2018-02

Pesticide Residues in Vegetables: Practical Interventions to Minimize the Risk of Human Exposure in Tanzania

Kiwango A., P.

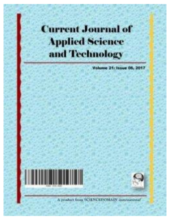
Current Journal of Applied Science and Technology

DOI: 10.9734/CJAST/2018/38976

Pesticide Residues in Vegetables: Practical Interventions to Minimize the Risk of Human Exposure in Tanzania

Article *in* Current Journal of Applied Science and Technology · February 2018

DOI: 10.9734/CJAST/2018/38976



Current Journal of Applied Science and Technology

26(1): 1-18, 2018; Article no.CJAST.38976
Previously known as British Journal of Applied Science & Technology
ISSN: 2231-0843, NLM ID: 101664541

Pesticide Residues in Vegetables: Practical Interventions to Minimize the Risk of Human Exposure in Tanzania

P. A. Kiwango[1*], N. Kassim[1] and M. E. Kimanya[1,2]

[1]The Nelson Mandela African Institution of Science and Technology, P.O.Box 447, Arusha, Tanzania.
[2]Department of Rural Economy and Agriculture, African Union Commission, P.O.Box 3243, Addis Ababa, Ethiopia.

Authors' contributions

This work was carried out in collaboration between all authors. Author PAK prepared the first draft of the manuscript. Authors NK and MEK reviewed the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/38976
Editor(s):
(1) Lesley Diack, Professor, School of Pharmacy and Life Sciences, Robert Gordon University, UK.
Reviewers:
(1) Moustafa Mohamed Saleh Abbassy, Alexandria University, Egypt.
(2) Fábio Henrique Portella Corrêa de Oliveira, Universidade Federal Rural de Pernambuco, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/23292

Review Article

Received 23rd November 2017
Accepted 29th January 2018
Published 22nd February 2018

ABSTRACT

Malpractices in the use of pesticides in vegetable production have been reported in the horticultural sector in developing countries. This can result in excessive use of pesticides and, subsequently, in unacceptable levels of pesticide residues in foods of horticultural origin. Consumption of vegetables containing unacceptable levels of pesticide residues is of public concern due to its potentially harmful effects on human health. In this work, we reviewed the current status of pesticide application, the occurrence and exposure of pesticide residues in vegetables as well as factors influencing the problem of pesticide exposure in Tanzania. The review has realized that pesticides are rarely applied to vegetables following good agricultural practices. Further, pesticide residues in vegetables are not monitored and exposure studies are limited. Studies on the influence of vegetable processing on pesticide residues at household level have been done at laboratory scale. However, the influence of these processes to the residues at the community level is unknown. The review suggests the need for broader research on the pesticide application practices to establish

**Corresponding author: E-mail: puriandrew@gmail.com; puriand@yahoo.com;*

the important practices that have significant association with the occurrence of pesticide residues in vegetables. Results from this research will allow for the allocation of resources for improvement, monitoring and control of these practices to minimize the risk of unwanted pesticide residues in vegetables. Continuous monitoring of pesticide residues in food, as well as the correlated human dietary exposure, is highly recommended in order to inform policymakers and risk managers of the status of the risk of exposure to pesticide residues.

Keywords: Pesticide residues; application practices; household vegetable processing; exposure assessment.

1. INTRODUCTION

The occurrence of unacceptable levels of pesticide residues in horticultural produce has been a growing public health concern worldwide. High pest infestation forces farmers to apply pesticides intensively to rescue crop loss. It is reported that the crop loss due to pest infestation can be as high as 100% if they are not controlled [1]. However, good pesticide application practices have to be observed to protect and promote public health. If not well controlled, pesticide use may result in unsafe pesticide residues in agricultural produce which in turn results in excessive pesticide exposure in human and animals. Consumption of pesticide containing food is the major route of chronic exposure to pesticides. It is estimated that dietary pesticide exposure is five times higher than exposure through other routes which include inhalation and contact [2,3]. Health risks associated with exposure to pesticide residues range from acute characterized with coughing, headache, nausea, stomachache, diarrhoea and vomiting to chronic in the form of endocrine disruption, reproduction and immune systems malfunctioning and development of some cancers [4-5].

Several initiatives have been taken to ensure pesticide safety of vegetables and other foods. Some of these include the establishment and enforcement of maximum residue levels (MRLs). Countries or the Codex Alimentarius Commission set MRLs based on reference limits such as acceptable daily intakes (ADI) and acute reference dose (ARfD) prescribed by The Joint Meeting of Food and Agriculture Organization (FAO) and World Health Organization (WHO) on Pesticide Residues (JMPR). MRLs are established based on data obtained from field supervised trials following good agricultural practices (GAP) whereas ADI and ARfD are established based on international dietary risk assessment data [6]. The MRLs are set much higher above the ADI to ensure that, if the food produced under GAP is consumed in the entire lifetime of the consumer, the adverse health risks associated with the particular pesticide will not be manifested [7].

Furthermore, international treaties and codes on pesticides trade encourage governments to establish and/or review regulations and policies related to chemical trading, use and disposal to ensure protection of human, animal and environment. Of these, are the FAO code of conduct on the distribution and use of pesticides adopted in 2002 [8], The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade adopted in 1998 in Rotterdam, Netherlands and The Stockholm Convention on Persistent Organic Pollutants (POPs) adopted in 2001 in Stockholm Sweden [9]. Countries establish pesticide policies and regulations to manage transportation, storage, use and disposal of pesticides, based on the international treaties and codes of practices. For instance, Tanzania has established policies and legislation for that purpose. Among others, these are the Agricultural and livestock policy of 1997, Pesticide Control Regulation of 1984 and Plant Protection Act number 13 of 1997. Establishment of the Tropical Pesticide Research Institute under the Act number 18 of 1979 was also done objectively to ensure effective use of pesticides for the public health protection in Tanzania [10].

Nonetheless, presence of policies, regulations and codes of practices in subsistence communities of developing countries like Tanzania cannot guarantee presence of acceptable levels of pesticides in food. Surveys in the developing countries such as Nigeria [11,12], Ghana [13,14], Zimbabwe [15], Palestine [16] and Tanzania [17,18] reported misuse and overuse of pesticides, non-adherence to the pre-harvest interval, poor storage and disposal of pesticide containers and use of banned and counterfeit pesticides. As aforestated, indiscriminate use of pesticides may result in excessive pesticide residues in food and the environment. Levels of pesticide residues in food may be altered during household operations or industrial processing. However, most of the studies reporting pesticide reduction in food were conducted under laboratory conditions [19]. This implies that the alteration may not necessarily represent what happens in real life situations at household level.

It is therefore imperative to gather, analyse and document farmers' and householders' practices that can influence presence and exposure of pesticides in developing countries. The information can be used by agricultural extension agents and food safety regulatory authorities to amend policies, regulations and codes of practices with a view to minimizing the problem of pesticide exposure in those countries.

This is a critical review of reports to unveil pesticide application or handling practices leading to unsafe residues in vegetables and subsequent exposure and recommend practical interventions to mitigate the problem among the communities of Tanzania.

2. VEGETABLE PRODUCTION IN TANZANIA

In Tanzania, vegetables are produced at small, medium and large scale mainly for commercial purposes. It is reported that, of the vegetables produced in the country, 10% only is for household consumption [20]. The vegetable production subsector contributes about 7% of the Gross Domestic Product (GDP) [21]. Major vegetables cultivated in the country include tomato, cabbage, carrot, onions, kale, spinach, amaranth, nightshade and pumpkin leaves [20]. Vegetable production is mainly concentrated in northern zone regions of Arusha and Kilimanjaro, coastal zone regions of Tanga and southern corridor zone regions of Morogoro and Iringa but 85% of the production is from the northern zone [20–22].

3. HEALTH BENEFITS OF VEGETABLE CONSUMPTION

Vegetables are important sources of macro- and micro-nutrients and phytochemicals necessary for boosting body immunity thus maintaining health and preventing diseases in human. It is in this context that nutrition guidelines contain a recommendation that a balanced diet should include vegetables. Beyond advocacy of vegetable consumption for general health promotion and prevention of diseases [23], dieticians prescribe higher amounts of vegetable and fruits consumption for people suffering from non-communicable diseases (NCDs). As a result, there is an increase in awareness about the health benefits of vegetables in human diets [24].

The increased awareness of health benefits of vegetables and fruit has contributed to the increased consumption and demand of these products [25]. Since the risk of pesticide exposure is higher in populations consuming high levels of fruit and vegetables compared to those consuming moderate amounts [26], there is an urgent need to ensure the safe use of pesticides in fruit and vegetables.

4. PESTICIDE USE IN TANZANIA

Pesticide use in the country increased rapidly in 1992 when Tanzania adopted the trade liberalization policy. Following adoption of the policy, the Government suspended subsidies of agricultural inputs and allowed importation and distribution of agrochemicals through trade dealers [27]. Removal of subsidies in agricultural inputs resulted in decreased returns from cash crops due to increased production costs [28]. Consequently, there was a paradigm shift of farmers from cash crops to vegetables and other food crops offering short duration of investment and quick realization of earnings [27]. In addition, trade liberalization has increased pesticide availability locally and in retail shops and therefore increased accessibility and rate of use [17,18]. This is reflected in the increased volume of pesticides imported: from 500 MT in 2000 to 2500 MT in 2003 [22] and then from 2500 MT in 2003 to 11,482 MT in 2014 [28,29]. The number of formulations registered for use in Tanzania also increased from 450 [30] in 2012 to 1,182 in 2014 [29]. The later author reports that, of the 1,182 formulations registered for use in Tanzania in the financial year 2013/2014, 83.4% (986) is for use in agriculture whereby horticulture, a sub-sector in agriculture consumes the largest proportion of 41.2% (406).

The pesticides registered for use in Tanzania are mostly pyrethroids 230 (27.2%) and organophosphates 135 (15.9%) as reported by Lekei, et al. [29], whereas the organochlorine pesticides (endosulfan) previously (2011) listed as provisionally registered pesticides were no

Table 1. Registered pesticides in their categories and respective uses in Tanzania

Category	n	%	Use
Insecticides	493	41.7	Manage insects
Fungicides	321	27.2	Manage fungi
Herbicides	289	24.5	Manage weeds
Acaricides	56	4.70	Manage mites
Growth regulators	10	0.80	Enhance growth
Rodenticides	8	0.70	Manage rodents
Nematicides	3	0.30	Manage nematodes
Avicides	2	0.20	Manage birds

Source: [29,31,32]

longer in this categorization. Organochlorines are among the persistent organic pollutants which were banned from use in agriculture in the country since 1997 due to their bio-accumulating properties in environment, mammalian and other non-target organisms body tissues [10], associated with an adverse effect on human and animal health. Based on target pest, most of the registered pesticides are insecticides (493, 41.7%), fungicides (321, 27.2%) and herbicides (289, 24.4%) [29], see Table 1.

In horticultural farming, insecticides are most frequently applied followed by fungicides and herbicides, a trend which is reflected in the pesticide registration, see Table 1. A survey done in 2007 by Ngowi et al. [17] reported that 59% of farmers interviewed applied insecticides; 29% fungicides and 2% herbicides. It was also documented by Nonga et al. [18] in 2011 that 50% of vegetable farmers applied insecticides; 37.5% fungicides and 12.5% herbicides [29]. This trend implies that insects are the main challenge in horticultural farming as compared to other types of pests. According to WHO, pesticides have been classified into classes Ia – extremely hazardous, Ib - highly hazardous, II - moderately hazardous and III - slightly hazardous and U - unclassified [33]. Most of the pesticides applied in vegetable farming in Tanzania are classified as moderately (II) and slightly hazardous (III), though highly hazardous pesticides have also been reported at a lower proportion [18]. Extremely and highly hazardous pesticides are registered for restricted use and must be used by specifically trained personnel or under supervision of specifically trained personnel [34]. Most of these pesticides are cholinesterase inhibitors (16%) and classified as WHO class I and II (50%) [29]. The use of these pesticides in the horticulture industry indicates a potential risk of dietary exposure through vegetable consumption if good agricultural practices (GAP) are not well observed. This review, therefore, calls for the need for monitoring of pesticide residues and analysis of the risk of exposure among consumers.

The number of active ingredients applied in vegetables farming in the country have been well documented in various studies [17,18,22,31], of which the majority are in the groups of organophosphates (profenofos, dimethoate, chlorpyrifos, pirimiphos-methyl and fenitrothion), pyrethroids (cypermethrin, lambda-cyhalothrin, permethrin, and deltamethrin) and organochlorines (endosulfan), mancozeb and metalaxyl. Endosulfan, an endocrine disruptor, is also reported as the most frequently used pesticide in vegetables [18,36], whereas carbamate (carbofuran) is reported to be used at a lower extent. Bio-pesticides which are regarded as safer and biodegradable are limited in use [37]. The pesticides that are more frequently used are associated with potential health risks to human and non-target organisms. Their use in horticultural crops should carefully be controlled and minimized by including integrated pest management approaches to ensure that residues do not exceed MRLs [43]. There is a need to perform more research on biodegradable pesticides in order to provide safer pest management options [37].

5. MALPRACTICES IN PESTICIDE APPLICATION IN TANZANIA

Poor pesticide application practices in vegetable production have been reported. These include use of unregistered pesticides, inappropriate dosage, lack of adherence to pre-harvest interval, use of banned pesticides, inappropriate use of pesticides such as inappropriate pesticide/crop combination and the use of a mix of pesticides in a single spray [17,18, 32,33].

The Plant Protection Act of 1997 and the Plant Regulation Act of 1999 require all pesticides to be registered by the Pesticide Registrar before they can be used in Tanzania [39]. However, surveys show that unregistered pesticides are sold and used in vegetable production in various regions across the country. A post-registration surveillance of pesticides towards best practices of pesticide management (BPPM) for environmental and human health protection in Tanzania done in Mtwara and Lindi regions in 2012 revealed 39.4% of pesticide shops selling unregistered pesticides [30]. Also, a survey by Ngowi et al. [17] found out that 19% of the pesticides applied to vegetables by smallholder farmers in northern Tanzania were not registered. Of special concern is the lack of validation of unregistered pesticides, their application rates, pre-harvest intervals and crop/pesticide combinations in the country. Therefore, overdosing and harvesting of crops before pre-harvest intervals is a possible scenario, and would result in unacceptable pesticide residues in vegetables with a subsequent increased risk of human exposure.

Another survey observed misuse of pesticides in Mindu dam [40] whereby sumithrin-piperonylbutoxide registered for control of mosquitoes was used to control fungi in tomato, diazinon for ectoparasites in animals was used for armyworms in maize and chlorfenvinphos for control of ticks was used to control aphids in tomatoes and onions. Misuse of pesticides could be due to ignorance or limited pesticide options. Since there are no studies on the important safety measures and limits for such product/crop combinations, there might be a potential risk of high residues in the crop that can affect consumer health. It is suggested to create awareness among the farmers on the importance of adherence to the directives of pesticide uses as per label for protection of their own and consumer health.

Adherence to the recommended dosage and frequency of application of pesticides is one of the requirements of GAP that would ensure acceptable pesticide residues in food crops and the environment and hence protect consumer and farmer's health [42]. However, inappropriate dosages and application rates of pesticides in vegetable farming have been reported in most of the vegetable production areas. For instance, a study in Mang'ola district reports that farmers apply pesticides on vegetables at over-dosage levels [36]. Other studies in the Manyara basin and Arumeru district showed that farmers applied pesticides on vegetables on a routine basis as a means of protection even though no pest had been observed on the plants [17,18]. This can result in unnecessary production costs and/or unacceptable pesticide residues in the vegetables. It is also reported that farmers mix two or more pesticides in the same spray with the aim of increasing efficacy, even though this is not recommended. For instance, the study in northern Tanzania by Ngowi et al. [17] reported that 33.3 % of the farmers mix two or more pesticides in the same spray tank, and about 90% of them mix three or more pesticides. In Mang'ola district it is reported that farmers mix two or more pesticides of a different brand but containing the same active ingredients [36]. Depending on the nature of the pesticides, mixing of pesticides in the same spray tank can result in more or less effective pesticide mixtures which can affect plant health, reduce yield and result in multiple pesticide residues in vegetables [17,37] as well as high production costs. Codes of best practices prohibit use of a mixture of pesticides unless advised by the manufacturer or inherent in the formulation [35,38]. Farmer's mix pesticides in the same sprayer to save money and water for reconstitution [44]. Other farmers think that by mixing pesticides, they become more effective. Since the manufacturers include inert material in the formulation of the pesticide which is usually unknown to the end user it is difficult to understand the compatibility of the pesticides being mixed [17]. It is recommended that agricultural extension officers establish demo farms where farmers can learn best pesticide application practices using a practical training approach [45].

It is further reported that majority of the farmers' store remains of pesticides in the kitchen or general stores with food [17,18,32,36] and dispose of empty pesticide containers on the farms. This may result in pesticide contamination of food and the environment. For instance, persistent pesticides such as dichlorodiphenyltrichloroethane (DDT) can be absorbed by the crop during growth and end up being consumed [41]. In addition, farmers follow advice from pesticide retailers on the choice and application of pesticides rather than guidance from agricultural extension officers. The majority of pesticide retailers are business oriented and have low knowledge of GAP which may result in provision of wrong advice to farmers [46,47]. Farmers have been reported to have a low level of education and limited professional pesticide application training. These limitations are linked to poor pesticide handling practices which contribute to the increased risk of human exposure through occupation and food consumption [17,18,32,33,40]. However, association of the poor pesticide handling practices and dietary exposure is not well established in these studies. It is recommended to establish the association between various pesticide application practices and the pesticide exposure levels so that the most important practices are identified. This will enable a more focused allocation of resources for control of poor application of pesticides.

6. OCCURRENCE OF PESTICIDE RESIDUES IN VEGETABLES

Despite well documented poor pesticide handling and application practices in vegetable farming, monitoring of pesticide residues in vegetables is not a common practice in Tanzania. Only limited studies have evaluated pesticide residues in vegetables. Mahugija et al. [41] evaluated pesticide residues in raw cabbage, onions and spinach whereas Ndossi and Cram [48] analyzed pesticide residues in ready-to-eat amaranths (spinach) from markets in Dar es Salaam. Kariathi et al. [49] and Mahugija et al. (b) [50] analyzed pesticide residues in raw tomatoes from farmers in Ngarenanyuki -Arumeru district and Dar es Salaam markets, respectively. Also, Mhauka [36] reported pesticide residues in raw vegetables, the data of these studies are presented in Table 2. With exception of the residues detected in the study by Ndossi and Cram [48], one or more types of pesticide residues reported in these studies were above the recommended MRL [36,41,49,50].

The study by Ndossi and Cram [48] analyzed 33 amaranths samples for pesticide residues in Dar es Salaam markets and quantified gamma-hexachlorocyclohexane (g-HCH) 1,1-dichloro-2,2-bis (p-chlorophenyl) ethylene (pp-DDE), dichlorodiphenyltrichloroethane (pp-DDT), and chlorpyrifos residues in 72.7% of the samples. All the residues were well below the Codex MRL of 0.01mg kg^{-1} g-HCH, pp-DDE and (pp-DDT), and 1 mg kg^{-1} for chlorpyrifos. The study by Mahugija et al. [41] analyzed 72 vegetable samples of cabbage, spinach and onions and found pesticide contamination in 83.3%, 75% and 50% of the samples, respectively. The detected pesticide residues were α- and β-endosulfan, p,p'-DDD o,p'-DDD, p,p'-DDT, chlorpyrifos and cypermethrin. The residue concentrations in cabbage, spinach and onion exceeded their respective MRLs in 41.7%, 50% and 33.3% of samples, respectively. Another study by Mahugija et al. (b) [50] quantified p,p-DDD, α- and β-endosulfan, chlorpyrifos and cypermethrin residues in 91.7%, 50%, 50%, 41.7% and 33.3% of tomato samples from Dar es Salaam market whereby chlorpyrifos residues exceeded the Codex-MRL of 0.5 mg kg^{-1}. The study by Kariathi et al [49] analyzed 50 samples of tomato from farmers in Ngarenanyuki and quantified chlorpyrifos and permethrin in 46.15% of the samples. The later mentioned study also reported quantifying ridomil in four percent of the samples. Ridomil that is registered for use in Tanzania is a formulation with metalaxyl and mancozeb as active ingredients. The study did not indicate whether the active ingredients detected were metalaxyl or mancozeb [34]. All quantified pesticide residues in the later mentioned study were above their respective MRL. However, none of these analyses was done as part of a routine monitoring system to ensure consumer protection and was performed for scholarly or research projects which are location and time specific and target fewer vegetables. There is, therefore, a need for continuous monitoring of pesticide residues in vegetables and other foods and need of conducting assessments of the risk of exposure to the pesticide residues. This will enable policy makers and risk managers to formulate measures for management of the risks associated with pesticide residues exposure.

High pesticide residue levels above MRLs are also reported in other developing countries. For instance, Darko and Akoto [51] analyzed pesticide residues in tomato, eggplant and pepper from Kumasi markets and found dichlorvos residues above MRLs in 48% of tomato, 42% of eggplant and 26% of pepper. The dichlorvos residues were also quantified by Esturk [52] in spinach, parsley and lettuce obtained from markets in Turkey whereby 85% of spinach, 70% of parsley and 40% of lettuce samples were contaminated with dichlorvos residues at concentration levels above their corresponding EU-MRL. Another study in Togo analyzed pesticide residues in cabbage, lettuce and tomato and found 100% of the vegetables contaminated with one or more organochlorine pesticides, with 16.68% of the residues above their respective EU-MRL [53] although none was above the Codex MRL.

Table 2. Occurrence of pesticide residues in vegetables grown in Tanzania

Vegetable	Area	Pesticide group	Pesticide residue	Range of pesticide residues (mg/kg)	Mean concentration (mg/kg)	Prevalence (%)	Prevalence >MRL	MRL (mg/kg)	Source
Amaranthus	Dar es Salaam	Organochlorine	g-HCH	-	0.00008	6.01	0	0.01	[48]
Amaranthus	Dar es Salaam	Organochlorine	pp-DDE	-	0.00074	30.03	0	0.01	[48]
Amaranthus	Dar es Salaam	Organophosphate	Chlorpyrifos	-	0.00002	96.97	0	1	[48]
Amaranthus	Karatu	Pyrethroid	λ-cyhalothrin	-	0.21	6.25	0	0.5	[36]
Amaranthus	Karatu	Organophosphate	Dimethoate	-	0.012	6.25	0	0.02	[36]
Amaranthus	Karatu	Organophosphate	Profenofos	-	0.6	18.75	33.3	0.01	[36]
Amaranthus	Karatu		Tebuconazole	-	0.42	6.25	16.7	0.01	[36]
Amaranthus	Karatu	Organophosphate	Chlorpyrifos	-	0.74	12.5	16.7	0.02	[36]
Amaranthus	Karatu	Pyrethroid	Cypermethrin	-	0.22	12.5	16.7	0.02	[36]
Spinach	Dar es Salaam	Organochlorine	p,p'-DDD	0.001-0.64	0.64	75	8.3	0.2	[41]
Spinach	Dar es Salaam	Organochlorine	o,p'-DDD	0.01-0.000		16.7	8.3	0.2	[41]
Spinach	Dar es Salaam	Organochlorine	α-endosulfan	0.14-0.24	0.20	33.3	33.3	0.05	[41]
Spinach	Dar es Salaam	Organochlorine	β-endosulfan	0.05-0.08	0.068	75	75	0.05	[41]
Spinach	Dar es Salaam	Organophosphate	Chlorpyrifos	1.31-3.0	2.006	41.7	41.7	0.5	[41]
Spinach	Dar es Salaam	Pyrethroid	Cypermethrin	0.01-0.04	0.021	33.3	0	0.02	[41]
Spinach	Karatu	Organophosphate	Dimethoate	-	0.3	6.25	100	0.02	[36]
Spinach	Karatu	Triazole	Tebuconazole	-	1.6	-	100	0.05	[36]
Spinach	Karatu	Organochlorine	Endosulfan	--	0.14	-	100	0.05	[36]
Spinach	Karatu	Pyrethroid	λ-cyhalothrin	-	0.67	-	100	0.5	[36]
Cabbage	Dar es Salaam	Organochlorine	p,p'-DDD	0.001-0.01	0.005	-	-	-	[41]

Table 2 continued……..

Vegetable	Area	Pesticide group	Pesticide residue	Range of pesticide residues (mg/kg)	Mean concentration (mg/kg)	Prevalence (%)	Prevalence (%) >MRL	MRL (mg/kg)	Source
Cabbage	Dar es Salaam	Organochlorine	o,p'-DDD	-	0.001	83.3	0	0.02	[39]
Cabbage	Dar es Salaam	Organochlorine	total DDT	-	0.012	83.3	0	0.02	[39]
Cabbage	Dar es Salaam	Organochlorine	α-endosulfan	0.1-0.6	0.365	33.3	8.3	0.5	[39]
Cabbage	Dar es Salaam	Organochlorine	β-endosulfan	0.03-0.21	0.128	33.3	8.3	0.5	[39]
Cabbage	Dar es Salaam	Organophosphate	Chlorpyrifos	0.04-2.40	2.275	33.3	33.3	1	[39]
Cabbage	Dar es Salaam	Pyrethroid	Cypermethrin	0.03-0.04	0.023	25	0	1	[39]
Kale	Karatu	Organophosphate	Profenofos	-	18.1	-	0	0.05	[34]
Tomato	Ngarenanyuki	Organophosphate	Chlorpyrifos	0.83-6.3.6	7.53	46.2	46.2	1	[46]
Tomato	Ngarenanyuki	Pyrethroid	Permethrin	0.69-29.05	5.29	46.2	46.2	1	[46]
Tomato	Karatu	Organophosphate	λ-cyhalothrin	-	0.079	6.25	0	0.1	[34]
Tomato	Karatu	Triazole	Tebuconazole	-	0.075	-	0	1	[34]
Tomato	Karatu	Organophosphate	Chlorpyrifos	-	0.16	12.5	0	0.2	[34]
Tomato	Karatu	chloronitrile	Chlorothalonil	-	0.045	12.5	16.7	0.02	[34]
Tomato	Karatu	Organophosphate	Dimethoate	-	0.017	12.5	0	0.02	[34]
Tomato	Karatu	Organophosphate	Profenofos	-	0.031	12.5	0	10	[34]
Tomato	Dar es Salaam	Organochlorine	p,p'-DDD	0.001-0.011	-	91.7	0	0.02	[50]
Tomato	Dar es Salaam	Organochlorine	α-endosulfan	0.11-0.33	-	50	0	0.5	[50]
Tomato	Dar es Salaam	Organochlorine	β-endosulfan	0.04-0.12	-	50	0	0.5	[50]
Tomato	Dar es Salaam	Organophosphate	Chlorpyrifos	0.53-2.34	-	41.7	41.7	0.5	[50]
Tomato	Dar es Salaam	Pyrethroid	Cypermethrin	0.01-0.03	-	33.3	0	0.2	[50]
Onion	Dar es Salaam	Organophosphate	Chlorpyrifos	0.1-2.12	1.86	25	25	0.2	[39]
Onion	Dar es Salaam	Pyrethroid	Cypermethrin	0.014-0.04	0.01	16.7	8.3	0.01	[39]
Onion	Dar es Salaam	Organochlorine	p,p'-DDD	0.01-0.001	0.0102	50	0	0.2	[39]
Onion	Dar es Salaam	Organochlorine	α-endosulfan	0.02-0.22	0.19	16.7	16.7	0.05	[39]
Onion	Dar es Salaam	Organochlorine	β-endosulfan	0.07-0.3	0.06	16.7	16.7	0.05	[39]
Onion	Karatu	Organophosphate	Chlorpyrifos	-	0.022	6.25	0	0.02	[34]
Onion	Karatu	Organophosphate	Profenofos	-	0.59	12.5	100	0.05	[34]

Note: - = Unavailable data; Source: [36,41,48,49]

Table 3. Estimated dietary pesticide daily intakes and hazard indices

Pesticide group	Pesticide	EDI (mg/kg bw/day)	ADI (mg/kg bw/day)	EDI/ADI	Vegetable	Reference
Organophosphates	Dimethoate	1.584×10^{-4}	0.001	0.1584	Amaranthus	[36]
	Dimethoate	2.14×10^{-4}	0.001	0.2142	Tomato	[36]
	Dimethoate	4.14×10^{-5}	0.001	0.0414	Spinach	[36]
	Chlorpyrifos	9.78×10^{-3}	0.01	0.976	Amaranthus	[36]
	Chlorpyrifos	2.016×10^{-3}	0.01	0.2016	Tomato	[36]
	Chlorpyrifos	0.0293	0.01	2.9293	Tomato	[49]
	Chlorpyrifos	6.6×10^{-9}	0.01	6.6×10^{-6}	Amaranthus	[48]
	Profenofos	1.32×10^{-3}	0.03	0.044	Amaranthus	[36]
	Profenofos	0.0145	0.03	0.1196	Onion	[36]
	Profenofos	3.906×10^{-4}	0.03	0.1534	Onion	[36]
	Profenofos	0.10498	0.03	3.4993	Kale	[36]
Organochlorine	g-HCH	$2.66 \text{ X } 10^{-3}$	0.001	$2.66 \text{ X } 10^{-5}$	Amaranthus	[48]
	DDT	$9.6 \text{ X } 10^{-7}$	0.01	$9.6 \text{ X } 10^{-4}$	Amaranthus	[48]
	Endosulfan	1.932×10^{-5}	0.006	3.22×10^{-3}	Spinach	[36]
Chloronitrile	Chlorothalonil	5.67×10^{-4}	0.015	0.0378	Tomato	[36]
Triazole	Tebuconazole	5.544×10^{-3}	0.05	0.1848	Amaranthus	[36]
	Tebuconazole	9.45×10^{-4}	0.05	0.0315	Tomato	[36]
	Tebuconazole	2.205×10^{-4}	0.05	7.36×10^{-3}	Spinach	[36]
Pyrethroids	Permethrin	0.0206	0.005	0.4117	Tomato	[49]
	Cypermethrin	2.90×10^{-3}	0.015	0.1936	Amaranthus	[36]
	λ-cyhalothrin	2.772×10^{-3}	0.005	0.5544	Amaranthus	[36]
	λ-cyhalothrin	9.954×10^{-4}	0.005	0.19908	Tomato	[36]
	λ-cyhalothrin	9.246×10^{-5}	0.005	0.01849	Spinach	[36]

Source: [36,48,49]

When compared to results of pesticide residues in vegetables from European Union (EU) monitoring programme, it shows that vegetables from EU and countries that export to this region have very low levels of pesticide residues with pesticide residues in most vegetables at levels below MRL. For instance, the 2015 and 2014 EU monitoring programme reports showed that only 1.6% of the food samples contained residues above the MRLs.

Based on the fact that monitoring of pesticide residues in the potential vegetable production areas where poor pesticide applications have been reported are limited, this review suggests the need for increased monitoring programmes. The results of these monitoring efforts would inform policymakers and regulators on necessary action such as organizing intervention programmes and reinforcement of regulations.

7. DIETARY EXPOSURE TO PESTICIDE RESIDUES AND POSSIBLE HEALTH EFFECTS

Studies on dietary exposure to pesticide residues in Tanzania are limited. This is due to lack of monitoring data on pesticide residues in vegetables and other food crops in the country, contrary to developed countries where these data are regularly collected and made available. The in-country available information on exposure to pesticides was from the earlier reported studies by Ndossi and Cram [48], Mhauka [36] and Kariathi et al [49]. The results on estimated exposure levels from these studies are presented in Table 3. Similarly, the coverage of these studies was limited to scholarly or research project scope.

Ndossi and Cram [48] assessed exposure of adult individuals to pesticide residues in Dar es Salaam. The study used average body weight of a Tanzanian adult man of 60 kg and national food consumption data of 2004. The estimated daily intakes of pesticide residues through vegetable consumption were found below the ADI and therefore no significant risk was associated with the dietary exposure to pesticide residues. These results may be different from results obtained for vegetables from areas with more potential for vegetable production and that use a wider variety of pesticides in pest management. In such areas, Arusha is reported as the major pesticide trader and user [10].

The study by Mhauka [36] assessed the risk of vegetable dietary exposure to pesticide residues in adults in nine households from Karatu district. Consumption data were obtained by weighing bundles of raw vegetable purchased from retail selling points equivalent to portion size consumed in the households. Then the average weight of the raw vegetable was used to compute the weight of vegetables consumed per day and the processing factor of one applied. Household handling such as washing, peeling and cooking could alter the residues levels in the cooked vegetables. The processing factor of one implies that the effect of these processes in pesticide residues was not accounted for [54]. Together with the consumption data, secondary retrieved data on pesticide residue concentrations in 16 vegetable samples and adult weight of 50 kg were used to compute exposure levels. The results found that individuals were at risk of exposure to organophosphates with EDI to ADI ratio [also referred to as hazard index (HI)] of 5.9 and pyrethroids with HI of 0.96. Although the study provided information of the exposure to these residues, the sample size of nine households is insufficient to make statistical inference on the risk levels to the general population [55]. The weight of the adult person used in this study is lower than the average body weight estimated for African adult person which is 60 kg [41,53,56]. Also, estimation of the weight of vegetables consumed by an individual as the average of the weight of vegetable selling unit is considered a weak approach.

Kariathi et al. [49] determined dietary exposure levels of permethrin and chlorpyrifos in vegetable farmers in Ngarenanyuki. The study estimated exposure levels by combining the estimated amount of raw tomato consumed per day and pesticide residues levels in the tomatoes assuming the adult weight of 60 kg. The study revealed that 5 (10%) of the farmers were at risk of exposure to permethrin and chlorpyrifos residues. The results of this study suggest that the vegetable farmers may be at a higher risk of exposure to pesticide residues than reported as they consume not only tomatoes but also other types of vegetables.

Other developing countries have performed studies on the pesticide residues exposure through vegetable consumption. For instance, the study by Darko and Akoto estimated the risk of exposure to methyl- and ethyl- chlorpyrifos, omethoate, and monocrotophos in eggplant, tomato and pepper and found that, the hazard indices (HI) of methyl-chlorpyrifos, ethyl-chlorpyrifos and omethoate in tomato and eggplant were above one, indicating pesticide-health risks associated with consumption of eggplant and tomato, whereas there were no health effects associated with consumption of pepper as its HI was below one. Another study in Cairo assessed pesticide exposure in adults through vegetable consumption and found the highest exposure in ethion and chlorpyrifos, with Hazard quotient (HQ) of 15.04% and 2.45% of their respective ADI, respectively, indicating negligible risk [57]. For vegetable farmers, the risk is not only associated with dietary exposure but also with the occupational exposures as most of the reports show that vegetable farmers do not wear appropriate protective gears [17,38].

Regular risk assessment studies are important in order to facilitate management of the risk of exposure to pesticide residues in the community. Exposure studies are useful to policymakers and managers to make decisions based on scientific evidence and therefore appropriate management options. Exposure information is much more important for high vegetable production areas and particularly where there is a high potential of exposure to vulnerable groups including women and children. Vegetable consumption data in Tanzania are also limited or out-dated [58] and therefore exposure studies will require a fresh collection of information on vegetable consumption.

8. PESTICIDE HEALTH EFFECTS

Pesticides are toxic to target pests, however, when mishandled, the toxicity can spill over to non-target organism such as beneficial insects, human and animals as well as the environment. Symptoms associated with acute exposure to pesticide residues in human include coughing, nausea, vomiting, abdominal pain, headache, diarrhoea and loss of vision [38]. Chronic exposure to pesticide residues is associated with endocrine disruption, neurotoxicity, cytogenetic damage and effects in the reproductive and immunological system [59]. Dietary pesticide residues exposure is the major source of pesticide exposure followed by inhalation and dermal exposure [60,61].

Health effects resulting from exposure to pesticide residues vary with the nature of the pesticide and the mode of action [62]. Organophosphate pesticides are associated with inhibition of cholinesterase and affect neurologic and cognitive development in children [60]. A birth cohort study examined the association between prenatal and post-natal exposure to organophosphate pesticides and cognitive abilities in school-age children and found a positive association in prenatal but not in postnatal exposure to organophosphate pesticides and cognitive development [63]. Carbamates are also cholinesterase inhibitors though its activity is reversible [58] whereas that of organophosphate is not. [64]. They are also associated with endocrine disruption and it is evident that they affect cellular metabolic mechanisms and mitochondrial functions. They also cause reproduction disorders and are cytotoxic and genotoxic [65]. Organochlorine pesticides disrupt the endocrine system and alter the haematological and hepatic function [65] in addition to being suspected of being carcinogenic. Studies have found a high association between the high levels of DDE in blood samples from women with breast cancer. Also, a significant association was found between male farmers exposed to DDT and prostate cancer although the association is not yet ascertained due to other confounding factors such as diet and exposure to other chemicals such as tobacco [66].

Pyrethroid pesticides which include cyhalothrin, permethrin and deltamethrin are associated with endocrine disruption and are linked to DNA damage in human sperm thus affecting the human reproductive system [65]. In Tanzania studies on the health effects of exposure to pesticide residues have been directed to occupational acute exposures and these studies suggest the need of performing long-term exposure analysis [33,61,67]. Based on the indiscriminate pesticide application to vegetables reported in literature [17,18,38] the farmers and other vegetable consumers may be exposed to pesticide residues through their diets. Therefore there is a need to estimate dietary pesticide exposure to vegetable consumers in Tanzania. This will inform risk managers and policymakers about the health risks associated with exposure to the residues so that necessary steps can be taken in case a risk is revealed.

9. HOUSEHOLD VEGETABLE PREPARATION PRACTICES AND FATE OF PESTICIDE RESIDUES

In the Tanzanian context, most vegetables are usually prepared and heat-processed before consumption. Among processes reported to have considerable effect on pesticide residues in vegetables are washing, peeling and cooking [62, 63]. Most of these processes result in reduction of the pesticide in the vegetables thus reducing the risk of human exposure to these residues [70]. On the other hand, processes that tend to concentrate product may lead to increase of the pesticide residues in the final product [54,62]. The physical and chemical properties of pesticide residues in the vegetable, such as volatility, hydrolytic rate, solubility and physical structure of the vegetables influence the removal of these residues [54]. These practices have been tested based on practices in other countries and at experimental levels which may not be applicable in Tanzania as the practices differ from one ethnic group to another, and across geographical locations [71]. It is therefore important to assess these practices at local level to find out what would need to change to minimize the pesticide residues in the vegetables.

9.1 Effect of Washing

Washing of vegetables with tap water has been reported as one of the common procedures applied at household levels when preparing vegetables for family meals. Saeid and Selim [69] studied the effect of household processing of vegetables on pesticide residues and found out that washing of sweet pepper with tap water could reduce the concentration of methomyl, dimethoate, pirimiphos-methyl, metalaxyl, endosulfan, dicofol and cypermethrin by 59%, 15%, 10%, 30%, 49%, 67%, and 65%, respectively. Addition of acetic acid to the washing water increased the percentage reduction of residues for methomyl (99.7%), dimethoate (34%), pirimiphos-methyl (89%), metalaxyl (61%), endosulfan (90%), dicofol (100%), and cypermethrin (100%). Similarly, other studies reported reduction of pesticide residues in vegetables due to washing. Bonnechère et al [72] found reduction of up to 90% of boscalid, chlorpyrifos, tebuconazole, dimethoate, difenoconazole and linuron in carrots, whereas Randhawa [73] who studied the influence of household processes on the removal of endosulfan revealed that endosulfan was reduced by 30% in okra, 25% in tomato, 22.2% in spinach and 10% in brinjal. Sheikh [74] also found endosulfan to be reduced by 36.42% in okra. Moreover, lambda-cyhalothrin residues could be reduced by 37-40% in tomatoes [75]. Another study found that washing olives in water reduce chlorpyrifos by 26-36%, lambda-cyhalothrin by 26-39%, cypermethrin by 48%, profenofos by 66%, and diazinon by 67%. However, a study by Chavarria [76] reported different results on washing of asparagus in which the washing process did not alter the levels of chlorpyrifos residues significantly. The studies suggest that solubility has no significant influence on pesticide removal, but that the removal is rather influenced by the mechanical action of washing, the nature of the surface of the vegetable and contact duration with the pesticide [62,65,69]. Washing is reported as the most effective preparatory step for pesticide removal in vegetables [68]. The reported effects of washing were based on experimental scale results which call for a need to study the effects at community level.

9.2 Effect of Peeling

It is a common practice to peel bulb, root and tuber vegetables before they are consumed. Pesticides are usually applied on the surface of vegetables, so they can be removed with the peel in the peeling process [78]. It is reported that peeling is effective in reduction of lindane, profenofos, dimethoate, and pirimiphos-methyl from tomatoes by 80.6-89.2% [79], endosulfan residues from potatoes by 76% and eggplant by 60% [73] and chlorpyrifos from asparagus by 60% [76]. Further, peeling removes up to 65% of malathion residues, 66% of methomyl, 80% of dicofol and 83% of abamectin. Diazinon and carbaryl in cucumber are reported to be reduced by 67.3% and 40%, respectively [79]. Also peeling was found to reduce carbaryl residues by 40% in cucumber [80]. Contrarily, in the study by Bonnechère et al [72] could not find any considerable reduction of pesticide residues by peeling. For instance, in this study, there was no decrease in the levels of dimethoate and omethoate residues in carrot. Similar to the studies on the effect of washing, peeling effects were also derived from studies at laboratory scale which may not reflect what is happening at the community level and therefore emphasize the need of studying the effects at community level.

9.3 Effect of Cooking

Cooking processes including blanching, boiling, frying and roasting enhance the hydrolysis and volatilization of chemicals, thus altering their level in the food. Studies show that cooking reduces deltamethrin residues in vegetables by 19-40% [78]. Reduction of pesticide residues in vegetables by cooking is influenced by the physical-chemical structure of the pesticide. For instance, the study by Bonnechère et al. [72] found that the effect of blanching on reduction of difenoconazole, tebuconazole and linuron which have low water solubility of 15 mg/l, 36 mg/l, 63.8mg/l, with a log-octanol-water partitioning coefficient of 4.2, 3.7, and 3, respectively, was relatively lower than compared to the effect of reduction of dimethoate and omethoate levels which both have higher water solubility of 39,800 mg/l and 10,000 mg/l, and lower coefficients of 0.704 and -0.74, respectively. Blanching is reported to reduce up to 72% of fat-soluble and up to 79% of water-soluble pesticide residues in cauliflower [81]. This study reports further that blanching reduces residues of endosulfan by 58.95%, bifenthrin by 72.18% and profenofos by 67.34%. Boiling processes were reported to reduce organophosphate pesticide residues by 32-100% [82]. The 100% reduction was observed in brinjal, followed by cauliflower (92%) and okra (75%). Another study by Satpathy [83] found that boiling reduced the organophosphate residues in tomato, bean, okra, eggplant, cauliflower and capsicum by 52-100%. Frying is reported to reduce endosulfan, bifenthrin and profenofos which are fat-soluble pesticides by 94.32%, 98.71%, and 96.75%, respectively. In another study, cooking reduced monochrotophos and endosulfan by 85.78% and 64.22%, respectively [77]. On the other hand, processes like pre-heating, pulping, evaporation and half-pasteurization was found to increase deltamethrin levels by 2.33% while decreasing endosulfan residues by 66.5% [78].

However, most of the studies on the influence of the household processes on pesticide residues are carried at laboratory level which cannot reflect the variations in the processes occurring at community level. Types of vegetables and household handling of these vegetables differ between household preferences, tribes, and geographical location [84]. This necessitates the need of performing studies on the actual household vegetable handling practices in order to ascertain their practical effect on pesticide residues.

10. CONCLUSIONS AND RECOMMENDATIONS

This review shows that vegetables have high potential to the economy, and food and nutrition security of the people in Tanzania, but their quality and safety has and is not been critically monitored. As in other developing countries, the current status shows that vegetables are intensively treated with pesticide during production. However, there is very limited information on the occurrence of pesticide residues in these vegetables. Moreover, the association of these practices with pesticide residues in the vegetables is not well studied. Based on the existing information Tanzania should establish pesticide application practices that are more associated with occurrence of pesticide residues in the vegetables. This will allow a more focused allocation of resources in controlling pesticide residues in the food thus minimizing pesticide exposure among vegetable consumers in Tanzania. As vegetable consumption levels influence the extent of dietary pesticide exposures, consumption studies should also be updated as the existing data are largely outdated. This implies further that once new data on pesticide contamination in vegetables and updated data on consumption of vegetables are available the current status of pesticide exposure in Tanzania will be assessed. From the review it is acknowledged that the findings of the influence of vegetable processing under experimental conditions on reducing pesticide residues are a foundation for formulation of pesticide control interventions. However, it calls for further research to carry out household-based studies in order to validate the actual impact of vegetable processing on pesticide reduction at that level.

COMPETING INTERESTS

Authors have declared that no competing interests exist

REFERENCES

1. Rajabu J, Tarimo M, Hangali T. Health effects, trends and knowledge on pesticide use in Tanzania; Review. 2017;4(1).
2. Bempah CK, Buah-Kwofie A, Denutsui D, Asomaning J, Tutu AO. Monitoring of pesticide residues in fruits and vegetables and related health risk assessment in Kumasi Metropolis, Ghana. Res J Environ Earth Sci. 2011;3(6):761–71.
3. Fothergill A, Abdelghani A. A review of pesticide residue levels and their related health exposure risks. 2013;170:195–205. Available:http://library.witpress.com/viewpaper.asp?pcode=FENV13-018-1
4. Thatheyus AJ, Gnana Selvam AD. Synthetic pyrethroids: Toxicity and

biodegradation. Appl Ecol Environ Sci [Internet]. 2013;1(3):33–6.
Available:http://pubs.sciepub.com/aees/1/3/2/index.html

5. Toft G, Hagmar L, Giwercman A, Peter J. Epidemiological evidence on reproductive effects of persistent organochlorines in humans. 2004;19:5–26.
6. WHO. Guidelines for predicting dietary intake of pesticide residues. 1997;41.
7. Claeys WL, De Voghel S, Schmit J-F, Vromman V, Pussemier L. Exposure assessment of the Belgian population to pesticide residues through fruit and vegetable consumption. Food Addit Contam Part A [Internet]. 2008;25(7):851–63.
Available:http://www.tandfonline.com/doi/abs/10.1080/02652030701854741
8. FAO. International Code of Conduct on the Distribution and Use of Pesticides. Revised version [Internet]. Food and Agriculture Organization of the United Nations. Rome: FAO; 2005.
Available:http://www.fao.org/docrep/018/a0220e/a0220e00.pdf
9. UNEP. Stockholm Convention on Persistent Organic Pollutants (POPs) [Internet]. Secretariat of the Stockholm Convention on Persistent Organic Pollutants. Geneva; 2009.
Available:http://www.wipo.int/edocs/lexdocs/treaties/en/unep-pop/trt_unep_pop_2.pdf
10. Agenda. Pesticide and poverty: A case study on trade and utilization of pesticides in Tanzania: Implication to Stockpiling. Dar es Salaam; 2006.
11. Ugwu JA, Omoloye AA, Asongwa EU, Aduloju AR. Pesticide-handling practices among smallholder Vegetable farmers in Oyo state, Nigeria. Sci Res J. 2015;3(4): 40–7.
12. Banjo AD, Aina SA, Rije OI. Farmers' Knowledge and Perception Towards Herbicides and Pesticides Usage in Fadama Area of Okun-Owa, Ogun State of Nigeria. African J Basic Appl Sci. 2010; 2(56):188–94.
13. Amoabeng BW, Asare KP, Asare OP, Mochiah MB, Adama I, Fening KO, et al. Pesticides Use and Misuse in Cabbage Brassica oleracea var. capitata L. (Cruciferae) Production in Ghana: The Influence of Farmer Education and Training. J Agric Ecol Res Int. 2017; 10(October 2016):1–9.
14. Afari-sefa V, Asare-bediako E, Kenyon L, Micah JA. Advances in crop science and technology pesticide use practices and perceptions of vegetable farmers in the cocoa belts of the Ashanti and Western Regions of Ghana. 2015;3(3).
15. Zimba M, Zimba M. Pesticide management practices among rural market gardening farmers near Harare, Zimbabwe. 2016; 112(9):71–6.
16. Zyoud SH, Sawalha AF, Sweileh WM, Awang R, Al-Khalil SI, Al-Jabi SW, et al. Knowledge and practices of pesticide use among farm workers in the West Bank, Palestine: Safety implications. Environ Health Prev Med. 2010;15(4):252–61.
17. Ngowi, Mbise TJ, Ijani ASM, London L, Ajayi OC. Smallholder vegetable farmers in Northern Tanzania: Pesticides use practices, perceptions, cost and health effects. Crop Prot. 2007;26(11):1617–24.
18. Nonga, et al. Assessment of farming practices and uses of agrochemicals in Lake Manyara basin, Tanzania. J Agric Res. 2011;6(10):2216–30.
19. Keikotlhaile BM, Spanoghe P, Steurbaut W. Effects of food processing on pesticide residues in fruits and vegetables. Food Engineering & Ingredients. 2010;35:34–6.
20. SCF. High value and fresh vegetables for local market sub-sector analysis Tanzania: Executive summary [Internet]. Dar es Salaam; 2008.
Available:http://www.tzdpg.or.tz/fileadmin/_migrated/content_uploads/Vegetables_-Executive_Summary_FFV_Studies_pdf_1_.pdf
21. Putter H De, Koesveld MJ Van. Overview of the vegetable sector in Tanzania [Internet]. Netherlands; 2007.
Available:http://edepot.wur.nl/30946
22. Lema E, Machunda R, Njau KN. Agrochemicals use in horticulture industry in Tanzania and their potential impact to water resources. Int J Biol Chem Sci. 2014;8(2):831–42.
23. WHO. Diet, nutrition and the prevention of chronic diseases. World Health Organ Tech Rep Ser [Internet]. 2003;916:i–viii-1-149-backcover.
Available:http://eutils.ncbi.nlm.nih.gov/entrez/eutils/elink.fcgi?dbfrom=pubmed&id=12768890&retmode=ref&cmd=prlinks%5Cnpapers3://publication/uuid/734F6B31-260B-4545-A8E4-57F7D35DDEB8

24. Food and Agriculture Organization of the United Nations. Promotion of Fruit and Vegetables for Health [Internet]. Rome; 2015.
Available:http://www.fao.org/3/a-i4935e.pdf
25. HODECT. Tanzania development strategy 2012-2021 [Internet]. Arusha; 2012. Available:file:///C:/Users/Admin/Downloads/National Horticulture Development Strategy (1).PDF
26. FAO/WHO. Principles and methods for the risk assessment of chemicals in food. International Programme on Chemical Safety; 2009.
27. Bee FK, Mosh C. The changing farming environment in Tanzania : the case of selected villages in Kilimanjaro. Afr Study Monogr [Internet]. 1997;18(2):59–71. Available:https://repository.kulib.kyoto-u.ac.jp/dspace/bitstream/2433/68155/1/ASM_18_59.pdf
28. de Bon H, Huat J, Parrot L, Sinzogan A, Martin T, Malezieux E, et al. Pesticide risks from fruit and vegetable pest management by small farmers in sub-Saharan Africa. A review. Agron Sustain Dev. 2014;34(4): 723–36.
29. Lekei, Elikana E, Mkalanga, H, Mununa F. Characterization and potential health risks of pesticides registered and used in Tanzania. African Newsl Occup Heal Saf [Internet]. 2014;24(3):56–9.
Available:http://www.ttl.fi/en/publications/electronic_journals/african_newsletter/Documents/AfricanNewsletter2-2014.pdf
30. Mununa, F.T, Mkenda, J, Sikay M. Post-registration surveillance of pesticides: Towards Best Practices of Pesticide Management (BPPM) for environmental and human health protection in Tanzania. African Newsl [Internet]. 2014;24(2):2. Available:http://www.ttl.fi/en/publications/electronic_journals/african_newsletter/Documents/AfricanNewsletter2-2014.pdf
31. Śpiewak R. Pesticides as a cause of occupational skin diseases in farmers. Ann Agric Environ Med [Internet]. 2001;8(1): 1–5.
Available:http://mail.radoslawspiewak.net/2001-1.pdf
32. Marčić D, Perić P, Milenković S. Acaricides - Biological Profiles, Effects and Uses in Modern Crop Protection. In: Stoytcheva M, editor. Pesticides - Formulations, Effects, Fate [Internet]. Serbia: In Tech. 2011;37–62.
Available:http://www.intechopen.com/books/pesticides-formulations-effects-fate/acaricides-biological-profiles-effects-and-uses-in-modern-crop-protection
33. IPCS. The WHO recommended classification of pesticides by hazard and guidelines to classification [Internet]. Geneva: WHO; 2010.
Available:http://www.who.int/ipcs/publications/pesticides_hazard_2009.pdf
34. URT. Orodha ya viuatilifu vilivyosajiliwa Tanzania Toleo la November, 2011 [Internet]. Arusha. 2011;2505871. Available:http://www.tpri.or.tz/news/Pesticides_Gazette_2011.pdf
35. Ngowi A, Mrema E, Kishinhi S. Pesticide Health and Safety Challenges Facing Informal Sector Workers. NEW Solut A J Environ Occup Heal Policy [Internet]. 2016;26(2):220–40.
Available:http://journals.sagepub.com/doi/10.1177/1048291116650262
36. Mhauka AB. Assessment of pesticide exposure pathways on humans in Mang'ola ward, Karatu district-Arusha, Tanzania. [Morogoro]: Sokoine Univerity of Agriculture; 2014.
37. Moshi AP, Matoju I. The status of research on and application of biopesticides in Tanzania. Review. Crop Prot [Internet]. 2017;92:16–28.
Available:http://dx.doi.org/10.1016/j.cropro.2016.10.008
38. Lekei EE, Ngowi A V, London L. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health [Internet]. 2014;14(1):389.
Available:http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3999359&tool=pmcentrez&rendertype=abstract
39. Mushobozi WL. Good Agricultural Practices (GAP) on horticultural production for extension staff in Tanzania: Training Manual. FAO GAP Work Pap Ser [Internet]. 2010;13:101–10.
Available:http://www.fao.org/docrep/013/i1645e/i1645e00.pdf
40. Mdegela RH, Mosha RD, Moshi HA, Nonga H. Environmental and health impact associated with usage of agrochemicals in mindu dam catchment area, Morogoro, Tanzania. J Open Univ Tanzania. 2013; 15(255).
41. Mahugija JAM, Khamis FA, Lugwisha EHJ. Determination of levels of organochlorine, organophosphorus, and pyrethroid

pesticide residues in vegetables from markets in Dar es Salaam by GC-MS. Int J Anal Chem [Internet]. 2017;2017:1–9. Available:file:///C:/Users/Admin/Downloads/4676724.pdf
42. Code of good agricultural practices (gap) for fresh fruits and vegetable farming. Philipp Certif Scheme Good Agric Pract Fresh Fruits Veg Farming. 1–10.
43. FAO. Guidelines on Good Practice for Ground Application of Pesticides. 2001;36.
44. Manyilizu WB, Mdegela RH. Self-reported health effects among short and long-term pesticide sprayers in Arusha, Northern Tanzania: A cross sectional study. Occup Med Heal Aff [Internet]. 2015;3(6). Available:http://www.esciencecentral.org/journals/selfreported-health-effects-among-short-and-longterm-pesticide-sprayersin-arusha-northern-tanzania-a-cross-sectional-study-2329-6879-1000223.php?aid=65301
45. Davis RF, Nematologist E, Harris GH, Agronomist E, Roberts PM, Entomologist E. Designing research and demonstration for tests for farmers' fields (B 1177) [Internet]. Georgia: University of Georgia; 2017;1–8.
Available:https://secure.caes.uga.edu/extension/publications/files/pdf/B 1177_4.PDF
46. Lekei EE, Ngowi A V, London L. Pesticide retailers' knowledge and handling practices in selected towns of Tanzania. Environ Heal [Internet]. 2014;13:79.
Available:http://www.ehjournal.net/content/13/1/79
47. Lekei EE, Ngowi A V, London L. Pesticide retailers' knowledge and handling practices in selected towns of Tanzania. Environ Heal [Internet]. 2014;13(1):79.
Available:http://www.ehjournal.net/content/13/1/79
48. Ndengerio-Ndossi JP, Cram G. Pesticide residues in table-ready foods in Tanzania. Int J Environ Health Res [Internet]. 2005;15(2):143–9.
Available:http://www.tandfonline.com/doi/abs/10.1080/09603120500061922
49. Kariathi V, Kassim N, Kimanya M. Pesticide exposure from fresh tomatoes and its relationship with pesticide application practices in Meru district. Cogent Food Agric [Internet]. 2016;2(1):1–12.
Available:https://www.cogentoa.com/article/10.1080/23311932.2016.1196808
50. Mahugija JAM, Khamis FA, Lugwisha EHJ. Assessment of pesticide residues in tomatoes and watermelons (fruits) from markets in Dar es Salaam, Tanzania. J Appl Sci Environ Manag. 2017;21(3):497–501.
51. Darko G, Akoto O. Dietary intake of organophosphorus pesticide residues through vegetables from Kumasi, Ghana. Food Chem Toxicol [Internet]. 2008;46(12): 3703–6.
[Cited 2017 Aug 7]
Available:http://linkinghub.elsevier.com/retrieve/pii/S0278691508005462
52. Esturk O. Pesticide residue analysis in parsley, lettuce and spinach by LC-MS / MS. J Food Sci Technol. 2014;51:458–66.
53. Kolani L, Mawussi G, Sanda K. Assessment of Organochlorine Pesticide Residues in Vegetable Samples from Some Agricultural Areas in Togo. Am J Anal Chem [Internet]. 2016;7(7):332–41. Available:http://www.scirp.org/journal/ajac%5Cnhttp://dx.doi.org/10.4236/ajac.2016.74031%5Cnhttp://creativecommons.org/licenses/by/4.0/
54. Keikotlhaile BM, Spanoghe P, Steurbaut W. Effects of food processing on pesticide residues in fruits and vegetables: A meta-analysis approach. Food Chem Toxicol [Internet]. 2010;48(1):1–6.
Available:http://dx.doi.org/10.1016/j.fct.2009.10.031
55. Hulley SB, Cummings SR, Browner WS, Grady D. Designing Clinical Research [Internet]. 4th ed. 2013;75.
Available:https://www.bjcancer.org/Sites/Uploaded/File/2016/11/306361609431156678937582961.pdf
56. Walpole SC, Prieto-Merino D, Edwards P, Cleland J, Stevens G, Roberts I. The weight of nations: An estimation of adult human biomass. BMC Public Health [Internet]. 2012;12(1):439.
Available:http://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-12-439
57. Gad-Alla SA, Loutfy NM, Shendy AH, Ahmed MT. Hazard Index, a tool for a long term risk assessment of pesticide residues in some commodities, a pilot study. Regul Toxicol Pharmacol [Internet]; 2015. Available:http://dx.doi.org/10.1016/j.yrtph.2015.09.016
58. Weinberger K, Swai I. Consumption of traditional vegetables in Central and

Northeastern Tanzania. Ecol Food Nutr. 2006;45(2):87–103.
59. Nasreddine L, Rehaime M, Kassaify Z, Rechmany R, Jaber F. Dietary exposure to pesticide residues from foods of plant origin and drinks in Lebanon. Environ Monit Assess [Internet]. 2016;188(8). Available:http://dx.doi.org/10.1007/s10661-016-5505-y
60. Lu C, Barr DB, Pearson MA, Waller LA. Dietary intake and its contribution to longitudinal organophosphorus pesticide exposure in urban/suburban children. Environ Health Perspect. 2008;116(4): 537–42.
61. Lemos J, Sampedro MC, de Ariño A, Ortiz A, Barrio RJ. Risk assessment of exposure to pesticides through dietary intake of vegetables typical of the Mediterranean diet in the Basque Country. J Food Compos Anal [Internet]. 2016;49:35–41. Available:http://dx.doi.org/10.1016/j.jfca.2016.03.006
62. Kariathi V, Neema K, Martin K. Risk of exposures of pesticide residues from tomato in Tanzania. African J Food Sci [Internet]. 2017;11(8):255–62. Available:http://academicjournals.org/journal/AJFS/article-abstract/92CEBDD65179
63. Bouchard M, Chevrier J, Harley KG, Kogut K, Vedar M, Calderon N, Trujillo C, Johnson C, Bradman A, Barr BB, Eskenazi B. Prenatal exposure to organophosphate pesticides and IQ in 7-year-old children. Environ Health Perspect. 2011;119(8): 1189–95.
64. Wong WWK, Yau ATC, Chung SWC, Lam C, Ma S, Ho YY, et al. Dietary exposure of Hong Kong adults to pesticide residues: Results of the first Hong Kong total diet study. Food Addit Contam Part A. 2014;49(December 2016):852–71.
65. Nicolopoulou-Stamati P MS, Kotampasi C SP and HL. Chemical pesticides and human health: The urgent need for new concept in Agriculture. Front Public Heal [Internet]; 2016. [Cited 2017 Aug 9];4:148. Available:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4947579/pdf/fpubh-04-00148.pdf
66. Mnif W, Hassine AIH, Bouaziz A, Bartegi A, Thomas O, Roig B. Effect of endocrine disruptor pesticides: A review. Int J Environ Res Public Health. 2011;8(6):2265–303.
67. Ngowi AV. Health Impact of Exposure to Pesticides in Agriculture in Tanzania; 2002.
68. Yang A, Park JH, Abd El-Aty AM, Choi JH, Oh JH, Do JA, et al. Synergistic effect of washing and cooking on the removal of multi-classes of pesticides from various food samples. Food Control. 2012;28(1): 99–105.
69. Selim MT, EL-Saeid MH, Dossari IMA-. Multi-residues Analysis of Pesticides using Gas Chromatography Mass Spectrometry: I- Leafy Vegetables. Res J Environ Sci. 2011;5(3):248–58.
70. FAO/WHO. Guidelines for predicting dietary intake of pesticide residues [Internet]. Switzerland; 1997. Available:http://www.who.int/foodsafety/publications/chem/en/pesticide_en.pdf
71. Shackleton C, Pasquini M, Drescher A. African indigenous vegetables in urban agriculture. First edit. London: Earthscan; 2009.
72. Bonnechere A, Hanot V, Jolie R, Hendrickx M, Bragard C, Bedoret T, et al. Processing factors of several pesticides and degradation products in carrots by household and industrial processing. J Food Res. 2012;1(3):68–83.
73. Randhawa MA, Anjum FM, Asi MR, Butt MS. Removal of endosulfan residues from vegetables by household processing. J Sci Ind Res (India). 2007;66(October):849–52.
74. Sheikh SA, Nizamani SM, Jamali AA, Mirani BN, Aasia A, Channa MJ. Effect of household processing on the removal of pesticide residues in okra vegetable. 2012;74–8.
75. Chauhan R, Monga S, Kumari B. Effect of processing on reduction of ??-cyhalothrin residues in tomato fruits. Bull Environ Contam Toxicol. 2012;88(3):352–7.
76. Chavarri MJ, Herrera A, Ariño A. Pesticide residues in field-sprayed and processed fruits and vegetables. J Sci Food Agric. 2004;84(10):1253–9.
77. Thanki N, Joshi P, Joshi H. Effect of household processing on reduction of pesticide residues in Brinjal (Eggplant, Solanum melongena). 2012;3(5):2860–5.
78. Tomer, V. and Sangha JK. Vegetable processing at household level: Effective tool against pesticide residues exposure. J Environ Sci Toxicol Food Technol [Internet]. 2013;6(2):43–53. [Cited 2017 Aug 9]

Available:http://www.iosrjournals.org/iosr-jestft/papers/vol6-issue2/I0624353.pdf?id=7685

79. Djordjevic T, Djurovic-Pejcev R. Food processing as a means for pesticide residue dissipation. Pestic i fitomedicina [Internet]. 2016;31(3–4):89–105. Available:http://www.doiserbia.nb.rs/Article.aspx?ID=1820-39491604089D
80. Hassanzadeh N, Bahramifar N, Esmaili-Sari A. Residue content of carbaryl applied on greenhouse cucumbers and its reduction by duration of a pre-harvest interval and post-harvest household processing. J Sci Food Agric. 2010;90(13): 2249–53.
81. Sheikh SA, Nizamani SM, Panhwar AA, Mirani BN. Monitoring of pesticide residues in vegetables collected from markets of Sindh Pakistan. 2013;4(1):41–5. Available:http://oaji.net/articles/2014/27-1394777966.pdf
82. Kumari B. Effects of household processing on reduction of pesticide residues in vegetables. ARPN J Agric Biol Sci. 2008; 3(4):46–51.
83. Satpathy G, Tyagi YK, Gupta RK. Removal of Organophosphorus (OP) Pesticide Residues from Vegetables Using Washing Solutions and Boiling. J Agric Sci [Internet]. 2012;4(2):69–78. Available:http://www.ccsenet.org/journal/index.php/jas/article/view/10640
84. Keding G, Weinberger K, Swai I, Mndiga H. Diversity, traits and use of traditional vegetables in Tanzania [Internet]. Technical Bulletin. 2007;40:53. Available:http://libnts.avrdc.org.tw/scripts/minisa.dll/144/VAVLIB/VAVLIB_SDI_REPORT/SISN+9326?SESSIONSEARCH

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/23292