Original Research Article

Prevalence of organophosphate pesticide residues and the associated risks of dietary exposure through selected vegetables from Ilala, Dar es Salaam

Abstract

The increasing reliance on pesticide use in agricultural practices, particularly in developing regions such as Tanzania, poses significant risks to food safety and public health. This study investigates the prevalence and concentration of organophosphate pesticide residues in commonly consumed vegetables specifically amaranth, Chinese cabbage and sweet potato leaves cultivated in Ilala district of Dar Es Salaam. Utilizing 24-hour dietary recall method and data were collected from 138 vegetable farmers. Reference standards for these pesticides were sourced from Sigma-Aldrich, with certified purities ranging from 97- 99%. The analytical methodology employed gas chromatography coupled with mass spectrometry (GC-MS). Vegetable samples were prepared through a series of extraction and purification steps. The results revealed significant variation ($P < 0.05$) in organophosphate residue concentrations across the different vegetable types and sampling sites, for instance the average residual concentration of diazinon in Gongolamboto was 0.158 ± 0.192mg/kg, while in KLinyerezi it was significantly lower at 0.052 ± 0.049mg/kg, this disparity underscores the impact of local agricultureal practices and environmental conditions on pesticide application and residue accumulation. The average residual concentration of profenofos in chinese cabbage was found to be 0.044 ± 0.014mg/kg, while in amaranth exhibited a higher concentration of 0.182 ± 0.056mg/kg. Notably, the concentration of diazinon in amaranth reached 0.272 ± 0.156mg/kg, indicating a significant presence of this pesticide. From the study chlorpyrifos and marathion merged as the predominant pesticides, significantly surpassing Maximum Residue Limits (MRLs) established by international food safety standards. To evaluate the potential health risks associated with dietary exposure to these pesticide residues deterministic approaches was employed. The EDI for chlorpyrifos was determined to be 0.004mg/kg body weight per day, with an ADI of 0.01mg/kg body weight per day, the resulting HI values for chlorpyrifos in both chinese cabbage and amaranth >1 , indicating a significant risk of adverse health effects from chronic exposure. The findings ounderscore a critical public health concern as consumption of these vegetables may expose consumers to harmful pesticide levels, particularly vulnerable populations such as children and agricultural workers.

UNDER PEER REVIEW

Keywords: Pesticide residues, organophosphate, hazard, risk, vegetable, dietary exposure,

1. INTRODUCTION

Governmental health agency campaigns promote the use of fresh vegetables as a vital component of a balanced diet since they are a source of essential micronutrients and have preventive effects against non-communicable diseases (Kapeleka *et al.*, 2020), however, the greatest significant threat to fresh vegetables safety is thought to be pesticide residues. Pesticide residues are more likely to contaminate vegetables that are typically consumed raw or partially prepared, when these vegetables are grown, harvested, and transported, they may become contaminated with pesticide residues (Macieira & Teixeira, 2021).

Pesticide residues in food, raises the possibility of human exposure through dietary consumption(Victoria *et al.*, 2017). The development of cancer, immune system and genetic abnormalities, and neurological diseases have all been linked to dietary exposure to intolerable amounts of pesticide residues (Kiwango *et al.*, 2018). The Environmental Protection Agency (EPA) and the Codex Alimentarius Commission have established maximum tolerated residual levels (MRLs) for specific pesticides in food, including vegetables, to guarantee the safety of these and other foods (Kiwango, 2019).

Organophosphate pesticides are among the pesticides registered in Tanzania and approved to be used, and as highlighted by Kapeleka *et al.* (2020), they are the most common chemicals used in horticultural production. It is established that, they are one of the major constituents of herbicides and insecticides, having intensive application in agriculture (Sidhu *et al.*, 2019). They are considered as safe to be used in agriculture but acute and chronic exposure to organophosphates can produce varying levels of toxicity in humans (Sidhu *et al.*, 2019). However, for vegetables farmers the risks are not only associated with the dietary exposure but also exposure through farming activities (Lekei *et al.*, 2014).

Among food crops with a very high probability of harboring pesticides residues are vegetables, which are essential components of the human diet (Donkor *et al*., 2016). According to surveys conducted in developing nations, indiscriminate pesticides usage in vegetables to control diseases and pests, along with noncompliance with pre-harvest intervals and ignorance of pesticide use, may lead to excessive pesticide residues in vegetables (Chekol, 2024). A study by Micah *et al.* (2024) done in Nigeria revealed that pesticide residues such as Dimethoate in cabbage 0.202mg/kg and Lambda-Cyhalothrin 0.067mg/kg and Chlorpyrifos 0.195mg/kg in okra were found to be above the establish permissible limit, in Thailand, (Chaikasem & Roi-Et, 2020) the positive of

UNDER PEER REVIEW

screening vegetables were most obviously contaminated with organophosphate (95%) and the combined risk index of pesticide residues showed significant health risks to humans.

According to Victoria *et al.* (2017), the intake of pesticide active ingredients through food ingestion has been shown to be up to five times higher than other exposure routes such as ingestion through drinking water and air inhalation. Also the use of pesticides in vegetables cultivation has raised concerns about their safety and potential health risks to consumers (Afonne & Ifediba, 2020). Consequently, it is crucial to quantify the levels of pesticide residues in vegetables in order to craft ways to mitigate the potential health risks associated with their consumption. Despite the recommended dosage, there is still evidence of organophosphate pesticide residues in various vegetables due to the lack of knowledge of most farmers on to the toxic effects of pesticide overdoses (Akomea *et al*., 2017). However, their use has been linked to various health risks such as developmental abnormalities, cancer and impairment to the neurological system, liver and kidneys, particularly when they are present in vegetables that are freshly consumed. Studies have shown that exposure to pesticides have dose-related chronic and acute toxicities in humans through different mechanisms (El-Sheik *et al.*, 2022).

So, this study examines vegetable samples for organophosphate residues, with a focus on selected vegetables that are often consumed in the area. The goal of quantifying these residues is to assess the possible risks to consumers in order to established safety criteria. Additionally, by adding to the expanding body of research on pesticide control and food safety, this study offers insights that could influence consumer choices and policy.

2. MATERIAL AND METHODS

2.1. Study area

Ilala city is one of five districts of the Dar Es Salaam region of Tanzania. Ilala has an area of 210 km^2; it lies between longitude 39° and 40° East between 6° and 7° South of the Equator. The city is divided into 26 wards, the main cash crops farmed in Ilala city include a range of vegetables such as amaranth, chinese cabbage, egg plants, okra, spinach, kale and sweet potato leaves. This study was conducted at Gongolamboto and Kinyerezi wards in Ilala district, Dar Es Salaam, because they are known for cultivation of the selected vegetables which are amaranth, chinese cabbage and sweet potato leaves.

UNDER PEER REVIEW

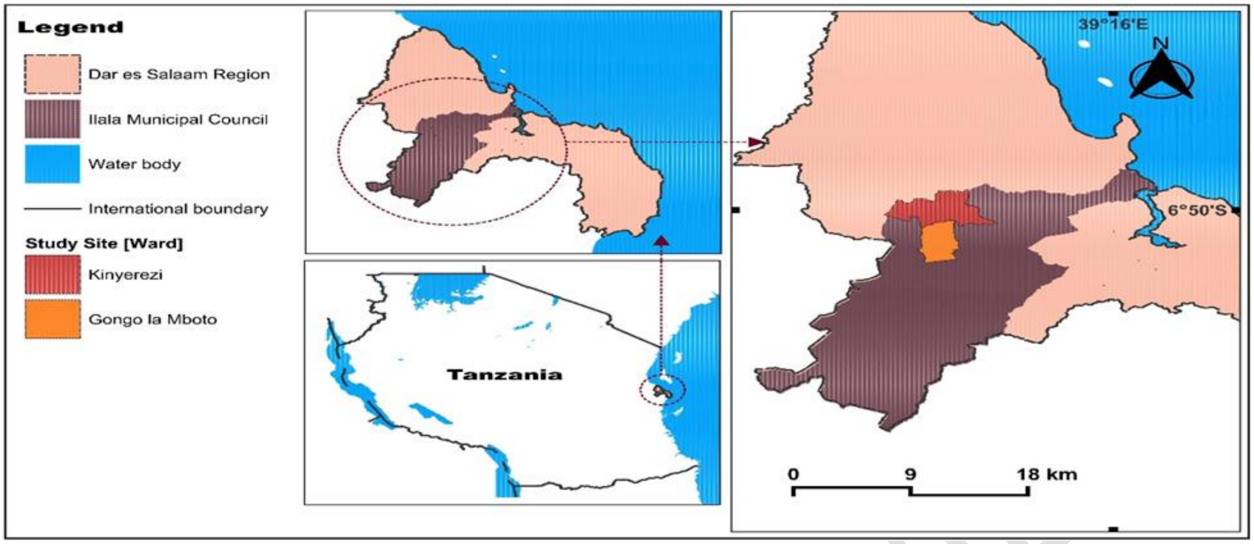

Figure 1: a map showing study areas.

2.2. Study design and sample size

Farmers and vegetable sample sizes were estimated by using a formula from a prevalence study (Kiwango, 2019) and (Charan & Biswas, 2013), whereby 138 vegetable farmers were selected using a given criteria which were willingness of a farmer to participate and also the participant must have consumed vegetables in past 24 hours. Then the selected vegetable samples (chinese cabbage, amaranth and sweet potato leaves) were collected after every five farmers making a total of 30 bundles of selected vegetable that`s 10 bundles of each vegetable samples (amaranth, chinese cabbage and sweet potato leaves).

$$n = Z^2 \frac{(P \times Q)}{d^2} \ldots\ldots\ldots\ldots \text{(i)}$$

where n is the sample size, P is the estimated proportion of the study variable (90%), Q is (1-P) (10%), d is the margin of error (0.05%) and Z score is 1.96 for 0.05%. This translates to n = 138.

2.3. Data collection

Detailed information on vegetables consumption among study participants were further collected using 24 hours dietary recall. Fresh samples of selected vegetables that were amaranth, chinese cabbage and sweet potato leaves from both study areas were also collected equally making a total of 30 vegetable samples; ten of each selected vegetable.

UNDER PEER REVIEW

2.4. Sampling and quantification of fresh selected vegetables

To estimate the amount of each selected vegetables consumed by the farmers 24-hour dietary recall was employed through farm visit and the respondent farmers were asked to recall what type of vegetable they consumed on past 24 hours. The study participants were also asked to estimate the amounts of vegetables consumed in a previous day by using a bowl and table spoon then participant's body weights were measured. The selected vegetable samples (chinese cabbage, amaranth and sweet potato leaves) were collected after every five farmers. Vegetable samples were then mixed to make a total of five bundles of each vegetable sample from both study areas, and then the vegetable samples were kept in a cool box with ice blocks and transported to Mwanza at National Fish Quality Control Laboratory (NFQCL) for pesticide analysis.

2.5. Analysis of organophosphate pesticide residues in fresh vegetables

2.5.1. Chemicals and reagents

Pesticide reference standards for organophosphate pesticides and reagent grade were obtained from Sigma-Aldrich (Germany) with certified purity ranging from 97% to 99%. Standard solutions (stock, composite, calibration, and surrogate (analyte) were stored at < 6◦C in polytetrafluoroethylene (PTFE)-sealed containers in the dark. Anhydrous magnesium sulfate (MgSO4), acetonitrile (CH_3CN), n-hexane, glacial acetic acid (CH_3COOH), Bondesil Primary Secondary Amine (PSA, 40 µm) and sodium acetate ($NaCH_3COOH$) were supplied from Agilent (Germany).

2.5.2. Sample extraction

The vegetable samples extraction and partitioning were carried out according to a modified version of the QuEChERS (Quick, Easy, Cheap, Effective, Rugged and Safe) procedure with the aid of d-SPE clean-up method as per the official method of AOAC 2007.01 as follows: About 1 kg of each vegetable sample was homogenized in a blender and 15 g aliquot of the chopped and homogenized sample of a vegetable was weighed into 50 mL plastic centrifuge tubes on a sensitive analytical balance and left to hydrate for 30 min after the addition of 10 mL distilled water and stirring for 30 seconds. Two ceramic homogenizers were added to each 50 mL tube. Then, 10 mL of acetonitrile with 1% glacial acetic acid (v/v) (buffering media) was added into the homogenized vegetable sample using a micropipette, and samples were shaken by hand for 1 minute to increase interaction between the solvent and the sample for each pesticide analyte. Six (6 g) of anhydrous magnesium sulfate and 1.5 g sodium acetate were then added followed by vigorously shaking the sealed tubes for 1 minute by vortex mixer and centrifuging for 5 minutes at 4500 rpm.

2.5.3. Dispersive SPE clean-up

A 6 mL aliquot amount of the (upper) acetonitrile layer was transferred into Bond Elute d-SPE 15-mL plastic centrifuge tubes containing 150 mg primary secondary amine (PSA). Next, 5 mL of 20% (w/w) aqueous sodium chloride solution and 1 mL n-hexane

UNDER PEER REVIEW

were added. The tube was robustly vortexed for 1 min and then centrifuged for 2 minutes at 4500 rpm. A portion of the (upper) n-hexane layer was filtered through a teflon filter 0.45 µm and 1–2 mL of the extracts were transferred into an auto sampler then injected into the Gas Chromatography System.

2.5.4 Calibration standards

Ten (10) µg of each pesticide were dissolved in 10 mL volumetric flasks containing acetonitrile to prepare 1 mg/L or 1000 ppb of each pesticide stock standard solutions and stored in a refrigerator below 6˚C. Calibration standard solutions of the six organophosphorus pesticides with concentration ranges of 2–200 ppb (w/w) spiked with sample matrix were prepared in acetonitrile and stored at 4˚C. Other working solutions were prepared by dilutions of intermediate solutions.

2.5.5 Analytical instrumentation and conditions

Analysis was made by the Varian 450 Gas Chromatography, coupled with a Varian 320 Mass Spectrometer (Varian 320 MS). The sample was introduced in splitless mode. A GsBP-5 MS column with 30 m × 0.53 mm x 0.5 µm was used. A fused silica capillary column, 5%-phenyl-methylpolysiloxane as stationary phase (30 m × 0.25 mm internal diameter) and 0.25 µm film thickness was used with helium as carrier gas at a constant flow (1 mL/min). The system was equipped with a splitless injection inlet and a 1 µL aliquot of sample or standard was injected in splitless mode at 250˚C. The GC oven was operated with the following temperature program: initial temperature 100˚C held for 3 minutes, ramped at 25˚C/min to 175˚C not held, followed by a ramp of 8˚C/min to 290˚C and held for 5 minutes. The total run time was 25 minutes. The transfer line temperature was set at 275˚C and the source temperature at 175˚C. MS experimental conditions: Ionization mode: EI, EMV mode: Gain Factor, Gain Factor: 1, Transfer line temperature: 275˚C, Ion Source temp: 230˚C, Quad temp: 150˚C, Solvent delay: 3 min. The mass spectrometer was operated in selected ion monitoring mode (SIM).

2.6. Estimating risks of dietary exposure

2.6.1. Estimating dietary organophosphate pesticides exposure

Dietary exposure (mg/kg body weight per day) of adults was determined following the deterministic approach as guided by WHO and FAO (FAO/WHO, 2009). The deterministic approach involves multiplying concentration of organophosphate pesticides (mg/kg) in the vegetable's samples and the amounts of vegetables consumed by individuals per day (kg/day) and dividing by body weight (kg) of individual's farmers that was measured.

$$EDI = Q\left(\frac{kg}{day}\right) X\ C\left(\frac{mg}{kg}\right)/BW(kg) \ldots.. \text{(ii)}$$

Where; EDI is the estimated daily dietary intake of the organophosphate pesticide's residues in milligram per kg body weight of the consumer, Q is quantity of vegetables consumed per day (kg per day), C is the concentration of residue in the vegetables in mg/kg and BW is body weight in kg.

2.6.2. Estimating the risks of unacceptable exposure to organophosphate pesticides

The risk of unacceptable exposure of the organophosphate pesticide residues was determined by calculating the hazard quotient (HQ) of organophosphate pesticides using the equation as described by EFSA (2008) and USEPA (2005).

$$HQ = EDI/ADI \text{……..} \text{ (iii)}$$

Where; HQ is hazard quotient, EDI is the estimated daily intake (mg/kg BW /day) of organophosphate pesticides and ADI is the corresponding acceptable daily intake (mg/kg BW/day). Since there are various organophosphate pesticide residues, for multiple exposure of the pesticides falling under the same chemical group such as organophosphate pesticides the risks of exposure were calculated by adding the HQs of pesticides residues of the same group to obtain hazard index (EFSA, 2008; FAO/WHO, 2005; USEPA, 2005).

$$HI = \frac{EDIa}{ADIa} + \frac{EDIb}{ADIb} + \frac{EDIn}{ADIn} \text{……………} \text{ (iv)}$$

Where; HI is the hazard index, EDI is the estimated daily intake (mg/kg BW/day) of organophosphate pesticides and ADI is the corresponding acceptable daily intake (mg/kg BW/day). (FAO/WHO, 2005; USEPA, 2005) highlighted that HQ or HI ≤ 1 indicate that adverse health effect (s) are not likely to occur and the amount of pesticide residues consumed can be considered to have tolerable effect (s) while, HQ or HI > 1 indicate that the exposure is greater than ADI and this implies that there might be risks from the residues consumed and calls for risk management action to be taken

2.7. Data statistical analysis

Data from laboratory, 24 hours dietary recall and the body weights data were entered and then analyzed using Microsoft office excel 2016 and Statistical Package for Social sciences (SPSS) version 23. Descriptive results were expressed as mean for continuous variables, standard deviation, range, frequency and percentages were analyzed using SPSS software. Independent t test was used to determine statistical significance between mean residual concentration of two independent groups. One way ANOVA was used to determine if there is significance difference in mean residual concentration between vegetable samples.

UNDER PEER REVIEW

3. RESULTS AND DISCUSSION

Socio-demographic variables on vegetables cultivators in the study areas indicated that the highest percentage of respondents (24.82%) belonged to the 36-40 age group, their use of pesticides may be influenced by their expertise and capacity to adjust to new farming methods, which are characteristics of this age group. The highest percentage (58.39 %) of the respondents were men which is a recurring tendency in agricultural research in Africa and similar results were reported by Shammi *et al.* (2020). 72.39% of the study respondents had formal marriage, marital status are very important for agricultural decisions, such as the distribution of resources for pesticide use and instruction on safe handling techniques (Bagheri *et al.*, 2018). 39.42% of respondents attended primary education so their knowledge of safe pesticides uses and sophisticated farming methods may be limited by this educational background, which could raise the health hazards of pesticide exposure (Gesesew *et al.*, 2016).

T**able 1: Socio demographic characteristics of vegetable farmers**

VARIABLE		FREQUENCY	PERCENTAGE (%)
Age of respondents			
	<35	32	23.36
	36-40	34	24.82
	41-45	29	21.17
	46-50	27	19.71
	>50	14	10.94
Sex of respondents			
	Male	80	58.39
	Female	57	41.61
Marital status			
	Married	97	72.39
	Single	32	23.88
	Widowed	05	03.73
Education level			
	Primary education	54	39.42
	Secondary education	40	29.20
	Post-secondary education	23	16.79
	Never attended	20	14.59

Considering table 2 of this study, for the analyzed organophosphate pesticide residues in vegetable samples there was no any residue analyzed that was not found in vegetable samples so critical concerns regarding regulatory compliance and food safety requirements are brought up by the existence of these residues. A study by Fatunsin *et al.* (2020) indicated that vegetables had more organophosphate pesticide residues than other pesticides such as carbamates and organochlorines.

UNDER PEER REVIEW

Table 2: Average concentration (mg kg^{-1}), prevalence, MRL and >MRL

Vegetable	Pesticide (mg/kg)	prevalence	Average concentration ($mgkg^{-1}$) ± [a] SD	Maximum - minimum	[b] MRL	>MRL
Chinese cabbage	Chlorpyrifos	100%	0.005 ± 0.002	0.00625-0.004	0.01	**50% (5)**
	Profenofos	100%	0.044 ± 0.014	0.058-0.02915	0.5	0
	Diazinon	100%	0.021 ± 0.007	0.034-0.009	0.5	0
	Malathion	100%	0.062 ± 0.02	0.0893-0.0376	0.05	0
	Pirimiphos-methyl	100%	0.047 ± 0.015	0.06215-0.033	0.1	0
Amaranth	Chlorpyrifos	100%	0.01 ± 0.003	0.01315-0.008	0.01	0
	Profenofos	100%	0.182 ± 0.056	0.29295-0.071	0.5	0
	Diazinon	100%	0.272 ± 0.086	0.43615-0.116	0.5	0
	Malathion	100%	0.131 ± 0.041	0.1872-0.0814	0.05	**50% (5)**
	Pirimiphos - methyl	100%	0.05 ± 0.017	0.08685-0.017	0.1	0
Sweet potato leaves	Chlorpyrifos	100%	0.019 ± 0.006	0.0325-0.0056	0.01	**50% (5)**
	Profenofos	100%	0.016 ± 0.005	0.0196-0.012	0.5	0
	Diazinon	100%	0.023 ± 0.007	0.0269-0.0152	0.5	0
	Malathion	100%	0.048 ± 0.015	0.067-0.024	0.05	**100%(10)**
	Pirimiphos - methyl	100%	0.447 ± 0.141	0.9263-0.012	0.1	0

Note: [b] MRLs (Maximum residues limits) set by CODEX Alimentarius commission,

[a] standard deviation

For all organophosphate pesticide analyzed malathion had a notably high residue concentration of (0.062 ± 0.02) mg/kg, these results are consistent with the earlier studies showing that malathion is widely used because it works well against a variety of pests, but they also raise questions about its persistence and possible negative health effects (Dinede *et al.*, 2023), whereas chlorpyrifos was detected at (0.005 ±0.002) mg/kg. In Chinese cabbage vegetable samples malathion had the highest residue concentration that was 0.0893mg/kg and chlorpyrifos had the lowest (0.00415mg/kg), while in amaranth vegetable samples diazinon had the highest residue concentration (0.43615mg/kg) these results are consistent with a research conducted by Akan, (2013) which documented higher residues levels of diazinon and chlorpyrifos in leafy vegetables thus indicating significant contamination levels that exceeded the acceptable limits for human consumption. Chlorpyrifos had the lowest (0.0078mg/kg) and for sweet potato leaves displayed a particularly alarming concentration of pirimiphos-methyl at (0.9263mg/kg) alongside profenofos 0.001235mg/kg. These variances emphasize how crucial it is to keep an eye on particular vegetable because cultivation methods and insect pressures can have a substantial impact on residue levels (Jara & Winter, 2019).

UNDER PEER REVIEW

For all organophosphate pesticide residues analyzed (table 02), 50% of chinese cabbage vegetable samples; chlorpyrifos was above Maximum Residues Levels (MRL) (0.01mg/kg) standard set by WHO/FAO according to USEPA, 2006 chlorpyrifos associate with difference health effects in human such as cholinesterase inhibition causing nausea, dizziness, confusion and at a very high exposure respiratory paralysis and death may occur, these results are in line with those obtained by Calista *et al*. (2022) and Kapeleka *et al.* (2020), similarly malathion level surpasses MRL (0.05mg/kg) to 50% of amaranth samples which are similar to the results obtained by Hossain *et al.* (2015) and Darko & Akoto, (2008) and in sweet potato leaves; 50% of vegetable samples analyzed ; chlorpyrifos was above MRL, 73.33% of the sweet potato leaves malathion was above MRL, suggesting a significant risk for consumers since according to IARC, (2015) evaluations malathion and diazinon were classified as probably carcinogenic to human (group 2A) known for causing prostate cancer, lung cancer, disruption of homornal pathways and DNA or chromosomal damage. This is in line with results from past research that found significant concentrations of pesticide residues in vegetables, which can have negative health impacts including disrupting hormones and raising the risks of cancer (Ali *et al.*, 2021). These findings are consistent with research by Kiwango *et al*. (2018), which found that chlorpyrifos and other organophosphates were frequently found in vegetable samples, with many of them exceeding the permissible MRLs. These results highlight significant issues with public health and food safety, indicating the urgent need for more stringent oversight and control of pesticide usage in vegetable cultivation (Fatunsin *et al.*, 2020).

This study found that the mean concentrations of organophosphate pesticide residues varied significantly between Kinyerezi and Gongolamboto figure (2), suggesting that agricultural methods or environmental conditions may have a major impact on residue levels (Ore *et al.*, 2023). Profenofos, diazinon, malathion, and pirimiphos-methyl concentration in vegetables samples varied significant between the study areas while chlorpyrifos showed no significant differences among vegetable samples between the study areas.

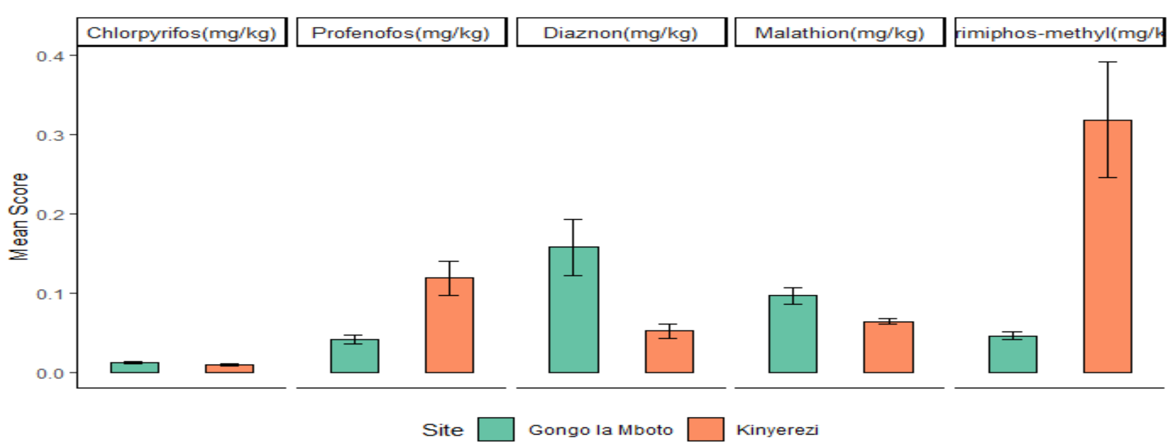

Figure 2: showing residual concentrations difference between the study areas

Table 3: Study areas, vegetables, average concentration (mg kg^{-1}), and P- value

Variable		Chlorpyrifos (mg/kg)	Profenofos (mg/kg)	Diaznon (mg/kg)	Malathion (mg/kg)	Pirimiphos-methyl (mg/kg)
Vegetable						
	Chinese cabbage	0.005 ± 0.002^{c}	0.044 ± 0.014^{a}	0.021 ± 0.007^{a}	0.062 ± 0.021^{a}	0.047 ± 0.015^{b}
	Sweet potato leaves	0.019 ± 0.006^{a}	0.016 ± 0.005^{a}	0.023 ± 0.007^{a}	0.048 ± 0.015^{a}	0.447 ± 0.141^{a}
	Amaranth	0.010 ± 0.003^{b}	0.182 ± 0.056^{b}	0.272 ± 0.086^{b}	0.131 ± 0.041^{b}	0.054 ± 0.017^{b}
Site						
	Gongo la mboto	0.013 ± 0.008^{a}	0.042 ± 0.030^{a}	0.158 ± 0.192^{a}	0.097 ± 0.060^{a}	0.047 ± 0.027^{a}
	Kinyerezi	0.010 ± 0.007^{a}	0.119 ± 0.118^{b}	0.052 ± 0.049^{b}	0.065 ± 0.020^{b}	0.318 ± 0.400^{b}

From table (3) chlorpyrifos varied significant in residual concentration between all vegetable samples, while in amaranth profenofos, diazinon, malathion, and pirimiphos-methyl residual concentration were significant difference compared to other analyzed vegetable samples ($P<0.05$).These results are in line with the study by Ssemugabo *et al.*(2022) which indicated that organophosphates were found in 91.3% of the samples examined in a study on pesticide residues in vegetables carried out in the Kampala Metropolitan Area, depending on where the vegetable came from, the study found that different pesticide residues were prevalent and varied in concentration. This implies that residue levels are greatly influenced by farming techniques and environmental conditions, much as the distinctions between Kinyerezi and Gongolamboto. Similar these results research by El-Sheik *et al.* (2022) which discovered that 40.7% of the pesticide residues observed in vegetables were higher than MRLs and significant variations in residue levels were seen in the study among the various vegetable varieties, suggesting that some vegetables may acquire more residues as a result of variables including growth conditions and pesticide application techniques. Also, researchers discovered that 48% of vegetable samples in a cross-sectional survey carried out in central and eastern Ethiopia had detectable pesticide residues, with notable differences depending on the type of vegetable. It was observed further that certain organophosphates, such as diazinon, were prevalent (Dinede *et al.*, 2023).

Overall risks of organophosphate pesticide exposure assessment of chronic exposure to organophosphate pesticide residues through leafy vegetable consumption indicates potential health risks to vegetable farmers. Exposure levels and hazard indices of organophosphate pesticides to vegetable farmers in Kinyerezi and Gongolamboto in Ilala district are presented in table 4.

UNDER PEER REVIEW

Table 4: EDI (mg kg^{-1} $BWday^{-1}$), ADI (mg/kg BW day^{-1}), HQ and HI for organophosphate pesticides in individual vegetables

vegetable	Pesticide (mg/kg)	Average[1] EDI	[2]ADI	Average [3]HQ	[4]HI
Chinese	Chlorpyrifos	4.27 x 10^{4}	0.01	0.043	1.54
	Profenofos	2.992 x 10^{3}	0.03	0.1	3.59
	Diazinon	2.066 x 10^{3}	0.01	0.21	7.44
	Malathion	2.465 x 10^{3}	0.3	0.01	0.295
	Pirimiphos-methyl	7295 x 10^{3}	0.05	0.15	5.25
Amaranth	Chlorpyrifos	4.18 x 10^{4}	0.01	0.04	2.134
	Profenofos	2.929 x 10^{3}	0.03	0.01	4.98
	Diazinon	2.022 x 10^{3}	0.01	0.2	10.31
	Malathion	2.413 x 10^{3}	0.3	0.01	0.41
	Pirimiphos-methyl	7.141 x 10^{3}	0.05	0.14	7.28
Sweet potato leaves	Chlorpyrifos	3.74 x 10^{4}	0.01	0.04	1.608
	Profenofos	2.618 x 10^{3}	0.03	0.09	3.753
	Diazinon	1.808 x 10^{3}	0.01	0.18	7.774
	Malathion	2.157 x 10^{3}	0.3	0.01	0.309
	Pirimiphos-methyl	6.384 x 10^{3}	0.05	0.13	5.49

Note: Source of values for acceptable daily intake ([2]ADI): WHO/FAO 2015, [1]EDI (Estimated dietary intake), [3]HQ (Hazard quotient), [4]HI (Hazard index)

As stated hazard quotients/indices less than one indicates that adverse health effects are not likely to occur and thus the amount of pesticide residue consumed can be considered to have tolerable effects and when hazard quotient/ index is greater than one means the exposure is greater than allowable dietary intake (ADI), this mean there might be risk of pesticide residues consumed (Kiwango, 2019). From the study the HQ of organophosphate pesticide residues through consumption of vegetables has been calculated using equation (iii) and the same have been tabulated in Table 4. None of the vegetable samples had HQ values >1 thereby indicating that the residues detected from the samples were within safe limits and will not cause any significant hearth risks to farmers, similar results were reported by (Thasale *et al.*, 2022).

HI values for chlorpyrifos, profenofos, diazinon and pirimiphos-methyl were >1 for both vegetables (amaranth, chinese cabbage and sweet potato leaves), and for the remaining pesticide malation was found to be <1. The study highlighted the long term health concerns associated with eating contaminated vegetables, especially the neurotoxic effects for organophosphates like diazinon and chlorpyrifos. Due lack of proper control and monitoring procedures puts citizens in underdeveloped nations at disproportionate risks of pesticide exposure. Children and agricultural workers are especially susceptible to the negative consequences of pesticide residues, according to the study (Tudi *et al.*, 2022). A study in Egypt reports cumulative hazard indices for organophosphates higher than those of pyrethrods but both of them below one (Gad-Alla *et al.*, 2015).

UNDER PEER REVIEW

4. CONCLUSION

This study has revealed significant concerns regarding the presence of organophosphate pesticide residues in selected vegetable from Kinyerezi and Gongolamboto highlighting the potential health risks associated with their consumption. The findings indicated that urban farming practices may contribute to higher pesticide residue levels compared rural areas, likely due to the diverse pest population encountered in urban settings, which necessitate more intensive pesticide applications. Additionally, the assessment of hazard quotient (HQ) and hazard indices (HI) revealed that body weight plays a crucial role in determining exposure risks, with havier individuals potentially experiencing lower relative risks. Furthermore, the educational background of farmers significantly influences their understanding of safe practices use, with those having limited education facing higher exposure risks. While for hazard quotient (HQ) most samples were within safe limits, the elevated hazard indices for vulnerable populations such as agricultural workers. The findings emphasize the urgent need for improved monitoring and regulation of pesticide use, alongside educational initiatives for farmers on safe application practices. Overall, this research underscores the importance of prioritizing food safety and public health in agricultural practices to mitigate the risks of pesticide exposure.

UNDER PEER REVIEW

5. ETHICAL CONSIDERATIONS

An ethical concern addressed in this research pertained to obtaining proper permissions for data collection, prior to sample collection from farmers at Kinyerezi and Gongolamboto, the necessary reach permits were obtained from the Vice Chancellor of Sokoine University of Agriculture, in accordance with established protocols. Additionally, the Municipal Director's was secured, ensuring that the study adhered to ethical guidelines and informed consent were maintained throughout the research process, reflecting our commitment to upholding ethical standards and conducting a responsible study.

.

UNDER PEER REVIEW

REFERENCES

Afonne, O. J., & Ifediba, E. C. (2020). Heavy metals risks in plant foods – need to step up precautionary measures. *Current Opinion in Toxicology*, 22: 1–6.

Akan, J. C. (2013). Organophosphorus Pesticide Residues in Vegetable and Soil Samples from Alau Dam and Gongulong Agricultural Areas, Borno State, Nigeria. *International Journal of Environmental Monitoring and Analysis*, 3(6):58-64.

Akomea-Frempong, S., Ofosu, I. W., Owusu-Ansah, E. D. G. J., & Darko, G. (2017). Health risks due to consumption of pesticides in ready-to-eat vegetables (Salads) in Kumasi, Ghana. *International Journal of Food Contamination*, 4(1): 1-11.

Ali, S., Ullah, M. I., Sajjad, A., Shakeel, Q., & Hussain, A. (2021). Environmental and health effects of pesticide residues. *Sustainable Agriculture Reviews 48: Pesticide Occurrence, Analysis and Remediation Vol. 2 Analysis*, 311-336.

Bagheri, A., Emami, N., Allahyari, M. S., & Damalas, C. A. (2018). Pesticide handling practices, health risks, and determinants of safety behavior among Iranian apple farmers. *Human and ecological risk assessment: an international journal*, 24(8): 2209-2223.

Calista, N., Haikael, M. D., Athanasia, M. O., Neema, K., & Judith, K. (2022). Does Pesticide exposure contribute to the growing burden of non - communicable diseases in Tanzania. *Scientific African*, 17: e01276.

Chaikasem, S., & Roi-Et, V. N. (2020). Health risk assessment of pesticide residues in vegetables from river basin area. *Applied Environmental Research*, 42(2): 46–61.

Charan, J., & Biswas, T. (2013). How to calculate sample size for different study designs in medical research? *Indian Journal of Psychological Medicine*, 35(2**)**: 121–126.

Chekol, G. M. (2024). *Understanding the Factors behind Non-Adherence to Pesticide Safety Guidelines among Smallholder Farmers in Fogera and Mecha Districts , Northwestern Ethiopia*.

Darko, G., & Akoto, O. (2008). Dietary intake of organophosphorus pesticide residues through vegetables from Kumasi, Ghana. *Food and Chemical Toxicology*, 46(12): 3703-3706.

Dinede, G., Bihon, W., Gazu, L., Foukmeniok Mbokou, S., Girma, S., Srinivasan, R., Roothaert, R., Grace, D., Gashaw, H., & Knight-Jones, T. J. D. (2023). Assessment of pesticide residues in vegetables produced in central and eastern Ethiopia. *Frontiers in Sustainable Food Systems*, 7(6):1143753.

Donkor, A., Osei-Fosu, P., Dubey, B., Kingsford-Adaboh, R., Ziwu, C., & Asante, I. (2016). Pesticide residues in fruits and vegetables in Ghana: a review. *Environmental Science and Pollution Research*, 23(19): 18966–18987.

European Food Safety Authority. (2008). Opinion of the Scientific Panel on plant protectionProducts and their residues to evaluate the suitability of existing methodologies and, if appropriate, the identification of new approaches to assess cumulative and synergistic. Risks from pesticides to health. *EFSA Journal*, 704: 1 - 84.

El-Sheikh, E. S. A., Ramadan, M. M., El-Sobki, A. E., Shalaby, A. A., McCoy, M. R., Hamed, I. A., ... & Hammock, B. D. (2022). Pesticide residues in vegetables and fruits from farmer markets and associated dietary risks. *Molecules*, 27(22): 8072.

Fatunsin, O. T., Oyeyiola, A. O., Moshood, M. O., Akanbi, L. M., & Fadahunsi, D. E. (2020). Dietary risk assessment of organophosphate and carbamate pesticide residues in commonly eaten food crops. *Scientific African*, 8: e00442.

UNDER PEER REVIEW

Food and Agriculture Organization and World Health Organization. (2005). Report of the Joint meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and the WHO Core Assessment Group on pesticide residues 20–29 September 2005. FAO/WHO, Geneva, Switzerland. 360pp.

Food and Agriculture Organization and World Health Organization. (2015). Report of the Joint meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and the WHO Core Assessment Group on pesticide residues 15–24 September 2005. FAO/WHO, Geneva, Switzerland. 647pp.

Gad-Alla, S. A., Loutfy, N. M., Shendy, A. H., & Ahmed, M. T. (2015). Hazard Index, a tool for a long term risk assessment of pesticide residues in some commodities, a pilot study. Regulatory Toxicology and Pharmacology.

Gesesew, H. A., Woldemichael, K., Massa, D., & Mwanri, L. (2016). Farmers knowledge, attitudes, practices and health problems associated with pesticide use in rural irrigation villages, Southwest Ethiopia. *PloS one*, 11(9): e0162527.

Hossain, M. S., Fakhruddin, A. N. M., Alamgir Zaman Chowdhury, M., Rahman, M. A., & Khorshed Alam, M. (2015). Health risk assessment of selected pesticide residues in locally produced vegetables of Bangladesh. *International Food Research Journal*, 22(1): 110–115.

International Agency for Research on Cancer. (2015). IARC Monographs Volume 112: evaluation of five organophosphate insecticides and herbicides. *World Health Organization, Lyon.*

Jara, E. A., & Winter, C. K. (2019). Safety levels for organophosphate pesticide residues on fruits, vegetables, and nuts. *International Journal of Food Contamination*, 6(1): 1–8.

Kapeleka, J. A., Sauli, E., Sadik, O., & Ndakidemi, P. A. (2020). Co-exposure risks of pesticides residues and bacterial contamination in fresh fruits and vegetables under smallholder horticultural production systems in Tanzania. *PLoS ONE*, 15(7 July), 1–23.

Kiwango, P. A. (2019). *Risk assessment for dietary exposure of pesticides among vegetables consumers in Arusha, Tanzania*. http://dspace.nm-aist.ac.tz/handle/20.500.12479/299%0Ahttp://dspace.nm-aist.ac.tz/bitstream/handle/20.500.12479/299/PhD_LiSe_Purificator_Kiwango_2019.pdf?sequence=1

Kiwango, P., Kassim, N., & Kimanya, M. (2018). Pesticide Residues in Vegetables: Practical Interventions to Minimize the Risk of Human Exposure in Tanzania. *Current Journal of Applied Science and Technology*, 26(1): 1–18.

Lekei, E., Aiwerasia, V. N., & Leslie, L. (2014). farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in tanzania,.

UNDER PEER REVIEW

BMC Public Health, 14(i389): 1–13.

Macieira, A., Barbosa, J., & Teixeira, P. (2021). Food safety in local farming of fruits and vegetables. *International Journal of Environmental Research and Public Health*, 18(18), 9733.

Micah, M. M., Peace, Z., Usaku, R., & Onyebuchi, P. U. (2024). Assessment of Heavy Metals and Pesticide Residues in Abelmoschus esculentus (Okro), Amaranthus cruentus (Spinach), Hibiscus sabdariffa (Roselle) and Cabbage Vegetables from Agricultural Area of Boronji Jimeta, Adamawa State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 28(7): 1993–1998.

Ore, O. T., Adeola, A. O., Bayode, A. A., Adedipe, D. T., & Nomngongo, P. N. (2023). Organophosphate pesticide residues in environmental and biological matrices: Occurrence, distribution and potential remedial approaches. *Environmental Chemistry and Ecotoxicology*, 5, 9-23.

Sidhu, G. K., Singh, S., Kumar, V., Dhanjal, D. S., Datta, S., & Singh, J. (2019). Toxicity, monitoring and biodegradation of organophosphate pesticides: A review. *Critical Reviews in Environmental Science and Technology*, 49(13): 1135–1187.

Shammi, M., Sultana, A., Hasan, N., Rahman, M. M., Islam, M. S., Bodrud-Doza, M., & Uddin, M. K. (2020). Pesticide exposures towards health and environmental hazard in Bangladesh: A case study on farmers' perception. *Journal of the Saudi Society of Agricultural Sciences*, 19(2): 161-173.

Ssemugabo, C., Bradman, A., Ssempebwa, J. C., Sillé, F., & Guwatudde, D. (2022). Pesticide Residues in Fresh Fruit and Vegetables from Farm to Fork in the Kampala Metropolitan Area, Uganda. *Environmental Health Insights*, 16(7): 11786302221111866.

Tudi, M., Li, H., Li, H., Wang, L., Lyu, J., Yang, L., Tong, S., Yu, Q. J., Ruan, H. D., Atabila, A., Phung, D. T., Sadler, R., & Connell, D. (2022). Exposure Routes and Health Risks Associated with Pesticide Application. *Toxics*, 10(6): 1–23.

Thasale, R., Kumar, D., Mehta, T. G., & Limbachiya, R. (2022). Human health risk assessment of pesticide residues in vegetable and fruit samples in Gujarat State, India. *Heliyon*, 8(10): e10876.

USEPA. (2005). Environmental Protection Agency. Guidelines for carcinogen risk assessment. Washington, DC. [https://www3.epa.gov/airtoxics/cancer_guidelines_final_3-25-05.pdf.]. Accessed on October 11, 2014.

USEPA. (2006). Registration Eligibility Decision for Chlorpyrifos.

Victoria, K., Neema, K., & Martin, K. (2017). Risk of exposures of pesticide residues from tomato in Tanzania. *African Journal of Food Science*, 11(8): 255–262.

UNDER PEER REVIEW

UNDER PEER REVIEW