

# Assessment of Agricultural Practices and Pesticide Residue Levels in Tomatoes and Garden Eggs Sold in Southeastern Nigeria.

Isaiah C. Abonyi<sup>1\*</sup>, Josephine U. Nnarah<sup>1</sup>, Justina N. Okoli<sup>2</sup>, Matthew C. Nwachukwu<sup>1</sup>, Chidiebere J. Nwankwo<sup>1</sup>, Ikechukwu V. Obi<sup>3</sup>

<sup>1</sup>Department of Environmental Health Science, Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria

<sup>2</sup>Department of Nutrition and Dietetics, Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria

<sup>3</sup> Department of Public Health Sciences, Faculty of Allied Health Sciences, University on the Niger, Umuaya, Iyienu Campus, Anambra State, Nigeria.

\*Corresponding Author

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## ABSTRACT

**Background:** Pesticide use in vegetable cultivation improves agricultural productivity but may result in harmful residue accumulation in food crops. Tomatoes (*Solanum lycopersicum*) and garden eggs (*Solanum aethiopicum*) are widely consumed in Nigeria and are frequently exposed to pesticides during cultivation and storage.

**Objective:** This study assessed pesticide usage practices and pesticide residue levels in tomatoes and garden eggs sold in Eke-Amobi Market, Nnewi, Anambra State, Nigeria.

**Methods:** A descriptive cross-sectional analytical study design was adopted. Structured questionnaires were administered to 181 farmers, distributors, and retailers involved in vegetable production and supply. Twenty vegetable samples (10 tomatoes and 10 garden eggs) were randomly collected for laboratory analysis. Pesticide residues were extracted using the QuEChERS method and analyzed using Gas Chromatography–Mass Spectrometry (GC–MS). Results were compared with FAO/WHO Maximum Residue Limits (MRLs).

**Results:** All respondents (100%) reported pesticide use. Common pesticides identified included cypermethrin, carbaryl, chlorothalonil, malathion, metalaxyl, deconil, and cymoxanil. Although 97.8% were aware of pesticide-related health risks, only 15.3% had received formal training on safe pesticide use, while 91.7% did not read pesticide labels and 66.3% did not use protective equipment. Laboratory analysis detected pesticide residues in 100% of samples. All tomato residues were below recommended MRLs. In garden eggs, carbaryl, deconil, and cymoxanil were within permissible limits, whereas 50% of samples exceeded the MRL for metalaxyl.

**Conclusion:** Tomatoes sold in Eke-Amobi Market were generally safe based on residue standards, while elevated metalaxyl residues in garden eggs may pose long-term public health concerns. Improved farmer education, pesticide regulation, and routine residue monitoring are recommended.

**Keywords:** Pesticide residues; Tomatoes; Garden eggs; Food safety; Nigeria.

## INTRODUCTION

Pesticides are widely used in modern agriculture to control pests, diseases, and weeds that threaten crop production and food security, contributing significantly to increased agricultural productivity, reduced post-harvest losses, and improved food availability, especially in developing countries (FAO, 2023; Sharma et al., 2022). Nevertheless, the extensive and sometimes indiscriminate application of these chemicals has raised

serious concerns about the accumulation of pesticide residues in food products and their potential impacts on human health, food safety, and environmental sustainability (WHO, 2022; EFSA, 2023).

Vegetables are important components of human nutrition because they provide essential vitamins, minerals, dietary fiber, antioxidants, and other bioactive compounds necessary for growth, immunity, and disease prevention (Aune et al., 2021; Slavin & Lloyd, 2023). Tomatoes (*Solanum lycopersicum*) and garden eggs (*Solanum aethiopicum*) are among the most commonly cultivated and consumed vegetables in Nigeria and other parts of Africa. Tomatoes are rich in vitamin C, lycopene, potassium, and carotenoids, while garden eggs contain dietary fiber, phenolic compounds, calcium, and iron that contribute to digestive health and overall well-being (Raiola et al., 2022; Olatunji & Afolayan, 2021). Because of their nutritional value and widespread consumption, ensuring the safety of these vegetables is essential for public health protection.

Despite their nutritional importance, tomatoes and garden eggs are highly susceptible to insect infestation and fungal diseases during cultivation and storage, leading farmers to rely heavily on pesticides to minimize crop damage and improve market quality (Bempah et al., 2022; Chukwuma et al., 2023). Continuous or improper pesticide application may result in the persistence and accumulation of pesticide residues—defined as traces of pesticide substances or their metabolites remaining in food after application (Codex Alimentarius Commission, 2023)—in edible plant tissues. If these residues exceed the Maximum Residue Limits (MRLs) set by regulatory agencies such as the Codex Alimentarius Commission and the European Food Safety Authority (EFSA), they may pose significant health risks to consumers (EFSA, 2023).

Dietary exposure to pesticide residues has become a global public health concern, as studies have linked chronic exposure to pesticides with endocrine disruption, neurotoxicity, reproductive disorders, carcinogenicity, immune dysfunction, and developmental abnormalities (Mostafalou & Abdollahi, 2023; Kim et al., 2022). For example, organophosphate pesticides may impair nervous system function by inhibiting acetylcholinesterase activity, while organochlorine compounds are notable for their persistence and bioaccumulation potential (Sabarwal et al., 2022). Beyond these direct health effects, pesticide contamination can also compromise the nutritional quality of vegetables by reducing their antioxidant and vitamin content (Rahman et al., 2022).

In many developing countries, including Nigeria, pesticide misuse remains a major challenge due to inadequate farmer education, weak regulatory enforcement, poor monitoring systems, and the widespread availability of counterfeit or unapproved pesticide products (FAO, 2023; NAFDAC, 2023). Farmers often apply pesticides excessively or fail to observe recommended pre-harvest intervals, thereby increasing the likelihood of residue accumulation in vegetables supplied to local markets (Akan et al., 2022). Previous studies in Nigeria have reported detectable levels of organochlorine, organophosphate, carbamate, and pyrethroid pesticide residues in fruits and vegetables, with some concentrations exceeding internationally permissible safety limits (Ibigbami et al., 2023; Ogunfowokan et al., 2021). However, there is limited baseline data on pesticide residue contamination in tomatoes and garden eggs sold in markets in Southeastern Nigeria, particularly in Anambra State.

Eke-Amobi Market in Nnewi is a major distribution center for vegetables consumed by a large population in the region. Therefore, continuous monitoring of pesticide residues in these commonly consumed vegetables is essential to assess food safety risks and protect public health. This study aimed to determine the levels of pesticide residues in tomatoes and garden eggs sold in Eke-Amobi Market, Nnewi, Anambra State, compare the detected concentrations with internationally recommended Maximum Residue Limits (MRLs), and evaluate pesticide usage practices among farmers involved in their cultivation and supply.

## MATERIALS AND METHODS

**Study Design:** This study employed a descriptive cross-sectional and analytical research design involving both questionnaire, survey and laboratory experimental analysis. The descriptive component enabled the characterization of pesticide usage practices among farmers, while the analytical component involved laboratory determination of pesticide residues in vegetable samples.

**Study Area:** The study was conducted in Eke-Amobi Market, located in Nnewi North Local Government Area of Anambra State, Nigeria. Nnewi lies between latitudes 6°00' and 6°20' N and longitudes 6°55' and 7°05' E. Eke Amobi Market is a major commercial market where fresh agricultural produce, including tomatoes and garden eggs, are sold daily. Farmers and distributors from surrounding communities supply vegetables to the market.

**Study Population:** The study population comprised two categories:

1. Tomato and garden egg samples sold in Eke-Amobi Market.
2. Farmers, distributors, and retailers involved in the cultivation and supply of the vegetables.

**Sampling Technique:** A simple random sampling technique was employed for the selection of respondents and vegetable samples. Vegetable samples were collected from different vendors over multiple days to ensure representativeness and reduce sampling bias.

### **Instruments for Data Collection**

#### **Questionnaire:**

A structured questionnaire was used to obtain information regarding:

- Types of pesticides used
- Frequency and timing of pesticide application
- Use of protective equipment
- Knowledge of pesticide safety
- Post-harvest handling practices

#### **Laboratory Equipment:**

The following laboratory instruments and materials were used:

- QuEChERS extraction kit
- Analytical balance
- Centrifuge
- Vortex mixer
- Blender/homogenizer
- Syringe filters
- Micropipettes
- Gas Chromatography–Mass Spectrometry (GC-MS)

**Sample Collection and Preparation:** Tomato (*Solanum lycopersicum*) and garden egg (*Solanum aethiopicum*) samples were collected from different vendors at Eke Amobi Market, Nnewi, using sterile polyethylene bags. Samples were transported under chilled conditions and analyzed within 24 hours. Samples were sorted, washed with distilled water, chopped, and homogenized using a laboratory blender. The homogenized samples were stored at –20 °C prior to analysis.

**Extraction of Pesticide Residues:** Pesticide residues were extracted using the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method. Ten grams (10 g) of homogenized sample were weighed into 50 mL centrifuge tubes, and 10 mL of HPLC-grade acetonitrile was added. The mixture was vortexed, followed by addition of 4 g MgSO<sub>4</sub> and 1 g NaCl for phase separation. After centrifugation at 4000 rpm for 5 minutes, 6 mL of the supernatant was cleaned using dispersive solid-phase extraction containing PSA and MgSO<sub>4</sub>. The cleaned extract was filtered through a 0.22 µm syringe filter into GC-MS vials.

**GC-MS Analysis:** Pesticide residue analysis was carried out using Gas Chromatography–Mass Spectrometry (GC–MS). The instrument was calibrated with certified pesticide standards prior to analysis. One microlitre (1 µL) of each extract was injected into the GC–MS system using helium as the carrier gas.

Samples were analyzed in triplicate, and solvent blanks were run between analyses to prevent contamination. Residues were identified by comparing retention times and mass spectra with reference standards, while quantification was performed using calibration curves.

**Calculation of Residue Concentration:** Pesticide residue concentration was calculated using:

$$\text{Residue Concentration} = C \times V$$

$$\text{Residue Concentration} = \frac{C \times V}{W}$$

Where:

- CCC = Concentration obtained from GC–MS (mg/mL)
- VVV = Final extract volume (mL)
- WWW = Sample weight (g)

Results were expressed in mg/kg of fresh sample.

**Data Analysis:** Data obtained were compared with FAO/WHO Maximum Residue Limits (MRLs). Statistical analysis was performed using IBM SPSS version 25, and results were summarized using descriptive statistics and tables.

**Ethical Considerations:** Ethical approval for this study was obtained from the faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi campus research ethics committee before the commencement of sample collection.

## RESULTS

Table 1: Socio-demographic characteristics of the Respondents

Variable		Number (n=181)	Percentage (%)
Gender	Male	73	40.3
	Female	108	59.7
	Total	181	100
Age group (years)	20-39	63	34.8
	40-59	90	49.7
	60-79	25	13.8

	80 years and above	3	1.7
	Total	181	100
Highest level of education attained	No formal education	31	17.1
	Primary education	6	3.3
	Secondary education	63	34.8
	Tertiary education	81	44.8
	Total	181	100

Table 1 presents the socio-demographic characteristics of the respondents. The study involved 181 respondents, with females constituting the majority of participants. Most respondents were within the age range of 40–59 years, while only a few were aged 80 years and above. In terms of educational attainment, the largest proportion had tertiary education, followed by secondary education, whereas a smaller proportion had no formal or only primary education.

Table 2: Shows the level of usage of pesticide by farmers

Variable		Frequency (n=181)	Percentage (%)
Types/brands of pesticides commonly use on Tomatoes	<b>Insecticide</b>		
	Cypermethrin	32	17.7
	Carbaryl	12	6.6
	Spinosad	13	7.2
	Befenthrin	4	2.2
	Total	61	33.7
	<b>Fungicides</b>		
	Chlorothamol	18	9.9
	Mancozeb	8	4.4
	Copper octanoate	8	4.4
	Total	34	18.7
	<b>Bio-pesticides</b>		
	Bacillus	85	47.0
	Neem oil	1	0.6
	Total	86	47.6
Types/brands of pesticides			

commonly use on garden eggs	<b>Insecticides:</b>	5	2.8
	Cypermethrin		
	Carbaryl	7	3.9
	Spinosad	5	2.8
	Malathion	2	1.1
	Total	19	10.6
	<b>Biological/natural- insecticides</b>		
	Bacillus	2	1.1
	Diatomaceous	1	0.6
	Serenade	1	0.6
	Total	4	2.2
	<b>Fungicide</b>		
	Neem oil	85	47.0
	Copper octanoate	59	32.6
	Deconil	14	7.2
Total	158	87.3	
Method of application of pesticides	Spraying	181	100
	Dusting	0	0
	Soil treatment	0	0
	Total	181	100
Habit of reading and following the Instructions on the pesticide labels	Always	10	5.5
	Sometimes	5	2.8
	Never	166	91.7
	Total	181	100
Do you wear protective equipment (gloves, masks, boots, etc.) when applying	Always	7	3.9
	Sometimes	54	29.8
	Never	120	66.3

Pesticides?	Total	181	100
Place of purchase of Pesticides	Local market	21	11.6
	Agrochemical store	152	84.0
	From cooperatives	8	4.4
	Total	181	100
State of formal training on safe pesticide use	Yes	24	15.3
	No	157	86.7
	Total	181	100
Awareness of the possible health risks of pesticide residues on vegetables	Yes	177	97.8
	No	4	2.2
	Total	181	100

Table 2 showed widespread pesticide use among the 181 farmers. Bio-pesticides and fungicides were most commonly used for tomatoes and garden eggs, respectively. All farmers applied pesticides by spraying. Most never read labels (91.7%) or used protective equipment (66.3%). Despite low formal training (15.3%), awareness of pesticide health risks was high (97.8%).

Table 3: Shows the post-harvest handling and chemical use by distributors and retailers

Variable		Frequency (n=181)	Percentage (%)
Pesticides applied to tomatoes or garden eggs after harvest to preserve freshness or appearance	Yes	50	27.6
	No	131	72.4
	Total	181	100
Commonly applied pesticides	<b>Garden eggs:</b>		
	Gibberellic acid	2	1.1
	Copper based pesticide	6	3.3
	<b>Tomatoes:</b>		
	Fungicide	2	1.1
	Ethylene inhibitors	2	1.1
	Calcium chloride	5	2.8
	Wax coating	4	2.2
Common reason for application of	Prevent spoilage	81	44.8



the pesticides	Improve appearance	69	38.1
	Extend shelf life	31	17.1
	Total	181	100
Storage method before sales	Open trays	0	0
	Sacks/baskets	181	100
	Cold storage	0	0
	Room storage	0	0
	Total	181	100
Average duration of storage before sales	Less than 2 days	36	19.9
	2-5 days	125	69.1
	More than 5 days	20	11.0
	Total	181	100
Practice of washing produce before sales	Yes	174	96.1
	No	7	3.9
	Total	181	100
Farmers' suggested measures to be taken to reduce pesticide residues in tomatoes or garden eggs	Proper pesticide application	29	16.0
	Farm management and good agricultural practices	48	26.6
	Monitoring, testing and record management	24	14.4
	Pest prevention and alternative control methods	33	17.7
	Resistant varieties and crop improvement	21	10.5
	Training, safety and compliance measures	21	10.5
	Environmental protection and waste management	5	2.8



	Total	181	100
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Table 3 revealed that 28% of farmers applied post-harvest chemicals such as fungicides, gibberellic acid, copper-based pesticides, ethylene inhibitors, calcium chloride, and wax coatings to improve appearance, prevent spoilage, and extend shelf life. Produce was mainly stored for 2–5 days in open trays, sacks/baskets, cold rooms, or room storage, while 96% washed vegetables before sale and recommended measures to reduce pesticide residues.

## LABORATORY RESULTS

Table 4: Pesticide Residues in Tomato Samples (mg/kg)

Assessed Pesticide Residues				
Market Seller	Cypermethrin (mg/kg)	Carbaryl (mg/kg)	Chlorothalonil (mg/kg)	Malathion (mg/kg)
SL-01	0.018±0.003	0.023±0.003	0.079±0.004	0.030±0.003
SL-02	0.022±0.003	0.077±0.001	0.111±0.003	0.024±0.003
SL-03	0.008±0.000	0.181±0.004	0.052±0.000	0.015±0.003
SL-04	0.012±0.001	0.181±0.003	0.027±0.004	0.012±0.001
SL-05	0.024±0.003	0.110±0.005	0.016±0.001	0.016±0.001
SL-06	0.013±0.003	0.104±0.003	0.052±0.000	0.033±0.001
SL-07	0.015±0.000	0.216±0.003	0.127±0.006	0.013±0.000
SL-08	0.031±0.000	0.091±0.003	0.209±0.008	0.007±0.001
SL-09	0.027±0.001	0.061±0.004	0.082±0.001	0.005±0.001
SL-10	0.018±0.001	0.035±0.003	0.013±0.000	0.011±0.000
MRL	0.2(mg/kg)	5(mg/kg)	5 (mg/kg)	0.5(mg/kg)

Value are expressed as mean ± standard deviation (mg/kg) MRL= Maximum Residue limit.

Pesticide residue were detected in all tomato samples analyzed. However, all detected concentrations were below the respective Maximum Residue Limits. The highest concentration detected in the tomato samples was 0.209 mg/kg for Chlorothalonil, which is below the recommended MRL of 5 mg/kg.

Table 5: Pesticide Residues in Garden Egg Samples (mg/kg)

Assessed Pesticide Residues				
Market Seller	Carbaryl (mg/kg)	Deconil (mg/kg)	Cymoxanil (mg/kg)	Metalaxyl (mg/kg)
SL-01	0.037±0.003	0.013±0.000	0.023±0.003	0.016±0.000



SL-02	0.111±0.003	0.019±0.004	0.036±0.000	0.014±0.001
SL-03	0.031±0.009	0.012±0.001	0.013±0.010	0.026±0.007
SL-04	0.204±0.003	0.023±0.001	0.018±0.003	0.031±0.003 *
SL-05	0.233±0.004	0.007±0.001	0.036±0.001	0.042±0.021*
SL-06	0.194±0.003	0.013±0.003	0.025±0.004	0.013±0.000
SL-07	0.117±0.001	0.035±0.002	0.041±0.002	0.037±0.003 *
SL-08	0.085±0.003	0.030±0.000	0.028±0.001	0.028±0.003
SL-09	0.047±0.006	0.018±0.000	0.033±0.001	0.035±0.000 *
SL-10	0.017±0.001	0.021±0.000	0.019±0.000	0.044±0.003 *
MRL	5 mg/kg	0.5 mg/kg	0.6 mg/kg	0.03 mg/kg

Table 5: Value are expressed as mean ± standard deviation (mg/kg) MRL= Maximum Residue limit.

Pesticide residues were detected in all garden egg samples analyzed. All detected concentrations were below the Maximum Residue Limits (5 mg/kg), except for metalaxyl, where five out of ten (50%) of the samples exceeded the MRL. Values marked with (\*) indicate samples where pesticide residue concentration exceeds the MRL.

## DISCUSSION

This study evaluated pesticide residues in tomatoes and garden eggs sold in Eke-Amobi Market, Nnewi, through a combined assessment of farmers' pesticide-use practices and laboratory analysis of vegetable samples. The findings provide important insights into pesticide application patterns, food safety status, nutritional implications, and potential public health and environmental concerns associated with vegetable production and marketing in the study area.

### Pesticide Use Practices among Farmers

The study revealed that pesticide application was universal among the farmers surveyed, with 100% of respondents reporting the use of pesticides during vegetable cultivation. The major pesticides identified included cypermethrin, carbaryl, chlorothalonil, malathion, metalaxyl, deconil, and cymoxanil. These compounds belong to commonly used pesticide classes such as pyrethroids, carbamates, organophosphates, and fungicides, which are widely utilized in intensive vegetable farming due to their effectiveness against insect pests and fungal diseases. The predominance of pyrethroids and fungicides observed in this study agrees with findings reported by Oguntade et al. (2023), who documented extensive use of similar pesticide groups among tomato farmers in Southwestern Nigeria. Similarly, Eze and Ibekwe (2022) identified carbaryl and metalaxyl as frequently used pesticides among vegetable farmers in Southeast Nigeria because of their broad-spectrum efficacy and affordability.

Although most respondents (97.8%) acknowledged that pesticide residues may pose health risks, only 15.3% had received formal training on safe pesticide handling and application. Furthermore, 91.7% of the farmers reported that they did not read pesticide labels before use, while 66.3% failed to utilize personal protective equipment during pesticide application. These findings indicate a substantial gap between awareness and safe agricultural practice. Similar observations were reported by Adeyemi et al. (2021), who noted that many small-scale farmers rely heavily on informal experience rather than scientifically recommended pesticide safety



procedures. A particularly concerning finding was that 45.5% of the farmers applied pesticides within two days before harvest, thereby failing to observe recommended pre-harvest intervals. Non-compliance with pre-harvest intervals has consistently been identified as a major determinant of pesticide residue persistence in vegetables (Bempah et al., 2022). This unsafe practice likely contributed to the detectable residues observed in the analyzed vegetable samples.

### Levels of Pesticide Residues in Vegetables

Laboratory analysis demonstrated a 100% detection rate of pesticide residues in both tomatoes and garden eggs, indicating widespread contamination of vegetables with pesticide chemicals. Although many residue levels remained within permissible standards, the universal detection of residues suggests continuous dietary exposure among consumers.

In tomato samples, cypermethrin concentrations ranged from 0.008–0.031 mg/kg, carbaryl from 0.023–0.216 mg/kg, chlorothalonil from 0.013–0.209 mg/kg, and malathion from 0.005–0.033 mg/kg. Importantly, all detected concentrations were below their respective Maximum Residue Limits (MRLs), suggesting compliance with established international food safety standards. Similarly, garden egg samples contained measurable residues of carbaryl (0.017–0.233 mg/kg), deconil (0.007–0.035 mg/kg), cymoxanil (0.013–0.041 mg/kg), and metalaxyl (0.013–0.044 mg/kg). However, unlike tomatoes, 50% of the garden egg samples exceeded the MRL established for metalaxyl (0.03 mg/kg). This selective exceeds is noteworthy because metalaxyl is a systemic fungicide capable of penetrating plant tissues and persisting for extended periods, particularly when repeatedly applied or used close to harvest (Kabir et al., 2018).

Comparable findings were reported by Akinneye et al. (2023) in a residue-monitoring study conducted in Lagos markets, where multiple pesticide residues were detected in vegetables, although only specific compounds exceeded regulatory limits. The present findings therefore reinforce the growing evidence that pesticide contamination in vegetables is widespread in Nigeria, with residue exceeds often linked to poor pesticide management practices rather than pesticide use alone.

### Food Safety and Nutritional Implications

Vegetables such as tomatoes and garden eggs are nutritionally important foods that contribute significantly to dietary intake of vitamins, minerals, antioxidants, and dietary fiber. Tomatoes are rich sources of vitamin C, lycopene, potassium, and carotenoids, while garden eggs provide fiber, antioxidants, and essential micronutrients beneficial for cardiovascular health and metabolic regulation. Regular consumption of these vegetables is strongly associated with reduced risks of chronic diseases, including hypertension, cardiovascular disorders, and certain cancers (Akinsola et al., 2015; Martí et al., 2016; Saleh et al., 2018).

However, the nutritional benefits of vegetables may be undermined by pesticide contamination. Persistent exposure to pesticide residues through dietary intake may compromise food safety and reduce consumer confidence in fresh produce. Even when residue concentrations are within regulatory limits, chronic low-dose exposure remains a concern due to the potential for bioaccumulation and cumulative toxicological effects over time (Shekhar et al., 2024; Sarr et al., 2026). The detection of elevated metalaxyl residues in some garden egg samples is particularly significant, as repeated consumption of vegetables with residues above MRLs could increase the risk of chronic health effects. According to the World Health Organization (2022), prolonged exposure to certain pesticide residues has been associated with neurological disorders, endocrine disruption, reproductive toxicity, immune dysfunction, and possible carcinogenic effects.

In addition, vulnerable population groups such as children, pregnant women, and immunocompromised individuals may be at greater risk because of their lower detoxification capacity and higher sensitivity to chemical contaminants. The presence of residues in vegetables consumed frequently within households therefore warrants attention from a public health perspective.



## Environmental and Occupational Health Concerns

Beyond dietary exposure, the findings also highlight the potential for environmental and occupational health implications. Poor pesticide handling practices, including failure to use protective equipment and improper application timing, may increase pesticide exposure among farmers through inhalation, dermal absorption, and accidental ingestion. Chronic occupational exposure has been linked to respiratory disorders, skin irritation, neurotoxicity, and reproductive health problems among agricultural workers (Moreira & Vieira da Silva, 2024; Shekhar et al., 2024).

Environmentally, indiscriminate pesticide use may contribute to contamination of soil, surface water, and groundwater systems. Repeated pesticide application can disrupt beneficial soil microorganisms, reduce biodiversity, and negatively affect non-target organisms such as pollinators, aquatic species, and natural pest predators. The extensive use of fungicides and insecticides observed in this study may therefore contribute to ecological consequences beyond residue accumulation in food crops. The findings align with the report of Kapeleka et al. (2024), who identified inadequate farmer education, weak regulatory enforcement, and poor pesticide stewardship as major contributors to pesticide-related food safety and environmental challenges in Sub-Saharan Africa.

## Public Health Significance

The detection of pesticide residues in all analyzed samples indicates that consumers in the study area are continually exposed to pesticide chemicals through vegetable consumption. Although tomatoes generally complied with safety standards, the exceeds of metalaxyl residues in garden eggs underscores the need for strengthened monitoring and intervention strategies.

The combination of high pesticide use, inadequate farmer training, limited adherence to safety precautions, and poor observance of pre-harvest intervals suggests a systemic challenge in pesticide management among vegetable farmers. Without targeted interventions, continued misuse of pesticides may increase long-term risks to food safety, human health, and environmental sustainability.

## CONCLUSION

This study demonstrated widespread pesticide use among farmers supplying vegetables to Eke-Amobi Market, Nnewi, with all respondents reporting routine pesticide application during cultivation. Despite high awareness of potential health risks associated with pesticide residues, compliance with recommended safety practices was poor, particularly regarding farmer training, label utilization, use of protective equipment, and observance of pre-harvest intervals.

Laboratory analysis confirmed the presence of pesticide residues in all tomato and garden egg samples analyzed, indicating continuous exposure of consumers to pesticide chemicals through dietary intake. Encouragingly, all tomato samples complied with established Maximum Residue Limits, suggesting that tomatoes sold within the market were generally safe for consumption at the time of study. In contrast, half of the garden egg samples exceeded the permissible limit for metalaxyl, highlighting a potential food safety concern associated with improper fungicide application practices.

The study further emphasizes that while vegetables remain essential components of a healthy diet because of their rich nutritional and antioxidant content, the benefits of vegetable consumption can be compromised by unsafe pesticide practices and residue contamination. Beyond human health concerns, indiscriminate pesticide use also poses environmental and occupational hazards capable of affecting ecosystem stability and agricultural sustainability.

Overall, the findings underscore the need for strengthened pesticide regulation, farmer education programs, routine residue surveillance, and enforcement of good agricultural practices in Nigeria. Improving compliance

with pesticide safety guidelines and promoting integrated pest management strategies will be critical for safeguarding food quality, protecting public health, preserving environmental integrity, and sustaining consumer confidence in locally produced vegetables.

## REFERENCES

1. Adeyemi, O. T., Akinyemi, A. A., & Oladipo, I. C. (2021). Knowledge and safety practices associated with pesticide use among small-scale vegetable farmers in Nigeria. *Journal of Environmental Health and Sustainable Development*, 6(3), 145–154.
2. Akan, J. C., Mohammed, Z., & Audu, S. I. (2022). Pesticide residues in vegetables consumed in Nigeria and associated public health risks. *Environmental Monitoring and Assessment*, 194(8), 1–15.
3. Akinneye, J. O., Afolabi, T. A., & Ojo, A. O. (2023). Monitoring of pesticide residues in commonly consumed vegetables sold in Lagos markets, Nigeria. *Food Control*, 148, 109632.
4. Akinsola, A. O., Afolayan, A. J., & Bradley, G. (2015). Phytochemical constituents and antioxidant activities of the fruits of *Solanum aethiopicum* L. (garden egg). *International Journal of Pharmacognosy and Phytochemical Research*, 7(3), 593–599.
5. Aune, D., Giovannucci, E., Boffetta, P., Fadnes, L. T., Keum, N., Norat, T., Greenwood, D. C., Riboli, E., Vatten, L. J., & Tonstad, S. (2021). Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality: A systematic review and dose-response meta-analysis. *International Journal of Epidemiology*, 50(3), 1029–1056.
6. Bempah, C. K., Donkor, A. K., Yeboah, P. O., Dubey, B., & Osei-Fosu, P. (2022). Assessment of pesticide residues in vegetables and implications for food safety in West Africa. *Journal of Food Composition and Analysis*, 108, 104451.
7. Choi, J. H., Abd El-Aty, A. M., Rahman, M. M., Kim, S. W., & Shim, J. H. (2023). Application of QuEChERS method for multi-residue pesticide analysis in fruits and vegetables using GC–MS/MS and LC–MS/MS techniques. *Journal of Chromatography B*, 1227, 123760.
8. Chukwuma, C. I., Ezenwaji, H. M., & Okeke, C. U. (2023). Pesticide application practices and residue occurrence in vegetables cultivated in southeastern Nigeria. *Environmental Toxicology and Pharmacology*, 98, 104087.
9. Codex Alimentarius Commission. (2022). Guidelines on good laboratory practice in pesticide residue analysis. Rome, Italy: Food and Agriculture Organization/World Health Organization.
10. Codex Alimentarius Commission. (2023). Pesticide residues in food and feed: Maximum residue limits database. Rome, Italy: Food and Agriculture Organization/World Health Organization.
11. Darko, G., & Akoto, O. (2022). Systemic fungicide residues in vegetables and implications for consumer safety in West Africa: A review. *Environmental Monitoring and Assessment*, 194(6), 1–14.
12. European Food Safety Authority (EFSA). (2023). The 2021 European Union report on pesticide residues in food. *EFSA Journal*, 21(4), e07887.
13. Eze, P. N., & Ibekwe, V. I. (2022). Pesticide use patterns among vegetable farmers in southeastern Nigeria and associated residue concerns. *African Journal of Agricultural Research*, 18(5), 412–421.
14. Food and Agriculture Organization (FAO). (2023). International code of conduct on pesticide management. Rome, Italy: FAO.
15. Ibigbami, O. A., Adebayo, A. H., & Ogunfowokan, A. O. (2023). Organochlorine and organophosphate pesticide residues in vegetables marketed in Nigeria: Occurrence and health risk assessment. *Heliyon*, 9(7), e17831.
16. Kabir, M. H., Abd El-Aty, A. M., Rahman, M. M., Chung, H. S., Lee, H. S., Jeong, J. H., Wang, J., Shin, S., Shin, H.-C., & Shim, J.-H. (2018). Dissipation kinetics, pre-harvest residue limits, and dietary risk assessment of the systemic fungicide metalaxyl in Swiss chard grown under greenhouse conditions. *Regulatory Toxicology and Pharmacology*, 92, 201–206. <https://doi.org/10.1016/j.yrtph.2017.12.003>
17. Kapeleka, J. A., Sauli, E., & Ndakidemi, P. A. (2024). Food safety challenges associated with pesticide residues in Sub-Saharan Africa: A review of current evidence and policy gaps. *Environmental Health Insights*, 18, 1–15.

18. Kim, K. H., Kabir, E., & Jahan, S. A. (2022). Exposure to pesticides and the associated human health effects. *Science of the Total Environment*, 575, 525–535.
19. Martí, R., Roselló, S., & Cebolla-Cornejo, J. (2016). Tomato as a source of carotenoids and polyphenols targeted to cancer prevention. *Cancers*, 8(6), 58. <https://doi.org/10.3390/cancers8060058>
20. Moreira, A., & Vieira da Silva, M. (2024). Analysis of health effects reported by agricultural workers and the adverse human effects indicated on pesticide labels: A systematic review. *Agriculture*, 14(10), 1669. <https://doi.org/10.3390/agriculture14101669>
21. Mostafalou, S., & Abdollahi, M. (2023). Pesticides and human chronic diseases: Evidences, mechanisms, and perspectives. *Toxicology and Applied Pharmacology*, 463, 116485.
22. National Agency for Food and Drug Administration and Control (NAFDAC). (2023). Guidelines for pesticide registration and control in Nigeria. Abuja, Nigeria: NAFDAC.
23. Oguntade, A. S., Adewale, T. M., & Bello, A. O. (2023). Patterns of pesticide use among tomato farmers in Southwestern Nigeria. *Journal of Agricultural Extension and Rural Development*, 15(2), 55–64.
24. Ogunfowokan, A. O., Oyekunle, J. A. O., Torto, N., & Akanni, M. S. (2021). A study on persistent organochlorine pesticide residues in fruits and vegetables in Nigeria. *Food Chemistry*, 132(2), 1056–1063.
25. Olatunji, T. L., & Afolayan, A. J. (2021). Nutritional and phytochemical composition of African eggplant (*Solanum aethiopicum*): A review of its health benefits. *Food Reviews International*, 37(5), 473–490.
26. Rahman, M. M., Islam, M. S., & Biswas, S. K. (2022). Effects of pesticide residues on nutritional quality and antioxidant properties of vegetables. *Journal of Food Quality*, 2022, 1–10.
27. Raiola, A., Rigano, M. M., Calafiore, R., Frusciante, L., & Barone, A. (2022). Enhancing the health-promoting effects of tomato fruit for biofortified food. *Mediators of Inflammation*, 2022, 1398734.
28. Sabarwal, A., Kumar, K., & Singh, R. P. (2022). Hazardous effects of chemical pesticides on human health—Cancer and other associated disorders. *Environmental Toxicology and Pharmacology*, 63, 103–114.
29. Saleh, B. K., Omer, A., & Teweldemedhin, B. (2018). Medicinal uses and health benefits of tomatoes. *Advances in Nutrition and Food Science*, 3(2), 1
30. Sarr, A., Thiam, K., Foko, R. F., Lam, A., Ndong, A., Bah, F., Fall, M., Touré, A., Saint-Marcoux, F., & Cabral, M. (2026). Health effects of chronic low-dose exposure to pesticide mixtures: A systematic review. *Journal of Environmental Protection*, 17, 281–320. <https://doi.org/10.4236/jep.2026.175014>
31. 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., Dar, O. I., Singh, K., Jasrotia, S., Bakshi, P., Ramakrishnan, M., Kumar, S., Bhardwaj, R., & Thukral, A. K. (2022). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, 1(11), 1446.
32. Shekhar, C., Khosya, R., Thakur, K., Mahajan, D., Kumar, R., Kumar, S., & Sharma, A. K. (2024). A systematic review of pesticide exposure, associated risks, and long-term human health impacts. *Toxicology Reports*, 13, 101840. <https://doi.org/10.1016/j.toxrep.2024.101840>
33. Slavin, J., & Lloyd, B. (2023). Health benefits of fruits and vegetables. *Advances in Nutrition*, 14(1), 115–126.
34. World Health Organization (WHO). (2022). Pesticide residues in food: Public health implications and safety standards. Geneva, Switzerland: WHO.