



Environmental and Public Health Implications of Pesticide Residues: From Soil Contamination to Policy Interventions

Chinwe Onwudiegwu¹, Godgift Nabebe², Sylvester Chibueze Izah^{*3}

¹African Institute for Science Policy and Innovation, Faculty of Technology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

²Department of Biological Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

³Department of Microbiology, Faculty of Science, Bayelsa Medical University, Yenagoa, Bayelsa state, Nigeria.

ARTICLE INFO

Article No.: 120424187

Type: Research

Full text: [PDF](#), [PHP](#), [EPUB](#), [MP3](#)

DOI: [10.15580/gjbs.2025.1.120424187](https://doi.org/10.15580/gjbs.2025.1.120424187)

Accepted: 10/12/2024

Published: 13/01/2025

***Corresponding Author**

Sylvester Chibueze Izah

E-mail: chivestizah@gmail.com

Keywords: Pesticide residues, soil contamination, sustainable agriculture, public health, Integrated Pest Management, biodiversity loss, policy interventions

ABSTRACT

The extensive use of pesticides in modern agriculture has sparked serious concerns regarding environmental and public health, primarily due to the accumulation of pesticide residues in soil, water, and food. This paper examines the ecological and public health ramifications of these residues, highlighting the urgent need for sustainable agricultural practices, targeted public health initiatives, and policy reforms aimed at reducing the risks posed by pesticide exposure. The paper found that soil contamination from pesticide residues disrupts microbial ecosystems, compromises soil health, and leads to water pollution, ultimately contributing to biodiversity loss. Pesticide exposure, whether through direct contact or contaminated food, poses significant risks to farmworkers and consumers. Public health strategies such as Integrated Pest Management (IPM) and biological control methods offer sustainable alternatives that help reduce dependency on chemical pesticides. Adopting organic farming methods, enhancing public knowledge of the safe use of pesticides, and providing comprehensive education on related risks are key strategies for reducing exposure and ensuring public health protection. Collaboration among stakeholders, including policymakers, farmers, industry leaders, and consumers, is essential for building a safer and more sustainable agricultural system. Additionally, bridging research gaps—particularly those related to the long-term health effects of pesticide exposure and the development of safer alternatives—is crucial for guiding informed policy decisions. As the global demand for safer food continues to increase, cohesive and strategic efforts are imperative to establish a resilient food production system that emphasizes environmental sustainability and human health. Policymakers must prioritize the creation and enforcement of robust regulations while fostering incentives for sustainable agricultural practices. Such measures are essential to safeguard public health and preserve environmental integrity, ensuring that food systems can meet present and future challenges effectively.

1. INTRODUCTION

The use of pesticides in modern agriculture is a multifaceted issue involving the need to increase agricultural productivity, the environmental impact of pesticide residues, and the public health risks linked to exposure. The growing dependence on pesticides in modern agriculture is undoubtedly due to the escalating global demand for food, driven by population growth and shifting dietary preferences. Pesticides play an essential role in managing pests and diseases that threaten crop yields, thereby contributing to food security and economic stability for farmers (Keo, 2022). The growing reliance on chemical inputs in agriculture has raised significant concerns about the persistence of pesticide residues in the environment (Inyang et al., 2020, 2019a, b, 2018), especially in soil and water systems, where they can have harmful effects on ecosystems and human health (Sharma et al., 2019). The challenge lies in finding a balance between the benefits of pesticide use and the need to minimize its negative impacts on the environment and public health. Balancing the benefits of pesticide use with its potential adverse effects on the environment and public health is a critical challenge in modern agriculture.

While pesticides are indispensable for managing pests and ensuring food security, their persistence in soil and water systems is an issue of growing concern. Studies have shown that many pesticides remain in the environment long after their application, accumulating in both soil and aquatic ecosystems (Keo, 2022). This can have significant ecological consequences, including adverse impacts on life, particularly fish populations, which are exposed to pesticide residues through contaminated water bodies (Inyang et al., 2016a, b, c, d, e; Aghoghovwia and Izah, 2018; Aghoghovwia et al., 2019). One of the most concerning effects of pesticide persistence is its impact on soil health. Pesticides can disrupt microbial communities in the soil, which play a crucial role in maintaining soil fertility and ecosystem functions, such as nutrient cycling and organic matter decomposition. The alteration of these microbial communities due to pesticide exposure can lead to reduced soil biodiversity, impairing vital processes that sustain plant growth and agricultural productivity (Sharma et al., 2019). Furthermore, this disruption can make soils more vulnerable to erosion, reduce crop yields, and hinder long-term sustainability in agricultural practices (Sharma et al., 2019). Pesticide runoff into water bodies has been shown to cause water pollution, negatively affecting aquatic ecosystems and the organisms that depend on them. The contamination of water resources also poses significant risks to human health, polluted water, and marine life (Keo, 2022; Sharma et al., 2019). As a result, addressing pesticide residues in the environment is essential for preserving agricultural productivity and protecting ecological integrity.

The public health risks associated with pesticide exposure are particularly concerning for vulnerable populations, such as farmworkers, children, and pregnant women (Sawyer et al., 2024). Farmworkers face the highest risk of direct pesticide exposure, which can lead to immediate health effects and long-term issues, including respiratory diseases and neurological disorders (Sharma et al., 2019). Consumers are also at risk due to the potential presence of pesticide residues in food, raising concerns about food safety and the possible health consequences of chronic exposure (Sharma et al., 2019). Vulnerable groups, such as children and pregnant women, are especially at risk which can disrupt development and result in negative health consequences (Sharma et al., 2019). The long-term health risks associated with pesticide exposure highlight the importance of implementing strict regulations and monitoring pesticide residues in food and the environment to protect public health.

Integrated Pest Management (IPM) has emerged as a sustainable alternative to traditional pesticide use, prioritizing ecological balance and reducing chemical inputs. IPM incorporates various strategies, such as biological control, cultural practices, and resistant crop varieties, to manage pests while minimizing environmental impact (Sharma, 2023; Kaur & Kaur, 2020). Among these, biological control has gained prominence as an effective means of reducing dependence on chemical pesticides (Seiyaboh et al., 2020a, b; Izah, 2019; Izah et al., 2019; Youkparigha and Izah, 2019; Izah and Youkparigha, 2019). By using natural predators and parasitoids, farmers can sustainably manage pest populations and promote biodiversity within agricultural systems (Lenteren et al., 2017; Dey et al., 2021). Adopting organic farming practices offers a promising way to reduce pesticide use, although obstacles such as market access and certification requirements remain (Rodrigues et al., 2022). Case studies demonstrating the success of IPM and organic farming reveal the potential of these approaches to enhance agricultural sustainability while maintaining high levels of productivity (Wochner et al., 2021).

This paper addresses the environmental and public health risks linked to pesticide residues, particularly their persistence in soil and water, and their impact on biodiversity and human health. It underscores the importance of sustainable agricultural practices like IPM and organic farming to reduce pesticide dependence and minimize exposure risks. Additionally, it advocates for stronger policy measures, enhanced public health education, and collaborative initiatives to foster a more resilient and health-conscious agricultural system.

2. PESTICIDE RESIDUES AND ENVIRONMENTAL HEALTH

Pesticide residues pose substantial risks to environmental health, primarily by contaminating soil,

polluting water systems, and threatening biodiversity (Figure 1). The complex interplay of these factors demands a thorough understanding of how pesticide residues influence soil microbiota, water quality, and overall ecosystem health.

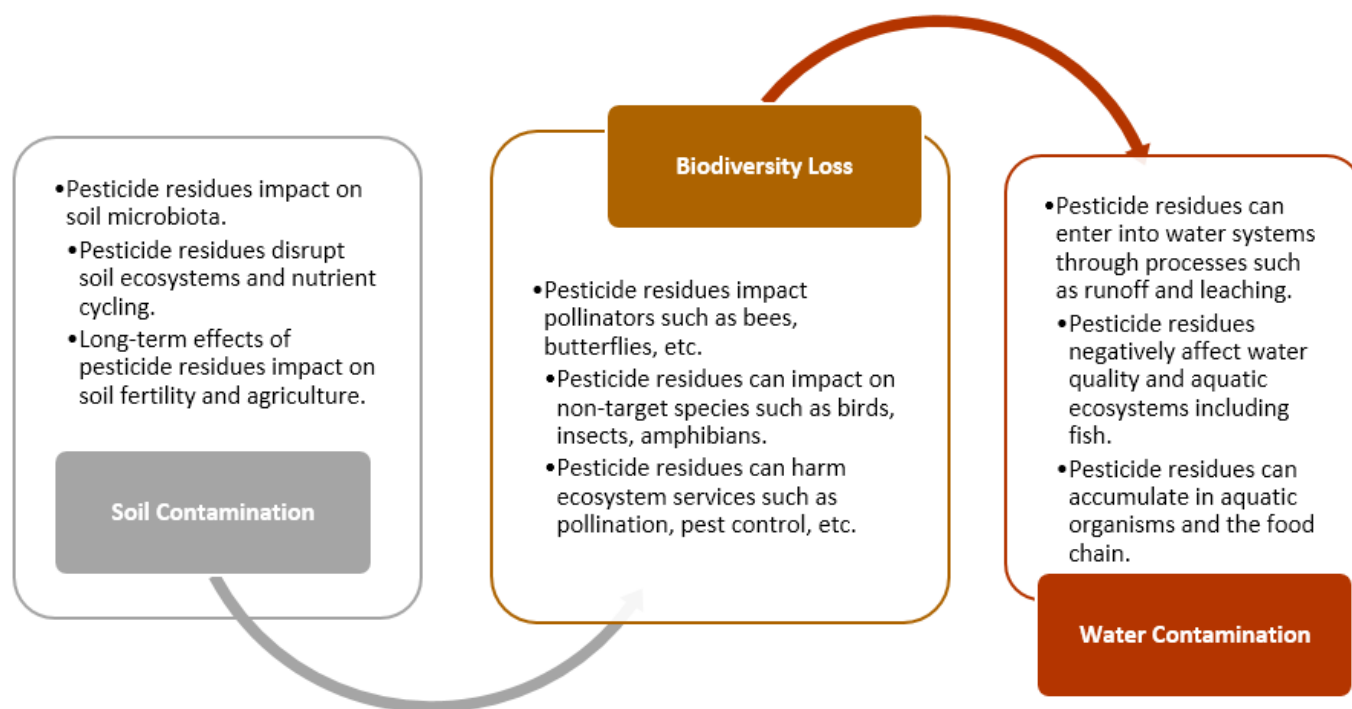


Figure 1: Environmental Impacts of Pesticide Residues

2.1 Soil Contamination

Pesticide residues in soil can significantly disrupt the delicate balance of soil microbiota, which is crucial for nutrient cycling and maintaining soil fertility. Excessive use of pesticide can reduce microbial diversity and functionality, essential for sustaining soil health and fertility. Research shows pesticide exposure can disrupt soil microbial communities, diminishing beneficial microorganisms, nutrient cycling, and organic matter decomposition (Sharma et al., 2023; Sharma et al., 2019). Such disruptions can trigger cascading effects on soil ecosystems, with reduced microbial diversity impairing the soil's capacity to support plant growth and ultimately diminishing agricultural productivity (Bernardes et al., 2015).

Long-term exposure to pesticide residues can result in persistent soil contamination, affecting microbial communities and posing risks to higher trophic levels, including plants and animals that rely on healthy soil ecosystems (Pathak et al., 2022). Pesticide accumulation in soil can result in bioaccumulation within the food chain, harming non-target species. This process can lead to toxic effects in organisms that feed on contaminated plants or soil species, jeopardizing biodiversity and disrupting ecosystem balance (Sharma et al., 2019).

2.2 Water Contamination

Pesticide residues can infiltrate water systems through pathways such as runoff and leaching. Agricultural activities often contribute to pesticide runoff into nearby water bodies, where these chemicals can accumulate and persist, threatening aquatic ecosystems (Sharma, 2021). This contamination degrades water quality and causes harmful effects on marine organisms. Researchers have demonstrated that pesticide residues can interfere with the endocrine systems of aquatic wildlife, causing reproductive and developmental problems (Jayaraj et al., 2023). The effects of pesticide contamination extend beyond individual species, disrupting entire marine ecosystems. Aquatic organisms, including fish and invertebrates, can accumulate toxic compounds through the food chain, resulting in population declines and reduced biodiversity (Tavaliere et al., 2020). Additionally, pesticides in water systems can compromise drinking water quality, posing health risks to humans who consume contaminated water (Centner & Eberhart, 2014). The presence of pesticide residues in water systems underscores the need for effective management practices to reduce contamination and safeguard aquatic life.

2.3 Biodiversity Loss

The impact of pesticides on biodiversity is especially evident in their effects on pollinators like bees and butterflies. Pesticides, particularly neonicotinoids, have been shown to impair cognitive functions in bees, affecting their foraging behavior and memory (Jemal et al., 2023; Demarco et al., 2022). This impairment reduces pollination efficiency, which is essential for many flowering plants and the overall health of ecosystems. The decline in pollinator populations due to pesticide exposure poses a significant threat to ecosystem services, including crop production and natural plant communities (Jemal et al., 2023). Furthermore, pesticides indiscriminately affect target and non-target species, causing unintended harm to birds, amphibians, and beneficial insects (Almeida et al., 2021; Glinski et al., 2018). The decline of these species disrupts ecological processes such as pest control and nutrient cycling, further exacerbating the challenges (Bernardes et al., 2015). Loss of biodiversity due to pesticide use threatens ecosystem stability and undermines critical services, such as food security and climate regulation (Sharma et al., 2019).

3. POLICY AND PUBLIC HEALTH INTERVENTIONS

The intersection of policy and public health interventions to reduce pesticide use in agriculture is a critical area of focus, particularly concerning Integrated Pest Management (IPM) strategies. IPM is widely recognized as a sustainable approach that incorporates a range of pest control methods, including biological controls, cultural practices, and the selective use of pesticides. This integrated approach minimizes environmental impacts while ensuring agricultural productivity (López-Antia et al., 2016). The European Directive 128/2009/EC underscores the importance of reducing pesticide use and promotes alternatives wherever feasible, ensuring that economic justification governs pesticide application decisions (López-Antia et al., 2016). This directive supports sustainable agriculture's broader goals, which aim to balance agricultural productivity with ecological integrity.

Table 1 provides an overview of the implications associated with reducing pesticide use in agriculture, public health campaigns, and alternative farming practices.

Table 1: Overview of the implications related to reducing pesticide use in agriculture, public health campaigns, and promoting alternative farming practices

Category	Implications
Reducing Pesticide Use in Agriculture	- Enhanced sustainability through the implementation of Integrated Pest Management (IPM). - Improved ecosystem health via biological controls and precision agriculture - Increased soil fertility and biodiversity through organic and sustainable practices
Public Health Campaigns	- Increased awareness of risks associated with pesticide use leading to informed consumer choices - Reduced consumer exposure through safe food handling practices (washing, cooking, peeling) - Improved farmer safety through education on pesticide application methods
Promotion of Alternative Farming Practices	- Greater adoption of organic farming reducing chemical dependence - Healthier ecosystems fostered by agroecology and permaculture - Financial incentives motivating farmers to transition to sustainable practices

Promoting biological controls and precision agriculture is a fundamental aspect of the Integrated Pest Management (IPM) framework. Biological control utilizes natural predators or parasites to manage pest populations, significantly reducing dependence on chemical pesticides (Furlan & Kreutzweiser, 2014). In contrast, precision agriculture leverages technology to monitor and manage field variability, enabling targeted pesticide application that minimizes waste and reduces environmental contamination (Furlan & Kreutzweiser, 2014). Integrating these methods improves pest management efficiency while promoting sustainable agricultural practices by minimizing chemical inputs and reducing their risks to human health and the environment (Tudi et al., 2022). Transitioning to organic and sustainable farming practices is another critical element in reducing pesticide use. Organic farming avoids synthetic pesticides and fertilizers, focusing instead on natural alternatives and practices that improve soil health and support biodiversity (Ssemugabo et al., 2023). The benefits of organic farming extend beyond reducing pesticide reliance; they include enhanced soil quality,

improved ecosystem services, and potentially healthier food products (Ssemugabo et al., 2023). However, transitioning to organic farming requires substantial support in the form of education, resources, and financial incentives to encourage farmer-adoption of these practices (Piñeiro et al., 2020). Research suggests that farmers who perceive economic benefits and have access to adequate training are more likely to adopt organic farming methods (Piñeiro et al., 2020). Public health campaigns play a vital role in raising awareness of the risks associated with pesticide residues in food and the environment. These campaigns can inform consumers about the potential health risks linked to pesticide residues, which have been associated with chronic health issues, including cancer and endocrine disruption (Wanwimolruk et al., 2015). By educating the public on the importance of washing, cooking, and peeling fruits and vegetables, these campaigns can help reduce consumer exposure to pesticide residues (Ssemugabo et al., 2023). Furthermore, such campaigns can encourage the consumption of organic produce, which typically contains lower pesticide residues, thereby contributing to improved public health outcomes (Winter, 2015).

Education on safe pesticide application is crucial for mitigating the risks associated with pesticide use in agriculture. Training programs that emphasize adherence to safety protocols and the use of personal protective equipment (PPE) can significantly reduce pesticide exposure among agricultural workers (Lari et al., 2023). Research has demonstrated that proper training, combined with the consistent use of PPE, can minimize the toxicological effects of pesticides, thereby safeguarding the health of farmworkers and surrounding communities (Lari et al., 2023). Policymakers should prioritize the development of educational resources and training programs to equip farmers with the necessary knowledge and tools for safe pesticide application (Tudi et al., 2022).

Promoting alternative farming practices is essential for reducing pesticide dependence and enhancing agricultural sustainability. Agroecology and permaculture are two approaches that emphasize ecological principles and biodiversity, promoting healthier ecosystems and reducing reliance on chemical inputs (Ssemugabo et al., 2023). These practices contribute to improved soil health, increased resilience to pests and diseases, and greater food security (Ssemugabo et al., 2023). Incentives to encourage farmers to adopt these sustainable practices are critical, as financial support can help alleviate the economic challenges of transitioning to alternative methods (Piñeiro et al., 2020). Research shows that both compulsory and voluntary incentive programs can be effective in encouraging sustainable practices, though voluntary programs may face challenges due to uncertainty in farmer decision-making (Piñeiro et al., 2020).

The benefits of organic farming extend beyond environmental considerations, encompassing significant

economic and social dimensions. Organic agriculture often allows farmers to command premium prices for their products, thereby improving their livelihoods (Piñeiro et al., 2020). Additionally, organic practices contribute to healthier food systems by reducing pesticide exposure, which can lead to better public health outcomes (Ssemugabo et al., 2023). However, transitioning to organic farming requires a concerted effort from policymakers, agricultural organizations, and the scientific community to providing farmers with the necessary support, training, and resources (Piñeiro et al., 2020).

Incentives to encourage the adoption of sustainable agricultural practices can take various forms, including financial subsidies, technical assistance, and improved market access for organic products (Piñeiro et al., 2020). Research has shown that economic incentives can significantly influence farmers' decisions to adopt conservation practices by mitigating the financial risks associated with transitioning to new methods (Gladkikh et al., 2020). Policymakers should consider implementing comprehensive incentive programs that address the unique challenges faced by farmers in different regions, ensuring accessibility and effectiveness in promoting sustainable practices (Piñeiro et al., 2020).

Consumer awareness and perceptions of health risks from pesticide residues in food are critical factors driving public health interventions. Studies indicate that increasing consumer concern about pesticide residues in fruits and vegetables may reduce the consumption of these health-promoting foods (Winter, 2015). Public health campaigns aimed at educating consumers about the risks of pesticide residues and promoting strategies to minimize exposure can help address these concerns (Ssemugabo et al., 2023). Furthermore, providing information about the benefits of organic options can encourage consumers to make healthier dietary choices and support organic agriculture (Winter, 2015).

The importance of agroecology and permaculture in fostering healthier ecosystems cannot be overstated. These practices prioritize biodiversity, soil health, and ecological balance, all of which are essential for sustainable food production (Ssemugabo et al., 2023). By promoting a more resilient agricultural system, agroecology and permaculture reduce the reliance on chemical inputs, thus minimizing the risks associated with pesticide use (Ssemugabo et al., 2023). Policymakers should support research and education initiatives that promote these practices, as they offer viable alternatives to conventional agriculture while aligning with public health goals (Ssemugabo et al., 2023).

4. COMMUNITY AND STAKEHOLDER ENGAGEMENT

The collaboration between consumers, farmers, and industries is vital in ensuring safer food production, particularly in the context of pesticide use and

contamination (**Table 2**). Consumers play a pivotal role in shaping market dynamics through their purchasing decisions, which can encourage producers to adopt safer and more sustainable practices. For instance, the growing demand for organic produce has prompted many farmers to reduce pesticide use, decreasing the prevalence of pesticide residues in food products (Kazimierczak et al., 2022; Barański et al., 2014). This underscores the importance of consumer awareness and education in advancing food safety, as informed choices can drive the adoption of agricultural practices that prioritize environmental sustainability and public health (Franc-Dąbrowska et al., 2021; Ssemugabo et al., 2023)

Table 2: Possible Actions and Consequences of Stakeholder Engagement in Pesticide Management

Category	Actions	Implications
Role of Consumers, Farmers, and Industries	Collaboration between consumers and producers for safer food production.	Improved food safety and quality.
	Industries play a critical role in mitigating pesticide contamination by promoting alternatives	Decreased pesticide use and enhanced sustainability in agriculture.
Educational Programmes	Training programs for farmers on safe pesticide use and alternatives.	Increased awareness and safer practices among farmers.
	Consumer education on food preparation to reduce pesticide residue intake.	Reduced pesticide exposure for consumers.
Advocacy for Stricter Policies	The role of civil society in advocating stricter pesticide regulations.	Enhanced regulatory framework and improved environmental health.
	Importance of transparency in food labeling and pesticide residue testing.	Informed consumer choices and greater accountability in food safety.

Farmers play a critical role in food production and directly influence pesticide residue levels in agricultural products. By adopting Integrated Pest Management (IPM) practices, they can significantly reduce dependence on chemical pesticides, thereby lowering the risk of contamination in food (Perez et al., 2016; Romanazzi et

al., 2022). Providing educational and training programs for farmers is essential, as these initiatives equip them with knowledge on safe pesticide application techniques and the benefits of alternative pest control methods. Such training fosters improved agricultural practices that safeguard consumer health while promoting the sustainability of farming operations (Sekabojja et al., 2021; Wanwimolruk et al., 2019).

Industries are also vital in reducing pesticide contamination and promoting safer alternatives. They can invest in research and development of biopesticides and other sustainable agricultural inputs less harmful to human health and the environment (Romanazzi et al., 2022; Qiu & Zhi, 2019). Furthermore, industries can collaborate with farmers to implement better pesticide application practices and ensure compliance with safety standards. For example, establishing monitoring programs to track pesticide residues in food products can help identify areas for improvement and promote transparency in the food supply chain (Jallow et al., 2017; Sapbamrer & Chittrakul, 2022). This collaboration can lead to reduced pesticide residues and increased consumer trust in food safety.

Educational programs targeting farmers and consumers are critical for fostering a safety culture in food production and consumption. For farmers, training on the safe use of pesticides and the importance of adhering to pre-harvest intervals can significantly reduce the likelihood of pesticide residues in food products (Wanwimolruk et al., 2015; Wanwimolruk et al., 2022). Educating consumers about effective food preparation techniques, such as washing, peeling, and cooking, can minimize pesticide exposure (Mekonen et al., 2019; Mekonen et al., 2015). Research has demonstrated that these household practices can substantially reduce pesticide residues, thereby enhancing food safety for consumers (Rasolonjatovo et al., 2017; Noh et al., 2019).

Consumer education is crucial in raising awareness about the health risks associated with pesticide residues. Programs that inform consumers about the presence of pesticides in food and the importance of selecting low-residue options can empower them to make safer choices (Ssemugabo et al., 2023; Wang et al., 2022). For instance, studies have shown that consumers are willing to pay a premium for low-residue vegetables, indicating a strong preference for safer food options (Wang et al., 2022). This willingness to invest in food safety underscores the need for effective communication strategies highlighting the benefits of choosing products with lower pesticide residues. Advocacy for stricter pesticide regulations is another critical aspect of ensuring food safety. Civil society organizations play a significant role in this advocacy by raising awareness about the risks associated with pesticide use and pushing for more stringent regulations (Sekabojja et al., 2021; Simoglou, 2023). Their efforts can lead to policies limiting pesticide usage and promoting safer agricultural practices. Moreover, transparency in food labeling and pesticide residue testing is essential for building consumer trust

and ensuring informed decision-making (Franc-Dąbrowska et al., 2021; Sapbamrer & Chittrakul, 2022). Consumers are more likely to support regulations prioritizing their health and safety when they access precise and reliable food information.

The importance of transparency in food labeling cannot be overstated. Clear labeling of pesticide residues, along with certifications for low-residue products, empowers consumers to make informed choices (Simoglou, 2023; Wang et al., 2022). Additionally, regular testing of food products for pesticide residues provides consumers with confidence in the safety of their food. This transparency strengthens the consumer's trust and encourages producers to comply with safety standards, knowing that their products will be closely scrutinized (Qiu & Zhi, 2019; Ssemugabo et al., 2023). Establishing robust monitoring systems for pesticide residues further deters non-compliance and promotes accountability throughout the food supply chain.

5. RESEARCH GAPS AND FUTURE DIRECTIONS

Exploring research gaps and future directions in pesticide exposure and its health implications is critical for public health and agricultural sustainability (Table 3). One of the most pressing needs is the establishment of long-term epidemiological studies that can elucidate the chronic health effects of low-dose pesticide exposure. Current literature indicates that acute pesticide toxicity is well-documented, but chronic effects remain inadequately understood, particularly at low exposure levels. Studies have shown that chronic exposure to pesticides can lead to neuropsychological impacts, including anxiety and depression, particularly among agricultural workers (N et al., 2019; Ramírez-Santana et al., 2014). This knowledge gap underscores the need for comprehensive longitudinal studies that track health outcomes over extended periods, offering more accurate insights into the long-term effects of pesticide exposure.

Table 3: Research gaps and future directions in pesticide safety and regulation

Research Gap	Future Direction
Need for Long-Term Epidemiological Studies	Conduct studies on chronic health effects of low-dose pesticide exposure; focus on vulnerable populations and regional disparities.
Innovations in Safer Pesticides	Develop biopesticides and less toxic alternatives; implement technologies to reduce pesticide application and drift.
Global Coordination in Monitoring and Regulation	Strengthen international cooperation on pesticide residue standards; harmonize Maximum Residue Levels across borders.

Moreover, there is a pressing need for research on vulnerable populations and regional disparities in pesticide exposure and health outcomes. Demographics such as children, pregnant women, and low-income agricultural workers may face heightened risks due to socioeconomic factors and limited access to protective measures (Ren & Jiang, 2022; Aschebrook-Kilfoy et al., 2014). For instance, pesticide-related health issues in rural areas of developing countries are often compounded by limited healthcare access and insufficient regulatory frameworks (Gangemi et al., 2016). Future research should prioritize these vulnerable groups, using targeted epidemiological approaches to assess specific risks and inform tailored interventions.

In addition to epidemiological studies, there is a pressing need for innovations in safer pesticide formulations. Developing biopesticides and less toxic alternatives is crucial in mitigating the health risks associated with conventional pesticides. Biopesticides, derived from natural materials, have shown promise in reducing environmental and health impacts while maintaining agricultural productivity (Sun et al., 2019; Elhalwagy & Hussein, 2019). Furthermore, research into the efficacy and safety of these alternatives must be expanded to ensure they can effectively replace more harmful chemicals without compromising crop yields. This shift addresses health concerns and aligns with sustainable agricultural practices that consumers and regulatory bodies increasingly demand.

Technological advancements also play a vital role in reducing pesticide application and drift. Precision agriculture technologies, including drone applications and sensor-based systems, can optimize pesticide use, minimizing unnecessary exposure to agricultural workers and nearby communities (Srilesin, 2022; Martín Reina et al., 2017). These technologies can facilitate targeted applications that reduce the volume of pesticides used while maintaining effectiveness against pests. Future research should focus on integrating these technologies into standard agricultural practices and assessing their impact on health outcomes and environmental sustainability. Global coordination in monitoring and regulating pesticide use is another critical area that requires attention. Strengthening international cooperation on pesticide residue standards is essential to maintain food safety across borders. Current discrepancies in Maximum Residue Levels (MRLs) can lead to trade barriers and public health risks, as consumers may be exposed to harmful levels of pesticide residues in food products (Łozowicka et al., 2015; Kaewboonchoo et al., 2015). Collaborative efforts among countries to harmonize MRLs can enhance food safety and consumer confidence while promoting fair trade practices.

Furthermore, robust monitoring systems are essential to track pesticide use and its health impacts on a global scale. These systems should integrate data from diverse stakeholders, including farmers, agricultural cooperatives, and health organizations, to create a

comprehensive picture of pesticide exposure and its effects (Gong et al., 2023; Alavanja et al., 2013). By promoting a multi-stakeholder approach, countries can gain a deeper understanding of pesticide use patterns and their implications, enabling the development of more effective regulatory frameworks that safeguard public health.

There is an urgent need for strengthened occupational health and safety regulations for agricultural workers. Many workers are exposed to significant risks due to inadequate protective measures and insufficient training on the safe use of pesticides (Karunaratne et al., 2019; Tago et al., 2014). Research has shown that enhancing safety protocols and educating workers about the risks of pesticide exposure can greatly reduce negative health impacts (Lahr et al., 2016). Future efforts should prioritize development of comprehensive training programs that provide workers with the essential knowledge and resources to minimize exposure and safeguard their well-being.

In addition, the role of government in regulating pesticide use and ensuring safe agricultural practices is crucial. Effective governance can improve compliance with safety standards and reduce pesticide misuse (Sapbamrer et al., 2023; Li et al., 2021). Policymakers must prioritize the establishment of clear regulations that restrict the use of highly hazardous pesticides, especially in vulnerable regions where safe handling practices may be difficult to implement. Moreover, introducing incentive programs for farmers who adopt safer pest management practices can encourage the transition to sustainable agriculture. Research on the economic implications of pesticide regulation is also vital. Understanding the cost-benefit dynamics of pesticide use can help policymakers recognize the long-term financial advantages of investing in safer alternatives and practices (Alavanja & Bonner, 2012; Yang et al., 2019). Studies show that the long-term health costs linked to pesticide exposure often exceed the immediate economic benefits, underscoring the need for a shift toward more sustainable agricultural practices (Damalas & Koutroubas, 2016). Future research should focus on quantifying these economic impacts to inform the development of policies that prioritize sustainability.

Finally, the psychological and social aspects of pesticide exposure, particularly in rural communities, deserve more attention. The mental health consequences of pesticide exposure, such as increased anxiety and depression among agricultural workers, are critical but largely unexplored.

6. CONCLUSION

Pesticide residues pose significant risks to environmental and public health, including soil contamination, water degradation, biodiversity loss, and human exposure. Addressing these challenges demands a coordinated effort among stakeholders, focusing on developing sustainable agricultural practices such as Integrated Pest Management (IPM), biological controls,

and organic farming. Strengthening regulatory frameworks and advancing research into safer pesticides are critical to mitigating these risks. Public health interventions, including education campaigns and improved food labeling transparency, can empower consumers and reduce exposure, especially among vulnerable populations. Promoting community-driven change and fostering collaboration between farmers, industries, and consumers will support the transition to safer food production systems. By prioritizing these actions, we can create a healthier, more resilient agricultural system that safeguards human well-being and environmental integrity.

REFERENCES

- Aghoghovwia, O. A., & Izah, S. C. (2018). Acute toxicity of paraquat dichloride-based herbicide against *Heterobranchus bidorsalis* fingerlings. *EC Agriculture*, 4(2), 128–132.
- Aghoghovwia, O. A., Morgan, P. I., & Izah, S. C. (2019). Behavioral response and acute toxicity of fingerlings of African cat fish, *Clarias gariepinus*, exposed to paraquat dichloride. *Journal of Plant and Animal Ecology*, 1(3), 13–20.
- Alavanja, M. C., & Bonner, M. R. (2012). Occupational pesticide exposures and cancer risk: a review. *Journal of Toxicology and Environmental Health Part B*, 15(4), 238–263. <https://doi.org/10.1080/10937404.2012.632358>
- Alavanja, M. C., Ross, M. K., & Bonner, M. R. (2013). Increased cancer burden among pesticide applicators and others due to pesticide exposure. *CA: A Cancer Journal for Clinicians*, 63(2), 120–142. <https://doi.org/10.3322/caac.21170>
- Almeida, R. A., Lemmens, P., De Meester, L., & Brans, K. I. (2021). Differential local genetic adaptation to pesticide use in organic and conventional agriculture in an aquatic non-target species. *Proceedings of the Royal Society B*, 288(1963), 20211903. <https://doi.org/10.1098/rspb.2021.1903>
- Aschebrook-Kilfoy, B., Ward, M. H., Della Valle, C. T., & Friesen, M. C. (2014). Occupation and thyroid cancer. *Occupational and Environmental Medicine*, 71(5), 366–380. <https://doi.org/10.1136/oemed-2013-10192>
- Barański, M., Średnicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G.B., Benbrook, C., Biavati, B., Markellou, E., Giotis, C. and Gromadzka-Ostrowska, J., 2014. Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. *British Journal of Nutrition*, 112(5), 794–811. <https://doi.org/10.1017/s0007114514001366>
- Bernardes, M. F. F., Pazin, M., Pereira, L. C., & Dorta, D. J. (2015). Impact of pesticides on environmental and human health. *Toxicology studies-cells, drugs*

- and environment, 195-233. <https://doi.org/10.5772/59710>
- Centner, T., & Eberhart, N. (2014). Requiring pollutant discharge permits for pesticide applications that deposit residues in surface waters. *International Journal of Environmental Research and Public Health*, 11(5), 4978-4990. <https://doi.org/10.3390/ijerph110504978>
- Cha, E. S., Chang, S. S., Gunnell, D., Eddleston, M., Khang, Y. H., & Lee, W. J. (2016). Impact of paraquat regulation on suicide in South Korea. *International journal of epidemiology*, 45(2), 470-479. <https://doi.org/10.1093/ije/dyv304>
- Damalas, C. A., & Koutroubas, S. D. (2016). Farmers' exposure to pesticides: toxicity types and ways of prevention. *Toxics*, 4(1), 1. <https://doi.org/10.3390/toxics4010001>
- Demarco, M., Rosa Gasparin, B., Vizzotto, A., Alves, H., Restello, R. M., Luis Cansian, R., & Aparecida Mielniczki-Pereira, A. (2022). Comparative study of pesticides effects on artemia salina (leach, 1819) survival and morphology. *Acta Scientiarum Biological Sciences*, 44, e61715. <https://doi.org/10.4025/actasciobiolsci.v44i1.61715>
- Dey, U., Sarkar, S., Malik, M., Sehgal, M., Debbarma, P., & Chander, S. (2021). A promising sustainable pest management technology: microbial bio-control agent. *Microbiology Research Journal International*, 23-26. <https://doi.org/10.9734/mrji/2021/v31i1230361>
- Elhalwagy, M. E., & Hussein, R. H. (2019). Chronic impact of contaminated grapes with pesticides residues on some biological activities in albino rats. *Int. J. Adv. Res. Biol. Sci*, 6(2), 1-12. <https://doi.org/10.22192/ijarbs.2019.06.02.001>
- Franc-Dąbrowska, J., Ozimek, I., Pomianek, I., & Rakowska, J. (2021). Young consumers' perception of food safety and their trust in official food control agencies. *British Food Journal*, 123(8), 2693-2704. <https://doi.org/10.1108/bfj-11-2020-0992>
- Furlan, L., & Kreutzweiser, D. (2014). Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry. *Environmental Science and Pollution Research*, 22(1), 135-147. <https://doi.org/10.1007/s11356-014-3628-7>
- Gangemi, S., Gofita, E., Costa, C., Teodoro, M., Briguglio, G., Nikitovic, D., Tzanakakis, G., Tsatsakis, A.M., Wilks, M.F., Spandidos, D.A. and Fenga, C., (2016). Occupational and environmental exposure to pesticides and cytokine pathways in chronic diseases (review). *International Journal of Molecular Medicine*, 38(4), 1012-1020. <https://doi.org/10.3892/ijmm.2016.2728>
- Gladkikh, T. M., Collazo, J. A., Torres-Abreu, A., Reyes, A. M., & Molina, M. (2020). Factors that influence participation of puerto rican coffee farmers in conservation programs. *Conservation Science and Practice*, 2(4). <https://doi.org/10.1111/csp2.172>
- Glinski, D. A., Henderson, W. M., Van Meter, R. J., & Purucker, S. T. (2018). Using in vitro derived enzymatic reaction rates of metabolism to inform pesticide body burdens in amphibians. *Toxicology Letters*, 288, 9-16. <https://doi.org/10.1016/j.toxlet.2018.02.016>
- Gong, J., Du, H., & Sun, Y. (2023). Collaboration among governments, pesticide operators, and farmers in regulating pesticide operations for agricultural product safety. *Agriculture*, 13(12), 2288. <https://doi.org/10.3390/agriculture13122288>
- Inyang, I. R., Tegu, D. U., & Izah, S. C. (2020). Electro-metabolic aberrations in New Zealand rabbit (*Oryctolagus cuniculus*) induced by chlorpyrifos. *Journal of Biochemical Technology*, 11(1), 45-48.
- Inyang, I. R., Izah, S. C., & Suobo, K. (2019a). Effect of phenol on the kidney and liver biochemical and metabolites of *Clarias gariepinus*. *Noble International Journal of Scientific Research*, 3(3), 33-40.
- Inyang, I. R., Akparata, O. J., & Izah, S. C. (2019b). Evaluation of some blood cells and metabolites of *Heterobranchus bidorsalis* (Hybrid) exposed to sublethal concentrations of sarosate. *International Journal of Research in Environmental Science*, 5(1), 17-23.
- Inyang, I. R., Ayogoi, T. A., & Izah, S. C. (2018). Effect of lindane on some selected electrolytes and metabolites of *Clarias gariepinus* (juveniles). *Advances in Plants and Agricultural Research*, 8(5), 394-397.
- Inyang, I. R., Okon, N. C., & Izah, S. C. (2016a). Effect of glyphosate on some enzymes and electrolytes in *Heterobranchus bidorsalis* (a common African catfish). *Biotechnological Research*, 2(4), 161-165.
- Inyang, I. R., Akio, K., & Izah, S. C. (2016b). Effect of dimethoate on lactate dehydrogenase, creatinine kinase, and amylase in *Clarias lazera*. *Biotechnological Research*, 2(4), 155-160.
- Inyang, I. R., Thomas, S., & Izah, S. C. (2016c). Activities of electrolytes in kidney and liver of *Clarias gariepinus* exposed to fluazifop-p-butyl. *Journal of Biotechnology Research*, 2(9), 68-72.
- Inyang, I. R., Thomas, S., & Izah, S. C. (2016d). Evaluation of activities of transferases and phosphatase in plasma and organs of *Clarias gariepinus* exposed to fluazifop-p-butyl. *Journal of Environmental Treatment Techniques*, 4(3), 94-97.
- Inyang, I. R., Kenobi, A., & Izah, S. C. (2016e). Effect of dimethoate on some selected metabolites in the brain, liver, and muscle of *Clarias lazera*. *Sky Journal of Biochemistry Research*, 5(4), 63-68.
- Izah, S. C. (2019). Activities of crude, acetone, and ethanolic extracts of *Capsicum frutescens* var. minima fruit against larvae of *Anopheles gambiae*. *Journal of Environmental Treatment Techniques*, 7(2), 196-200.

- Izah, S. C., & Youkparigha, F. O. (2019). Larvicidal activity of fresh aqueous and ethanolic extracts of *Cymbopogon citratus* (DC) Stapf on malaria vector, *Anopheles gambiae*. *BAOJ Biotech*, 5, 040.
- Izah, S. C., Chandel, S. S., Epidi, J. O., Venkatachalam, T., & Devaliya, R. (2019). Biocontrol of *Anopheles gambiae* larvae using fresh ripe and unripe fruit extracts of *Capsicum frutescens* var. *baccatum*. *International Journal of Green Pharmacy*, 13(4), 338-342.
- Jayaraj, J., Shibila, S., Ramaiah, M., Alahmadi, T.A., Alharbi, S.A., Mideen, P.K., Sakthiganesh, K. and Sivagnanam, A. (2023). Isolation and identification of bacteria from the agricultural soil samples to tolerate pesticides dimethoate, thiamethoxam and imidacloprid. *Environmental Research Communications*, 5(7), 075011. <https://doi.org/10.1088/2515-7620/ace68b>
- Jallow, M. F., Awadh, D. G., Albaho, M. S., Devi, V. Y., & Ahmad, N. (2017). Monitoring of pesticide residues in commonly used fruits and vegetables in Kuwait. *International journal of environmental research and public health*, 14(8), 833. <https://doi.org/10.3390/ijerph14080833>
- Jemal, T., Astatke, H., Terfe, A., & Mekonen, S. (2023). Effect of conventional and household water treatment technologies on the removal of pesticide residues in drinking water, Jimma town, Southwestern, Ethiopia. *PloS one*, 18(7), e0288086. <https://doi.org/10.1371/journal.pone.0288086>
- Kaewboonchoo, O., Kongtip, P., & Woskie, S. (2015). Occupational health and safety for agricultural workers in Thailand: gaps and recommendations, with a focus on pesticide use. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, 25(1), 102-120. <https://doi.org/10.1177/1048291115569028>
- Karunarathne, A., Gunnell, D., Konradsen, F., & Eddleston, M. (2020). How many premature deaths from pesticide suicide have occurred since the agricultural Green Revolution? *Clinical toxicology*, 58(4), 227-232. <https://doi.org/10.1080/15563650.2019.1662433>
- Kaur, T., & Kaur, M. (2020). *Integrated pest management: a paradigm for modern age*. IntechOpen. <https://doi.org/10.5772/intechopen.92283>
- Kazmierczak, R., Średnicka-Tober, D., Golba, J., Nowacka, A., Hołodyńska-Kulas, A., Kopczyńska, K., Góralska-Walczyk, R. and Gnusowski, B., (2022). Evaluation of pesticide residues occurrence in random samples of organic fruits and vegetables marketed in Poland. *Foods*, 11(13), 1963. <https://doi.org/10.3390/foods11131963>.
- Keo, S., Eang, K. E., Phat, C., Yoeun, S., Meak, L., Chhuon, K., & Massuel, S. (2022). Detection of Pesticide Residues in The Canal Irrigation System of The Upper Mekong Delta, Cambodia. *Indonesian Journal of Limnology*, 3(1), 10-17. <https://doi.org/10.51264/inajl.v3i1.24>
- Lahr, J., Buij, R., Katagira, F., & Van Der Valk, H. (2016). *Pesticides in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT): A scoping study of current and future use, associated risks and identification of actions for risk mitigation* (No. 2760). Wageningen Environmental Research. <https://doi.org/10.18174/394164>
- Lari, S., Yamagani, P., Pandiyan, A., Vanka, J., Naidu, M., Senthil Kumar, B., Jee, B. and Jonnalagadda, P.R., (2023). The impact of the use of personal-protective-equipment on the minimization of effects of exposure to pesticides among farm-workers in India. *Frontiers in Public Health*, 11. <https://doi.org/10.3389/fpubh.2023.1075448>
- van Lenteren, J. C., Bolckmans, K., Köhl, J., Ravensberg, W. J., & Urbaneja, A. (2018). Biological control using invertebrates and microorganisms: plenty of new opportunities. *BioControl*, 63, 39-59. <https://doi.org/10.1007/s10526-017-9801-4>
- Li, Z., Hu, R., Zhang, C., Xiong, Y., & Chen, K. (2022). Governmental regulation induced pesticide retailers to provide more accurate advice on pesticide use to farmers in China. *Pest Management Science*, 78(1), 184-192. <https://doi.org/10.1002/ps.6622>
- Lopez-Antia, A., Feliu, J., Camarero, P. R., Ortiz-Santaliestra, M. E., & Mateo, R. (2016). Risk assessment of pesticide seed treatment for farmland birds using refined field data. *Journal of Applied Ecology*, 53(5), 1373-1381. <https://doi.org/10.1111/1365-2664.12668>
- Lozowicka, B., Hrynko, I., Kaczynski, P., Rutkowska, E., Jankowska, M., & Mojsak, P. (2015). Occurrence of pesticide residues in fruit from Podlasie (Poland) in 2012. *Journal of plant protection research*, 55(2), 142-150. <https://doi.org/10.1515/jppr-2015-0018>
- Martín Reina, J., Duarte, J. A., Cerrillos, L., Bautista Palomas, J. D., & Moreno Navarro, I. M. (2017). Insecticide reproductive toxicity profile: organophosphate, carbamate and pyrethroids. *Journal of Toxins*, 4 (1), 1-7. <https://doi.org/10.13188/2328-1723.1000019>.
- Mekonen, S., Ambelu, A., & Spanoghe, P. (2015). Effect of household coffee processing on pesticide residues as a means of ensuring consumers' safety. *Journal of agricultural and food chemistry*, 63(38), 8568-8573. <https://doi.org/10.1021/acs.jafc.5b03327>
- Mekonen, S., Ambelu, A., & Spanoghe, P. (2019). Reduction of pesticide residues from teff (*Eragrostis tef*) flour spiked with selected pesticides using household food processing steps. *Heliyon*, 5(5), e01740. <https://doi.org/10.1016/j.heliyon.2019.e01740>
- Noh, H.H., Lee, J.Y., Park, H.K., Lee, J.W., Jo, S.H., Lim, J.B., Shin, H.G., Kwon, H. and Kyung, K.S.,

- (2019). Dissipation, persistence, and risk assessment of fluxapyroxad and penthiopyrad residues in perilla leaf (*perilla frutescens* var. *japonica* hara). *Plos One*, 14(4), e0212209. <https://doi.org/10.1371/journal.pone.0212209>
- Pathak, V.M., Verma, V.K., Rawat, B.S., Kaur, B., Babu, N., Sharma, A., Dewali, S., Yadav, M., Kumari, R., Singh, S., et al. (2022). Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: a comprehensive review. *Frontiers in Microbiology*, 13. <https://doi.org/10.3389/fmicb.2022.962619>
- Pérez, J. J., Ortiz, R., Ramírez, M. L., Olivares, J., Ruíz, D., & Montiel, D. (2016). Presence of organochlorine pesticides in xoconostle (*Opuntia joconostle*) in the central region of Mexico. *International Journal of Food Contamination*, 3, 1-7. <https://doi.org/10.1186/s40550-016-0044-4>
- Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A.M., Kinengyere, A., Opazo, C.M., Owoo, N., Page, J.R., Prager, S.D. and Torero, M., (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, 3(10), 809-820. <https://doi.org/10.1038/s41893-020-00617-y>
- Qiu, M., & Zhao, Z. (2019). Behavioral patterns of consumers participating in food safety and social co-governance: consumption choices and environmental improvement. In *E3S Web of Conferences* (Vol. 131, p. 01086). EDP Sciences. <https://doi.org/10.1051/e3sconf/201913101086>
- Ramírez-Santana, M., Iglesias-Guerrero, J., Castillo-Riquelme, M., & Scheepers, P. T. (2014). Assessment of health care and economic costs due to episodes of acute pesticide intoxication in workers of rural areas of the Coquimbo region, Chile. *Value in Health Regional Issues*, 5, 35-39. <https://doi.org/10.1016/j.vhri.2014.07.006>
- Rasolonjatovo, M.A., Cemek, M., Cengiz, M.F., Ortaç, D., Konuk, H.B., Karaman, E., Kocaman, A.T. and Göneş, S., (2017). Reduction of methomyl and acetamiprid residues from tomatoes after various household washing solutions. *International Journal of Food Properties*, 20(11), 2748-2759. <https://doi.org/10.1080/10942912.2016.1250099>
- Ren, Z., & Jiang, H. (2022). Risk cognition, agricultural cooperatives training, and farmers' pesticide overuse: Evidence from Shandong Province, China. *Frontiers in public health*, 10, 1032862. <https://doi.org/10.3389/fpubh.2022.1032862>
- Rodrigues, L. C. C., Fortini, R. M., & CR Neves, M. (2023). Impacts of the use of biological pest control on the technical efficiency of the Brazilian agricultural sector. *International Journal of Environmental Science and Technology*, 20(1), 1-16. <https://doi.org/10.1007/s13762-022-04032-y>
- Romanazzi, G., Orçonneau, Y., Moumni, M., Davillerd, Y., & Marchand, P. A. (2022). Basic substances, a sustainable tool to complement and eventually replace synthetic pesticides in the management of pre and postharvest diseases: reviewed instructions for users. *Molecules*, 27(11), 3484. <https://doi.org/10.3390/molecules27113484>
- Sapbamrer, R., & Chittrakul, J. (2022). Determinants of Consumers' Behavior in Reducing Pesticide Residues in Vegetables and Fruits, Northern Thailand. *International Journal of Environmental Research and Public Health*, 19(20), 13033. <https://doi.org/10.3390/ijerph192013033>
- Sapbamrer, R., Kitro, A., Panumasvivat, J., & Assavanopakun, P. (2023). Important role of the government in reducing pesticide use and risk sustainably in Thailand: current situation and recommendations. *Frontiers in Public Health*, 11, 1141142. <https://doi.org/10.3389/fpubh.2023.1141142>
- Seiyaboh, E. I., Odubo, T. C., & Izah, S. C. (2020a). Larvicidal activity of *Tetrapleura tetraptera* (Schum and Thonn) Taubert (Mimosaceae) extracts against *Anopheles gambiae*. *International Journal of Advanced Research in Microbiology and Immunology*, 2(1), 20-25.
- Seiyaboh, E. I., Seiyaboh, Z., & Izah, S. C. (2020b). Environmental control of mosquitoes: A case study of the effect of *Mangifera indica* root-bark extracts (Family Anacardiaceae) on the larvae of *Anopheles gambiae*. *Annals of Ecology and Environmental Science*, 4(1), 33-38.
- Sekabojja, D., Atuhaire, A., Nabankema, V., Sekimpi, D., & Jôrs, E. (2023). Consumer risk perception towards pesticide-stained tomatoes in Uganda. *Plos one*, 18(12), e0247740. <https://doi.org/10.1101/2021.02.15.431249>
- Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G.P.S., Handa, N., Kohli, S.K., Yadav, P., Bali, A.S., Parihar, R.D. et al. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, 1(11). <https://doi.org/10.1007/s42452-019-1485-1>
- Sharma, S., Pandey, J. G., & Barhaganj, G. (2021). Chemical pesticides and their impact on agriculture and health-a review. *Journal Global Values*, 12(2), 218-229. <https://doi.org/10.31995/jgv.2021.v12i02.028>
- Sharma, S. (2023). Cultivating sustainable solutions: integrated pest management (ipm) for safer and greener agronomy. *Cop. Sust. Manag.*, 1(2), 103-108. <https://doi.org/10.26480/csmj.02.2023.103.108>
- Sharma, T., Sirpu Natesh, N., Pothuraju, R., Batra, S. K., & Rachagani, S. (2023). Gut microbiota: a non-target victim of pesticide-induced toxicity. *Gut Microbes*, 15(1), 2187578. <https://doi.org/10.1080/19490976.2023.2187578>
- Sawyer, WE; Nabebe, G; Izah, SC (2024). Public Health Implications of Pesticide Residues in Food: Risks, Regulations, and Interventions. *Greener Journal of Biomedical and Health Sciences*, 7(1), 31-46, <https://doi.org/10.15580/gjbhs.2024.1.102024144>.

- Simoglou, K. B., Skarpa, P. E., & Roditakis, E. (2023). Pesticide Safety in Greek Plant Foods from the Consumer Perspective: The Importance of Reliable Information. *Agrochemicals*, 2(4), 484-502. <https://doi.org/10.3390/agrochemicals2040027>
- Strilesin, C., Ruttanapattanakul, J., Amornlertwatana, Y., Watcharakawin, R., & Jaikang, C. (2022). Hematological Parameters Alteration in Thai Garlic Farmers Exposed to Mixed Pesticides. *Indian Journal of Forensic Medicine & Toxicology*, 16(3), 108-111. <https://doi.org/10.37506/ijfamt.v16i3.18263>
- Ssemugabo, C., Bradman, A., Ssempebwa, J. C., & Guwatudde, D. (2023). Consumer awareness and health risk perceptions of pesticide residues in fruits and vegetables in Kampala metropolitan area in Uganda. *Environmental Health Insights*, 17, <https://doi.org/10.1177/11786302231184751>
- Sun, S., Hu, R., Zhang, C., & Shi, G. (2019). Do farmers misuse pesticides in crop production in china? evidence from a farm household survey. *Pest Management Science*, 75(8), 2133-2141. <https://doi.org/10.1002/ps.5332>
- Tago, D., Andersson, H., & Treich, N. (2014). Pesticides and health: a review of evidence on health effects, valuation of risks, and benefit-cost analysis. *Preference measurement in health*, 203-295. https://doi.org/10.1108/s0731-2199_2014_0000024006
- Tavaliere, Y. E., Galoppo, G. H., Canesini, G., Luque, E. H., & Muñoz-de-Toro, M. M. (2020). Effects of agricultural pesticides on the reproductive system of aquatic wildlife species, with crocodilians as sentinel species. *Molecular and Cellular Endocrinology*, 518, 110918. <https://doi.org/10.1016/j.mce.2020.110918>
- Tudi, M., Li, H., Li, H., Wang, L., Lyu, J., Yang, L., Tong, S., Yu, Q.J., Ruan, H.D., Atabila, A. et al. (2022). Exposure routes and health risks associated with pesticide application. *Toxics*, 10(6), 335. <https://doi.org/10.3390/toxics10060335>
- Wang, J., Zhou, L., Ni, Z., Wu, W., Liu, G., Fu, W., Zhang, X. and Tian, J., (2022). Consumer preference and willingness to pay for low-residue vegetables: evidence from discrete choice experiments in China. *Frontiers in Sustainable Food Systems*, 6. <https://doi.org/10.3389/fsufs.2022.1019372>
- Wang, L., Wu, Y., Yin, P., Cheng, P., Liu, Y., Schwebel, D.C., Qi, J., Ning, P., Liu, J., Cheng, X. et al. (2018). Poisoning deaths in china, 2006–2016. *Bulletin of the World Health Organization*, 96(5), 314-326A. <https://doi.org/10.2471/blt.17.203943>
- Wanwimolruk, C., Phopin, K., & Wanwimolruk, S. (2019). Food safety in Thailand 6: How to eat guava fruits safely? Effects of washing and peeling on removing pesticide residues in guava fruits. *Journal of Food Safety*, 39(4), e12654. <https://doi.org/10.1111/jfs.12654>
- Wanwimolruk, C., Wanwimolruk, S., Kuaykaimuk, K., Buddhaprom, J., Saenserm, P., & Soikham, S. (2022). Food Safety of Thailand's Pineapples, Bananas, and Dragon Fruits from Pesticide Contamination: a Study Using GC-MS Analysis. *Philippine Journal of Science*, 151(6B), 2315-2326. <https://doi.org/10.56899/151.6b.02>
- Wanwimolruk, S., Kanchanamayoon, O., Boonpangrak, S., & Prachayasittikul, V. (2015). Food safety in Thailand 1: it is safe to eat watermelon and durian in Thailand. *Environmental Health and Preventive Medicine*, 20, 204-215. <https://doi.org/10.1007/s12199-015-0452-8>
- Winter, C. K. (2015). Chronic dietary exposure to pesticide residues in the United States. *International Journal of Food Contamination*, 2, 1-12. <https://doi.org/10.1186/s40550-015-0018-y>
- Wochner, D., Simonato, J., Grigolli, J. J., Farinha, M. S., Bernardo, L. M., Ruviaro, C., & Gimenes, R. T. (2021). Cost-Benefit Analysis of Integrated Pest Management in Soybean Crops in the Midwest Region of Brazil. <https://doi.org/10.21203/rs.3.rs-827064/v1>
- Yang, M., Zhao, X., & Meng, T. (2019). What are the driving factors of pesticide overuse in vegetable production? Evidence from Chinese farmers. *China Agricultural Economic Review*, 11(4), 672-687. <https://doi.org/10.1108/caer-08-2018-0170>
- Youkparigha, F. O., & Izah, S. C. (2019). Larvicidal efficacy of aqueous extracts of *Zingiber officinale* Roscoe (ginger) against malaria vector, *Anopheles gambiae* (Diptera: Culicidae). *International Journal of Environmental and Agricultural Sciences*, 3, 020.