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Assessment of Pesticide Usage by Kales Farmers in Kiegoi, the Upper Nyambene Carchement, Meru County, Kenya

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***Abstract*: Pesticides are widely used to protect crops from pests and diseases infestations. However, the use of pesticides in most developing countries poses serious environmental and food safety hazards. These chemicals often leave residues in vegetables post-harvest and may contaminate water sources through runoff and groundwater percolation. Given their intrinsic toxicity, the production, distribution, and use of pesticides require strict regulation and control. This study investigated the commonly used pesticides, analysed pesticides residues in kales samples. A total of 68 respondents were purposively sampled using structured questionnaire. Using a stratified random sampling method, 54 kale samples were collected and analyzed across wet and dry seasons. Samples were packed in labelled zip-lock bags, placed in a cool box, and transported to KEPHIS Analytical Chemistry Laboratory in Nairobi, Kenya where extracts were analyzed using MO301-GC-MS/MS. The Quick, Easy, Cheap, Effective, Rugged, and Safe (QuEChERS) protocol was followed for sample preparation and data processed using SPSS version 26. An independent t-test determined statistically significant differences in pesticide residue concentrations in kales and domestic water source between dry and wet seasons and compared to WHO's designated MRLs. The results indicated that 97.1% of farmers use pesticides to protect kale from pests and diseases. The most commonly used pesticides were Dithane M-45 (22.1%), Deltanex (14.7%), Nuvan (11.8%), and Captan 50 WP (11.8%). Other pesticides like Diazinol, Cyperkill, and Trophy each accounted for 7.4%, while Rufast and Roundup made up 4.4% and 1.5%, respectively. (80.9%) reported pesticide applications conducted on a weekly basis with Diazinol, Captan 50 WP, and Dithane M-45 being the most frequently applied pesticide while 16.2% of the respondents reported using Glyphosate (Roundup) on a monthly basis. 85.3% of respondents use diazinol, captan 50 WP and deltanex on their kale crops to combat aphids, leaf spot diseases, and powdery mildew and 5.9%, reported treating maize and potatoes with Dithane M-45 and Roundup. Residue analysis showed Captan concentrations ranged from 0.01533 mg/kg in the wet season to 0.04700 mg/kg in the dry season, showing a statistically significant difference (p=0.001). Deltamethrin residues ranged from 0.01467 mg/kg in the wet season to 0.04200 mg/kg in the dry season, with a significant difference (p=0.000). Diazinon concentrations increased from 0.01567 mg/kg in the wet season to 0.02567 mg/kg in the dry season (p=0.046). Dichlorvos and Diazinon residues exceeded their MRLs of 0.02 mg/kg and 0.01 mg/kg, respectively, while Dieldrin surpassed the WHO MRL of 0.05 mg/kg during the dry season, suggesting a potential food safety hazard. Mancozeb and Deltamethrin concentrations in water were found to be within the WHO MRLs of 0.02 mg/l and 0.5 mg/l, respectively. However, Diazinon and Dieldrin levels exceeded the WHO MRLs of 0.01 mg/l and 0.05 mg/l. According to the WHO classification of pesticides, Dieldrin is a Class 1a pesticide that is extremely hazardous and restricted for use. Cypermethrin, Acetochlor, and Acrinathrin levels were below their respective WHO MRLs of 0.1 mg/l, 0.3 mg/l, and 0.05 mg/l in both seasons.**

***Keywords*: assessment, pesticide use practices, systemic pesticides, organophosphates contact pesticides, characterization.**

1. Introduction

Pesticides are chemicals used in modern agriculture to control pest in order to improve crop yield as part of a pest management strategy that benefits public health by suppressing certain insect vector transmission diseases (Ahoudi *et al*., 2018). Globally, the use of pesticides in paddy cultivation contributes to 15% of the total pesticide use in agricultural activities (Sabran & Abas, 2021). In Malaysia, pesticides are conventionally and commonly used by farmers, especially in paddy cultivation, for pest control. The safety and quality of food have since raised serious concerns in the production and marketing of agricultural products, especially those for paddies (Sabran & Abas, 2021).

Farmers in developing countries usually have too little knowledge on the proper handling of pesticides, and as a result, do not normally handle the products according to best agricultural practices (Ali *et al*., 2020). According to the World Health Organization (WHO), developing countries account for 20% of global pesticide usage (Mwanja *et al*., 2017). Over the last several decades, there has been a significant rise in the amount and usage of pesticides in the agricultural sector (Mwanja *et al*., 2017). Due to the poor pesticide handling practices and use of more toxic pesticides by farmers as well as inadequate management and regulation of these chemicals in developing countries (Syed *et al.,*2014), the occurrence of pesticide poisonings in developing countries is far greater than that of the developed countries (Syed *et al.,*2014).

In Kenya, pesticides are of great benefit to agriculture by decreasing crop losses due to insects, weeds, plant diseases, rodents and other pests. They save lives through control of disease carrying insects and increase the quality and quantity of agricultural produce. However, pesticides are poisons and can

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contaminate the environment (Mutuku *et al*., 2014). Pesticide residues have been detected in various food products from different parts of the world (Marete *et al*., 2020). However, there is scanty data on pesticide use practices and concentrations of pesticide residues in horticultural products from Meru County which are exported and consumed locally in Kenyan markets. The absence of such data implies that the underlying potential risks are unknown. Assessment of pesticide use practices and residue levels in locally produced kales and domestic water sources is necessary to generate data for enhancement of good pesticide use practices in Kiegoi Location, Meru County. Thus, the current study was carried out to assess pesticide use practices and residue levels in locally produced kales and domestic water sources in Kiegoi Location, Meru County where safe pesticides use is depended upon for provision of water quality and food safety.

2. Methodology

A. Study Area

Kiegoi lies approximately between Latitude 0.233682^0 and 0.233835^0 East and Longitude 37.874765^0 and 37.876923^0 North. The long rain comes in March and May and the short rains from October to December and annual rainfall ranges between 300mm per annum on the lower midlands to 2500mm in the South East. Distribution of the rainfall over the year is not equal, but bimodal. The region experiences an average temperature that ranges between a minimum of 8^0C and a maximum of 32^0C.

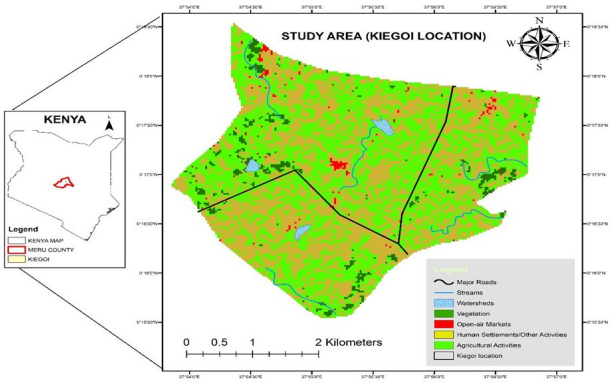

Fig. 1.

B. Data Collection Procedure

A cross-sectional study design was employed, where a household survey was performed using a structured questionnaire. The 83 questionnaires were administered to gather information from horticultural farming households on pesticide use practices in the upper Nyambene catchment, Meru County, Kenya

3. Results and Discussions

The study sought information on the type of pesticides commonly used among kales farmers and their residues levels in kales. The information obtained is discussed hereunder:

A. Horticultural Farmers Using Pesticides

The study sought information on horticultural farmers using pesticides. The result revealed that the majority of respondents (97.1%) reported employing pesticides on their vegetables to manage weeds, pests, and diseases. Only a small fraction of respondents (2.9%) stated that they did not use pesticides in their agricultural practices in the study area. These findings are displayed in Table 1.

Table 1
Horticultural farmers using pesticides

Response	Percent
Yes	97.1
No	2.9
Total	**100.0**

The high percentage of respondents (97.1%) indicating the use of pesticides on their kales in the study area is attributed to their widespread utilization in agriculture for managing weeds, pests, and diseases. Pesticides are recognized as effective tools for safeguarding crops and optimizing yields, serving both preventive and reactive purposes against various biotic stresses that threaten crop health and productivity. The incidence of pests and diseases in the area was observed by farmers relying on pesticides to prevent crop losses and protect their agricultural livelihoods. Additionally, pesticides are perceived by farmers in the study area as a convenient and readily accessible solution to address pest and disease management challenges, especially in the absence of alternative methods or resources for sustainable pest control. The results agreed with the study by Kariathi and Kimanya, (2016) which reported majority of farmers (84%) engaging on pesticide handling activities in their study in Meru district, Kenya. Similarly, Obonyo (2017) in the study on Pesticides use in Kisumu County, Kenya reported majority of farmers (63%) involved on agricultural pesticide use.

B. Type of Pesticides Commonly Used on Kales

The study sought information on the type of commonly used pesticides by farmers using pesticides. The findings are depicted in Table 2.

Information on Table 3 reveals that fungicides and insecticides were the primary categories of pesticides utilized. Among the fungicides, Dithane M-45 was the most commonly used pesticide on kales, accounting for 22.1% of the reported pesticide usage. This fungicide was commonly employed for the regulation of diseases such as powdery mildew and leaf spot diseases in various crops; including kales and potatoes as observed during field.

Table 3
Frequency of pesticide application

Type of Pesticide	Application rate	Percent
Diazinol, Captan 50 WP & Dithane M-45	Weekly	80.9
Glyphosate (Roundup)	Monthly	16.2
Total		**97.1**

Deltanex was the second most commonly used pesticide, representing 14.7% of reported usage. Deltanex was an

Table 2
Type of pesticides commonly used

Classification of pesticide (chemical composition)	Type of pesticide	Trade Name (Kenya)	WHO class	Toxicity Level	Year of Registration by PCPB	%
Fungicide	Mancozeb	Dithane M-45	U	Unlikely to present acute hazard	1994	22.1
Insecticide	Deltamethrin	Deltanex	II	Moderately hazardous	2000	14.7
Insecticide	Dichlorvos	Nuvan	1b	Highly hazardous	1992	11.8
Fungicide	Captan	Captan 50 WP	U	Unlikely to present acute hazard	1995	11.8
Insecticide	Diazinon	Diazinol	II	Moderately hazardous	1993	10.3
Insecticide	Dieldrin	Dieldrin	1a	Extremely hazardous	1950	5.9
Insecticide	Cypermethrin	Cyperkill	II	Moderately hazardous	1998	7.4
Herbicide	Acetochlor	Trophy	II	Moderately hazardous	1997	7.4
Insecticide	Acrinathrin	Rufast	II	Moderately hazardous	2005	4.4
Herbicide	Glyphosate	Roundup	U	Unlikely to present acute hazard	1974	1.5
Total						**97.3**

insecticide commonly used to control an extensive series of pests, including aphids, caterpillars, and leafhoppers. Other organophosphate pesticides reported in the study include Nuvan, Captan 50 WP, Diazinol, and Cyperkill, each with varying levels of usage. These pesticides were known for their effectiveness against specific pests and diseases, and their application on kales reflects the diverse pest pressures faced by farmers in the study area. Synthetic pyrethroids were also widely used on kales, with a preference of 46% reported in the survey. Pyrethroids such as Trophy and were commonly used insecticides known for their broad-spectrum activity against a wide range of insect pests. Glyphosate herbicide was also mentioned, although less frequently, because herbicide use was not a common practice in weed control in the study area.

The results align with those of Nyakundi et al., (2012) regarding the prevalent use of pesticides among farmers in the Rift Valley and Central Provinces of Kenya. Their research demonstrated that pesticides were easily accessible and widely employed on farms. Primary N-(phosphonomethyl) glycine) included Linurex 50 WP and Diurex 80 WP, while methyl-4-pyrimidinyl] phosphorothioate comprised Diazol 60 EC and Methomex 90 S. The result implies that Dieldrin and carbamates such as Mocap were hardly used on Kales in the study area. These findings are attributed to regulatory restrictions of Dieldrin in Kenya due to their persistence in the environment, environmental concerns and the availability of more effective and safer alternatives like integrated Pest Management (IPM) Nyakundi *et al*., (2012). The preference for certain types of pesticides, such as organophosphates and synthetic pyrethroids, highlights the importance of understanding the specific pest and disease pressures faced by kale growers and selecting appropriate pest management strategies. However, it is crucial to consider the potential risks associated with pesticide use, including environmental contamination, human health impacts, and pesticide resistance.

C. Frequency of Pesticides Application

The study aimed to establish the frequency of pesticide application on Kales. The findings observed that majority of respondents (80.9%) reported pesticide applications conducted on a weekly basis with Diazinol, Captan 50 WP, and Dithane M-45 being the most frequently applied pesticide while 16.2% of the respondents reported using Glyphosate (Roundup) on a monthly basis. This is illustrated in Table 3.

The high frequency of weekly applications for Diazinol, Captan 50 WP, and Dithane M-45 was attributed to high pest-related challenges in the areas where kale cultivation occurs. Pesticides play a crucial role in pest and fungal disease management in the study area (Syed *et al.,* 2014). The common infestations were aphids and caterpillars, as well as diseases such as downy mildew and powdery mildew.

The findings agreed with the study by Otieno (2017), in Laikipia County, Kenya who observed majority of farmers applying pesticides on the vegetables after every two weeks. This frequent application pattern implies a reliance on pesticides as a primary means of pest management and crop protection in agricultural operations. The study observed a significant frequency of pesticide application may have several implications for agricultural practices and pesticide management. Frequent pesticide use indicated a reactive approach to pest management, where farmers apply pesticides as a response to observed pest infestations or crop diseases. While pesticides can effectively control pests and diseases, their frequent and indiscriminate use may lead to pesticide resistance, where pests develop resistance to the chemicals, rendering them less effective over time (Syed *et al.,* 2014).

The frequent application of pesticides could raise concerns such as food contaminations regarding the potential build-up of pesticide residues in the environment, including water sources

and food crops (Adeyeye *et al*., 2021). Pesticide residues have the ability to persist in the environment for prolonged periods, posing risks to both human health and environmental integrity through various exposure routes such as ingestion, inhalation, and skin contact. The variability in pesticide application frequency holds particular significance within the scope of this study, as the researcher aimed to investigate whether the frequency of pesticide application could influence the concentrations of pesticide residues. Understanding the correlation between pesticide application frequency and residue levels was crucial for assessing potential risks to human health and the environment, as well as for guiding pesticide management approaches (Adeyeye *et al*., 2021).

1) Crops Treated with Pesticides

The study aimed to identify the crops treated with pesticides and the specific pesticides used, along with the diseases and pests they control. The results revealed that 85.3% of respondents use diazinol, captan 50 WP and deltanex on their kale crops to combat aphids, leaf spot diseases, and powdery mildew while a smaller proportion of respondents, 5.9%, reported treating maize and potatoes with Dithane M-45 and Roundup. The findings are illustrated in Table 4.

The findings indicate that the majority of respondents predominantly apply pesticides to their Kale crops. This trend is closely linked to kale's susceptibility to various diseases like downy mildew, powdery mildew, and bacterial leaf spot in the study area. These diseases proliferate swiftly due to the region's high humidity and inadequate air circulation. Consequently, farmers resort to frequent pesticide applications as a key component of their disease management strategy. The survey underscores that most farmers in the area lack awareness of the potential hazards associated with excessive pesticide use, including environmental contamination, pesticide resistance, and adverse effects on beneficial insects. Compounded by the absence of comprehensive education and outreach initiatives, farmers persist in their heavy reliance on pesticides, neglecting alternative methods.

The results disagreed with the study on pesticide handling practices by Otieno (2017), in Laikipia County, Kenya which observed majority of farmers applying pesticides on maize crop. The lower frequency of pesticide treatment observed in maize crops compared to kales is attributed to maize being primarily cultivated for subsistence purposes, whereas kales are grown for commercial use. As a result, farmers heavily rely on pesticides to enhance Kales yields in the study area.

The findings imply the significant importance of pesticide application in the production of kales in the agricultural practices of the studied community. The crops identified in the study are widely cultivated food crops in numerous agricultural environments. Kale, maize, and potatoes serve as staple foods for many communities, supplying vital nutrients and playing a key role in ensuring food security (Marete *et al*., (2019). Nevertheless, these crops are vulnerable to a range of pests, diseases, and weed infestations, which have the potential to impact both yield and quality if not properly addressed. The use of pesticides to treat these crops reflects farmers' efforts to protect their crops from pest and disease damage and ensure optimal production. However, it is essential to consider the potential risks associated with pesticide use, including environmental contamination, human health impacts, and pesticide residues in food crops.

The findings also observed the need for tailored pest management strategies for different crops, considering their unique pest profiles, agronomic practices, and production systems. Integrated pest management (IPM) strategies, which integrate cultural, biological, and chemical control techniques, could reduce dependence on pesticides and advocate for more sustainable and eco-friendly approaches to pest management.

D. Pesticide Residue Concentrations in Locally Produced Kales

The results present mean concentrations of pesticide residue concentrations in locally produced kales during wet and dry seasons. Captan and Deltamethrin show significant increases in mean concentrations from the wet to the dry season. Captan rises from 0.01533 mg/kg during the wet season to 0.04700 mg/kg in the dry season, with a statistically significant difference ($p = 0.001$). Deltamethrin increases from 0.01467 mg/kg in the wet season to 0.04200 mg/kg in the dry season, showing a significant difference ($p = 0.000$). Diazinon displays a significant rise in mean concentration from the wet (0.01567 mg/kg) to the dry (0.02567 mg/kg) season ($p = 0.046$).

Acetochlor demonstrates an increase in mean concentration from 0.02233 mg/kg in the wet season to 0.05200 mg/kg in the dry season, but the difference is not statistically significant ($p = 0.367$). Glyphosate, Dichlorvos, and Dieldrin were detected during the dry season, with concentrations below the limit of detection (LOD) in the wet season. However, the disparity between the two seasons was not statistically significant. Cypermethrin and Acrinathrin levels were below the limit of detection (LOD) in both seasons. This is illustrated in Table 5.

These findings indicate the pesticide residue concentrations in locally produced kales during the wet and dry seasons in Kiegoi, upper Nyambene catchment. The significant increases in mean concentrations of Captan, Deltamethrin, and Diazinon from the wet to the dry season could be attributed to factors influencing pesticide residue levels in locally produced kales such as the difference in weather conditions between the two seasons, with the dry season characterized by lower humidity and less rainfall. These conditions may lead to reduced degradation and dilution of pesticides, resulting in higher residue levels in crops. Agricultural practices such as increased pesticide application during the dry season to control pests or

Table 4
Crops treated with pesticides

Type of pesticide	Type of crop	Diseases /pest controlled	Percent
Diazinol, Captan50 WP & Deltanex & Dithane M-45	Kales	Aphids, Leaf Spot Diseases: & Powdery Mildew	85.3
Glyphosate (Roundup)	Maize	Leaf Spot Diseases: &weeds control	5.9
Dithane M-45	Potatoes	Powdery Mildew & Rust	5.9
Total			**97.1**

Table 5
Pesticide residue concentrations in locally produced kales

Pesticide Type	Season	N	Conc in Mg/kg Mean	Std. Deviation	Std. Error Mean	P- value	WHO MRL mg/kg
Captan	Wet	3	.01533	.002517	.001453	.000	0.5
	Dry	3	.04700	.001000	.000577		
Deltamethrin	Wet	3	.01467	.001528	.000882	.000	0.5
	Dry	3	.04200	.001000	.000577		
Dichlorvos	Wet	3	LOD	.000000	.000000	.032	0.02
	Dry	3	.01807	.004336	.002504		
Diazinon	Wet	3	.01567	.004726	.002728	.037	0.01
	Dry	3	.02567	.003055	.001764		
Dieldrin	Wet	3	LOD	.000000	.000000	.013	0.05
	Dry	3	.02433	.005859	.003383		
Cypermethrin	Wet	3	LOD	.000000[a]	.000000	.000	0.1
	Dry	3	LOD	.000000[a]	.000000		
Acetochlor	Wet	3	.02233	.001155	.000667	.312	0.02
	Dry	3	.05200	.001000	.000577		
Acrinathrin	Wet	3	LOD	.000000[a]	.000000	.000	0.6
	Dry	3	LOD	.000000[a]	.000000		
Glyphosate	Wet	3	LOD	.000000	.000000	.000	0.7
	Dry	3	.02137	.017012	.009822		

(Independent t-test, LOD = Limit of detection)

weeds could contribute to the elevated residue concentrations observed.

The lack of statistically significant difference in mean concentration of Acetochlor between wet and dry seasons indicates relatively stable residue levels regardless of seasonal variations. This could be attributed to factors such as the chemical properties of Acetochlor, its application methods and its persistence in the environment. The detection of Glyphosate, Dichlorvos and Dieldrin during the dry season, with concentrations below the limit of detection in the wet season could be attributed to potential contamination sources such poor disposal of used pesticides containers, poor storage practices, excessive use of pesticides as well as environmental persistence of these pesticides. The detection below the limit (LOD) during wet season could be attributed high humidity and dilution effect leading to low pesticide residues concentrations. The detection of Cypermethrin and Acrinathrin below the limit in both seasons suggests minimal presence or absence of these pesticides in locally produced kales. This could indicate differences in pesticide usage patterns and susceptibility to degradation, between these pesticides.

The comparison of pesticide residue concentrations in mg/kg with the WHO Maximum Residue Limits (MRLs) standards across wet and dry seasons reveals several significant findings. Both Captan and Deltamethrin show substantial increases in mean concentrations from the wet to the dry season. Captan rises from 0.01533 mg/kg to 0.04700 mg/kg, while Deltamethrin increases from 0.01467 mg/kg to 0.04200 mg/kg. However, despite these increases, their concentrations in both seasons remain below the WHO MRLs of 0.5 mg/kg, indicating compliance with safety standards. Dichlorvos, Diazinon, and Dieldrin display concentrations below the limit of detection (LOD) during the wet season but exceed the WHO MRLs in the dry season. Dichlorvos and Diazinon exceed the MRLs of 0.02 mg/kg and 0.01 mg/kg, respectively, while Dieldrin surpasses the WHO MRL of 0.05 mg/kg during the dry season. This suggests a potential risk of contamination during the dry season. On the other hand, Cypermethrin, Acetochlor, Acrinathrin, and Glyphosate either exhibit concentrations below the LOD or maintain consistent levels between wet and dry seasons that comply with WHO MRLs. These findings highlight the importance of ongoing monitoring and regulatory measures to ensure food safety and mitigate potential health and environmental risks associated with pesticide residues in agricultural products.

This finding is in consensus with a study conducted by Nyantakyi *et al*., (2022) on Assessment of pesticides residues levels in vegetables in Greece, which reported similar trends of higher pesticide residue levels of cypermethrin, dieldrin and Diazinon during the dry season compared to rainy season. However, it contrasts with a study by Otieno (2019) in Laikipia County, which demonstrated higher pesticide residues of deltamethrin and Acrinathrin in vegetables grown during the wet season compared to the dry season. The high detection of commonly used pesticide residues in locally produced kales in the study area during the dry season could be associated to excessive pesticide usage on kales grown observed during the study in the farm fields as opposed to wet season where there was minimal vegetable grown.

4. Future Study

In order to create a comprehensive understanding on pesticide use practices in Meru County, study of the pesticides use practices throughout the year is necessary. This will generate reliable data on food quality in the county.

5. Conclusion

The study concludes that pesticide use is widespread among horticultural farmers, particularly in kale farming, due to the need for pest and disease control. Fungicides and insecticides are the most commonly used, with some highly hazardous pesticides still in circulation despite regulatory concerns. Farmers frequently apply pesticides, especially in the dry season, leading to increased residue levels in kales, some of which exceed recommended safety limits. This poses potential health risks to consumers and raises environmental concerns. The findings highlight the need for better pesticide regulation, safer farming practices, and increased awareness of sustainable alternatives such as integrated pest.

The study identifies variations in pesticide residue concentrations between wet and dry seasons in both water sources and locally produced crops. While some pesticides exhibit consistent concentrations across seasons, others show significant increases during the dry season, suggesting potential seasonal effects on pesticide accumulation. The detection of certain pesticides predominantly during the dry season indicates heightened usage or environmental exposure during this period. However, despite these fluctuations, some pesticides remain undetected in both seasons, highlighting the variability in residue levels across different environmental conditions. These findings emphasize the importance of ongoing seasonal monitoring and management strategies to address potential health and environmental hazards linked to pesticide residues in water sources and agricultural products.

6. Recommendations

1. The farmers should be well exposed to a variety and knowledge of the different types of pesticides. This will ensure effective pesticide characterization and handling.
2. Implementation of Seasonal Monitoring Programs is essential to monitor fluctuations in pesticide residue concentrations in water sources and agricultural products.

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References

[1] Ahoudi, H., Gnandi, K., Tanouayi, G., Ouro-Sama, K., Yorke, J. C., Creppy, E. E., & Moesch, C. (2018). Assessment of pesticides residues contents in the vegetables cultivated in urban area of Lome (southern Togo) and their risks on public health and the environment, Togo. *International Journal of Biological and Chemical Sciences*, *12*(5), 2172-2185.

[2] Akashe, M. M., Pawade, U. V., & Nikam, A. V. (2018). Classification of pesticides: A review. Int. J. Res. Ayurveda Pharm, 9(4).

[3] Ali, M. P., Kabir, M. M. M., Haque, S. S., Qin, X., Nasrin, S., Landis, D., ... & Ahmed, N. (2020). Farmer's behavior in pesticide use: Insights study from smallholder and intensive agricultural farms in Bangladesh. Science of the Total Environment, 747, 141160.

[4] Mutuku, M., Njogu, P., & Nyagah, G. (2014). Assessment of pesticide use and application practices in tomato based Agrosystems in Kaliluni sub location, Kathiani District, Kenya. *Journal of Agriculture, Science and Technology*, *16*(2), 34-44.

[5] Mwanja, M., Jacobs, C., Mbewe, A. R., & Munyinda, N. S. (2017). Assessment of pesticide residue levels among locally produced fruits and vegetables in Monze district, Zambia. *International Journal of Food Contamination*, *4*(1), 1-9.

[6] Syed, J. H., Alamdar, A., Mohammad, A., Ahad, K., Shabir, Z., Ahmed, H., ... & Eqani, S. A. M. A. S. (2014). Pesticide residues in fruits and vegetables from Pakistan: a review of the occurrence and associated human health risks. *Environmental Science and Pollution Research*, *21*(23), 13367-13393.

[7] Kaur, R., Mavi, G. K., Raghav, S., & Khan, I. (2019). Pesticides classification and its impact on environment. *Int. J. Curr. Microbiol. Appl. Sci*, *8*(3), 1889-1897.

[8] Jayaraj, R., Megha, P., & Sreedev, P. (2016). Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment. *Interdisciplinary toxicology*, *9*(3-4), 90-100.

[9] Osoro, E., Wandiga, S. O., Abongo, D. A., Madadi, V. O., & Macharia, J. W. (2016). Organochlorine pesticides residues in water and sediment from Rusinga Island, Lake Victoria, Kenya. *Journal of Applied Chemistry*, *9*(9), 56-63.

[10] Akoto, O., Azuure, A. A., & Adotey, K. D. (2016). Pesticide residues in water, sediment and fish from Tono Reservoir and their health risk implications. *SpringerPlus*, *5*(1), 1-11.

[11] Mekonen, S., Ibrahim, M., Astatkie, H., & Abreha, A. (2021). Exposure to organochlorine pesticides as a predictor to breast cancer: A case-control study among Ethiopian women. *PloS one*, *16*(9), e0257704.