How Pesticides Can Harm You and Your Environment: A Review of Drift Exposure Routes and Health Risks

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ABSTRACT

The plant protection measure is one of the significant farm practices in the field of agriculture in terms of preventing crops from pest infestations and enhancing the crop produce while ensuring better quality yield as well as quantity. With the huge demand for crop production to meet global food security, farmers are applying excessive amounts of pesticides to keep the crop free from pest invasions. Generally, pesticides are specifically noxious to targeted pests, but the danger created when intensive applications of pesticides also affect other nontargeted species of the environment including humans, animals, soil microenvironment, and other living beings. However, the unintentional movement of pesticidal drift has a detrimental impact on humans and the environment remains a major concern in recent days. Therefore, we need to focus on pesticide application methods, routes of human exposure, and imposing threats to non-targeted species due to the pesticide application. The purpose of this article is to discuss the negative impact of

pesticidal drift on the nontargeted environmental components especially on human health.

INTRODUCTION

Pesticides play a vital role in protecting crops from pests and ensuring global food security in modern agriculture. Nevertheless, the extensive utilization of these chemical substances makes people worry about how they might affect our health and the environment. The Pesticides are essential because they help prevent crop loss, increase yields, and make food more affordable and better in quality (Taufeeq *et al.*, 2021). During World War II (1939–1945), there was a big push to develop pesticides to produce more food. Since the 1940s, using synthetic crop protection chemicals has further improved food production (Carvalho *et al.*, 2017).

Pesticide drift happens when these chemicals unintentionally move from where they were supposed to be used, carried by the wind or water. This can contaminate air, water, and soil nearby, risking the health of humans and wildlife depending on the type and amount of exposure. Up to 88.8% of sprayed pesticides may be lost as drift, including droplets, particles, or vapour (Druart *et al*., 2011; Gil and Sinfort, 2005). In general, Pesticides, meant to target specific pests, often impact many living and non-living elements in the environment. About 95% of the pesticides used affect non-targeted wildlife because they spread widely and stay in the environment for a long time (Simeonov, Macaev, & Simeonova, 2013). Additionally, the extensive use of these chemicals leaves residues in almost all environmental components, prompting the exploration of various physical and chemical methods for pesticide residue treatment in water sources (Dehghani *et al*., 2021). As a result, this contamination can be a serious threat to both people and the environment. This article seeks to investigate the diverse pathways by which pesticides can pose threats to individuals and ecosystems, focusing on drift exposure routes and the associated health risks. Understanding how pesticide drift happens is crucial to come up with good ways to reduce it and promote farming practices that are good for the environment.

The Growing Relevance of Pesticidal Drift: Examining Why and How It Matters

The airborne particles of pesticidal properties may cause serious damage to humans, animals, and other living organisms since pesticidal drift exposure is one of the major sources of airborne environmental contamination at the time of application. The book written by Racheal Carson “Silent Spring” in the year of 1962, emphasized the negative impact of pesticides on the soil microenvironment, airborne pollution, and human exposure generally which are non-targeted species in our environment. This raised a major concern about the understanding of the relevance of the pesticidal drift and its hazardous impact on living beings. It has been estimated that about 97% of the applied pesticides caused enormous harm to the non-targeted organisms due to their wide spreading capacity and high persistence in nature. Pesticidal droplets show extreme persistence and the residue may be observed in almost every corner including targeting and on-targeting sites.

Exposure and threats to humans and other living organisms have the alarming concerns for the past few decades. It may be causing harm to human health directly and indirectly. Pesticide manufacturing sites, transport, and applications in the field triggered direct contact with the human body. During the field application of pesticides, there is a risk of the adsorbed or absorbed molecules being carried

down through leaching or surface runoff, potentially accumulating in groundwater or adjacent water bodies. The utilization of this contaminated water by all living organisms could significantly contribute to its entry into the food chain for both humans and animals. The indirect exposure of the pesticide's molecule through the dietary intake enters the food chain and surrounding environment. The operators, who are going to apply pesticides in the agricultural field might be the major targeted living being exposed to the detrimental impact of pesticides. Molecules get adsorbed in their clothes, and skin, enter through the lungs, and are affected in several ways including respiratory problems, asthma, dermal disease, and even cancer.

Factors affecting pesticide drift

The use of pesticides and their application methods are being designated based on the characteristics of the pest habit, their feeding nature, lifecycle, and the composition of the pesticidal active ingredient. The commonly used pesticide application methods are foliar spraying, band application, broadcast spraying, soil application, and spot treatment. Detailed descriptions of various factors contributing to drift hazards for the sprayer are provided below, encompassing aspects such as droplet size, flow rate, pressure, boom height, wind speed, and direction.

1. Size of droplets

The droplet size of the spraying particles is one of the major factors that determines the carrying capacity of the pesticidal active ingredients in the air shown in Table 1. The smaller the droplet size, the more likely to be float by the air movement in a broad range of area. The larger size droplets, heavier than air parcels easily fall into the ground. Therefore, small-size droplets along with heavy wind, can persist in the air for long periods and blow out into the targeted as well as nontargeted areas.

Table 1. Effect of droplet size on the potential drift hazards

Size of droplets	Droplet diameter (µ)	Persist in the air
Very fine	<100	Very long
Fine	100	long
Medium	240	Medium
Coarse	400	less

(Source: Kruger *et al*., 2019)

2. Application Equipment and Techniques

The type of equipment used and the application techniques employed can significantly influence drift. Properly maintained and calibrated equipment, along with correct application practices, can reduce the risk of drift. Nozzle in a sprayer is one of the major components, that determines the pressure on the liquid, and droplet distribution. A flat-fan nozzle enables the liquid droplets to spread in a thin sheet. Several factors can influence the hazard and extent of pesticide drift. It is important to consider these factors to minimize the risk of unintended pesticide movement.

3. Wind Speed and Direction

Wind speed and direction are some of the main reasons that induce most of the pesticide loss from the targeted area and travel more distance as the wind speed increases. Wind is a major factor influencing pesticide drift, especially if the wind is blowing toward sensitive areas. Wind direction is crucial in determining where the drift is likely to occur.

4. Application Height and Angle

The height at which pesticides are applied can affect drift. Spraying closer to the target and using proper nozzle angles can help minimize drift. Lowering the boom height or using shielded equipment can also be effective in reducing drift.

5. Temperature and Humidity

Environmental conditions, such as temperature and humidity, can impact the volatility of pesticides. High temperatures and low humidity may increase vaporization, leading to drift. Applicators should consider weather conditions before spraying.

6. Pesticide Formulation and Volatility

The formulation of the pesticide plays a role in its potential for drift. Some formulations are more prone to drift than others. Additionally, the volatility of certain pesticides can contribute to drift, as they can turn into vapors and move away from the target area.

7. Surface runoff

Runoff means an excessive amount of water flowing over the soil surface without entering the soil profile. The flow of water over the soil surface may carry every minute stuff present on the soil surface including, soil particles, inert materials, and to some extent pesticide residue. Surface runoff may increase the potential threat to the movement of pesticidal residue from crop fields to sensitive areas.

Human Exposure routes to pesticides

1) Types of Exposures

Due to the increment in the applicability of pesticides in agricultural systems, almost every individual globally is exposed to pesticides to some extent causing numerous health issues. There are multiple ways a person can be exposed to pesticides. Consuming pesticides as a means of suicide can be counted under intentional exposure. Due to the easy availability of toxicants like pesticides, drinking them to give away life has become very common leading to 14-20% of suicidal deaths (Gunnel *et al*., 2007). Dwelling near a pesticide-exposed area leading to unknowing or accidental exposure leading to serious health issues is termed unintentional exposure (Boedeker *et al*., 2020). The exposure of the workers to pesticides by directly meeting manufacturing, packaging, and application in the field is called occupational exposure. Among them, the farmers and farm laborers directly linked with its application at the field level are most severely affected by to drift of toxicants. They do not follow the proper guidelines for spraying i.e. using a PPE kit, gloves, mask, etc. adds up the susceptibility of the exposed farmers. Apart from these types of exposure, dietary exposure is also very common these days. Harvesting the agricultural produce within the waiting period of pesticide application leads to the persistence of pesticide residue (active ingredient) in the food. Upon consuming this unhealthy food, the toxicants enter the human body and cause various diseases. Even it can be transmitted to the mother's milk and the baby foods (Palaniyappan *et al*., 2022). The frequency, dose, and exposure time are very important and decide its impact on the human body.

2) Routes of Pesticide Entry

The pesticide enters the human body mainly through three routes, respiratory, dermal, and oral routes.

i. Entry through the respiratory route

Entry of the volatile compounds present in the pesticide through the nose via inhalation or breathing is very common among the farmers who spray the pesticide in the crops. The breathing organs and the lungs are directly affected by inhaling air contaminated with pesticides (Tudi *et al*., 2022).

ii. Entry through the oral route

Entry of pesticides directly (intentionally or accidentally) or via contaminated food material is also common these days. Improper cleaning of hands after pesticide manufacture and application may lead to the entry of toxicants through the mouth. Severe food

poisoning is very common in this case of exposure (Damalas *et al*., 2011).

iii. Entry through the dermal route

Pesticide residue may enter the body through the skin. Dermal exposure to pesticides is very common among agricultural laborers who do not use recommended protection measures while mixing and application of pesticides in the field. Intensive skin irritations can occur due to dermal pesticide exposure (Krieger *et al*., 2000).

Health risks due to pesticide exposure

Exposure to pesticides causes numerous health problems causing severe diseases like cancer and even death. The health effects can be classified as acute and chronic based on their occurrence. The spectrum of general health disorders encompasses minor manifestations of discomfort, including but not limited to nausea, headache, vomiting, and diarrhea. Respiratory allergies, stemming from diverse pest-repellent sprays, contribute to an intricate cascade of physiological responses. Many pesticide compounds, upon absorption into the gastrointestinal tract, precipitate hormonal imbalances and endocrine disruption in humans. Alterations in sex hormones manifest concomitantly as reduced sperm count, abnormal sperm morphology, defective fertilization, and give rise to neurological dysfunctions and respiratory disorders. The well-documented carcinogenic effects of pesticides underscore the heightened susceptibility to various malignancies, encompassing cancer of the blood, breast, ovary, lungs, and prostate those subjected to chronic pesticide exposure (Bonner *et al*., 2017). Furthermore, pesticides exhibit a propensity to induce neurological symptoms and syndromes, notably Alzheimer's and Parkinson's disease, in a significant proportion of exposed individuals (Sa´nchez-Santed *et al*., 2016). Respiratory complications, including wheezing, nasal irritation, cough, chest tightness, breathlessness, and dry/sore throat, emerge as prevalent consequences of pesticide exposure (Zuskin *et al*., 2008). This synthesis underscores the imperative for rigorous regulatory measures and further investigational pursuits aimed at mitigating the adverse health effects concomitant with pervasive pesticide exposure.

Environmental impact

Pesticide residues persisting in soil present a significant threat to soil-dwelling microorganisms integral to nutrient cycling, disrupting the delicate ecological balance depicted in Fig 1. This imbalance permeates through ecosystems, impacting soil health and the intricate relationships within the soil microbiome. Runoff of pesticides from crop fields into nearby water bodies exacerbates the issue, fostering biomagnification and bioaccumulation of toxicants. Aquatic ecosystems suffer as water quality parameters degrade, disturbing the equilibrium of aquatic flora and fauna. Instances of mortality among aquatic organisms become prevalent, underscoring the severity of the ecological toll (Kaur *et al*., 2023). Simultaneously, pesticide drift compounds the issue, severely impacting populations of beneficial pests, pollinators, natural enemies, and non-target pests (Serraoet *et al*., 2022). This multifaceted impact across soil and water ecosystems necessitates urgent measures to mitigate the consequences, emphasizing the importance of sustainable agricultural practices and robust regulatory frameworks to safeguard ecosystems and promote environmental health.

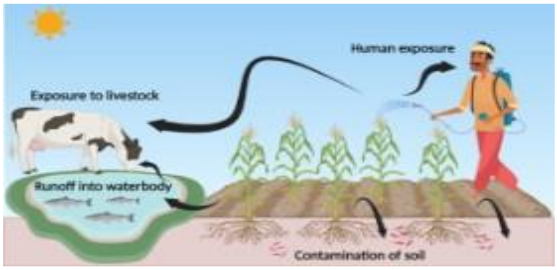

Fig 1: Environmental impacts of pesticide drift

Control Measure:

Pesticide drift refers to the unintentional movement of pesticides away from the target area during application. Various critical factors influencing pesticide drift include the generation of small-sized droplets through high-pressure cone nozzles, increased wind speed, elevated boom height (resulting in a greater nozzle-to-crop canopy distance), and environmental conditions such as relative humidity and temperature. Additionally, the use of spray thickeners can contribute to drift. To mitigate pesticide drift, it is essential to implement management practices characterized by scientific precision.

1. **Optimizing Application Equipment**

To enhance application efficiency, minimize spray solution loss, and reduce pesticide residue in the environment, the critical first step is selecting the appropriate sprayer type. Studies suggest that choosing battery-powered backpack sprayers, standing upwind, and monitoring boom nozzles from a distance can effectively reduce inhalation exposure. Additionally, utilizing flat spray nozzles for herbicide application in pump backpack sprayers may further decrease inhalation exposure.

2. **Pesticide Formulation Strategies**

Select formulations less prone to drift, such as granules or pellets, and avoid ultra-low volume (ULV) formulations that produce smaller, more drift-susceptible droplets.

3. **Adhering to Label Instructions**

Thoroughly understand and follow label instructions to ensure the safe and effective use of pesticides while minimizing environmental risks. Each pesticide has specific application sites and methods, and non-compliance can lead to increased drift hazards.

4. **Effective Use of Additives**

Incorporate recommended additives according to label guidelines to maximize effectiveness and minimize drift hazards.

5. **Nozzle Selection for Drift Reduction**

Option for drift-reduction nozzles that produce larger droplets at low pressure. Choose nozzles with a higher flow rate to generate larger droplets and reduce the potential for drift.

6. **Strategic Boom Configuration**

Avoid high spray boom pressure, as it tends to result in finer droplet size. Enhance boom stability by using wide-angle nozzles and maintaining a low boom height. Operate the sprayer perpendicularly to prevent the boom from rising significantly above the target surface.

7. **Consideration of Wind Conditions**

Maintain a wind velocity within the range of 3 mph to 10 mph for lower drift hazard. Avoid spraying during temperature inversions that can trap and concentrate pesticide droplets close to the ground. Additionally, be mindful of high wind flow towards sensitive areas, such as crops, livestock, or water bodies. Establishing buffer zones is recommended to reduce the risk of pesticides reaching non-target areas.

CONCLUSIONS

The application of pesticides in the crop field while safeguarding human health risks, as well as non-targeted species in the environment, should be the emerging topic of research. Several factors including droplet size, flow rate, boom height, wind speed, and direction, foster the potential risks associated with pesticide drift. Addressing these issues necessitates a comprehensive approach that integrates precise application techniques, advanced technology, and stringent regulations to mitigate the adverse effects of pesticidal

drift on our health and the environment. It underscores the importance of sustainable agricultural practices that prioritize the protection of both human welfare and the delicate balance of our ecosystems.

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