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Martin, Haikael

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Does Pesticide exposure contribute to the growing burden of non - communicable diseases in Tanzania

Nicholaus Calista[a,*], Martin D. Haikael[a], Matemu O. Athanasia[a], Kassim Neema[a], Kimiywe Judith[b]

[a] Department of Food Biotechnology and Nutrition Sciences Nelson Mandela African Institution of Science and Technology, P.O Box 447 Arusha, Tanzania

[b] Department of Food, Nutrition and Dietetics Kenyatta University, Nairobi, Kenya

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ABSTRACT

Pesticide exposure is becoming a public health concern in Tanzania. This review highlights the existing information on pesticide exposure, health effects, knowledge, and awareness on pesticide handling and management and in the current pesticide regulations in Tanzania. There was a significant increase in pesticides importation of up to 4.5 million liters' in 2017 and registration of 1,114 pesticides in 2018. Food, water and soil are subjected to unacceptable levels of pesticide residues. Inadequate awareness of the effects of pesticides among the population of Tanzania was observed. Even though there are existing regulations governing pesticides, the inadequate management of pesticide in Tanzania was identified to contribute the malpractices in pesticide usage. Persistence of the malpractice in pesticide handling has been observed which argues for immediate intervention. Limited information concerning pesticide poisoning and adverse health effects has been reported but the magnitude of the health effects is not well known. There is scarce data on the association between pesticide and non-communicable diseases (NCDs) in Tanzania. This review is informative to the policy, practices, and intervention towards the existing situation of pesticide in Tanzania. In addition, it calls for further investigation of the absence of data on pesticide exposure and NCDs.

Introduction

The eradication of hunger and malnutrition is still a significant challenge in most developing countries/low and middle-income countries (LMICs) which rely on agriculture as a source of food and livelihoods [16,28]. Concomitantly, these countries are faced with an exponential increase in non-communicable diseases (NCDs) which are disproportionately related to their unhealthy diets [97,99]. The urgency to produce nutritious foods in abundance through subsistence farming to control hunger and reduce the NCDs is often in conflict with the profitability and livelihood aspects of agriculture. Moreover, the

Abbreviations: NCD, Non-communicable diseases; HCH, Hexachlorocyclohexane; MRL, Maximum Residue Limit; DDT, Dichloro-diphenyl-trichloroethane; HI, Hazard Index; OP, Organophosphate; DDE, Dichlorodiphenyldichloroethylene; ARfD, Acute Reference Dose.

* Correspondence.
E-mail address: calistanjau@yahoo.com (N. Calista).

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Table 1
Registered pesticides in Tanzania based on target pest.

Type of pesticides	Action/activity	n
Insecticides	Manage insect and arthropod	433
Fungicides	Destroy fungi	321
Herbicides	Destroy unwanted plant (weeds)	294
Acaricides	Inhibit growth of mites and insects eggs	56
Avicides	Manage birds	2
Rodentcides	Manage rodents	8

Source *(9, 8, 21)*

increased risks of climate change have threatened agricultural and environmental stability as a result of increased pests and diseases and the introduction of new pests to crops [27]. This reality has set the stage for the global demand for pesticides. In addition, other public health issues such as the control of malaria and dengue vectors and the suppression of fungal, bacterial, and algal pathogens have further increased the use of pesticides [49].

Generally, there is a drastic shift in agricultural activities globally from traditional to non-traditional methods which have increased the reliance on pesticides to increase productivity [26]. The estimated pesticide-related deaths worldwide are 200,000 per year where 99% of these occur in developing countries despite the fact that the utilization of pesticides in these countries is only 25% [26,91]. In Tanzania, the increased use of pesticides is evidenced by massive importation. For instance, from 2014 to 2016, there were about 82% increased pesticide importation permits issued (The United Republic of Tanzania [87] 2018). Moreover, the imported pesticides were 4,039,243 liters in 2017 [87]. The uncontrolled issuing of these permits has created chances for the importation of fake pesticides and ease of access, hence, the unnecessary use of pesticides [67]· It is estimated that about 81% of pesticides in Tanzania are used for livestock and agriculture, 18% for public health such as the control of vectors, and 1% is for protecting buildings from damage by insects [39].

The significant effects of pesticides on agricultural productivity and the reduction of post-harvest losses worldwide are well documented [89]. On the other hand, the improper use of these chemicals potentiates negative effects on human health [13], which differ depending on the duration, levels, and routes of exposure as well as the pre-existing health status of individuals [48]. Additionally, physiological conditions and immaturity may increase the vulnerability of young children and adolescents to the deleterious health effects of exposure to pesticides [26]. The highly energetic young men and women who are involved in farming activities like spraying pesticide, weeding, pruning, and harvesting are also likely to be at more risk from the prolonged durations of exposure to pesticides [39,48]. Long term exposures to pesticides are associated with adverse effects on human health through the interference with almost all body systems such as the nervous, endocrine, immune, reproductive, renal, cardiovascular, and respiratory systems [63,68]. Various chronic diseases and their co-morbidities such as cancer, diabetes, and cardiovascular and respiratory illnesses have also been associated with exposure to pesticides [24,63,68].

Despite this, data on the relationships between pesticide exposure and NCDs in Tanzania is scarce. Therefore, this review places emphasizes on pesticide exposure, handling, knowledge, and awareness, as well as the health effects and the linkage between pesticide exposure and NCDs.

Pesticide use in Tanzania

The use of pesticides in Tanzania is on the rise and the trend is expected to continue if alternative measures are not taken [87]. In 2006, 682 different pesticides were registered in Tanzania, which increased to 874 and 1,114 in 2011 and 2018 respectively [87]. This trend must be considered in terms of the possible impacts on people and food chains. The increased pesticide uses among farmers in Tanzania has been contributed by the perception of low effectiveness of pesticides, limited access on the safe use of pesticides, low use of protective gears (Kapeleka, et al., 2021).

According to the World Health Organization, pesticides are classified based on their hazardous nature as extremely hazardous (Class 1a), highly hazardous (Class 1b), moderately hazardous (Class II), slightly hazardous (Class III) and not hazardous (Class IV) [96]. Likewise, pesticides are also grouped based on the chemical compositions which reveal the efficacy, physical and chemical properties that dictate the mode of application, storage, dosage, and safety measures associated with pesticides usage.

Moreover, pesticides are classified based on functions which include insecticides, fungicides, herbicides, acaricides, avicides, and rodenticides [29]. Insecticides, fungicides, and herbicides account for about 90% of all pesticide usage in agricultural activities in Tanzania [87]. Basing on this classification pesticide which have been registered for use in Tanzania are shown in Table 1.

Findings from a study conducted in Iringa, Kilimanjaro, Arusha and Manyara in Tanzania showed that the highly used pesticides (68.9%) were under class II WHO hazard and extremely hazards and highly hazards (1b) were also used in these regions (Kapeleka, et al. [30]) . Moreover, 47.9 % of all pesticides used by smallholders vegetable farmers were wrongly used (Kapeleka, et al., 2021) . Another study conducted among vegetable producers in Southern Highlands regions in Tanzania found that the most used pesticides were pyrethroids (31%) followed by carbamates (25.1%) and organophosphate (20.9%) [8] Moreover, the common pesticide used in Tanzania are detailed in Table 2.

Table 2
Pesticide commonly used in Tanzania.

Common name	Chemical category	Functional category	WHO classification
Cypermethrin	Pyrethroid	Insecticide	II
Deltamethrin	Pyrethroid	Insecticide	II
Permethrin	Pyrethroid	Insecticide	II
Lambda-cyclothrin	Pyrethroid	Insecticide	II
Primiphos methyl	Organophosphate	Insecticide	II
Chlorpyrifos	Organophosphate	Insecticide	II
Fenitrothion	Organophosphate	Insecticide	II
Carbofuran	Carbamate	Insecticide	1b
Copper oxychloride	Copper based	Fungicide	II
Copper hydrochloride	Copper based	Fungicide	II
Copper sulphate	Copper based	Fungicide	II
Mancozeb	Copper based	Fungicide	1V
Diclorovos	Organophosphate	Insecticide	1b
Profenofos	Organophosphate	Insecticide	II
Dichlorodiphenyltrichloroethan(DDT)	Organochlorine	Insecticide	II
Endosulfan	Organochlorine	Insecticide	II
Parathion	Organophosphate	Insecticide	1a
Malathion	Organophosphate	Insecticide	III
Glyphosate	Organophosphate	Herbicides	II
Dimethoate	Organophosphate	insecticides	1b

Source *(12,39,14,40,41)*.

Drawbacks in the regulations of pesticide in Tanzania

Even though pesticide regulatory bodies such as the Tanzanian Pesticide Research Institute (TPRI) are in place, malpractices in pesticide use still persist [87]. Registered pesticides in Tanzania are governed by the Plant Protection Act No.13 of 1997. However, in Tanzania there is inadequate management of pesticides both locally formulated and imported [87]. This was substantiated by the existence of a poor system for controlling the importation and selling of pesticides, lack of an updated list of registered pesticide to all stakeholders that include sellers, farmers, extension officers, and consumers, and inadequate training of the stakeholders [87]

Additionally, government auditing report of 2018 indicated that pesticide sellers often start pesticide businesses without training and thus provide inappropriate information to the end-users [87]. There is also inappropriate inspection of pesticides at the point of sales and ports of entry, and even where inspection is done; there is no follow up for implementation. This is elaborated by the lack of an inspection policy and procedure document to explain how the inspection should be carried out and what should be done for defaulters, lack of qualified and adequate staff for inspection. Furthermore, there is no pesticide database indicating the risks and types of pesticide and the amount of pesticide available in the shops [87].

Pesticide donated from developed countries, price subsidies and the often illegal markets of pesticides have all contributed to increased pesticide contamination in LMICs [67]. Similarly inadequate information and stock rotation which may lead to the accumulation of expired products in stock [67]. Besides this, the responsible government institutions have impaired the management of pesticide and failed to establish the magnitude of health and environmental effects caused by pesticide usage in the country [85,87]. The discrepancies in the management of pesticides together with the level of ignorance and poverty in the population have created a big gap in the implementation of pesticide intervention issues in Tanzania [87].

Pesticide handling: knowledge, awareness, and practices in Tanzania

The agricultural sector in Tanzania is largely dominated by small-scale farmers who are vulnerable to pesticide exposure from lack of awareness of pesticide application techniques [87]. The existence of regulatory authorities and policies regarding pesticides in the country does not guarantee knowledge and awareness of the effects associated with unacceptable levels of pesticide residues in foods. Kiwango et al., (2018) found that majority of vegetable farmers in Arusha have never received any training on pesticide application and were unaware of the health and environmental risks of exposure to pesticide residues. Further, Kiwango et al found that pesticide training could reduce the risks of exposure among farmers. Inadequate extension services and knowledge among producers, food handlers and consumers have led to the continued lack of awareness of the Maximum Residue Limit (MRL) and banned products, hence, food products have unacceptable levels of pesticide residues in Tanzania [39,70]. Furthermore, farmers often obtain information about pesticides from retailers or other farmers and purchase whatever chemicals are available rather than what is appropriate to their needs [84]. Nevertheless, majority of pesticide retailers have inadequate qualifications and are unlikely to provide appropriate advice to farmers regarding the pesticides safe use [42]. Besides, some retailers distribute products that are unregistered for use in Tanzania while others sell pesticides together with food or feeds [42].

Nonga, et al., [72] found that 76% of farmers in Manyara were unaware of the effects of pesticides in the environment. Furthermore, empty pesticide containers were re-used for other purposes, indicating limited knowledge of the health and environmental risks associated with inappropriate disposal of pesticides. Likewise, farmers did not adhere to good agriculture practices, like considering the withdrawal period before taking foods to markets which can lead to the presence of residues in foods above the recommended MRL [50].

Another study reported that rice farmers in Rufiji and Zanzibar used pesticides without knowing their names or the active compounds since they were decanted from their original containers [84]. Some common malpractices among farmers and pesticide vendors in handling pesticides include; purchasing diluted pesticide products and transferring the same pesticides to empty food containers like water or soft drink bottles without labeling, as well as mixing of pesticide using food utensils [5,84]. This indicates a serious existing gap in the control of pesticide use in Tanzania. A study by Manyilizu et al., [54] reported that pesticide applicators in Arusha had inadequate knowledge, poor attitudes and practices on pesticide use, for instance, spraying pesticide with no protective equipment, inability to differentiate between fungicides and insecticides or organochlorine and organophosphates, mixing different pesticide with similar or different active ingredients leading to over dosage and/or multiple exposures to farmers and consumers .

Regular pesticide applications can lead to chronic pesticide exposure and serious health and environmental consequences. These consequences are quickly accelerated when health literacy regarding pesticides is lacking. Pesticide application has also been mistaken as ‘more is better’ which has resulted in high frequencies of application up to more than 16 times per crop [70]. This was reported among tomato and onion farmers in Kilimanjaro and Arusha based on a misperception that this can prevent pest attacks [70]. Awareness education and protective equipment were provided in some cases but farmers continued to show negligence on safety precautions. This was observed among tea farmworkers who said holding tea nurseries with gloves and wearing gumboots was not comfortable [32]. The lack of technical advice concerning pesticide application is confounded by the inability to read instructions written in English, especially for the fieldworkers entrusted to apply these products [32].

Knowledge and awareness of pesticides are very important in the management of pesticide poisoning cases. However, health care providers in Kilimanjaro and Arusha regions were unable to mention the first aid options for pesticide poisoning correctly [70]. Similarly, knowledge about pesticide safety instruction labels and the classification of pesticides based on the chemical categories was lacking among the healthcare providers [70]. Therefore, training on pesticide application is crucial to raise awareness and equip farmers and other pesticide-handlers with adequate knowledge for safe use.

Pesticide exposures in Tanzania

Pesticide residues are described as pesticide or metabolic products of a pesticide that may remain after the application of pesticides [10]. The potential routes of pesticide exposure include the consumption of pesticide-contaminated foods and drinks, direct skin contact, and inhalation [10,93]. Unintentional exposure to pesticides is also common and dangerous [22,26,48]**.** The indiscriminate use of pesticides in developing countries has continued to be a major problem which has led to serious risk within the One Health Triad of humans, animals, and the environment. Most farmers and other pesticide-handlers are not aware of the health risks associated with pesticide exposure and the lack of precautionary equipment has continued to be common practice in LMICs [70,71].

Pesticide exposure through foods

Dietary ingestion is a major route of exposure due to increased pesticide contamination in a variety of food and drinks such as, raw and cooked fruits, vegetables, water, cereals, and legumes [37,51,53,65,79]. Environmentally persistent pesticide residues basically enter the food chain through water and air 1 [65,79]. Contaminated feeds are often fed to animals leading to contaminated animal products like milk, meat, and eggs that constitute a substantial risk of exposure [19,79]. It is worrying that some of the detected pesticide residue concentration levels in foods exceed the recommended MRL though may not necessarily imply a risk to health [58]. Therefore, health risks due to pesticide exposure are usually determined using a combination of the pesticide residues and food consumption data in relation to MRL and Acceptable daily intake (ADI) or Acute reference dose (ARfD) [78]. Food consumption studies are scarce in most developing countries hence pesticide dietary exposure data are also limited.

In Tanzania, horticultural and food grain crops are among crops with higher pesticide utilization [39,87]. Initially, vegetables were organically-produced but in recent years, the increased demand for vegetables has called for increased production thus making vegetable farming a commercial industry which employs the use of farm inputs like pesticides and fertilizers to maximize production [35,50]. Locally produced food, especially fresh vegetables are highly preferred by Tanzanians [73], therefore, efforts must be made to address the safety aspects of vegetables for consumption. The health benefits of vegetables are potentially outweighed by the health risks being imposed by the unacceptable levels of pesticide residues in fresh and cooked vegetables.

A study conducted in Arusha region in 2018 revealed unacceptable levels of pesticide residues above the MRL in leafy vegetables. About 40% of the studied vegetable samples had detectable levels of pesticide residues including dimethoate acephate, profenofos, malathion, dichlorvos, permethrin, cypermethrin and lambda-cyhalothrin [37]. Dimethoate and permethrin were above the MRL of 0.02 and 0.05 mg/kg respectively as per the recommendations of the European Commission, 2017 in kales (2.88-15.4 mg/kg), (2.62-4.48 mg/kg) and cabbages (4.58-8.37 mg/kg) (1.44-3.91 mg/kg). The presence of pesticide residues above the MRL is an indication of poor agricultural practices. In this study, multi-residue contamination was found in 14.9% of the vegetable samples which predicate increased health risks from the exposure to multiple pesticides [37]. The hazard index (HI) for organophosphates was 2.385 indicating that exposure to these pesticides might cause potential health risks to consumers [37].

Another study assessing pesticide residues in tomatoes in Arusha-Meru District showed that. Chlorpyrifos, permethrin and metalaxyl residues of 0.83-603, 0.69-29.06, and 2854 mg/kg respectively were all above the MRL in 12 samples of fresh tomatoes based on CODEX recommendations [34]. Spraying close to harvest time, overdose and application of mixed pesticides were mentioned as some of the reasons for the high concentration of residues in vegetables [34]. The estimated dietary exposure in this study indicated that the health risk indices for chlorpyrifos and ridomil were 2.929 and 138.851 respectively, implying that the prolonged consumption of contaminated fresh tomatoes can pose health risks to consumers.

Another study conducted in different markets in Dar-es-salaam on fresh cabbages, spinach, onions, and tomatoes indicated that 95.8% of the samples were contaminated with various pesticide residues and about 46% of the contaminated samples had contamination levels above the MRL [50]. The residues detected were organochlorine pesticide such as *pp*-DDT, *pp*-DDE, and endosulfan and organophosphate were Chlorpyrifos and permethrin [50]. The concentrations of endosulfan and Chlorpyrifos were both above the MRL [50]. Organochlorine pesticides are highly toxic and persistent compounds that bio accumulate in the food chain posing great health risks to humans, animals and the environment [75]. Organochlorines are also a potential risk factor for NCDs [63]. Most of the organochlorine pesticides were banned from use hence their presence in food is an indication of poor agriculture practices.

A study conducted in Mang'ola Arusha also found unacceptable levels of pesticide residues in vegetables. Residues of refenofos, tebukanazol, triadimefon ongmenol, Chlorpyrifos, cypermethrin, chlorthalonil, dimethioate, endosulfan, lambda cyhalothrin exceeded the MRL in amaranthuses, tomatoes, kale, onions, and spinach according to the EU and Codex Alimentarius Commission [58]· Moreover, the cumulative hazard index for organophosphate pesticide was 5.9 which is >1, indicating that the prolonged consumption of organophosphate contaminated vegetables poses significant health risks to consumers [58].

Pesticides exposure through water

Farming is usually done in areas where the water supply is assured but it also contributes to water pollution from fertilizers, pesticides and other pollutants [44]. The inappropriate and excessive use of agrochemicals in agriculture contribute to surface and underground water pollution which may impair the quality of water for various end uses [44,56]. Fertilizers and pesticides contributes to about 70% of the water pollution globally [47]. Pesticides are more detected in water during rainy season compared to dry season as they percolate in water sources through intensive irrigation and rainfall [47,56]. In developing countries surface water from rivers, lakes, boreholes are commonly used for domestic purposes like washing, drinking and animals consumption thus making water potential source of exposure to pesticide residues [44]. On the other hand, pesticide runoff into water bodies can also impair life to aquatic organisms [56,66].

A study conducted in Vikuge the former pesticides storage farm in Kibaha Tanzania found residues of Hexachlorocyclohexane (HCH), in water samples [59]. The concentrations of ΣHCHs in water were 0.95 mg/l in tap water, up to 0.44 µg/l, in surface water, and up to 6.15 µg/l in ground water [59]. However the concentration levels of HCHs showed that ground water samples had higher levels than either tap or surface water samples [59]. Likewise, tap water samples had high concentrations of the HCHs compared to surface water samples. The presence of HCHs in water bring thoughtful concern on the quality of the water. Other pesticide detected in surface and groundwater was Thiabendazole at a concentration of 0.17 µg/l in surface-water and up to 0.59 µ g/l in groundwater samples [59].

Hellar and Kishimba (2005) detected pesticide residues from water samples collected from TPC Sugarcane Plantation and its environs in Kilimanjaro region, the area with intensive use of pesticides in Tanzania. The organochlorines aldrin, dieldrin, heptachlor epoxide, HCHs, endosulfans and DDTs were detected with mean concentrations ranging from 1.1 to 636.7 ng/l. DDT and its metabolites were the most dominant in the detected residues (Hellar and Kishimba, 2005) .Likewise, In Kilombero valley, the pesticides detected in water were chlorpyrifos, propoxur and diuron and glyphosphate. The highest concentration was propoxur (62.5%), followed by diuron (37.5%), in the rainy season, while glyphosate was found (15.4%) in the dry season [56]. Moreover, pesticide residues were detected in water from Kilolo and Muheza in Iringa and Tanga region respectively. The detected pesticides were HCH, endosulfan, DDT and their metabolites [66]. All these pesticide residues were detected in dry and rainy seasons [66]. The presence of DDT in samples of water in Kilolo and Muheza and the ratio of DDT and DDE (DDE/ DDT) being less than 1 which indicates recent application of the pesticides in the environment [66]. Water bodies contaminated by pesticides either directly or indirectly, can lead to adverse effect to aquatic organisms, wildlife and human health especially when used for public consumption

Pesticide in soil and sediment

Pesticides which are improperly disposed, often leads to serious environmental contamination [52]. In Tanzania the common disposal methods include dispose of empty containers around the farm, dumping out leftover pesticides into either rivers or nearby bushes. open burning, discharge to sewer, and burying or landfill disposal, which are likely to cause severe damage to public health and the environment [29,42,57].

Mtashobya and Nyambo, [66] reported pesticides and their derivatives detected in soil samples collected in rainy season and dry season from Kilolo and Muheza were HCH, endosulfan and DDT and their metabolites [66]. In Vikuge Kibaha Tanzania the concentration of total HCH in sediments were in the range 280-7,400mg/kg dry weight [59]. DDT was also detected at the concentration range from 3,490 mg/kg to 99,620 mg/kg dry weight. Other pesticide residue detected in sediment samples was azinphos-methyl at a concentration of 360 mg/kg dry weight [59]. Similarly, higher levels of DDT and HCH were found in soil samples taken in both dry and wet seasons from TPC sugarcane plantations in Kilimanjaro region. Some samples from TPC indicated high levels of HCH compared to the other isomers implying recent use of HCH product [36].

Organochlorine pesticides are persistent to environmental degradation as compared to other classes of pesticide and thus become more concentrated up to the food chain [29,44]. This means that animals on top of the chain like humans can potentially get affected [29].The presence of these pesticides in samples of water, soil and sediment from different agricultural zones in the country urge for a strict regulation to ensure that their strictly prohibited from use.

Pesticide exposure from occupation and other pathways

Occupational exposure to pesticides is a particular concern where insufficient precautions are taken during pesticide preparation and application or while working on the sprayed fields [17,100]. Humans can be exposed to pesticides due to on-farm activities such as weeding, pruning, harvesting, pesticide applications, or re-entry for vegetable or firewood and through vector control in homes [1]. Similarly, exposure can occur to people who have proximity to agricultural areas [76]. Occupational exposure includes gases, vapors fumes, dust, and their composites [31]. Globally, more than 2.5 billion people depend on agriculture for their livelihoods and 60% of these are smallholder farmers in LMICs, hence the occupational exposure to pesticides could pose great public health risks [76]. Besides, the risk of occupational exposure to pesticides among agricultural workers from developing countries are higher due to insufficient knowledge of pesticide handling and lack of protective equipment [31]. Workers who are involved in pesticide industries, preparation and transportation of these chemicals, farmers, fruits, vegetables, and flower sellers and consumers are all exposed to different levels of pesticide [80]. Most likely, farmworkers have cocktail exposures from diet and workplace.

Other pathways of pesticide exposure include the indoor application of insecticides to repel or to kill insects and rodents in homes, application of pesticides in gardens and playgrounds and washing of the contaminated clothes [4,67].

Health effects associated with pesticide exposures

Pesticide residues have become a major issue to farmers, government, and consumers as they cannot be detected easily before or after consumption [1]. However, different countries have established control mechanisms such as they set MRL for various food products and ban of highly toxic and hazardous products [77].

Exposure to pesticides can be chronic or acute. The former is a prolonged period of being exposed to a low dose of pesticide which can be more harmful and may result in chronic toxicity hence serious chronic health problems [18]. This kind of exposure has been linked to various chronic diseases and their co-morbidities such as obesity, breast cancer [11,23], diabetes [3,82], and cardiovascular diseases [90].

Acute exposure to pesticides has been associated with adverse health effects such as dizziness, muscular pain, wheezing, coughing, sneezing, itching, skin disease, breathing difficulties, nausea and eye diseases [43]. Nearly one-third (32.4%) of tea workers in Tanzania tea companies self-reported symptoms of pesticide exposure like headache, skin irritation, chest pain and coughing [32]. Similar symptoms have been reported for small scale farmers in Uganda who fell sick after the regular application of pesticides [74].

Nevertheless, Self-poisoning by agricultural pesticides has become an increasingly common suicide method in developing countries, particularly in countries with majority of rural population engaged in small-scale agriculture [20,95]. Pesticide ingestion is responsible for up to 60% of suicides in rural China and South-East Asia [20]. However, the common use of pesticides for suicide attempt is a reflection of the availability and easy access to these chemicals among the farming households [95]. Normally, subsistence farmers keep pesticides within, or close to the household [20,42,84].

A study conducted in ten health facilities in three regions of Tanzania reported 108 Acute Pesticides Poisoning cases out of them 31 (28.7%) occurred among adolescent girls (10-19 years.) [41]. However, the leading poisoning circumstance in this study was attempted suicide (60.2%) among women (20-29) years [41].The main agent responsible for acute poisoning was organophosphate pesticides mainly WHO Class I and II pesticides [40,41].

Mrema *et al.*, [64] identified the most prevalent diseases among women in the horticultural regions with high pesticide use included upper respiratory infections, hypertension, gynecological diseases, rheumatoid and joint diseases, pregnancy complications, skin infection, non-fungal bronchial asthma, and diabetes mellitus. The regions which have high pesticides applications in Tanzania are Arusha, Kilimanjaro, Manyara, Morogoro, Njombe, Iringa, Mbeya, Ruvuma, Dodoma, Kagera, Mwanza, Tanga, and Dar-es-salaam [64].

Manyilizu et al., [55] found that biological markers of women farmworkers from Karatu in Manyara regions who were exposed to pesticides showed high white blood cells, lymphocytes and platelet counts while hematocrit and mean corpuscular volume (MCV) were low Elevated platelet counts have recently been associated with the progression of various cancers

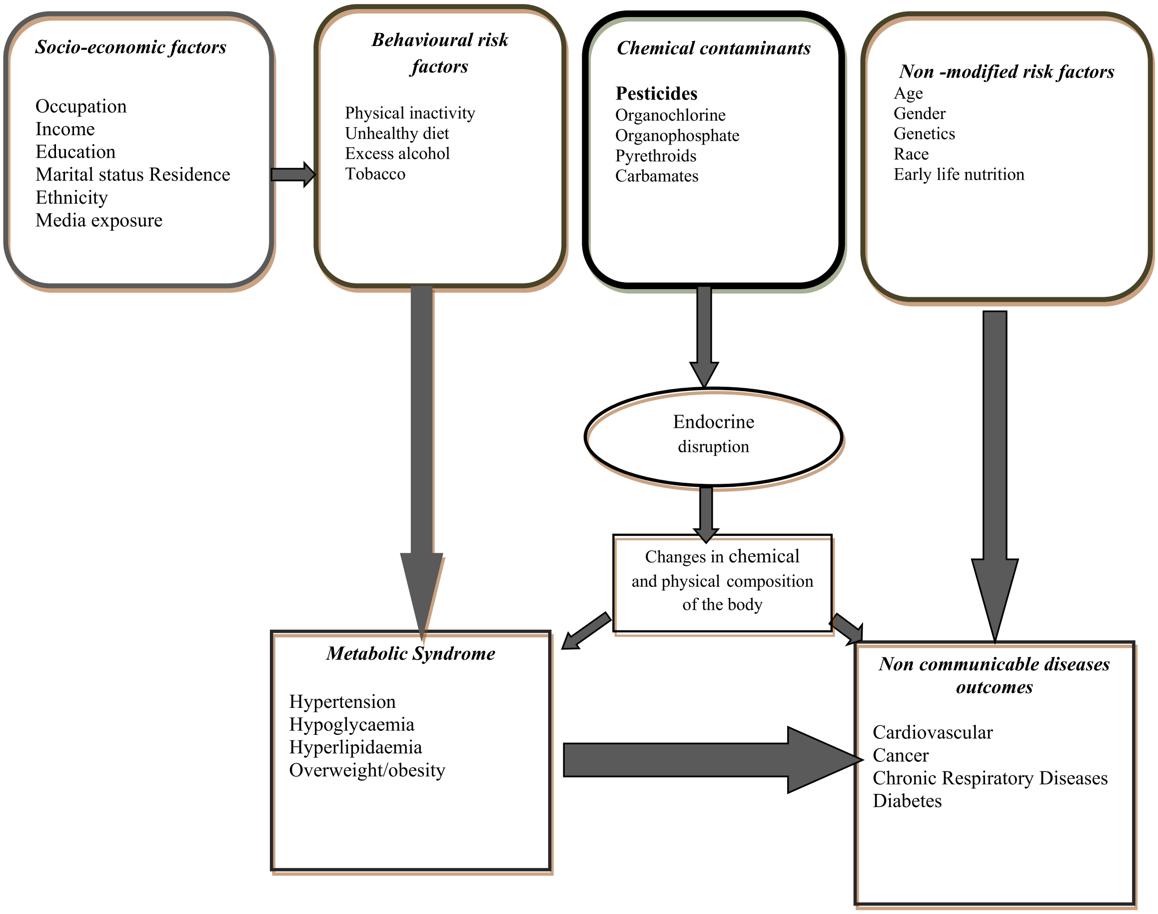

Fig. 1. Causes of non- communicable diseases adopted and modified from [98](9)

[38]. However, the evidence of this association was not established in Karatu but a highlight for further research considering an increase of cancer cases in Tanzania. Another study conducted in the Southern corridor of Tanzania reported that (15%) children of mothers who worked on sprayed tomato farms while pregnant were not well developed [8]. Likewise, children of mothers who most used pesticides were most likely to have neuro-development effects [8]. Moreover, Kapeleka et al., [32] found that farmers (15.6%) in Arusha and Iringa who were exposed to pesticides had acetylcholinesterase activity levels below the TPRI acceptable levels of 24.5U/g Hb [33]. Acetylcholinesterase is an important enzyme in the nervous system that terminates nervous impulses by catalyzing the hydrolysis of neurotransmitter, acetylcholine [45]. The inhibition of the acetylcholinesterase enzyme is the principal health effect of organophosphate pesticides [32].

In Tanzania pesticide exposure is a serious problem among the population but the magnitude of pesticide health effects is not well documented.

The status of NCD, s and the possible link with pesticide exposures

Globally, the burden of NCDs has increased tremendously with the highest prevalence in LMICs [88]. In Tanzania, the prevalence of NCDs is rapidly increasing and currently accounts for 33% of all death [94]. About 35,000 people are developing cancer yearly in Tanzania and the rate was expected to increase by 50% by 2030 [92]. Moreover, the prevalence of cardiovascular diseases, especially hypertension is 12%, while diabetes prevalence stands at 9% [99]. The prevalence of NCDs has increasingly been evidenced in adolescents and women, posing a greater risk to social capital in these productive groups [88].

The causes of NCDs are multi-factorial often involved modifiable factors, such as physical inactivity, malnutrition in early life and later on, unhealthy diets like high intake of salt, fat, and sugar, tobacco use, excessive alcohol and exposure to chemical contaminants [69,98] (Fig. 1). WHO stipulated that 8.2 million deaths caused by environmental contaminants are NCDs [98]. Chemical contaminants include chemicals that are found in pesticides, household detergents, plastics, cosmetics and disinfectants that enter the body and interfere with the endocrine system and result in adverse health effects [81]. These chemicals are termed as endocrine disruptors [81,86], and most of them are chemical pesticides [7,60,61]. The massive use of pesticides in everyday life may play a significant etiologic role in NCDs especially in LMICs due to inadequate knowledge and insufficient protective equipment [62].

The endocrine system consists of glands and hormones that are essential in the growth, development, reproduction, and behavior of animals [61]. Endocrine disruptors normally function by altering body functions by mimicking the natural hormones functions, transport, and storage or by blocking hormones, preventing or stimulating the metabolisms of hormones or shifting the way hormones travel in the body [81]. Further, the endocrine disruptors interfere with nervous, immune and cardiovascular systems, and are likely to induce teratogenicity, carcinogenicity, and mutagenicity [86]. Therefore, endocrine disruptors are linked to various diseases and their co-morbidity such as obesity, diabetes mellitus [9,12,76,83], asthma [24,25], cardiovascular diseases [6,21,46], and cancer [2,15]. Other diseases are reproductive disorders, neurodevelopment disorders and Parkinson's and Alzheimer's [75].

The association of pesticide and NCDs reported in various countries worldwide are presented in Table 3. However, there is scarce information on the association between pesticide exposures and chronic diseases in Tanzania. Moreover, no published study has linked pesticide exposure with NCDs in Tanzania.

Table 3
Contribution of pesticides exposure and its link to various non-communicable diseases.

Non Communicable Diseases	Study Design	Region	Pesticides	Reference
Endocrine				
Diabetes	Case-control	Korea	Beta- hexachlorocyclohexane, hexachlorobenzene, heptachlor epoxide, p,p′- dichlorodiphenyldi- chloroethylene (DDE), p,p′-DDD, p,p′- dichlorodiphenyltrichloroethane(DDT),o,p′-dichlorodiphenyltrichloroethane (DDT), oxychlordane, trans-nonachlor, and mirex)	[10]
Diabetes	Longitudinal	South Asia	p,p-dichlorodiphenyldi- chloroethylene (DDE), p,p-dichlorodiphenyltrichloroethane, b-hexachlorohexane (HCH), and poly- chlorinated biphenyl	[11]
Diabetes	Longitudinal		PCB170 (2,29,3,39,4,49,5-Heptachlorobiphenyl;Heptachlor epoxide	[12]
Diabetes	Prospective longitudinal	USA	Organophosphates, fonofos, phorate and parathion and Organochlorine: Dieldrin	[13]
Diabetes		USA	Organophosphate (diazinon and parathion)	[14]
Diabetes	Prospective longitudinal	USA	Organochlorine (Aldrin, chlordane, and heptachlor), Organophosphate insecticides: coumaphos, phorate, terbufos, and trichlorfon; and herbicides: (ala- chlor and cyanazine)	[15]
Diabetes	Case control	Thailand	Endosulfan, Mevinphos and carbaryl/ Sevin and Benlate	[16]
Diabetes	Cross section	USA	1,2,3,6,7,8- Hexachlorodibenzofuran; 1,2,3,4,6,7,8-Heptachlorodibenzofuran; Heptachlor epoxide; Oxychlordane;	[17]
Diabetes	Cross section	Mexico	Trans-nonachlor, oxychlordane, β-hexachlorocyclohexane, p,p≐ dichlorodiphenyltrichloroethane (DDT) and p,p≐ dichlorodiphenyldi- chloroethylene (DDE).	[18]
Diabetes	Case- control	USA	Oxychlordane, trans-nonachlor, and hexachlorobenzene	[19]
Diabetes			beta-hexachlorocyclohexane, p,p′- dichlorodiphenyldi- chloroethylene DDE, p,p′- dichlorodiphenyltrichloroethane (DDT), oxychlordane, trans-nonachlor, and heptachlor epoxide	[20]
Diabetes	Case-control	Benin	p,p′- dichlorodiphenyltrichloroethane (DDT), p,p′- dichlorodiphenyldi- chloroethylene (DDE), β-hexachlorocyclohexane (HCH) and trans-nonachlor	[21]
Cancers				
Lung Cancer	Longitudinal	USA	Metolachlor and pendimethalin Chlorpyrifos and Diazinon	[22]
Breast cancer	Cross- section	India	dichlorodiphenyldi- chloroethylene (DDE), heptachlor, dieldrin, and hexachlorocyclohexane (HCH)	[23]
Prostate cancer	Case-control	Italy	dichlorodiphenyltrichloroethane (DDT) and dicofol	[24]
Leukemia	Case-control	USA	Flea control products	[25]
Prostate cancer	Case-control	USA	β-hexachlorocyclohexane (HCH) trans-nonachlor and dieldrin, Oxychlordane and PCB 180	*[122,124]*
Bladder cancer	Case-control	Australia	Organophosphate pesticides	[28]
Cardiovascular				
Cardiovascular (animal study)	Experimental	Taiwan	Glyphosate, glufosinate, and atrazine	[29]
Cardiovascular	Randomised cluster	USA	PCB	[30]
Cardiovascular	Cross section	USA	Dioxin-like PCBs, nondioxin-like PCBs, and organochlorine pesticides	[31]

(*continued on next page*)

Table 3 (*continued*)

Non Communicable Diseases	Study Design	Region	Pesticides	Reference
Chronic Respiratory Disease				
Chronic respiratory disease	Cross section	Lebanon	Pesticides	[31]
Asthma& chronic respiratory diseases	Cross section	Southern Australia	Pesticides	[32]
Chronic bronchitis	Case -control	Lebanon	Pesticides	[33]
Obstruction of airways	longitudinal	Netherland	Herbicides and Insecticides	[34]
Reduction of lungs functions	Case control	India	Organophosphate and Carbamates pesticides	[35]
Asthma	longitudinal	USA	Organophosphate pesticides	[36]
Wheezing	Prospective cohort	USA	Organophosphate: Chlorpyrifos, malathion, and parathion were	[37]
Asthma	Cross section	USA	Herbicides; pendimethalin and insecticide; aldicarb.	[38]
Asthma	Prospective case control	USA	methyl parathion, lambda-cyhalothrin (Karate1), profenofos (Curacron1), acephate (Orthene1), cyfluthrin (Baythroid1), azinphos-methyl (Guthion1), oxamyl (Vydate1), methomyl (Lannate1), and thiodicarb (Larvin1).	[39]
Chronic Bronchitis	Prospective cohort	France	Pesticides	[40]

Conclusion

The review found a significant increase in pesticide use in Tanzania. Evidence of pesticide residues above the MRL and residues of highly toxic and banned compounds was found in various food crops, water, soil, and sediment. Lack of proper management and control of pesticide usage is evident in Tanzania's agro-food sector. Majority of farmers and pesticide handlers lack awareness of the health risks associated with pesticide exposure and are consequently at a high risk of exposure often due to the lack of protective measures. Inadequate training and lack of extension services are mentioned as among contributing factors for the pesticide malpractices. Although pesticide poisonings have been reported in various studies, there is limited information on the association between pesticide exposure and NCDs in Tanzania.

Recommendations

Policy related

The increased rate of pesticide uses in Tanzania is worrying, policymakers, researchers, and all stakeholders are to be more cautious and take appropriate measures for immediate intervention. The Ministry of Agriculture should establish a database for agrochemicals including pesticides for easy access to the updated information. There should be a rapid screening of food products for pesticide residues before releasing them to the market, food products with residues above the MRL should not be allowed to the market. The government through local governments should build and manage community-controlled pesticide stores where farmers can store their pesticide instead of unsafe keeping in their homes. Community storages will improve the safekeeping of pesticides; reduce easy access to pesticides by children to reduce unintentional poisoning. Moreover, a thorough assessment in terms of accessibility and additional costs to the farmers is needed

Intervention related

The Ministry of Agriculture should provide adequate, skilled and qualified extension officers who shall provide appropriate training to all stakeholders'/pesticide handlers and the training should go together with the supply of appropriate protective equipment. Moreover, thorough follow up on the adherence to good agricultural practices should be emphasized. The government through parliament should put stringent regulations governing the importation and selling of agrochemicals including pesticides. This can include sanctions on defaulters. However, the government should put more emphasis on integrated pest management techniques (IPM) to improve productivity and reduce the use of chemical pesticides among farmers in Tanzania .

Practice related

The Tanzania Pesticide Research Institute (TPRI) should emphasize proper pesticide management including proper registration, application, and all toxic and banned products must be removed out of the market. There should be an updated list of registered pesticides easily available to all stakeholders. The agro-shops should be managed by qualified personnel who can provide appropriate information and there should be an in-depth training and certification of the agro-dealers before the operation of pesticide businesses. Routine follow-ups to assess these implementations should be conducted with the relevant authorities. The application of pesticides in food crops should reflect the recommended level of residues in food products with an emphasis on the application of non-toxic and less toxic compounds. This can be achieved through in-depth training and awareness campaigns to farmers, pesticide applicators, pesticide-sellers and extension officers.

Further studies

The findings from this review identify a need to investigate the contribution of pesticide exposure to the increased rates of NCDs and other related co-morbidities in Tanzania. Therefore, the Ministry of Agriculture through TPRI in collaboration with the Ministry of Health, Ministry of Education and research institutions should conduct an epidemiological study to investigate the extent of pesticide effects on human health in the country.

Authors' contributions

Calista Nicholaus and Judith Kimiywe designed the work. Calista Nicholaus participated in the literature search and wrote a draft manuscript. Haikael Martin, Judith Kimiywe, Athanasia O. Matemu, and Neema Kassim reviewed and provided inputs to the manuscript.

Declaration of Competing Interest

The authors declare no competing interests.

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