotton farming. These laborers suffered severe respiratory distress and other acute symptoms after spraying pesticides without protective gear. The tragedy highlights the **lack of enforcement of occupational health safety** standards in India’s agricultural sector and insufficient farmer education about pesticide toxicity, (Anonymous, 2017. Perambalur Pesticide Deaths).

**6. BURDWAN PESTICIDE TRAGEDY - WEST BENGAL**

Despite a **bumper harvest**, multiple **potato farmers in Burdwan** (West Bengal) were reported to have **committed suicide**, largely driven by pesticide-induced health problems and financial distress due to **low selling prices**. Some of these suicides were a result of **direct pesticide ingestion**, pointing to both **mental health crises** and **unregulated pesticide accessibility** in farming communities, (Halder *et* al., 2017).

**7. PUNJAB PESTICIDE POISONING (2014) - BATHINDA AND MANSA DISTRICTS**

Punjab’s **Bathinda and Mansa districts** have witnessed high rates of **pesticide poisoning**, attributed to the excessive use of chemical pesticides in cotton cultivation. Over the years, local surveys and investigative reports have recorded rising cases of **cancer, respiratory issues, reproductive failures**, and **accidental deaths** related to pesticide exposure.

A Pulitzer Centre investigation titled The Poisoning of Punjab documents compelling visual and narrative accounts of health crises, poor regulations, and agrarian vulnerability in the region, (Anonymous 2014).

**8. PESTICIDE POISONING IN MAHARASHTRA AND YAVATMAL (2017)**

The pesticide poisoning incident in Yavatmal, Maharashtra, was a case of acute pesticide exposure involving a combination of insecticides, including Monocrotophos. The tragedy resulted in over 20 deaths and left hundreds hospitalized due to direct inhalation of toxic chemicals during spraying operations, which were conducted without adequate protective gear, (Karunarathne *et al*., 2021).

Pesticide poisoning has long posed a deadly threat to farmers and farm laborers in Maharashtra, though national attention sharply increased following the 2017 Yavatmal tragedy. That year, several fatalities due to toxic exposure during pesticide spraying drew widespread media and governmental scrutiny. However, data presented by the agriculture ministry in the Lok Sabha reveals that this issue is far from new. Over the past four years alone, Maharashtra has recorded 272 pesticide-related deaths, highlighting a persistent and overlooked crisis. Yavatmal district, which became the focal point of the 2017 incidents, continues to report high casualty numbers. The formation of a Special Investigation Team (SIT) to probe these deaths further underscored the urgency of reforming pesticide use practices. Inadequate training, poor protective measures and exposure to highly toxic chemicals have all contributed to the continuing toll, (Sreedhar, *et al*., 2018).

**9. PESTICIDE SUICIDES IN INDIA**

India has faced a severe public health crisis due to widespread pesticide poisoning, with organophosphates and aluminum phosphide being the most common agents (Mahajan et al.*,* 2022). This issue has been particularly acute in states like Andhra Pradesh, Tamil Nadu, and Maharashtra. The World Health Organization has identified India as having one of the highest suicide rates by pesticide poisoning globally. Easy access to highly toxic pesticides, combined with socio-economic distress among farmers, has made pesticide ingestion a tragically common means of suicide, demanding urgent regulatory and mental health interventions. Pesticide self-poisoning remains a major method of suicide in India, posing a critical public health challenge. Research has shown that banning highly hazardous pesticides (HHPs) can significantly reduce suicide rates without adversely impacting agricultural productivity, as observed in several South Asian nations. This study investigates the role of pesticide regulations at both national and state levels in influencing suicide trends across India from 1995 to 2015.

By October 2019, India had 318 registered pesticides, including 18 classified by the WHO as extremely (Class Ia) or highly (Class Ib) hazardous. Despite the continued availability of HHPs, significant regulatory steps were taken, such as the national ban on endosulfan in 2011 and Kerala’s bans on endosulfan in 2005 and 14 additional pesticides in 2011.

Between 1995 and 2015, India recorded 441,918 pesticide-related suicides, with 90.3% concentrated in 11 states. The data show a significant reduction in pesticide suicides following these bans. Nationally, there was a notable decline in pesticide suicides (Rate Ratio [RR] 0.52, 95% CI: 0.49-0.54) and in overall suicide rates (RR 0.90, 95% CI: 0.87-0.93) by 2014. In Kerala, similar patterns were observed, with significant decreases in pesticide suicide rates after both the 2005 and 2011 bans, although overall suicide trends remained largely unchanged. Crucially, these bans did not negatively impact agricultural productivity, (Bonvoisin, *et al*., 2020).

**10. ECOLOGICAL COLLAPSE IN NORTH EAST INDIA**

In Assam and Manipur, an environmental disaster emerged from the excessive use of insecticides on rice crops. Intended to control pest populations, these chemicals instead triggered recurring outbreaks due to pest resistance and ecological imbalance. The overuse of insecticides led to the degradation of local ecosystems, causing the widespread death of beneficial insects and aquatic life. This disaster underscored the unintended consequences of chemical-intensive farming and the urgent need for ecologically balanced pest management strategies, (Sankoh *et al.,* 2016).

Traditionally, rice cultivation in Northeast India, particularly in Assam, has followed organic practices. However, the recent outbreak of the rice-swarming caterpillar (*Spodoptera mauritia* Boisduval) has disrupted this eco-friendly approach. In 2016, this pest infested over 56,768 ha of winter rice across 28 districts of Assam. In response, between 25,545 and 42,576 l of synthetic insecticides were applied-marking one of the highest insecticides loads ever recorded in the state’s rice-growing ecosystem. The scale of chemical intervention raises serious ecological concerns, especially if such outbreaks continue and lead to repeated application of harmful insecticides. Over time, this may compromise the natural resilience of the rice ecosystem, endangering soil health, biodiversity, and sustainability, (Sarma, *et al*., 2021).

**11. PESTICIDE RESISTANCE LEADING TO CROP FAILURE**

In 1987, an agricultural disaster unfolded in the states of Gujarat and Andhra Pradesh due to the widespread use of pyrethroids and organophosphates. These chemical pesticides, heavily applied to control cotton pests, inadvertently led to the development of resistance in the bollworm, a major pest of cotton. As a result, massive crop failures occurred, devastating the livelihoods of thousands of farmers. This incident highlighted the dangers of pesticide overuse and the urgent need for sustainable pest management practices in Indian agriculture.

Insect resistance to insecticides has been a recognized scientific phenomenon for over six decades. The first documented case dates back to 1914, when Melander reported the ineffectiveness of lime sulfur sprays in controlling the San Jose scale (*Aspidiotus perniciosus*) on apple trees in Washington’s Clarkson Valley. Since then, two generations of entomologists have witnessed a dramatic and steady rise in confirmed cases of insecticide resistance among pest species. Beginning in 1948, these cases have doubled approximately every six years, and the total has now surpassed 400 documented instances. Based on this growth trend, projections suggest that within the next decade, over 1,500 species may exhibit some form of resistance.

This development is especially alarming when considering that the United States alone has approximately 600 recognized major insect pests-representing just a small fraction (about 1%) of all described insect species. If current trends continue, it is likely that nearly every significant pest insect species could exhibit resistance to at least one form of insecticide by the end of the century. This progression represents a significant, albeit troubling, milestone in agricultural and environmental history. Yet, despite its implications for food security, public health, and ecological balance, this widespread emergence of resistance has received surprisingly little attention from academic institutions, government agencies, and society at large. The urgency of this issue demands greater awareness, investment in alternative pest management strategies, and a revaluation of current chemical-dependent control practices to mitigate long-term ecological and economic consequences, (Metcalf, 1983).

**12. CHRONIC EXPOSURE AND CANCER LINKS**

The region of Punjab, often referred to as India's "cancer belt," has experienced a long-term public health crisis linked to chronic pesticide exposure. Residues of harmful pesticides such as Atrazine, Endosulfan and DDT have been detected in local water sources and even in human blood samples. This exposure has been associated with a high prevalence of cancer, reproductive disorders, developmental delays and a range of other health issues (Rani *et al.,* 2021; Poudel *et al*., 2020). Pesticide use in India dates back to 1948 with the import of DDT for malaria control and benzene hexachloride (BHC) for locust management. By 1952, India had established domestic production facilities for these chemicals and by 1958, annual production exceeded 5,000 metric tons. Currently, around 145 pesticides are registered for use, with production levels reaching approximately 85,000 metric tonnes per year. Despite relatively low ha-1 pesticide consumption compared to countries like Korea and Japan, India faces severe challenges due to the unregulated and often unsafe use of pesticides. Reports indicate that 51% of food commodities contain pesticide residues, with 20% surpassing internationally accepted maximum residue limits. Long-term exposure, even at low doses, has been linked to immune suppression, hormonal disruption, cognitive impairments, and cancer, (Gupta,2004).

**13. REGULATORY GAPS AND WEAK ENFORCEMENT**

India has the Insecticides Act (1968), but enforcement remains inconsistent. Banned pesticides are still sold under new labels; small-scale farmers remain unaware of safe practices.

Agricultural development remains a cornerstone of India’s planning and policy framework, with pesticides playing a vital role in enhancing crop productivity and controlling vector-borne diseases. Despite their benefits, pesticide exposure-both occupational and environmental-has been increasingly associated with serious health concerns (Mitra *et al*., 2021; Singh *et al*., 2018). India, while having lower per capita pesticide consumption compared to many developed nations, is the largest producer in Asia and ranks 12th globally in pesticide usage. The country’s large agrarian workforce is routinely exposed to these chemicals, leading to heightened concerns about pesticide residues in crops, which have adversely impacted agricultural exports. A significant challenge lies in the improper use, lack of regulation, and inadequate awareness regarding pesticide application technologies, (Abhilash and Singh, 2009).

**14. Future Prospects for Pesticide Management in India:**

1. **Strengthening the Regulatory Framework**: The new proposed Pesticide Management Bill (PMB) 2020 seeks to replace the Insecticides Act of 1968, which has outlived its usefulness. The bill attempts to regulate all stages of the lifecycle of pesticides, including manufacture and import, sale, storage, distribution, use and disposal. Its proper enactment and stringent enforcement are, however, vital for the purposes of having available safer pesticides and reducing risks.
2. **Emphasis on Maximum Residue Limits (MRLs):** India is moving towards more stringent MRLs for pesticides in food products. This will push for safer agricultural practices and better-quality control, aligning India with international food safety standards.
3. **Promotion of Bio-pesticides and Sustainable Alternatives:** There's a growing recognition and push for the use of bio-pesticides and neem-based pesticides as alternatives to chemical ones. This involves incentivizing their development, production, and adoption by farmers.
4. **Digitization and Transparency:** Digitizing pesticide registration and licensing processes can enhance efficiency, transparency, and accountability within the regulatory system.
5. **Increased Research and Development:** Investing in research for new, greener pesticide molecules and technologies, as well as improved application methods, is vital for long-term sustainability.
6. **Farmer Education and Training:** Continuous and comprehensive training programs for farmers on the safe and judicious use of pesticides, understanding product labels, and adopting alternative pest management techniques are essential. This includes promoting Integrated Pest Management (IPM).
7. **Community Led Initiatives:** The continued rise of grassroots movements, particularly by women, demanding accountability and safer alternatives, creates a powerful impetus for policy change and sustainable practices.
8. **Harmonized agricultural development policy (HADP)** to align pesticide safety with productivity.
9. **Toxicity-weighted taxation** ("polluter pays") to discourage hazardous chemicals.

The lessons learned from India's experiences can provide valuable insights for other parts of the world. Here are key ways to prevent further pesticide harm:

1. **Investing in Alternatives:** Significant investment in research and development of non-chemical pest control methods, bio-pesticides and other sustainable agricultural innovations is vital.
2. **Widespread Adoption of IPM:** IPM is an ecologically sensitive approach that combines various pest control methods-physical, cultural, biological and chemical-to minimize harm. It emphasizes preventing pest problems first, and only using pesticides as a last resort and then in the most targeted and least harmful way possible.
3. **Education and Capacity Building:** Comprehensive training for farmers, agricultural workers and extension agents on safe pesticide handling, application techniques, and the benefits of alternatives. This also includes educating consumers about the risks of pesticide residues and the benefits of organically grown produce.
4. **Promotion of Bio-pesticides and Sustainable Alternatives:** There's a growing recognition and push for the use of bio-pesticides and neem-based pesticides as alternatives to chemical ones. This involves incentivizing their development, production and adoption by farmers.
5. **Digitization and Transparency:** Digitizing pesticide registration and licensing processes can enhance efficiency, transparency and accountability within the regulatory system.
6. **Community-Led Initiatives:** The continued rise of grassroots movements, particularly by women, demanding accountability and safer alternatives, creates a powerful impetus for policy change and sustainable practices.
7. **Banning Highly Hazardous Pesticides (HHPs):** Following the lead of states like Kerala in India, and many European countries, a systematic phase-out and ban of HHPs that pose severe risks to human health and the environment is critical.

**15. CONCLUSION**

India’s pesticide journey has laid bare the structural gaps in governance, justice and health. Despite recurring tragedies, it was the strength of affected communities-especially women-that had driven meaningful change. By pushing for agroecological practices, banning Highly Hazardous Pesticides, and embracing safer alternatives, India had begun to chart a path away from chemical dependency. Ensuring farmer education, regulation and accountability had proven essential in breaking the cycle and moving toward a more just and sustainable agricultural future.

Declaration

No animals and human participants are harmed.

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