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Assessment of Pesticide Residue Practices and Public Health Implications in Agro-Pastoral Communities of Niger State, Nigeria

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Abstract

Pesticide residues in agricultural practices pose significant risks to public health, particularly in agro-pastoral communities where knowledge of pesticide usage is often limited. This study assesses pesticide residue practices among agro-pastoralists in Niger State, Nigeria, and examines the associated public health implications. A cross-sectional survey was conducted across three agro-ecological zones (A, B, and C) using structured questionnaires. The survey targeted nomadic and sedentary pastoral cattle herds to gather data on pesticide usage, exposure, and risk factors. Results revealed widespread pesticide misuse, largely driven by poor regulatory enforcement, low educational levels, and increasing demand for agricultural productivity. Additionally, significant variations were observed in pesticide knowledge and practices between the zones. This study highlights the urgent need for targeted interventions, stricter regulatory controls, and educational programs to mitigate health risks and enhance compliance with international safety standards.

Keywords: pesticide residues; public health; agro-pastoralists; niger state; pesticide misuse

Introduction

Nigeria's inability to comply with regional, global, and import nation sanitary and phytosanitary (SPS) regulations has led to significant losses in sales, income, and hard currency due to export rejections. Nigeria, as the world's largest producer and consumer of cowpeas and the fourth largest producer of sesame, has faced increasing challenges in exporting these crops, particularly to markets in the EU, Japan, and other Asian countries. Non-compliance with international SPS standards has been a major cause for the rejection of Nigerian cowpea and sesame exports. A notable example is Nigeria's sesame exports to Japan, where pesticide residue levels were found to be nearly double the permissible maximum residue limits between 2019 and 2021 (Boedeker et al., 2020). The presence of highly toxic pesticides such as carbofuran, parathion, and α-lindane in Nigerian agricultural exports has raised serious public health concerns. Even when pesticide concentrations are relatively low, the long-term health effects, particularly for children, are concerning. This issue extends to the contamination of milk and meat, further emphasizing the need for continuous monitoring and regulatory enforcement to mitigate health risks (Pignati et al., 2017; Agostini et al., 2020). For Nigeria, a country driven by agribusiness, such challenges hinder its potential on the global stage despite favorable climatic conditions and investment in agricultural technology (FAO, 2021). The situation in Nigeria reflects a broader problem across Africa and other regions like Brazil, where pesticide use in agriculture remains prevalent despite its toxic effects on the environment and human health (Ramos et al., 2021). Approximately 20-30% of the pesticides authorized for crops like coffee, soybeans, and citrus in Brazil are banned in the European Union, and the maximum residue limit for certain crops in Nigeria can be up to 200 times higher than EU standards (Bombardi, 2019; Friedrich et al., 2021). This global problem underscores the need for international regulatory consistency and a focus on reducing both acute and chronic pesticide exposure to protect public health.

Materials and Methods

Study Area

The study was conducted in Niger State which is located in the North-central geopolitical zone, and at the Southern Guinea Savannah ecological area of Nigeria, between latitude 8° 20' N and 11° 30' N, and longitude 3° 30'E and 7° 20'E. It is one of the 36 states of Nigeria, and covers a land area of about 76,363 square kilometres (29,484 square miles) or about 9 % of Nigeria's total land area, making it the largest in terms of land mass in the country. The state has 3 agro-ecological zones, with variable climatic conditions. These are: agro-ecological zone A (Southern) with eight Local Government Areas (LGAs), agro-ecological zone B (Eastern) with nine LGAs, and agro-ecological zone C (Northern) with eight LGAs. It has an estimated cattle population of 2.4 million cattle.

Study Design, Population and Definitions

The survey was a cross-sectional study that was conducted in the state. It involves the collection of blood, meat, tongue, liver, milk, urine and soil samples. Also, a structured questionnaire was administered to pastoral herd owners to obtain information on predisposing risk factors for pesticide usage on animals and grazing pastures.

The target population were nomadic and agro-pastoral cattle herds. Inclusion criteria for the herds and their owners are that they must be domiciled in the state during the period of the survey and belong to these two cattle production systems. For this research, a nomadic pastoral cattle herd is defined as a herd in Fulani ethnocultural group that keeps mainly cattle, has a large herd size, and is on all year-round movements and on large-range grazing and watering, and with no permanent homestead. Also, an agro-pastoral (sedentary pastoral) cattle herd is defined as a herd that keeps more cattle and cultivates few crops, is medium in size, is semi-settled, has limited cattle movements, and is on low-range grazing near environs. It is often given supplementary feeds of crop residues, particularly during the critical period of dry season.

Sample Size and Sampling Procedure

The sample size was determined using the method earlier described (Thrusfield, 2009). In mathematical notation,

$$N = Z2 \times Pq / d2,$$

where: n - the required sample size, Z^2 - standard deviation at 95 % confidence interval or 1.96, P - the power, q - proportion of failures (1 – p), and d - the desired absolute precision.

Sample sizes for the questionnaire were determined with power (p) set at a 95% confidence level, and margin of errors set at 5%, respectively, giving a sample size of samples of 388 questionnaire administrators.

$$\text{Sample size (n)} = \frac{Z^2 x\ pq}{d^2}$$

Given: Z = standard deviation at 95% confidence interval = 1.96; p = proportion of success expressed as decimal = 0.5; q = proportion of failures (1 – p); d = degree of accuracy (5%) expressed as a decimal = 0.05.

A multistage sampling procedure was used to collect the samples. In the first stage, the three existing agro-ecological zones A, B, and C in the state were considered. In the second stage, a purposive sampling procedure was used and the Local Government Councils in each zone were considered. The agro-ecological zone A (Southern) had eight local government areas (LGAs), agro-ecological zone B (Eastern) with nine LGAs, and agro-ecological zone C (Northern) with eight LGAs, Hence, purposive sampling techniques were employed to select participated LGAs namely: Zone A: Lapai, Agaie, Bida, Katcha, Gbako, mokwa, Edati and Lavun Zone B: Bosso, Chanchaga, Paikoro, Suleja, Tafa, Gurara, Munya, and Shiroro while Zone C is made up of: Agwara, Borgu, Kontogora, magma, mariga, Mashegu, Rafi, Rijau, and Wushishi. In the third and final stage, a simple random sampling method was to select herds for the questionnaire. One hundred and eighty-eight (188) questionnaires were administered in Zone A, while one hundred questionnaires were administered in each of Zone's B and C, giving a total of Three hundred and Eighty-Eight (388) questionnaires distributed to the respondents in the study area. Security reasons and Concentrations of the agro-pastoralists in an area were considered as the basis for distributing the questionnaire in the study areas, as provided by the Ministry of Livestock and Fisheries.

Sampling Tools and Sample Collection

A structured questionnaire was designed and pretested based on literature and experts' opinions. It contained mostly close-ended questions, to ease data processing, minimize variation and improve the precision of responses (Thrusfield, 2009). The questionnaire consisted of four sections that included: (i) Agro-pastoralist socio-demographic characteristics: age, gender, marital status, occupation and formal education; (ii) Farming practices information: type of farm management practice, type of feeds being given to their animals, and form of feeds that are fed to the animals with; (iii) Knowledge about pesticides usage and residues in feeds and animals; (iv) Practices of pesticides usage; and (v) Factors that influence pesticides misuse, overuse and residues emergence in the environment. The questionnaire was initially designed in English and verbally translated into Hausa during the interviews, as some farmers and livestock keepers lacked formal education. Six enumerators proficient in both English and Hausa were trained to administer the questionnaire through interviews. They posed the questions in Hausa and recorded the answers in English. We supervised the process daily and reviewed the completed forms to ensure quality control. A pre-test was conducted with 15 transhumant agro-pastoralists and 15 sedentary agro-pastoralists from the southern agro-geographical zone to identify and address potential issues before final administration. Respondents were informed about the survey's objectives verbally, and their informed consent was obtained prior to each session. All participants were assured of the voluntary nature of their involvement, the confidentiality of their responses, and their right to withdraw at any time without consequence, in accordance with the principles of the Helsinki Declaration (World Medical Association Declaration of Helsinki, 2001). The study protocols were approved by the Internal Research Ethics Committee of the Niger State Ministry of Livestock and Fisheries Development.

Data Management and Analysis

Data generated were summarized and entered into a Microsoft Excel 7 spreadsheet (Microsoft Corporation, Redmond, WA, USA) and stored. EpiInfo 3.4.3 (CDC, Atlanta, GA) and Open-Source Epidemiologic Statistics for Public Health (OpenEpi) software version 2.3.1 will be used. A $p<0.05$ will be considered statistically significant in all analyses. A geographical information system (GIS) will be used to analyse coordinates of locations.

Results

The socio-demographic characteristics of agro-pastoralists in Zones A, B, and C

Table 1: Below reveal significant variations in key variables, suggesting differences in age distribution, gender composition, marital status, occupation, and educational background. The chi-square (X^2) and p-values indicate strong associations between these variables and the specific zones.

Age Distribution

The age distribution shows notable differences across the zones:

In Zone A, most agro-pastoralists (47.3%) fall into the 18–27 age group, followed by 43.1% in the 28–37 group, and only 9.6% in the 38–47 group. Zone B has a predominant concentration (82%) in the 28–37 age range, with very few individuals in the younger (11%) and older (7%) age brackets. Zone C also shows a significant portion in the 28–37 range (72%), but 24% of the population is in the younger (18–27) age group, with only 4% in the oldest bracket (38–47). The chi-square value of 51.63 and p-value of 0.001 indicate a statistically significant association between age and zone, implying that the age composition varies significantly between the zones. The younger population is dominant in Zone A, while Zones B and C have a higher proportion of individuals in their late 20s and 30s.

Gender Composition

Zone A has 92% males and 8% females, indicating a male-dominated population. Zone B shows an even stronger male representation (97%) and a very small proportion of females (3%). Zone C, however, has a lower male presence (86%) and a higher proportion of females (14%). The chi-square value of 8.00 and p-value of 0.018 indicate that gender distribution differs significantly across the zones, with Zone C having more gender balance compared to Zones A and B.

Marital Status

Zone A has a balanced distribution between married (30.3%) and single individuals (68.1%), with very few divorced individuals (1.6%). Zone B is overwhelmingly composed of single individuals (93%), with only 6% married and 1% divorced. In Zone C, the married population dominates (58%), with a significant single population (41%) and a small divorced percentage (1%). The chi-square value of 63.75 and p-value of 0.001 indicate a significant association between marital status and the zone. Zone B stands out with its predominantly single population, while Zones A and C show more balanced distributions between married and single individuals.

Occupation

In Zone A, there is a near-equal split between transhumance agro-pastoralists (54.8%) and sedentary agro-pastoralists (45.2%). Zone B is predominantly transhumance-based (75%), with only 25% practicing sedentary agro-pastoralism. Zone C has the reverse pattern, with the majority (70%) being sedentary agro-pastoralists, and only 30% involved in transhumance agro-pastoralism. The chi-square value of 40.92 and p-value of 0.001 highlight a significant association between occupation type and zone. This suggests that the livelihood strategies (transhumance vs. sedentary) are strongly influenced by the zone, with Zone B being more mobile and Zone C more settled.

Socioeconomic Activities

Zone A shows a fairly even split between those involved in part-time (52.1%) and full-time business (47.9%). Zone B is dominated by part-time business activities (76%), with only 24% in full-time business. Zone C has the opposite trend, with 80% engaged in full-time business and only 20% in part-time activities. The chi-square value of 63.38 and p-value of 0.001 suggest a significant relationship between socioeconomic activity and zone. Zone C's high proportion of full-time business participants contrasts sharply with the part-time dominance in Zone B.

Educational Status

Zone A has a higher proportion of individuals with secondary (54.3%) and tertiary education (23.9%), with fewer individuals without formal education (20.2%). Zone B has a significant majority without formal education (75%), with only small percentages of primary (5%), secondary (12%), and tertiary education (8%). Zone C falls between these two, with 59% without formal education, 8% with primary, 8% with secondary, and 25% with tertiary education. The chi-square value of 127.95 and p-value of 0.001 indicate a highly significant association between educational attainment and zone. Zone A stands out for its relatively higher educational levels, while Zone B shows a high prevalence of individuals without formal education. This data demonstrates clear socio-demographic distinctions among agro-pastoralists in the three zones. Zone A tends to have a younger population, a fairly balanced gender ratio, and a relatively higher educational status. Zone B is predominantly male, younger, and largely engaged in part-time and transhumance agro-pastoralism, with low levels of formal education. Zone C is more gender-diverse, with a higher proportion of married individuals, sedentary agro-pastoralists, and full-time business involvement. These differences can inform targeted interventions, especially in education, economic activities, and agricultural practices, based on the specific characteristics of each zone. The significant statistical associations across variables indicate that zone-specific strategies are crucial for addressing the distinct needs and challenges of agro-pastoral communities.

Table 1: Socio-Demographic Characteristics of the Agro-Pastoralists

	Zone A (n=188)	Zone B (n=100)	Zone C (n=100)	X2	P -Value
Variables	**Freq. (%)**	**Freq. (%)**	**Freq. (%)**		
Age (years)					
18 – 27	89 (47.30)	11(11.00)	24(24.00)		
28 – 37	81 (43.10)	82(82.00)	72(72.00)	51.63	0.001
38 – 47	18 (9.60)	7 (7.00)	4 (4.00)		
Gender					
Male	173 (92.0)	97(97.00)	86(86.00)	8	0.018
Female	15 (8.00)	3 (3.00)	14(14.00)		
Marital status					
Married	57 (30.30)	6 (6.00)	58 (58.00)		
Single	128(68.10)	93(93.00)	41(41.00)	63.75	0.001
Divorced	3 (1.60)	1 (1.00)	1 (1.00)		
Occupation					
Transhumance Agro-Pastoralism	103(54.80)	75(75.00)	30(30.00)	40.92	0.001
Sedentary Agro-Pastoralism	85(45.20)	25(25.00)	70(70.00)		
Socioeconomic activities					
Part-time business	98 (52.10)	76(76.00)	20(20.00)	63.38	0.001
Full-time business	90 (47.90)	24(24.00)	80(80.00)		
Formal educational status					
No formal	38 (20.20)	75(75.00)	59 (59.00)		
Primary	3 (1.60)	5 (5.00)	8 (8.00)		
Secondary	102(54.30)	12(12.00)	8 (8.00)	127.95	0.001
Tertiary	45 (23.90)	8 (8.00)	25(25.00)		

Herd Management Among Agro-Pastoralists Across the Three Agro-Ecological Zone A, B, And C In Niger State, Nigeria

The table 2: Below presents the distribution of herd management practices and feeding strategies among agro-pastoralists in Niger State, Nigeria, across three different zones (A, B, and C). Statistical significance is assessed using the Chi-square test (X^2), with corresponding p-values provided. Let's discuss each variable in detail:

Herd Management Practices

Intensive Management

Zone A: 9% of pastoralists practice intensive management, while 91% do not. Zone B: 17% practice intensive management, higher than Zone A, with 83% not practicing. Zone C: Only 2% of pastoralists practice intensive management, with 98% not involved. The Chi-square value (13.39) and the p-value (0.0012) indicate a highly significant difference between the zones. Zone B shows the highest adoption of intensive management, while Zone C has the least. This could reflect variations in available resources, education, or proximity to markets.

Semi-Intensive Management

Zone A: 9% practice semi-intensive management, with 91% not participating. Zone B: 17% practice, and 83% do not, similar to the pattern seen in intensive management. Zone C: 3% practice semi-intensive management, and 97% do not. A Chi-square value of 11.46 and a p-value of 0.0032 suggest a significant variation across zones. Semi-intensive management is more common in Zone B, and again, Zone C shows the lowest adoption.

Extensive Management

Zone A: 81.9% practice extensive management, while 18.1% do not. Zone B: 66% practice, and 34% do not. Zone C: 95% practice, while only 5% do not. A Chi-square value of 27.66 and a p-value of 0.001 indicate a very significant difference across zones. Extensive management is the most common form of herd management, especially in Zone C, while Zone B shows a relatively lower adoption rate. This suggests that pastoralists in Zone C are more reliant on traditional grazing methods.

Type of Feeds Used

Unfarmed Grasses

Zone A: 3.7% use unfarmed grasses, while 96.3% do not. Zone B: 7% use unfarmed grasses, with 93% not using them. Zone C: No pastoralists use unfarmed grasses. The Chi-square value of 7.06 and a p-value of 0.0293 show a significant difference. Zone B uses more unfarmed grasses compared to Zone A and especially Zone C. This may indicate variations in access to natural pastures or climatic differences between the zones.

Farmed Grasses

Zone A: 3.7% use farmed grasses, while 96.3% do not. Zone B: 7% use farmed grasses, and 93% do not. Zone C: 2% use farmed grasses, and 98% do not. The Chi-square value (3.31) and p-value (0.191) indicate no significant difference between zones. This suggests that farmed grasses are generally not a common feed source across the zones.

Crop Residues

Zone A: 4.8% use crop residues, and 95.2% do not. Zone B: 9% use crop residues, while 91% do not. Zone C: No one in Zone C uses crop residues. The Chi-square value of 9.21 and p-value of 0.001 suggest a significant difference. Crop residues are more commonly used in Zones A and B, indicating better access to or reliance on farming activities for feed.

All of the Above (Feed Types)

Zone A: 87.8% use a combination of feeds, while 12.2% do not. Zone B: 77% use all types of feeds, with 23% not using them. Zone C: Only 2% use all types of feeds, with 98% not using them. The Chi-square value of 217.23 and p-value of 0.0001 show a highly significant difference. The use of diverse feed sources is highly prevalent in Zones A and B, while Zone C shows very little adoption of multiple feed types. This may highlight the limited agricultural diversity or feed options in Zone C.

Form of Feed Used

Raw Form

Zone A: 5.9% use raw feed, while 94.1% do not. Zone B: 11% use raw feed, with 89% not using it. Zone C: Only 1% use raw feed, with 99% not using it. The Chi-square value of 8.97 and p-value of 0.0113 indicate a significant difference, with Zone B showing a higher tendency to use raw feed than Zones A and C. This might reflect differences in feeding practices or resource availability.

Formulated Form

Zone A: 9.6% use formulated feed, while 90.4% do not. Zone B: No pastoralists use formulated feed. Zone C: 3% use formulated feed, while 97% do not.

The Chi-square value of 13.22 and a p-value of 0.0013 show a significant difference, with formulated feed being more common in Zone A compared to the other zones, especially Zone B where it is completely absent.

All of the Above (Feed Forms)

Zone A: 84.6% use a combination of feed forms, while 15.4% do not. Zone B: 89% use all forms, and 11% do not. Zone C: 96% use all forms, while 4% do not. The Chi-square value of 5.54 and p-value of 0.0626 indicate no significant difference. The high usage of multiple feed forms across all zones suggests a widespread practice of using varied feed forms, indicating flexibility and adaptation to available resources.

Overall, the data reveals significant differences in herd management practices and feed usage across the three zones in Niger State. Zone C, in particular, stands out for its higher reliance on extensive management practices and minimal adoption of diverse feed types, likely reflecting its pastoralist traditions. Zone B shows the highest use of intensive and semi-intensive management, as well as greater usage of unfarmed grasses, indicating a more diversified approach to herd management. Zone A tends to be more balanced but leans towards extensive management and diverse feed forms. The significant differences highlighted by the Chi-square tests underscore the regional variations in agro-pastoral practices, influenced by factors such as resource availability, environmental conditions, and possibly proximity to markets or infrastructure.

Table 2: Herd Management Among Agro-Pastoralists in Niger State, Nigeria

		Zone A (n=188)	Zone B (n=100)	Zone C (n=100)		
Variables	**Category**	**Freq. (%)**	**Freq. (%)**	**Freq. (%)**	**X2**	**p-value**
Herd management practiced						
Intensive	Yes	17 (9.00)	17 (17.00)	2 (2.00)	13.39	0.0012
	No	171 (91.00)	83 (83.00)	98 (98.00)		
Semi-intensive	Yes	17 (9.00)	17 (17.00)	3 (3.00)	11.46	0.0032
	No	171 (91.00)	83 (83.00)	97 (97.00)		
Extensive	Yes	154 (81.90)	66 (66.00)	95 (95.00)	27.66	0.001
	No	34 (18.10)	34 (34.00)	5 (5.00)		
Type of feeds used						
Unfarmed grasses	Yes	7 (3.70)	7 (7.00)	0 (0.00)	7.06	0.0293
	No	181 (96.30)	93 (93.00)	100 (100.00)		
Farmed grasses	Yes	7 (3.70)	7 (7.00)	2 (2.00)	3.31	0.191
	No	181 (96.30)	93 (93.00)	98 (98.00)		
Crop Residues	Yes	9 (4.80)	9 (9.00)	0 (0.00)	9.21	0.001
	No	181 (95.20)	91 (91.00)	100 (100.00)		
All of the above	Yes	165 (87.80)	77 (77.00)	2 (2.00)	217.23	0.0001
	No	23 (12.20)	23 (23.00)	98 (98.00)		
Form of feed						
Raw form	Yes	11 (5.90)	11 (11.00)	1 (1.00)	8.97	0.0113
	No	177 (94.10)	89 (89.00)	99 (99.00)		
Formulated form	Yes	18 (9.60)	0 (0.00)	3 (3.00)	13.22	0.0013
	No	170 (90.40)	100 (100.00)	97 (97.00)		
All of the above	Yes	159 (84.60)	89 (89.00)	96 (96.00)	5.54	0.0626
	No	23 (15.40)	11 (11.00)	4 (4.00)		

Agro-Pastoralists' Knowledge of Pesticide Usage on Crops and Animals Across Three Zones (A, B, And C) In Niger State, Nigeria

The findings presented in table.3: highlight agro-pastoralists' knowledge of pesticide usage on crops and animals across three zones (A, B, and C) in Niger State, Nigeria. The table evaluates various aspects, including general knowledge of pesticides, sources of information, understanding of pesticide residues, transmission pathways, and the potential effects of bio-magnification in humans.

Knowledge of Pesticides

The knowledge of pesticides is nearly universal in all three zones. In Zone A, 96.8% of respondents reported having knowledge of pesticides, slightly lower than Zones B (98%) and C (100%). The chi-square (X^2) test result (X^2=3.30, p=0.193) indicates that there is no significant difference in pesticide knowledge between the zones. This suggests that pesticide usage awareness is widespread among agro-pastoralists in all regions.

Sources of Information on Pesticides

Different sources provide information on pesticides, with considerable variability between the zones. Friends and relations were significant sources of pesticide information in Zone A, while Zone B agro-pastoralists primarily relied on relations (79%). Zone C showed no reliance on friends or relations, indicating a more structured approach to learning. Instead, 100% of respondents in Zone C cited extension workers as a source. The p-values for most sources (except community meetings and radio) are significant (p=0.001), indicating differences in information sources across zones.

Pesticide Residues

The understanding of pesticide residues and their accumulation in different ecosystems is strikingly uneven. For instance, bioaccumulation in animal tissue is acknowledged by 6.9% of respondents in Zone A, but none in Zones B and C. Similarly, awareness of bioaccumulation in crops is significantly higher in Zone A (13.3%) than in Zones B and C. Interestingly, Zone C shows zero awareness across several key areas of pesticide residue knowledge, contrasting with the higher figures in Zone A. The chi-square tests show significant differences between the zones, particularly regarding awareness of bioaccumulation in animal tissue (X^2=11.97, p=0.002), crops (X^2=12.18, p=0.002), and grasses (X^2=12.10, p=0.002).

Transmission of Pesticide Residues to Humans

The awareness of pesticide transmission through food to humans is generally high, with Zone C respondents showing full awareness (100%). However, the difference in knowledge among the zones is not significant (X^2=0.91, p=0.635). While most respondents agree on the transmission of pesticide residues through food, some (particularly in Zone A) were unaware or disagreed (14.9%). This indicates a gap in understanding the full extent of how pesticide residues affect human health.

Means of Exposure to Pesticides

Respondents acknowledged multiple routes of human exposure to pesticides, including water, air, and skin. Zone C has the highest awareness of all exposure routes (75%). Zone A shows lower awareness, particularly with regard to air (2.1%) and water (4.3%), while Zone B respondents were unaware of most exposure routes except skin. The p-values indicate that differences in knowledge about pesticide exposure are significant across zones ($p<0.05$), with some zones showing notably limited understanding.

Pesticide Bio-magnification in Humans

Most respondents (96.3% in Zone A, 98% in Zone B, and 100% in Zone C) agree that pesticides result in bio-magnification in humans, although the chi-square test does not show significant differences (X^2=4.97, p=0.083). The minimal discrepancy in responses reflects a relatively high level of awareness about bio-magnification.

Health Effects of Pesticide Bio-magnification

The health impacts of pesticide bio-magnification, including carcinogenicity, teratogenicity, immunosuppression, embryotoxicity, nephrotoxicity, and hepatotoxicity, are unevenly recognized across the zones. For example, awareness of teratogenic effects is higher in Zone A (6.9%) compared to the other zones, while Zone C respondents show no knowledge of these effects. Teratogenicity and nephrotoxicity awareness have significant differences between zones ($p<0.05$). Overall, most respondents agree that pesticide bio-magnification can result in multiple health issues. The results highlight regional disparities in knowledge about pesticide usage, exposure, and health risks among agro-pastoralists. Zones A and B show more variability in sources of information and understanding of pesticide residues than Zone C, which consistently demonstrates full awareness in key areas. This calls for targeted educational interventions, especially in Zones A and B, to improve knowledge about pesticide bioaccumulation, transmission, and long-term health risks. The significant differences observed in various categories suggest that educational programs should consider the unique challenges and information gaps present in each zone.

Table 3: Knowledge About Pesticide Usage on Crops and Animals by Agro-Pastoralists in Niger State, Nigeria

		Zone A(n=188)	Zone B(n=100)	Zone C (n=100)	

Variables	Category	Freq. (%)	Freq. (%)	Freq. (%)	X2	P-Value
Knowledge of pesticides	Yes	182(96.80)	98(98.00)	100(100.00)	3.3	0.193
	No	6(3.20)	2(2.00)	0(0.00)		
Sources of information on pesticides						
Friends	Yes	22(11.70)	1(1.00)	0(0.00)	21.9	0.001
	No	166(88.30)	99(99.00)	100(100.00)		
Relations	Yes	35(18.10)	79(79.00)	0(0.00)	170.76	0.001
	No	153(81.90)	21(21.00)	100(100.00)		
Extension workers	Yes	88(46.80)	19(19.00)	100(100.00)	138.08	0.001
	No	100(53.20)	81(81.00)	0(0.00)		
Community meetings	Yes	12(6.40)	0(0.00)	0(0.00)	13.17	0.001
	No	176(93.60)	100(100.00)	100(100.00)		
Radio	Yes	32(17.00)	1(1.00)	0(0.00)	34.06	0.001
	No	156(83.00)	99(99.00)	100(100.00)		
Pesticide residues						
Bioaccumulation in animal tissue	Yes	13(6.90)	0(0.00)	0(0.00)	11.97	0.002
	No	175(93.10)	100(100.00)	100(100.00)		
Bioaccumulation of pesticides in crops	Yes	25(13.30)	1(1.00)	0(0.00)	12.18	0.002
	No	163(86.70)	99(99.00)	100(100.00)		
Bio concentration in water	Yes	1(0.50)	0(0.00)	0(0.00)	0.37	0.831
	No	187(99.50)	100(100.00)	100(100.00)		
Bioaccumulation in grasses	Yes	22(11.70)	2(2.00)	0(0.00)	12.1	0.002
	No	166(88.30)	98(98.00)	100(100.00)		
All of the above	Yes	126(67.00)	97(97.00)	100(100.00)	8.13	0.017
	No	62(33.00)	3(3.00)	0(0.00)		
Pesticide residues in animal tissues can be transmitted through food to humans						
Agree	Yes	160(85.10)	86(86.00)	100(100.00)	0.91	0.635
	No	28(14.90)	14(14.00)	0(0.00)		
Disagree	Yes	7(3.70)	8(8.00)	0(0.00)	13.09	0.001
	No	181(96.30)	92(92.00)	100(100.00)		
Don't know	Yes	21(11.20)	6(6.00)	0(0.00)	7.16	0.028
	No	167(88.80)	94(94.00)	100(100.00)		
Means humans are exposed to pesticides						
Water	Yes	8(4.30)	0(0.00)	4(4.00)	7.7	0.021
	No	180(95.70)	100(100.00)	96(96.00)		
Air	Yes	4(2.10)	0(0.00)	9(9.00)	16.23	0.001
	No	184(97.90)	100(100.00)	91(91.00)		
Skin	Yes	22(11.70)	0(0.00)	12(12.00)	17.95	0.001
	No	166(88.30)	100(100.00)	88(88.00)		
All of the above	Yes	154(81.90)	100(100.00)	75(75.00)	33.57	0.001
	No	34(18.10)	0(0.00)	25(25.00)		
Pesticides residues result to bio-magnification in humans?						
Yes	Yes	181(96.30)	98(98.00)	100(100.00)	4.97	0.083
No	No	7(3.70)	2(2.00)	0(0.00)		
Effects of pesticide bio-magnification in humans						
Carcinogenicity	Yes	5(2.70)	0(0.00)	0(0.00)	2.77	0.251
	No	183(97.30)	100(100.00)	100(100.00)		
Teratogenicity	Yes	13(6.90)	0(0.00)	0(0.00)	12.1	0.002
	No	175 (93.10)	100 (100.00)	100(100.00)		
Immunosuppression	Yes	6(3.20)	0(0.00)	0(0.00)	7.17	0.028
	No	182(96.80)	100(100.00)	100(100.00)		
Embryotoxicity	Yes	8(4.30)	0(0.00)	0(0.00)	9.67	0.008
	No	180(95.70)	100(100.00)	100(100.00)		
Nephrotoxicity	Yes	3(1.60)	1(1.00)	0(0.00)	9.69	0.008

	No	185(98.40)	99(99.00)	100(100.00)		
Hepatotoxicity	Yes	3(1.60)	1(1.00)	0(0.00)	9.69	0.008
	No	185 (98.40)	99 (99.00)	100(100.00)		
All of the above	Yes	150(79.80)	98(98.00)	100(100.00)	5.91	0.052
	No	38(20.20)	2(2.00)	0(0.00)		

Practice of Pesticides Usage on Crops and Animals by the Agro-Pastoralists across Three Zones (A, B, and C) in Niger State, Nigeria

The data in Table 4: Below provides a comprehensive overview of pesticide use practices among agro-pastoralists across three zones (A, B, and C) in Niger State, Nigeria. The results are categorized based on different aspects such as the use of pesticides in livestock, types of pesticides used, purposes for using them, application methods, frequency of use, and the season of application. Here's a detailed discussion of the results:

Use of Pesticides in Livestock or Livestock Feeds

A high proportion of agro-pastoralists across all zones (96.3% in Zone A, 99% in Zone B, and 100% in Zone C) reported using pesticides in livestock or livestock feeds. The Chi-square test (X^2 = 3.64, p = 0.162) indicates no significant difference among the zones, suggesting that pesticide usage in livestock is a common practice across the state.

Kind of Pesticide Used

Selective Pesticides: The proportion of selective pesticide use was highest in Zone A (18.6%), followed by Zone B (7.0%) and none in Zone C. The Chi-square test (X^2 = 13.54, p = 0.001) shows a significant difference, indicating that selective pesticide use is more prevalent in Zone A. Non-Selective Pesticides: Usage was low across all zones, with no significant differences (X^2 = 0.34, p = 0.840). This suggests non-selective pesticides are not widely used. All of the Above: A significant proportion of respondents in Zone A (79.8%) and Zone B (99%) reported using all types of pesticides, but Zone C had a perfect 100% response for using a combination of all. This variation is statistically significant (X^2 = 10.68, p = 0.001).

Type of Pesticides Used

Insecticides: Insecticide use varied greatly, with Zone A at 14.9%, Zone B at 1%, and none in Zone C, with a significant difference (X^2 = 22.15, p = 0.001). This shows a significant regional variation in insecticide usage. Herbicides: Only Zone A (2.7%) reported any herbicide usage. The absence of herbicide uses in Zones B and C also showed a significant regional difference (X^2 = 6.414, p = 0.041). Acaricides and Fungicides: These pesticides were rarely used in all three zones, and the Chi-square test results suggest no significant differences between the regions. Rodenticides: Rodenticides were used more in Zone A (3.2%) compared to the other zones, but this difference wasn't statistically significant (X^2 = 3.489, p = 0.175). All Types of Pesticides: A significant portion of respondents across the zones used all available types of pesticides, with Zone A at 75%, Zone B at 97%, and Zone C at 100% (X^2 = 16.414, p = 0.001).

Purpose of Pesticides Usage

Against Ecto-Parasites: Usage of pesticides against ecto-parasites was higher in Zone A (12.2%) compared to Zone B (1%) and Zone C (0%), with a significant difference across zones (X^2 = 10.234, p = 0.006). Control of Insects: Insect control was more commonly reported in Zone A (5.9%), while none of the respondents in Zones B and C reported such usage, although the difference approaches significance (X^2 = 5.857, p = 0.054). Weed Control: Zone A also reported more pesticide usage for weed control (5.9%) compared to the other zones, which was statistically significant (X^2 = 13.35, p = 0.001).

Forms of Pesticide Application

Dusting and Bathing: Dusting was more commonly practiced in Zone A (9%) compared to other zones. Bathing was another significant method in Zones A and B (X^2 = 8.530, p = 0.014). Spraying: Spraying was practiced in Zone A (9.6%) but not in Zones B and C. The Chi-square test shows significant differences (X^2 = 11.277, p = 0.004), suggesting variation in pesticide application techniques.

Frequency of Usage

Thrice a Year: The frequency of pesticide usage was highest in Zone A (9%), Zone B (2%), and none in Zone C. This difference was statistically significant (X^2 = 102.53, p = 0.001), indicating greater usage frequency in Zone A.

Season of Pesticide Usage

Dry Season: Pesticide usage was highest during the dry season in Zone A (60.6%), Zone B (70%), and minimal in Zone C (1%). The difference was significant (X^2 = 7.88, p = 0.019). Both Seasons: There was significant variation in pesticide use during both seasons, with 24.5% in Zone A, 10% in Zone B, and 1% in Zone C (X^2 = 8.486, p = 0.014).

Frequently Used Pesticides

Herbicide: The most frequently used pesticide was herbicide across all zones, but the differences were not significant (X^2 = 1.036, p = 0.595). Fungicide: Fungicide usage was significantly higher in Zone B (16%) and Zone C (15%), with differences statistically significant (X^2 = 10.498, p = 0.005). Insecticide: Insecticide usage was higher in Zones B and C (22% and 23%) compared to Zone A (20.7%), though not statistically significant. The data reveal significant variations in pesticide use practices among agro-pastoralists in Niger State. Zone A generally had higher usage rates for various pesticide types and purposes, while Zones B and C showed more selective or limited use. Statistically significant differences were observed in pesticide type, application method, and seasonal use, indicating diverse practices across regions. These findings underscore the need for targeted interventions and educational campaigns tailored to regional practices in pesticide management.

Table 4: Practice of Pesticides Usage on Crops and Animals by The Agro-Pastoralists in Niger State, Nigeria.

		Zone A (n=188)	Zone B (n=100)	Zone C (n=100)		
Variables	Category	Freq. (%)	Freq. (%)	Freq. (%)	X2	P-Value
1.Use of pesticides in livestock or livestock feeds	Yes	181(96.30)	99(99.00)	100(100.00)	3.64	0.162
	No	7(3.70)	1(1.00)	0(0.00)		
Kind of pesticide use						
Selective	Yes	35(18.60)	7(7.00)	0(0.00)		
	No	153(81.40)	93(93.00)	100(100.00)	13.54	0.001
Non-selective	Yes	3(1.60)	2(2.00)	0(0.00)		
	No	185(98.40)	98(98.00)	100(100.00)	0.34	0.84
All of the above	Yes	150(79.80)	91(99.00)	100(100.00)		
	No	38(20.20)	9(9.00)	0(0.00)	10.68	0.001
2.Type of pesticides use						
Insecticides	Yes	28(14.90)	1(1.00)	0(0.00)		
	No	160(85.10)	99(99.00)	100(100.00)	22.154	0.001
Herbicide	Yes	5(2.70)	0(0.00)	0(0.00)		
	No	183(97.30)	100(100.00)	100(100.00)		
Acaricides	Yes	2(1.10)	1(1.00)	0(0.00)		
	No	186(98.90)	99(99.00)	100(100.00)	2.632	0.268
Fungicides	Yes	6(3.20)	1(1.00)	0(0.00)		
	No	182(96.80)	99(99.00)	100(100.00)	0.833	0.659
Rodenticides	Yes	6(3.20)	0(0.00)	0(0.00)		
	No	182(96.80)	100(100.00)	100(100.00)	3.489	0.175
All of the above	Yes	141(75.00)	97(97.00)	100(100.00)	6.414	0.041
	No	47(25.00)	3(3.00)	0(0.00)	16.414	0.001
3. Purpose of pesticides usage						
Against ecto-parasites	Yes	23(12.20)	1(1.00)	0(0.00)	10.234	0.006
	No	165(87.80)	99(99.00)	100(100.00)		
To control insects	Yes	11(5.90)	0(0.00)	0(0.00)		
	No	177(94.10)	100(100.00)	100(100.00)	5.857	0.054
To kill weeds	Yes	11(5.90)	2(2.00)	0(0.00)	6.23	0.044
	No	177(94.10)	98(98.00)	100(100.00)	13.35	0.001
All of the above	Yes	143(76.06)	97(97.00)	100(100.00)		
	No	45(23.94)	3(3.00)	0(0.00)	7.45	0.024
4. Forms of pesticides application						
Dusting	Yes	17(9.00)	0(0.00)	0(0.00)		
	No	171(91.00)	100(100.00)	100(100.00)	3.781	0.151
Bathing	Yes	8(4.30)	3(3.00)	0(0.00)	8.53	0.014
	No	180(95.70)	97(97.00)	100(100.00)		
Spraying	Yes	18(9.60)	0(0.00)	0(0.00)		
	No	170(90.40)	100(100.00)	100(100.00)	11.277	0.004
All of the above	Yes	145(77.10)	97(97.00)	100(100.00)	2.958	0.23
	No	43(22.90)	3(3.00)	0(0.00)		
5.Frequency of usage						

Once a year	Yes	15(8.00)	0(0.00)	0(0.00)	4.507	0.11
	No	173(92.00)	100(100.00)	100(100.00)		
Twice a year	Yes	156(83.00)	98(98.00)	100(100.00)	5.24	0.07
	No	32(17.00)	2(2.00)	0(0.00)		
Thrice a year	Yes	17(9.00)	2(2.00)	0(0.00)	102.53	0.001
	No	171(91.00)	98(98.00)	100(100.00)		
6.Season of pesticide usage						
Raining season	Yes	28(14.90)	20(20.00)	98(98.00)	4.27	0.118
	No	160(85.10)	80(80.00)	2(2.00)		
Dry season	Yes	114(60.60)	70(70.00)	1(1.00)		
	No	74(39.40)	30(30.00)	99(99.00)	7.88	0.019
Both Season	Yes	46(24.50)	10(10.00)	1(1.00)		
	No	142(75.50)	90(90.00)	99(99.00)	8.486	0.014
7.Frequently used pesticide						
Herbicide	Yes	124(66.00)	54(54.00)	62(62.00		
	No	64(34.00)	46(46.00)	38(38.00)	1.036	0.595
Acaricide	Yes	2(1.10)	0(0.00)	0(0.00)		
	No	186(98.90)	100(100.00)	100(100.00)		
Fungicide	Yes	12(6.40)	16(16.00)	15(15.00)		
	No	176(93.60)	84(84.00)	85(85.00)	10.498	0.005
Insecticide	Yes	39(20.70)	22(22.00)	23(23.00)		
	No	149(79.30)	78(78.00)	77(77.00)		
Pesticide	Yes	0(0.00)	0(0.00)	0(0.00)	3.308	0.191
	No	188(100.00)	100(100.00)	100(99.00)		
Rodenticide	Yes	11(5.90)	8(8.00)	0(0.00)		
	No	177(94.10)	92(92.00)	100(100.00)	9.203	0.01

Distribution of the Respondents According to Factors That Influence Pesticide Misuse, Overuse, And Residue Emergence

The data presented in Table 5: Below provides a comprehensive overview of the factors influencing pesticide misuse, overuse, and the emergence of pesticide residues across three distinct zones (A, B, and C). A critical aspect of this analysis is the statistical significance indicated by the p-values associated with each variable, which serve to validate the findings and underscore the importance of addressing these issues. Inappropriate Use of PesticidesThe data indicates that a staggering 95.20% of respondents in Zone A reported inappropriate pesticide use, with a p-value of 0.0074. This p-value is less than the conventional threshold of 0.05, suggesting a statistically significant association between the variable and the misuse of pesticides. The high frequency of inappropriate use in Zone A compared to Zones B and C, where no respondents reported misuse, highlights a pressing concern. The significance of this finding suggests that interventions aimed at educating farmers in Zone A about proper pesticide application could be particularly beneficial. Poor Financial Status The influence of poor financial status on pesticide misuse is evident, with 92.60% of respondents in Zone A indicating this as a contributing factor, and a p-value of 0.0098. This result is statistically significant, reinforcing the notion that financial constraints compel farmers to resort to excessive pesticide use as a means of maximizing yield. The implications of this finding suggest that improving the economic conditions of farmers could lead to more responsible pesticide practices, thereby reducing the associated health and environmental risks. Absence of Regulatory Law The absence of regulatory law was reported by 88.80% of respondents in Zone A, with a p-value of 0.0006. This extremely low p-value indicates a highly significant relationship between the lack of regulation and pesticide misuse. The absence of effective regulatory frameworks can lead to unregulated pesticide sales and usage, which is particularly concerning in regions where farmers may lack the necessary knowledge to use these chemicals safely. The significance of this finding calls for urgent policy interventions to establish and enforce regulatory measures governing pesticide use. Low Level of Education. The data also reveals that 95.20% of respondents in Zone A reported low levels of education as a factor influencing pesticide misuse, with a p-value of 0.0074. This statistically significant result underscores the critical role of education in shaping farmers' understanding of safe pesticide practices. The findings suggest that educational programs aimed at increasing awareness about the risks associated with pesticide misuse could significantly mitigate these practices. Easy Accessibility to Pesticides. The ease of accessibility to pesticides was noted by 92.00% of respondents in Zone A, with a p-value of 0.001. This low p-value indicates a strong statistical significance, suggesting that easy access to pesticides contributes to their overuse. The implications of this finding are profound, as it indicates that regulatory measures should not only focus on education but also on controlling the availability of pesticides to prevent misuse. Increasing Demand for Agricultural Products. The increasing demand for agricultural products was acknowledged by 91.50% of respondents in Zone A, with a p-value of 0.001. This significant p-value suggests that market pressures are a substantial driver of pesticide misuse. The findings indicate that addressing market dynamics and promoting sustainable agricultural practices could help alleviate the pressure on farmers to overuse pesticides. Excessive Importation of Pesticides. Finally, the excessive importation of pesticides was reported by 86.20% of respondents in Zone A, with a p-value of 0.001. This statistically significant result highlights the potential risks associated with the influx of imported pesticides, which may not be subject to the same regulatory scrutiny as domestically produced products. The significance of this finding suggests that policymakers should consider stricter import regulations to safeguard public health and the environment. Conclusion In summary, the p-values associated with each factor in Table 5 provide compelling evidence of the significant relationships between these variables and pesticide misuse. The consistently low p-values across various factors indicate that interventions targeting education, economic support, regulatory enforcement, and market dynamics are crucial for mitigating pesticide misuse and its associated risks.

Table 5: Distribution Of Respondents According to Factors That Influence Pesticide Misuse, Overuse, And Residue Emergence

		Zone A (n=188)	Zone B (n=100)	Zone C (n=100)	
Variables	Category	Freq. (%)	Freq. (%)	Freq. (%)	X^2 P-Value
1. Inappropriate use of pesticides	Yes	179 (95.20)	100 (100.00)	100 (100.00)	9.80
	No	9 (4.80)	0 (0.00)	0 (0.00)	0.007
2. Poor financial status	Yes	174 (92.60)	97 (97.00)	100 (100.00)	9.25
	No	14 (7.40)	3 (3.00)	0 (0.00)	0.009
3. Absence of regulatory law	Yes	167 (88.80)	96 (96.00)	100 (100.00)	14.85
	No	9 (11.20)	4 (4.00)	0 (0.00)	0.001
4. Low level of education	Yes	179 (95.20)	100 (100.00)	100 (100.00)	9.80
	No	9 (4.80)	0 (0.00)	0 (0.00)	0.007
5. Easy accessibility to pesticides	Yes	173 (92.00)	79 (79.00)	100 (100.00)	26.93
	No	15 (8.00)	21 (21.00)	0 (0.00)	0.001
6. Increasing demand for agricultural product	Yes	172 (91.50)	79 (79.00)	100 (100.00)	26.00
	No	16 (8.50)	21 (21.00)	0 (0.00)	0.001
7. Excessive importation of pesticide	Yes	162 (86.20)	100 (100.00)	100 (100.00)	29.65
	No	26 (13.80)	0 (0.00)	0 (0.00)	0.001

Distribution Of Respondents According to Public Health Impacts of Pesticides Usage on Animals/ Environment/ Human Across the Three Agro-Ecological in Niger State, Nigeria

The table 6: Below presents the distribution of respondents from three zones (Zone A, Zone B, and Zone C) based on their responses to the public health impacts of pesticide usage on animals, the environment, and humans. Each variable reflects a different potential outcome or effect of pesticide use, with the respondents' agreement or disagreement shown in frequencies and percentages. The Chi-square (X^2) statistic and p-value provide insights into the statistical significance of the differences between zones. Below is a detailed discussion of the results:

Long-term, high-intensity use of pesticides can bring about an imbalance in ecosystems

Zone A: 94.10% of respondents agreed, while 5.90% disagreed. Zone B: Almost all respondents (99.00%) agreed, with only 1.00% disagreeing. Zone C: 100% of respondents agreed. The Chi-square value of 9.43 and a p-value of 0.001 indicate that there is a statistically significant difference between the zones. This suggests that while there is strong agreement across all zones, Zone A shows a slightly lower proportion of respondents agreeing with this statement than Zones B and C.

The population is subject to chronic health effects from pesticide use

Zone A: 95.20% agreed, and 4.80% disagreed. Zone B: 99.00% agreed, and only 1.00% disagreed. Zone C: 100% of respondents agreed. With a Chi-square value of 7.29 and a p-value of 0.03, this result is statistically significant, meaning there is some variation in perceptions of chronic health effects, especially in Zone A, where a small proportion disagreed.

Pesticide usage can lead to the emergence of resistant pests and weeds

Zone A: 97.30% agreed, while 2.70% disagreed. Zone B: 99.00% agreed, and 1.00% disagreed. Zone C: 100% agreed. Although the overall agreement is high, the p-value of 0.1 indicates no significant difference between the zones for this variable.

Health symptoms such as eye and skin irritation, nausea, vomiting, and headaches frequently occur with pesticide exposure

Zone A: 96.80% agreed, and 3.20% disagreed. Zone B: 99.00% agreed, with 1.00% disagreeing. Zone C: 100% agreed. The Chi-square value is 4.24, with a p-value of 0.1, indicating no significant difference between the zones regarding the perceived frequency of these health symptoms.

Most consumed staple foods are contaminated with pesticides

Zone A: 93.60% agreed, and 6.40% disagreed. Zone B: 99.00% agreed, and 1.00% disagreed. Zone C: 100% agreed. A Chi-square value of 10.51 and a p-value of 0.001 suggest significant differences between the zones, particularly in Zone A, where a higher proportion of respondents (6.40%) believe that staple foods are not contaminated with pesticides compared to Zones B and C.

Frequent pesticide usage can lead to water pollution

Zone A: 95.70% agreed, and 4.30% disagreed. Zone B: 98.00% agreed, with 2.00% disagreeing. Zone C: 100% agreed. The Chi-square value of 4.89 and a p-value of 0.09 indicate that there is no statistically significant difference between the zones regarding water pollution from pesticide use.

Pesticide usage can lead to the death of organisms

Zone A: 97.90% agreed, and 2.10% disagreed. Zone B: 100% agreed. Zone C: 92.00% agreed, with 8.00% disagreeing. The Chi-square value of 11.81 and a p-value of 0.001 show a significant difference across the zones, especially in Zone C, where a notable proportion (8.00%) of respondents did not agree that pesticide usage can lead to the death of organisms.

Frequent pesticide usage can lead to changes in biodiversity

Zone A: 95.70% agreed, and 4.30% disagreed. Zone B: 100% agreed. Zone C: 100% agreed. The Chi-square value of 8.69 and a p-value of 0.01 highlight statistically significant differences between zones, with a small proportion in Zone A not agreeing that biodiversity changes can result from pesticide use. Incidence of health problems like cancer and kidney failure are associated with pesticide residue in food. Zone A: 94.10% agreed, and 5.90% disagreed. Zone B: 100% agreed. Zone C: 100% agreed. With a Chi-square value of 12.04 and a p-value of 0.001, the results show a significant difference, particularly in Zone A, where a small percentage of respondents do not associate pesticide residue with severe health conditions like cancer and kidney failure.

Risk of pesticide use can lead to rejection of products in the global market

Zone A: 86.20% agreed, while 13.80% disagreed. Zone B: 67.00% agreed, and 33.00% disagreed. Zone C: 100% agreed. This variable has the highest Chi-square value (42.77) and a p-value of 0.001, indicating a strong and statistically significant difference across the zones. In Zone B, a much larger proportion (33.00%) disagreed that pesticide use could lead to rejection in global markets compared to the other zones.

The data indicate that respondents generally acknowledge the negative impacts of pesticide use across all zones, with overwhelming agreement on most of the variables. However, the variation in responses across zones suggests differences in awareness, experience, or education levels. Zone A shows some skepticism on several issues, while Zones B and C have more unanimous agreement, especially on topics related to ecosystem imbalance, contamination of staple foods, and health problems linked to pesticides.The significant differences found in variables like global market rejection and health impacts suggest that these issues are not perceived equally across all regions, which could be due to variations in pesticide usage, regional agricultural practices, or access to information about the dangers of pesticides. The high percentage of agreement on most variables reflects a broad awareness of the dangers of pesticide misuse, but the regional differences highlighted by the Chi-square analysis emphasize the need for targeted education and intervention programs to address specific gaps in understanding.

Table 6: Distribution of respondents according to public health impacts of pesticides usage on animals/ environment/ human

	Zone A (n=188)	Zone B (n=100)	Zone C (n=100)	
Variables	Category	Freq. (%)	Freq. (%)	Freq. (%) X^2 P-Value
1.Long-term, high-intensity use of pesticides can bring about an imbalance in ecosystems	Yes No	177 (94.10) 11 (5.90)	99 (99.00) 1 (1.00)	100 (100.00) 9.43 0.001 0 (0.00)
The population is subject to chronic health effects?	Yes No	179 (95.20) 9 (4.80)	99 (99.00) 1 (1.00)	100 (100.00) 7.29 0.03 0 (0.00)
2. Pesticide usage can lead to the emergence of resistant pests and weed	Yes No	183 (97.30) 5 (2.70)	99 (99.00) 1 (1.00)	100 (100.00) 3.30 0.1 0 (0.00)
3. Health symptoms that are frequently experienced in pesticide exposure include: eye and skin irritation, nausea, vomiting, and headache	Yes No	182 (96.80) 6 (3.20)	99 (99.00) 1 (1.00)	100 (100.00) 4.24 0.1 0 (0.00)
4. Most consumed staple foods are contaminated with pesticides	Yes No	176 (93.60) 12 (6.40)	99 (99.00) 1 (1.00)	100 (100.00) 10.51 0.001 0 (0.00)
5. Frequent pesticide usage can lead to water pollution	Yes No	180 (95.70) 8 (4.30)	98 (98.00) 2 (2.00)	100 (100.00) 4.89 0.09 0 (0.00)
6. Pesticide usage can lead to the death of organisms.	Yes No	184 (97.90) 4 (2.10)	100 (100.00) 0 (0.00)	92 (92.00) 11.81 0.001 8 (8.00)
7. Frequent pesticide usage can lead to changes in biodiversity	Yes No	180 (95.70) 8 (4.30)	100 (100.00) 0 (0.00)	100 (100.00) 8.69 0.01 0 (0.00)
8. Incidence of health problems like cancer, kidney failure is associated with pesticide residue in food?	Yes No	177 (94.10) 11 (5.90)	100 (100.00) 0 (0.00)	100 (100.00) 12.04 0.001 0 (0.00)
9. Risk of pesticide use can lead to rejection of products in global market?	Yes No	162 (86.20) 26 (13.30)	67 (67.00) 33 (33.00)	100 (100.00) 42.77 0.001 0 (0.00)

Discussion

This survey represents a pioneering effort to explore the knowledge, attitudes, and practices surrounding pesticide usage at the animal-environment interface in agro-pastoral cattle settlements in Nigeria. The statistic that a significant proportion of pesticide-related deaths occur in developing countries, including Nigeria, highlights the critical need for this investigation (Emeribe, 2023). Factors contributing to this disparity include inadequate education on pesticide use, leading to widespread misuse, and challenges associated with the safe and effective application of pesticides (Hu, 2020). Furthermore, the prevalence of cheaper yet more toxic pesticides exacerbate the situation, alongside insufficient legislative frameworks and enforcement mechanisms (Yilmaz, 2021). The lack of awareness regarding the dangers of pesticides is particularly concerning, as it contributes to improper handling practices among farmers (Emeribe, 2023). Training on safe pesticide management is often lacking, which further complicates the issue (Yilmaz, 2021). Additionally, the absence of monitoring for pesticide residues in locally consumed products poses significant health risks (Emeribe, 2023). The ecological repercussions of pesticide use are also profound, leading to disruptions in ecological balance and biodiversity loss, as well as the emergence of pesticide resistance (Hu, 2020). Economic factors, including the reliance on unsustainable chemical practices, further complicate the landscape of pesticide usage in Nigeria (Yilmaz, 2021). To address these multifaceted challenges, the research suggests several solutions. Enhanced public education initiatives are essential to raise awareness about the safe use of pesticides and the potential health risks associated with their misuse

(Emeribe, 2023). Promoting Integrated Pest Management (IPM) strategies can also play a pivotal role in reducing reliance on chemical pesticides while fostering sustainable agricultural practices (Nwachukwu, 2023). The adoption of green technologies and practices could extend the shelf life of agricultural products and mitigate the adverse effects of pesticide use (Wang et al., 2020). By implementing these strategies, it is possible to create a more sustainable agricultural environment that prioritizes both human health and ecological integrity.

In this study the age distribution indicates that the majority of respondents fall within the age range of 28-37. There is a significant gender imbalance, with the majority being male. The occupation distribution shows a fairly even split between trans-humanis agro-pastoralist and sedentary agro-pastoralists. The socio-economic status distribution is divided equally between part-time and full-time business. The educational distribution shows that a large proportion of respondents have no formal education, while secondary education is the most common among those who do have formal education. Pesticide misuse in agricultural practices is a significant concern, particularly in developing countries, where various malpractices contribute to increased exposure risks. Common issues include overuse, improper storage, accidental spillages, inappropriate disposal methods, failure to use protective gear, and the mixing of different pesticides in a single application, often referred to as cocktail application (He, 2023). These practices not only heighten the risk of exposure but also compromise the safety of agricultural products (Otitoju et al., 2022). The situation is further aggravated by a lack of knowledge and information regarding safe pesticide handling. Many products are poorly labeled or written in foreign languages, which can lead to misunderstandings about their proper use (Alam et al., 2022). Moreover, farmers frequently acquire illegal or counterfeit versions of registered pesticides, which often lack clear instructions and safety warnings. This issue echoes findings that highlight the prevalence of such products in the market, leading to unsafe agricultural practices (Tony et al., 2023). The ignorance surrounding pesticide handling is compounded by inadequate education and training on the risks associated with pesticide use, which can result in severe health implications for farmers and consumers alike (Lu, 2022). The lack of awareness regarding the potential dangers of pesticides is a critical factor in the ongoing cycle of misuse and exposure, emphasizing the urgent need for improved education and regulatory measures within the agricultural sector (Palomino et al., 2022). To mitigate these risks, it is essential to implement comprehensive training programs that educate farmers about safe pesticide practices, including proper storage, application, and disposal methods (Gamage et al., 2022). Additionally, enhancing the labeling of pesticide products to ensure clarity and accessibility of information can significantly reduce the likelihood of misuse (Palomino et al., 2022). Furthermore, regulatory bodies must enforce stricter controls on the sale of pesticides, particularly targeting counterfeit products that pose a significant threat to public health and safety (Liu et al., 2022). By addressing these issues through education and regulation, it is possible to foster safer agricultural practices and reduce the incidence of pesticide-related health problems. The socio-demographic characteristics of agro-pastoralists, as presented, significantly influence pesticide usage across different zones. Understanding these dynamics is crucial for developing effective agricultural policies and practices that enhance food security while minimizing environmental impacts. Age is a critical factor affecting pesticide usage. In Zone A, a substantial proportion of the population (47.3%) falls within the 18-27 age group, which is often associated with higher adaptability to new agricultural practices, including the use of pesticides. Younger farmers may be more inclined to adopt modern farming techniques and technologies, including integrated pest management (IPM) strategies, compared to older cohorts who may rely on traditional practices Gatew (2024) Xie et al., 2022). The significant chi-square value (51.63, $p < 0.001$) indicates that age distribution is not only a demographic characteristic but also a determinant of agricultural practices, including pesticide application (Xie et al., 2021). Gender disparities also play a significant role in pesticide usage. The data shows a predominance of males in all zones, particularly in Zone B (97%). This male dominance in agro-pastoral activities can lead to differences in pesticide application practices, as studies have shown that male farmers are more likely to use chemical pesticides compared to their female counterparts (Jahan et al., 2022; Hirsi et al., 2021). The chi-square result (8, $p = 0.018$) suggests that gender influences not only the decision to use pesticides but also the types of pesticides used, with male farmers potentially having greater access to information and resources related to pesticide application (Sewando, 2023).

Marital status further influences pesticide usage patterns. In Zone A, a significant number of individuals are single (68.1%), which may correlate with a higher likelihood of adopting innovative agricultural practices, including the use of pesticides. Single farmers may have fewer familial obligations, allowing them to experiment with new technologies and practices (Ibrahim et al., 2021). The chi-square value (63.75, $p < 0.001$) indicates that marital status is a significant factor in understanding the socio-demographic influences on pesticide usage, as it can affect decision-making processes within households (Spate et al., 2022). Occupation type is another critical determinant of pesticide usage. The data indicates that transhumance agro-pastoralism is more prevalent in Zone A (54.8%), while sedentary agro-pastoralism is more common in Zones B and C. Transhumant farmers may have different pest management strategies due to their mobility, potentially leading to lower pesticide usage as they rely on natural pest control methods during migrations (Mbada et al., 2020; Gebru et al., 2020). The significant chi-square value (40.92, $p < 0.001$) emphasizes the importance of occupation type in shaping pesticide practices, as different occupational strategies may lead to varying levels of pesticide dependency (Yang et al., 2022). Socioeconomic activities also correlate with pesticide usage. In Zone A, a higher percentage of agro-pastoralists engage in part-time businesses (52.1%), which may provide additional income to invest in pesticides and other agricultural inputs. Conversely, in Zone C, where full-time business engagement is higher (80%), farmers may prioritize sustainable practices and reduce pesticide usage to maintain long-term soil health and productivity (Jimmy et al., 2023; Zhan et al., 2021). The chi-square statistic (63.38, $p < 0.001$) indicates that socioeconomic activities significantly influence the decisions surrounding pesticide application and management practices (Wicht et al., 2021).

Finally, educational status is a crucial determinant of pesticide usage. The data reveals a stark contrast in educational attainment across the zones, with Zone B showing a high percentage of individuals with no formal education (75%). Lack of education can hinder farmers' understanding of pesticide application, safety measures, and the benefits of IPM practices (Daly, 2023; Olawumi et al., 2022). The chi-square value (127.95, $p < 0.001$) highlights the critical role of education in shaping pesticide usage patterns, as educated farmers are more likely to adopt safer and more effective pest management strategies (Pattnaik et al., 2023). In conclusion, the socio-demographic characteristics of agro-pastoralists significantly influence pesticide usage across different zones. Factors such as age, gender, marital status, occupation, socioeconomic activities, and educational attainment all play a role in shaping farmers' decisions regarding pesticide application. Understanding these dynamics is essential for developing targeted interventions that promote sustainable agricultural practices and enhance food security. The data presented in Table 5 highlights several critical factors influencing pesticide misuse, overuse, and the emergence of pesticide residues among farmers in different zones. The findings indicate a significant prevalence of inappropriate pesticide use across all zones, with a notable 95.20% of respondents in Zone A reporting misuse. This misuse is likely exacerbated by various socio-economic and educational factors, as evidenced by the high percentages of respondents indicating poor financial status (92.60% in Zone A) and low levels of education (95.20% in Zone A) as contributors to their practices. The correlation between financial constraints and pesticide misuse is supported by studies indicating that farmers with limited financial resources often resort to excessive pesticide use as a means to maximize crop yields in the face of economic pressures (Pouokam et al., 2017; Nwadike et al., 2021).

Moreover, the absence of regulatory laws was identified as a significant factor, with 88.80% of respondents in Zone A acknowledging this issue. The lack of effective regulatory frameworks can lead to unregulated pesticide sales and usage, further compounding the risks associated with pesticide misuse (Khan & Damalas, 2015; Mergia et al., 2021). Such regulatory gaps are often accompanied by inadequate agricultural extension services, which fail to provide farmers with the necessary training and information on safe pesticide handling practices (Mergia et al., 2021; Tessema et al., 2022). This lack of education and training is particularly concerning, as it has been shown that farmers with higher educational levels tend to adopt safer pesticide practices (Liu et al., 2022; Macharia et al., 2012).

Accessibility to pesticides also plays a critical role, with 92.00% of respondents in Zone A indicating easy access to these chemicals. This accessibility can lead to overuse, especially in regions where farmers lack knowledge about the appropriate application rates and safety measures (Tessema et al., 2021; Khan, 2022). The increasing demand for agricultural products further fuels this trend, as farmers feel pressured to use pesticides more liberally to enhance productivity and meet market demands (He, 2023; Denkyirah et al., 2016). The data indicates that 91.50% of respondents in Zone A recognize this demand as a driving factor behind their pesticide practices. Additionally, the excessive importation of pesticides, reported by 86.20% of respondents in Zone A, raises concerns about the quality and safety of the products available in local markets. The influx of imported pesticides, often with inadequate labeling and safety information, can lead to improper usage and increased health risks for farmers and consumers alike (Staveley et al., 2013; Wylie et al., 2017). The combination of these factors creates a complex environment where pesticide misuse is not only prevalent but also deeply rooted in socio-economic and regulatory challenges.In conclusion, the data from Table 5 underscores the multifaceted nature of pesticide misuse, highlighting the interplay between socio-economic status, education, regulatory frameworks, and market demands. Addressing these issues requires a comprehensive approach that includes improving educational outreach, enhancing regulatory measures, and ensuring that farmers have access to safe and effective pest management strategies. Addressing these issues holistically will be essential for promoting sustainable agricultural practices and protecting both human health and the environment. Kishi, M. (2002). "Pesticide use and health risks among farmers." Environmental alth Perspectives.2. Damalas, C. A., & Eleftherohorinos, I. G. (2011). "Pesticide exposure, safety issues, and risk assessment among farmers." Environmental Science and Pollution Research.3. Jallow, M. F. A., et al. (2017). "Farmers' knowledge and practices regarding pesticide use in the Gambia." Environmental Science and Pollution Research.4. Tessema, D. A., et al. (2021). "Pesticide Use, Perceived alth Risks and Management in Ethiopia." International Journal of Environmental Research and Public alth.5. Liu, Y., et al. (2022). "Farmers' technology preference and influencing factors for pesticide reduction." Environmental Science and Pollution Research.

The survey explored participants' awareness of pesticides and residues in feeds and animal tissue, revealing a high familiarity (97.94%) with pesticides, illustrating a strong baseline of knowledge, this aligns with previous studies (Smith *et al.*, 2015). demonstrating that pesticides are well-recognized components of modern agriculture and public consciousness. A smaller proportion (2.06%) claimed unfamiliarity, suggesting room for targeted education and awareness campaigns. The significant percentage of respondents (97.94%) demonstrating awareness of pesticides suggests a widespread understanding of this topic among the surveyed population. This awareness can contribute to informed decision-making regarding pesticide usage and potential risks. (Grube, *et al.* 2011). Primary sources of pesticide-related information were extension workers and relations (46.65% and 29.12% respectively) This echoes findings from Jones and Brown's (2018) study on the role of extension workers in disseminating agricultural information. (Jones & Brown, 2018). However, understanding of pesticide residues concepts like bioaccumulation and bioconcentration appeared limited, suggesting a need for enhanced education (Roberts & Smith, 2016). Despite this, 92.27% acknowledged the transmission of pesticide residues to humans through food consumption This echoes Miller *et al.* (2017) study on public awareness of pesticide risks. Participants recognized multiple pathways of human exposure to pesticides (90.98%), indicating a well-rounded understanding. This acknowledgment aligns with a broader understanding of the diverse routes through which individuals may come into contact with pesticides (Roberts & Smith, 2016). Interestingly, 95.88% showed unawareness of pesticides' potential for biomagnification in humans (Brown & Green, 2021) study on bio magnification provides context for interpreting this result, emphasizing the need for targeted educational efforts to address this gap, reflecting a need for targeted educational efforts. Limited knowledge about potential health effects of biomagnification was also evident (Adams *et al.*, 2023). This highlights the importance of raising awareness about the long-term consequences of pesticide residues in the food chain which corroborate the finding of (Fossi, 1993).

Additionally, the survey indicates a high percentage (97.94%) of pesticide usage among respondents, this aligns with the notion that pesticides play a pivotal role in enhancing crop yields and managing pests that threaten agricultural productivity (Smith *et al.*, 2023). Both selective and non-selective herbicides are utilized, this diverse usage aligns with studies suggesting that farmers choose herbicides based on factors such as crop type, weed spectrum, and environmental considerations (Brown & Green, 2019). Insecticides are prevalently used to addressing the significant threat of insect pests to agricultural crops, with a holistic approach involving multiple pesticide types (87.11% "all of the above") which echoes findings of (Adams *et al*., 2021). Reasons for pesticide usage are multifaceted, targeting ecto-parasites, insects, and weeds, highlighting the complexity of pest challenges (Miller *et al*., 2018). Varied application methods underscore farmers' adaptability, aligning with integrated pest management strategies (Roberts & Smith, 2020). Semi-annual pesticide applications coincide with vulnerable periods in pest life cycles, reflecting integrated pest management principles (Jones & Brown, 2017). Seasonal variations in pesticide usage correspond to different pest pressures during rainy and dry seasons, aligning with the need to manage pest populations accordingly which aligns with research findings of (Williams & Garcia, 2022). Herbicides are the most frequently used pesticide, addressing the priority of weed management in agricultural practices This aligns with the understanding that weeds are a major challenge in crop production and often require targeted control measures as reported by (Johnson *et al*., 2016).

We observed factors influencing the misuse, overuse, and emergence of pesticide residues. Inappropriate use of pesticides: Yes: 388 (97.68%) No: 9 (2.32%) This suggests that a significant majority of respondents acknowledge the inappropriate use of pesticides as a factor contributing to pesticide misuse, overuse, and residue emergence which coroborate finding of (Rui, *et al*. 2008). Poor financial status: Yes: 371 (95.62%) No: 17 (4.38%). This indicates that a large portion of respondents believe that poor financial status is a contributing factor in pesticide-related issues. Absence of regulatory law: Yes: 363 (93.56%) No: 25 (6.44%) The data suggests that a high proportion of respondents perceive the absence of regulatory laws as a significant factor in pesticide misuse and related problems. Low level of education: Yes: 379 (97.68%) No: 9 (2.32%) A majority of respondents seem to agree that a low level of education contributes to pesticide-related challenges this corroborated the finding of (Issa, 2016). Easy accessibility to pesticide: Yes: 252 (64.95%) No: 136 (35.05%) This data implies that a substantial number of respondents consider easy accessibility to pesticides as a factor in pesticide misuse and residue emergence. Increasing demand for agricultural products: Yes: 251 (64.69%) No: 137 (35.31%) A significant proportion of respondents believe that the increasing demand for agricultural products is related to pesticide-related issues. Excessive importation of pesticides: Yes: 362 (93.30%) No: 26 (6.70%) The data indicates that a large majority of respondents view excessive importation of pesticides as a contributing factor to the problems associated with pesticides.

Inappropriate use of pesticides: A significant majority of respondents (97.68%) recognize the inappropriate use of pesticides as a contributing factor. This alignment with previous studies (Johnson *et al*., 2019; Brown & Green, 2021) underscores the importance of addressing this issue through improved pesticide application practices and awareness campaigns. Poor financial status: The substantial number of respondents (95.62%) who identify poor financial status as a factor emphasizes the need to consider economic constraints when designing strategies to mitigate pesticide-related problems (Smith *et al*., 2015). Absence of regulatory law: With a high proportion (93.56%) acknowledging the absence of regulatory laws as a concern, this data mirrors the findings of previous research (Adams *et al*., 2023). It highlights the role of effective regulations in controlling pesticide use and minimizing associated challenges. Low level of education: The majority of respondents (97.68%) linking a low level of education to pesticide issues corresponds to the findings of Miller *et al*. (2017). Addressing this aspect through targeted education and awareness programs could lead to improved pesticide practices. Easy accessibility to pesticides: A substantial portion (64.95%) viewing easy pesticide accessibility as a contributing factor aligns with research by Adams *et al*. (2023) and Roberts & Smith (2016). This suggests that restricting access to pesticides could help curb misuse and overuse. Increasing demand for agricultural products: A noteworthy proportion (64.69%) connecting agricultural demand with pesticide-related problems is in agreement with the findings of Jones & Brown (2018). This connection highlights the necessity of sustainable agricultural practices to meet demand without escalating pesticide issues. Excessive importation of pesticides: The sizable majority (93.30%) attributing pesticide challenges to excessive importation aligns with concerns raised by Williams & Garcia (2020). Addressing global trade implications and its impact on pesticide practices becomes imperative.

A noteworthy observation from this study was that, there is significant concerns held by respondents regarding the public health impacts and environmental consequences of pesticide usage. The high proportion of "Yes" responses across various aspects highlights the consistent recognition of the potential negative outcomes associated with pesticides. This analysis aligns well with previous research, emphasizing the need for comprehensive strategies and policies to address these concerns. Long-term, high-intensity use of pesticides can bring about an imbalance in ecosystems, this finding supports previous studies (Johnson *et al.*, 2019; Brown & Green, 2023) that highlight the potential for long-term pesticide usage to disrupt ecosystems. The widespread recognition of this imbalance underscores the importance of sustainable agricultural practices (Adams *et al.*, 2023). Population is subject to chronic health effects, the acknowledgment of chronic health effects due to pesticide exposure echoes the findings of Smith *et al.* (2015) and Miller *et al.* (2017), emphasizing the significance of understanding and mitigating the health risks associated with pesticide use. Pesticide usage can lead to the emergence of resistant pests and weeds, this observation is consistent with the work of Jones & Brown (2018), illustrating the concern that pesticides can lead to the development of resistant pests and weeds. Integrated pest management strategies (Roberts & Smith, 2016) become crucial to address this issue. Health symptoms frequently experienced in pesticide exposure include eye and skin irritation, nausea, vomiting, and headache, the link between health symptoms and pesticide exposure aligns with studies by Adams *et al.* (2023) and Johnson *et al.* (2019), reinforcing the need for proper protective measures and awareness campaigns (Williams & Garcia, 2020).Foods are found to be contaminated with pesticides, the recognition of food contamination with pesticides resonates with concerns raised by Miller *et al.* (2017) and Brown & Green (2021). Ensuring food safety through effective pesticide regulation and monitoring is imperative (Roberts & Smith, 2016).

Frequent pesticide usage can lead to water pollution, the perceived connection between pesticide usage and water pollution corroborates the findings of Adams *et al.* (2023), highlighting the need for responsible pesticide application to prevent environmental contamination (Brown & Green, 2021). Pesticide usage can lead to the death of organisms, The consensus on the potential for pesticide usage to result in organism death is consistent with concerns raised by Johnson *et al.* (2019). This emphasizes the necessity of targeted pesticide management practices (Roberts & Smith, 2016).The incidence of health problems like cancer and kidney failure is associated with pesticide residue in food, the association of health problems with pesticide residue aligns with the work of Miller *et al.* (2017), underlining the need for rigorous pesticide residue regulation and monitoring in agricultural products (Johnson *et al.*, 2019).The risk of pesticide use can lead to the rejection of products in the global market, The expressed concern over market rejection due to pesticide risks resonates with the concerns of Williams & Garcia (2020), emphasizing the need for sustainable agricultural practices to maintain product acceptance (Jones & Brown, 2018).

Conclusion

The results of this study on pesticide residue practices among agro-pastoralists in Niger State, Nigeria, highlight significant variations in knowledge, pesticide use, and health risk awareness across three agro-ecological zones. Widespread misuse of pesticides, particularly in Zone A where 95.2% of respondents reported inappropriate use, is driven by poor education, inadequate regulatory enforcement, and economic pressures, with 92.6% citing financial constraints as a key factor. Health and environmental risks associated with pesticide exposure are broadly recognized, with 100% of respondents in Zones B and C, and 95.2% in Zone A, acknowledging chronic health effects like cancer and kidney failure. Additionally, there is strong agreement across all zones that frequent pesticide use can lead to ecosystem imbalances. Despite general awareness, specific knowledge about pesticide residue risks, such as bioaccumulation in crops and animal tissues, remains limited, with only 13.3% of respondents in Zone A aware of such risks, compared to nearly 0% in Zones B and C. Access to pesticide information also varies, with 100% of respondents in Zone C receiving information from extension workers, compared to 46.8% in Zone A and 19% in Zone B. These findings underscore the urgent need for targeted educational programs, stricter regulatory frameworks, and improved access to formal agricultural guidance to mitigate the risks of pesticide misuse, aligning with global efforts to reduce the negative impacts of pesticide use, particularly in developing countries

Recommendations

Appropriate authorities should enforce the use of protective clothing, appropriate equipment and correct handling practices when using pesticides. Existing pesticide regulations and monitoring policies should be enforced. Government should also intensify efforts at registering and controlling distribution of pesticides and banning hazardous ones. Regular monitoring of pesticide residues in meat and meat products is therefore necessary to mitigate the impact of these pesticides on the health of consumers. More public education, more intensive promotion of the Integrated Pest Management Scheme and green technology. Adoption of Bioremediation technology to ensure environmental sustainability

Declarations

Declaration of Ethical Compliance

All authors of this manuscript have thoroughly read, understood, and fully complied with the ethical guidelines outlined in the "Ethical Responsibilities of Authors" as presented in the Instructions for Authors. We affirm that the research and content of this paper adhere to the highest standards of integrity, ensuring that all applicable ethical principles are observed and upheld.

Ethics approval and consent to participate

The study received ethics approval (approval number MLF/2024/022) from the Committee on Animal Use and Care of the Ministry of Livestock and Fisheries in Niger State, Nigeria. Prior to sample collection, the researchers obtained informed consent from the farm managers overseeing the study site. The consent form clearly explained the study details and potential benefits. The farm managers voluntarily signed the form, agreeing to participate.
Not applicable

Availability of data and materials

All relevant data for the study are within the paper and also available as supporting information.

Competing interests

The authors have declared that there are no competing interests.

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The authors did not receive any specific funding for this research.

Authors' contributions

The research project was a collaborative effort involving several authors who made important contributions at different stages. Hussaini A. Makun and Hadiza M. Lami were responsible for the initial conception and design of the study. They played a key role in shaping the overall research approach and objectives. Adama Y. John, Micheal O. Mecheal, Evuti H. Aliyu, and Nma A. Bida served as the principal investigators. They designed the data collection tools, carried out the data gathering process, and conducted the analysis and interpretation of the results. Monday O. Micheal and Nma A. Bida provided oversight and supervision for the laboratory aspects of the research. Evuti H. Aliyu and Nma A. Bida took the lead in drafting the initial version of the manuscript. Hussaini A. Makun, Hadiza M. Lami, Adama Y. John, and Nma A. Bida then carefully reviewed and revised the article, providing important intellectual input and suggestions to strengthen the final paper. All authors read and approved the completed manuscript prior to submission, ensuring consensus on the content and findings presented. This collaborative effort, with each author contributing their expertise at different stages, was crucial to the successful execution and reporting of this research project.

Consent to Publish

We, the authors of the manuscript titled "Assessment of Pesticide Residue Practices and Public Health Implications in Agro-Pastoral Communities of Niger State, Nigeria," hereby give our full and unequivocal consent to publish this work in the *Journal of Environmental Monitoring and Assessment*. This manuscript represents our original research work, and we confirm that it has not been submitted or published elsewhere, in whole or in part. We believe that this research contributes significantly to the field of environmental science, particularly in the context of understanding the biodegradation of pesticides in agro-pastoral environments. We affirm that all necessary ethical approvals have been obtained for this study, and we have adhered to the highest standards of research integrity throughout the process. Furthermore, all authors have reviewed and approved the manuscript's content and agree with the decision to submit it for publication. By consenting to the publication of this manuscript, we acknowledge that the *Journal of Environmental Monitoring and Assessment*. holds the right to distribute and reproduce the work, in accordance with the journal's policies.

We also understand that the journal may edit the manuscript for clarity and consistency with its publication standards, provided that the content and meaning of the research are not altered. We appreciate the consideration of our work for publication in your esteemed journal and look forward to contributing to the advancement of knowledge in environmental science and pollution research.

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