Self-reported Health Effects among Short and Long-term Pesticide Sprayers in Arusha, Northern Tanzania: A cross Sectional Study

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Abstract

Background: The aim of the present study was to assess whether long-term exposure to pesticides is associated with adverse health effects in professional pesticide sprayers.

Methods: The study was conducted in Lake Eyasi Basin and Ngarenanyuki in Arusha region, during the dry season in September-October 2013. In a cross-sectional study, 97 short-term exposed men with at most three months as professional sprayers were compared with 60 long-term exposed men with experience of at least five years as professional sprayers. The study participants were aged 18-30 years, drawn from the same source population and interviewed using semi structured questionnaire. The questions focused on spraying procedures and on present and recurrent medical history including presence of selected six known pesticide induced health conditions.

Results: Organophosphates, carbamates, dithiocarbamates and pyrethroids were the most applied insecticides but also organochlorine fungicides and endosulfan were frequently applied. The majority of the sprayers reported unsafe pesticide use. Mean pesticide uses in litres, spray frequency per crop and per week were 637, and 1.3 respectively for about 270 days a year. Respiratory disease symptoms were the most frequently reported (46/157; 29.3%) followed by skin (27/157; 17.2%), and sight (24/157; 15.3%). When adjusted for age and other predictors, long-term exposed sprayers had significantly higher self-reported occurrences of peripheral neuropathy (OR=7.7, CI95%; 1.045-56.728, p=0.045) and respiratory disorders (OR=0.2, CI95%; 0.067-0.501, p=0.001) compared with short-term exposed. Furthermore, 10 sprayers, all long-term exposed reported poor libido and erection problems. Conclusions: These findings document lack of safety knowledge, safe pesticide management and the implementation of protective measures as well as suggesting that long-term exposure to pesticides increase the risk of experience disease conditions compared to short-term exposure.

Keywords: Exposure duration; Pesticides; Sprayers; Self-reported disease

Introduction

Pesticides are toxic chemicals used to protect crop against insects, other organisms harmful to cultivated plants including weeds thereby increasing crop yields and efficiency of food production. There are more than 1000 active ingredients, which are marketed as pesticides [1], and developing countries use 25% of the annual global consumption [2]. In Tanzania, a total of 300 active ingredients were registered and used by 2006 [3], including endosulfan, which is restricted by the Stockholm Convention due to its environmental persistence and the documented toxic potential [4]. Furthermore, the Tanzanian pesticide import increased from 500 to 2500 tonnes between 2000 and 2003 and the Arusha region, which is the study location of the present study, is one of the heavy pesticide users in Tanzania .

To control the trade and use of pesticides, Tanzania has developed a regulatory framework, adopted from the UN Food and Agriculture Organization (FAO), which aims to ensure best practices when using pesticides. Tanzania has also ratified the Stockholm convention, a global treaty under the United Nation Environment Program (UNEP), for protecting humans and environment from continued exposure to persistent Organic Pollutants (POPs).

However, despite the establishment of regulatory frameworks, a high degree of misuse among farmers are reported including over- and under-dosing, mixing of different pesticides, dangerous storage of pesticide and spraying equipment and poor use of personal protective gears [5]. Available data demonstrating unsafe pesticide handling practices in Tanzania suggest a high potential for human exposure, with the highest risk of occupational exposures among pesticide sprayers, farmers, and other agricultural workers. Accordingly, previous Tanzanian questionnaire-based studies identified unsafe pesticide use associated with acute pesticide poisoning as a major problem in the farming community [6,7]. Modern pesticides are reported to cause acute health effects in respondents exposed to high doses with unspecified symptoms such as headache, dizziness, respiratory problems, nausea, vomiting and eventually death. Furthermore, the data addressing potential adverse effects of long-term exposure to moderate pesticide levels suggest a wide variety of adverse health conditions, including central nervous-, reproductive- and immune system disorders, as well as cancers [8-21].

There is also circumstantial evidence on the association of exposure to pesticides with chronic diseases like respiratory problems, dermal disorders, cardiovascular disease, nephropathies, chronic fatigue syndrome and aging [1]. Since health-workers are not adequately trained to identify adverse effects of pesticides [22,23] and because of the
unspecific symptoms related to exposure to pesticides [24], a substantial underreporting of pesticide induced health effects is suspected in Tanzania and other developing countries [25]. In addition, the Health Management Information System (HMIS) in Tanzania has only one category for all cases of poisoning, reflecting a lack of comprehensive registry of adverse health effects associated with exposure to pesticides. Thus, studies which provide scientific based evidence documenting a link between unsafe pesticide-use and adverse health effects in Tanzania and other developing countries, is strongly needed for the initiation of interventions and outreach to improve public health.

In the study area, pesticides are applied to more than 5000 hectares farmland for more than 270 days between January and September each year. Among the professional sprayers there is a widespread praxis of poor pesticide handling such as improper storage, mixing several pesticides, bare hands loading, unhygienic spraying, lack of protective equipment use as well as haphazard disposal [26] of remnants and empty containers. The excess use of pesticides coupled with inadequate personal protection, is likely to increase the exposure dose among sprayers in the area [27]. Despite the contribution of these pesticides in improving agricultural production and protection of the harvests, they threaten the human health as a result of poor protection and indiscriminate use and handling [28].

Even though the first reports about extensive use and misuse in Tanzania were published for more than a decade ago, very few studies have assessed acute toxic effects while no studies have assessed association between long-term exposure to pesticides and adverse health effects. The main aim of the present study was to assess practice of pesticide use on farms and to assess potential associations between exposure duration and self-reported pesticide induced diseases among pesticide sprayers.

Materials and Methods

Time and study setting

Data were collected in dry season from 9 AM to 12 noon, Monday through Friday, between September and October of 2013 at health facilities in Ngerenanyuki along tomato and Mangola along onion farms in Arusha. It was warm with strong winds and with temperatures around 19°C, sometimes warmer and during day time up to 34°C. In these areas, onion and tomato farming is the major economic and subsistence activity. The sprayers were interviewed in the doctor's consultation room at the health facility. The room was quiet, with adequate privacy and a comfortable environment. The potential participant was asked to either accept or reject at reception desk at the health facility to participate in responding to occupational questions for at least 10 minutes after identifying himself occupationally as a sprayer-farm worker and after informed consent.

Recruitment

The study respondents were male farm workers involved in spraying onion and tomato farms using pesticides. They were recruited at outpatient clinic when escorting female partner or a child at pregnant women or child growth monitoring clinic respectively. The recruitment of a sprayer was based on the duration of time he had worked as sprayer, and was categorized as either short-term exposed or long-term sprayer. The short-term exposed sprayers were used as the contrast group, each with a history of regular spraying activity for 3 months or less. The long-term sprayers were farm workers involved in spraying for at least 5 years. Those that had history of smoking, taking alcohol, hypertensive, worked for more than 3 months but less than 5 years as sprayers were not recruited. Residential but seasonal sprayers were excluded, as well as individuals who had been diagnosed with diabetes, liver or kidney disease, or peripheral neuropathy before starting work as a sprayer were also excluded. The purpose of the research was explained to potential study respondents at each of the two health facilities' outpatient departments, and those who consented to a questionnaire interview were recruited. The consent form used was reviewed and approved together with ethical clearance by the Medical Research Coordinating Committee of the National Institute for Medical Research.

Exposure levels

Sprayers exposed for at least 5 years were defined as exposed (high exposure level) and the short-term exposed sprayers were defined as baseline or unexposed (low exposure level or contrast group) for comparison. The occurrence of pesticide-induced self-reported adverse health effects was proportionally explored using these two groups.

Sample size

Using the formula by Kelsey et al. (2007), the cross-sectional study required a total minimum of 118 sprayers. In a ratio of 1:1, 59 long-term and 59 short-term exposed sprayers were required as adequate representative sample for each subgroup to provide power of study of 80% at an estimated level of disease symptoms 50% and 25% in long-term and short-term exposed sprayers, respectively. This calculation was based on a significance level of α=0.05. In the field the data were collected from 157 sprayers, of whom 97 were short-term exposed and 60 long-term sprayers.

Questionnaire and definition of self-reported disease conditions

The questions focused on social and personal information, past and present medical history including whether there were pesticide induced health conditions among interviewees. The present study limited itself to neurologic, sight, skin, and heart, respiratory and reproductive and sexual complaints as a scope of conditions. All symptoms were defined and listed in the questionnaire for a selected provisional diagnosis the sprayer had. The peripheral neurological disease condition was defined if the respondent had experienced numbness, tingling, burning sensation of hands and or feet, and vision problem if had not been able to see properly, with no symptom of eye infection associated with pain. For skin disease condition was defined if he had rash, irritation/itching, eczematous reaction, or skin colour change, and for cardiovascular disease condition if he was told to have high blood pressure, or any heart problem diagnosis at health facility. A respiratory disease condition was defined by presence of wheezing, chest tightness, cough whereas sexual or fertility dysfunction if he had not been able to make babies for at least a year of unprotected sexual intercourse and if the respondent had erection problems.

Data collection and statistical analysis

Before data collection the questionnaire was pre tested and improved accordingly at Momella dispensary in Ngerenanyuki using 10 farm workers that came for outpatient clinic services. These were not included in data entry and analysis. The semi-structured questionnaire with mainly closed ended questions was administered in the doctor's consultation room by the investigator and an experienced, clinical medicine diploma holder that was specially trained for the present study. The respondents were asked about names and quantity of pesticides they used, quantity used per acre and frequency of spraying per crop and week. They were also asked whether they used personal...
predictive equipment such as mask, hat, gloves, shoes, glasses etc. The pesticide sprayers with experience ≤3 months were defined as short-term sprayers and coded 0 and sprayers with experience of ≥5 years were defined as long-term sprayers and coded 1. Thus, exposure variables included: Exposure duration (short and long-term: coded 0, 1) in occupation as a sprayer, age, spray frequency per week, spray frequency per crop, litres of pesticides applied per acre (as continuous variables). The responses whether the sprayer used protective devices were either no or yes which were coded as 0 or 1 respectively. The outcome variables were responses about self-reported symptoms clinically classified as peripheral neurological, visual/sight, dermatological/skin, respiratory and reproductive/sexual health disorders as dichotomous choices. After descriptive univariable and bivariable group comparisons using a student t-test for continuous variables and the chi square test for categorical variables, finally, a multivariable logistic regression was performed to statistically adjust for age as a potential confounding variable along with exposure duration to predict selected possible pesticide induced disease (0=absent; 1=present). The variables included in the model as predictors were age, exposure duration, spray history, litres of pesticides applied per acre, frequency of spray per crop and per week. All statistical analyses were performed using Stata v12 (SE 11 for Windows, StataCorp LP, College Station, TX).

Results

Respondent characteristics, pesticide use and potential exposure

The interviewed 157 men sprayers were at an average of 24 years (range 18-30), with 51.6% (81) from Ngarenanyuki (tomato farms) and 48.4% (76) from Mangóla (onion farms). About two third, 62.6% (97) were short-term exposed sprayers and 37.4% (58) were long-term sprayers. The mean age of the short-term exposed group was 22.7 ± SD of 3.9 and 25.5 ± SD of 3.4 years (p<0.01) for long-term sprayers. Out of 60 interviewed long-term sprayers, information about duration in occupation for two individuals was missing; they were therefore removed from analysis. The long-term exposed sprayers applied significantly more pesticides per acre per spray visit (p=0.005; mean 720 l) compared to the short-term exposed sprayers (mean 580 l). However, the long-term exposed group had significantly (p<0.001) lower mean frequency (mean 7 times versus 10) of spraying per crop during the growing season, whereas the difference of spray frequency per week was not significant between the two groups as shown in Table 1.

Applied pesticides including organophosphates, carbamates, pyrethroids were mainly class II, WHO hazard classification. More than 20% of the sprayers also used the internationally banned organochlorine endosulfan (https://en.wikipedia.org/wiki/Stockholm_Convention_on_Persistent_Organic_Pollutants). Furthermore, application of fungicides included triazoles (triadimefon), dithiocarbamates (mancozeb) and organochlorine (chlorothalonil). About half (49.4%), more than three quarters (85.1%) and about a quarter (23.4%) of the sprayers applied triadimefon, mancozeb and chlorothalonil among tomato sprayers respectively either single or combined formulation. At times they used the same ingredients in one container due to different brand names. The majority of the sprayers reported that they used to mix several pesticides for spraying and that more than 90% wore no personal protective devices at work. Table 2 shows the applied pesticides by brand names, active ingredients, mechanisms of action and the number and percentages of users. When asked to discriminate the pesticides they used, 12/157 (7.6%) and 28/138 (20.3%) of sprayers misclassified by giving incorrect responses between insecticides and fungicides respectively. Furthermore, 135/155 (87.1%) and 145/157 (92.4%) reported that they did not use any personal protective equipment for head and trunk skin, respectively.

Self-reported disease symptoms

Symptoms related to respiratory disease such as wheezing and coughing were the most frequently reported (46/157; 29.3%). In addition, peripheral neurological, sight, skin, heart and sexual health symptoms were reported by 5.1%, 15.3%, 17.2%, 5.1% and 6.4% respectively. Table 3 summarizes the multivariable logistic regression odds ratios (OR) and CI 95%. The logistic regression analyses showed that peripheral neuropathy (OR=7.7; CI95%; 1.05-56.7) and respiratory disorders (OR=0.2; 0.07-0.50) were significantly higher in sprayers with short-term exposure to pesticides compared to those with long-term exposure. The sight problem was significantly associated with quantity of pesticides a sprayer applied (OR=1.03; 1.01-1.07). Furthermore, 10 respondents, all of them from long-term exposed sprayers reported that they had sexual function problems, mainly erectile dysfunction and lack of libido. In particular, eight reported poor libido and erection as the problems whereas two of the respondents declined to specify their sexual function problem during the interview. Using exact logistic regression the results show a significant prediction of exposure duration on having a sexual health problem (OR=20.0; 3.1-infinity) among long-term exposed sprayers.

Although skin and heart related symptoms were not significantly different between the two exposure groups the level of skin problems was high in both the short-term and long-term exposed sprayers. The percentage of skin problems among the short-term exposed sprayers was 15.0% whereas the percentages for the long-term exposed was 20.7%. The occurrence of heart related symptoms were 3.1% short-term and 8.6% long-term exposed sprayers. A significantly (p=0.048) higher proportion (18/58; 31%) of the long-term exposed sprayers reported two or more pesticide disease conditions compared to (14/97; 14%) among short-term exposed sprayers. The majority of the short-term exposed sprayers were either free from any disease symptoms or had one (83/97; 86%) disease condition compared to long-term exposed sprayers (40/58; 69%) during the study period.

More than a quarter (26.2%, 32/122) of sprayers discretionally considered pesticides to influence the adverse health effects occurrence. The majority (91.6%; 141/154) of sprayers either agree or strongly agree that long-term exposure to pesticides might have long-term health effects to applicators as detailed in the Table 4. Table 5 shows the distribution of yes and no responses of the six pesticide induced disease conditions and their recurrence statuses among the two comparison groups. Peripheral neurologic and sexual health problems were significantly higher in the long-term exposed sprayers compared to short-term sprayers except for respiratory problems which were higher in the short-term exposed sprayers. However, the differences of sight, skin, and heart symptoms were not significant among the two groups of exposure duration.

Self-reported disease condition recurrences

When those who reported peripheral neurologic and sight problems were asked about recurrence of their condition, more recurrence was shown in the long-term compared to short-term exposed sprayers, with 87.5% compared to 12.5% for peripheral neurologic problems whereas 92.3% compared to 7.7% for sight problems. Among those who reported respiratory problems, a more recurrence was shown in the short-term exposed (64%) compared to long-term exposed sprayers (36%).
### Table 1a. Frequency distribution of exposure groups, exposure history, practice characteristics of sprayers

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number (n) of respondents</th>
<th>Category variable</th>
<th>Number of counts (%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure duration</td>
<td>155</td>
<td>≤ 3 months</td>
<td>97 (62.6)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 5 years</td>
<td>58 (37.4)</td>
<td>N/A</td>
</tr>
<tr>
<td>Have you been working as a pesticide sprayer in the farms before coming to this area?</td>
<td>155</td>
<td>No</td>
<td>135 (87.1)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>20 (12.9)</td>
<td>N/A</td>
</tr>
<tr>
<td>How many knapsacks of pesticides do you usually apply per acre every time you spray?</td>
<td>156</td>
<td>≤ 375 litres</td>
<td>78 (50)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 375 litres</td>
<td>78 (50)</td>
<td>N/A</td>
</tr>
<tr>
<td>How many times is the crop sprayed from planting till harvest?</td>
<td>156</td>
<td>&lt; 11 times/crop</td>
<td>79 (50.6)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 12 times/crop</td>
<td>77 (49.4)</td>
<td>N/A</td>
</tr>
<tr>
<td>How many times do you usually expose yourself through mixing, loading and spraying in a week?</td>
<td>152</td>
<td>≤ 2 times/week</td>
<td>141 (92.8)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 3 times/week</td>
<td>11 (7.2)</td>
<td>NA</td>
</tr>
<tr>
<td>Do you protect yourself by wearing PPD against inhaling (nose, mouth) pesticide when mixing, loading and spraying?</td>
<td>155</td>
<td>No</td>
<td>135 (87.1)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>20 (12.9)</td>
<td>N/A</td>
</tr>
<tr>
<td>Do you protect yourself by using wearing PPD against touching (hands, face/head, foot and trunk) pesticide when mixing, loading and spraying?</td>
<td>157</td>
<td>No</td>
<td>145 (92.4)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>12 (7.6)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**1b. Practice characteristics of new entry and long-term exposed sprayers compared (bivariate analysis)**

<table>
<thead>
<tr>
<th>Categorized variables</th>
<th>Number (n) of respondents</th>
<th>≤ 3 months n (%)</th>
<th>≥ 5 years n (%)</th>
<th>p value</th>
</tr>
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<tr>
<td>Apply ≤ 375 litres per acre (n=78)</td>
<td>61 (78.21)</td>
<td>17 (21.79)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Apply &gt; 375 litres per acre (n=76)</td>
<td>35 (46.05)</td>
<td>41 (53.95)</td>
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<tr>
<td>Spray frequency per crop ≤11 (n=77)</td>
<td>33 (42.86)</td>
<td>44 (57.14)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Spray frequency per crop ≥12 (n=77)</td>
<td>63 (81.82)</td>
<td>14 (18.18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray frequency per week ≤2 (n=139)</td>
<td>89 (64.03)</td>
<td>50 (35.97)</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Spray frequency per week ≥3 (n=11)</td>
<td>5 (45.45)</td>
<td>6 (54.55)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No mouth protection when spraying (n=133)</td>
<td>84 (63.16)</td>
<td>49 (36.84)</td>
<td>0.785</td>
<td></td>
</tr>
<tr>
<td>Protect mouth when spraying (n=20)</td>
<td>12 (60)</td>
<td>8 (40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No skin-trunk protection when spraying (n=143)</td>
<td>90 (62.94)</td>
<td>53 (37.06)</td>
<td>0.752</td>
<td></td>
</tr>
<tr>
<td>Protect skin-trunk when spraying (n=12)</td>
<td>7 (58.33)</td>
<td>5 (41.67)</td>
<td></td>
<td></td>
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</table>

1 knapsack = 15 litres of pesticides; PPD = Personal protective devices

### Table 1b. Practice characteristics of new entry and long-term exposed sprayers compared (bivariate analysis)

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<tr>
<th>Categorized variables</th>
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1 knapsack = 15 litres of pesticides; PPD = Personal protective devices

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**Table 1**: Exposure history, characteristics of study respondents and their occupational practice as sprayers
<table>
<thead>
<tr>
<th>Pesticide type (activity)</th>
<th>Brand name known by users</th>
<th>Active ingredients</th>
<th>Chemical classification name</th>
<th>Mechanism of action</th>
<th>Pesticide mentioned and used n (%)</th>
<th>Use of pesticide category aggregate* in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onion list of pesticides as mentioned by sprayers (users=76)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td>Marshal 250EC</td>
<td>Carbosulfan</td>
<td>Carbamate</td>
<td>Neurotoxin, inhibition of acetylcholinesterase (reversible)</td>
<td>75 (98.7)</td>
<td>98.7</td>
</tr>
<tr>
<td>Insecticide</td>
<td>Selectron 720EC</td>
<td>Profenofos</td>
<td>Organophosphate pesticides</td>
<td>Neurotoxin, inhibition of acetylcholinesterase (irreversible)</td>
<td>22 (29.5)*</td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td>Dursban 24ULV</td>
<td>Chlorpyrifos</td>
<td>Organophosphate pesticides</td>
<td>Neurotoxin, inhibition of acetylcholinesterase (irreversible)</td>
<td>4 (5.3)*</td>
<td>38.8</td>
</tr>
<tr>
<td>Insecticide</td>
<td>Bamiphos 500EC</td>
<td>Pirimiphosmethyl</td>
<td>Organophosphate pesticides</td>
<td>Neurotoxin, inhibitor of acetylcholinesterase (irreversible)</td>
<td>3 (4.0)*</td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td>Thionex 35EC</td>
<td>Endosulfan</td>
<td>Organochlorine</td>
<td>Neurotoxin, inhibitor of GABA gated chloride channel receptor (preventing chloride flux across membranes) thereby paralyzing the organism</td>
<td>7 (9.2)**</td>
<td>17.2</td>
</tr>
<tr>
<td>Insecticide</td>
<td>Karate 5CS, Decis 25EC, Ngao</td>
<td>Lambda-cyhalothrin, Deltamethrin,</td>
<td>Pyrethroids</td>
<td>Neurotoxin, axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes</td>
<td>4 (5.3)***</td>
<td>73.8</td>
</tr>
<tr>
<td>Acaricide and insecticide</td>
<td>Dipu (Alfanex 10%EC and Alphaguard 0.8ULV)</td>
<td>Alpha-cypermethrin</td>
<td>Pyrethroids</td>
<td>Neurotoxin, axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes</td>
<td>3 (4.0)***</td>
<td></td>
</tr>
<tr>
<td>Combined insecticides</td>
<td>Pyrolton P 440EC, Duduba 450EC</td>
<td>Profenofos + cypermethrin, Chlorpyrifos +cypermethrin</td>
<td>Organophosphate pesticides plus pyrethroids</td>
<td>Neurotoxin, inhibition of acetylcholinesterase (irreversible), plus neurotoxin, axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes</td>
<td>18 (23.7)*</td>
<td>64.5</td>
</tr>
<tr>
<td>Combined fungicide</td>
<td>Banko Plus</td>
<td>Chlorothalonil + Carbendazim</td>
<td>Organochlorine</td>
<td>Multisite inhibitor of enzymes and metabolic processes (reduces intracellular glutathione molecules to alternate forms)</td>
<td>6 (8.0)**</td>
<td>8.0</td>
</tr>
<tr>
<td>Tomato list of pesticides as mentioned by sprayers (users=81)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td>Selectron 720EC</td>
<td>Profenofos</td>
<td>Organophosphate pesticides</td>
<td>Neurotoxin, inhibitor of acetylcholinesterase (irreversible)</td>
<td>5 (6.2)*</td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td>Dursban 24ULV, Twigs phosph 48EC</td>
<td>Chlorpyrifos</td>
<td>Organophosphate pesticides</td>
<td>Neurotoxin, inhibitor of acetylcholinesterase (irreversible)</td>
<td>23 (28.4)*</td>
<td>76.5</td>
</tr>
<tr>
<td>Insecticide, acaricide</td>
<td>Dume 40EC, Twigathoate 40EC</td>
<td>Dimethoate</td>
<td>Organophosphate pesticides</td>
<td>Neurotoxin, inhibition of acetylcholinesterase (irreversible)</td>
<td>6 (7.4)*</td>
<td></td>
</tr>
<tr>
<td>Insecticide, acaricide</td>
<td>Thionex 35EC</td>
<td>Endosulfan</td>
<td>Organochlorine</td>
<td>Neurotoxin, inhibits GABA gated chloride channel receptor (preventing chloride flux across membranes) thereby paralyzing the organism</td>
<td>6 (7.4)**</td>
<td>30.8</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>---------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>Insecticide</td>
<td>Ninja 5EC, Karate 5CS</td>
<td>Lambda-cyhalothrin</td>
<td>Pyrethroid</td>
<td>Neurotoxin, axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes</td>
<td>18 (22.2)***</td>
<td>64.2</td>
</tr>
<tr>
<td>Insecticide, acaricide, nematicide</td>
<td>Abamectin 20EC, Vertigo 1.8EC</td>
<td>Abamectin</td>
<td>Avermectin</td>
<td>Neurotoxin, stimulates the release and binds gamma-aminobutyric acid (GABA) at nerve endings thereby causing irreversible paralysis of the neuromuscular systems</td>
<td>51 (63.0)</td>
<td>63.0</td>
</tr>
<tr>
<td>Insecticide, acaricide</td>
<td>Appolo</td>
<td>Clofentezine</td>
<td></td>
<td>Inhibits embryo development, non specific mode of action (mite growth inhibitor)</td>
<td>2 (2.5)</td>
<td>-</td>
</tr>
<tr>
<td>Combined insecticides</td>
<td>Duduba</td>
<td>Chlorpyrifos + cypermethrin</td>
<td>Organophosphate pesticides plus pyrethroids</td>
<td>Inhibitor of acetylcholinesterase (irreversible) plus neurotoxin, axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes and neurotoxin,</td>
<td>13 (16.0)*</td>
<td>14 (17.3)***</td>
</tr>
<tr>
<td>Combined insecticides</td>
<td>Fenom plus, Fenom</td>
<td>Profenofos + Lambda-cyhalothrin, Profenofos + Cypermethrin</td>
<td>Organophosphate pesticides plus pyrethroids</td>
<td>Neurotoxin, inhibition of acetylcholinesterase (irreversible) plus neurotoxin, Axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes</td>
<td>2 (2.5)**</td>
<td>5 (8.2)**</td>
</tr>
<tr>
<td>Combined insecticides</td>
<td>Dudukill</td>
<td>Lambda cyhalothrin + Carbaryl</td>
<td>Pyrethroid plus carbanate</td>
<td>Neurotoxin, axonic excitoxins, by closure prevention of voltage-gated Na+ channel in axonal membranes plus neurotoxin, inhibitor of acetylcholinesterase (reversible)</td>
<td>3 (3.7)***</td>
<td>-</td>
</tr>
<tr>
<td>Fungicide</td>
<td>Bayleton 250EC</td>
<td>Triadimefon</td>
<td>Triazole</td>
<td>Triazole= inhibits the cyt P450 enzyme 14-alpha sterol-demethylase to arrest fungal growth</td>
<td>40 (49.4)</td>
<td>49.4</td>
</tr>
<tr>
<td>Fungicide</td>
<td>Bravo, Linkonil</td>
<td>Chlorothalonil</td>
<td>Organochlorine</td>
<td>Chlorothalonil= Multisite inhibitor of enzymes and metabolic processes (reduces intracellular glutathione molecules to alternate forms)</td>
<td>12 (14.8)****</td>
<td>3 (3.7)****</td>
</tr>
<tr>
<td>Fungicide</td>
<td>Antracol 70WP</td>
<td>Propinbe</td>
<td>Dithiocarbamate</td>
<td>Propinbe=Inhibits enzymes involved in lipid and protein metabolism and respiration</td>
<td>4 (4.9)****</td>
<td>-</td>
</tr>
<tr>
<td>Fungicides</td>
<td>(Milthane super, Farmerzeb, Redofl)</td>
<td></td>
<td></td>
<td></td>
<td>24 (29.6)****</td>
<td>-</td>
</tr>
<tr>
<td>Fungicide</td>
<td>Tankopa 500WP</td>
<td>Copper oxychloride</td>
<td>Multi-site inorganic copper</td>
<td>Disrupts the enzyme system function</td>
<td>3 (3.7)</td>
<td>-</td>
</tr>
</tbody>
</table>
Combined fungicides | Ebony M72, Victory 72WP, Ridomil 68WG | Mancozeb + metalaxyl Dithiocarbamate | Mancozeb=Inhibits enzymes involved in lipid and protein metabolism and respiration | 21 (25.9)**** | 2 (2.5)*** |
|---------------------|-------------------------------------|-----------------------------------|--------------------------|----------------|----------------|
Combined fungicides | Banko plus Chlortalidion + Carbendazim | Organochlorine + Benzimidazole carbamate | Chlortalidion= Multisite inhibitor of enzymes and metabolic processes (reduces intracellular glutathione molecules to alternate forms) Carbendazim=inhibits fungal mitotic microtubule formation | 4 (4.9)***** |

**Table 2:** List of commonly applied pesticides by sprayers on onion and tomato farms in Mang’ola and Ngarenanyuki respectively.

### Discussion

In the present study, self-reported peripheral neuropathy and sexual health symptoms were significantly associated with long-term pesticide exposure. In contrast, the respiratory symptoms were significantly higher in the short-term exposed compared to long-term exposed. Although no difference in sight and skin symptoms were noted at the interview time, a higher occurrence was reported by the long-term exposed when asked whether their symptoms were chronic. Although the mean age was lower in the short-term exposed group, the difference showed no significant contribution to disease occurrence when adjusted for age in the regression model. Age ranged from 18 to 30 years in both comparison groups. This reflects that long-term use and handling of pesticides increase the exposure risk and may increase...
the risk of adverse health effects. Occupational exposure to pesticides among sprayers associated with increased occurrences of disease symptoms in the study area may be predictive of a potential range of health problems beyond the results of this study.

In the present study, the disease conditions reported by pesticide sprayers including neurologic, sight, skin, heart, respiratory, reproductive and sexual health were assessed. Each disease condition was identified using a list of certain criteria of symptoms that the sprayer was able to identify. Such symptoms were numbness and or burning or tingling sensation of either hands and or feet for peripheral neuropathy [20], wheezing, cough, chest tightness [29] without feeling high body temperature as respiratory disorder, skin reaction by itching, irritation, rash, change of colour or eczematous reaction [30]. Visual performance not related to eye infection was defined as sight problem [31]. Heart problem included being diagnosed as hypertensive or any disease condition related to heart problem at hospital. When asked about whether they had experienced reproductive and sexual problems the sprayers reported no reproductive but sexual health problems, these were impotence and libido.

A variety of adverse health effects associated with pesticide exposure is reported in humans [32-34]. However, the present study was limited to a scope of six selected disease conditions that have been associated with pesticide exposure in previous reports. The present study showed that long-term exposure to pesticides increased the risk of peripheral neuropathy conditions about eight times compared to short-term exposure. This finding is in line with previous data [38,35,36] which show association between peripheral neuropathies and chronic exposure to pesticides. Furthermore, endosulfan, which is banned in many countries due to its persistence and bio-accumulative properties, was used by more than 20% of the study participants. Endosulfan together with other modern pesticides that are frequently applied in the study area are likely to induce neurotoxic as well as other toxic effects in chronically exposed humans as previously described [37-39]. Endosulfan is banned in many countries due to its persistence and bio-accumulative properties, was used by more than 20% of the study participants. Endosulfan together with other modern pesticides that are frequently applied in the study area are likely to induce neurotoxic as well as other toxic effects in chronically exposed humans as previously described [37-39]. It is well documented that the nervous system represents a key target for both acute and chronic effects of pesticides [9,20]. Groups of pesticides with known effect on the nervous system include organochlorines, pyrethroids, organophosphates and carbamates. These compounds have the potential to alter neurological functions by interacting with among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE) (organophosphates and carbamates). The AChE is essential enzyme among other mechanisms, sodium and chloride channels activity (pyrethroids) and/or inhibiting the acetylcholinesterase (AChE).

### Table 1: Association between exposure duration (short-term or long-term) and selected known pesticide induced disease conditions and whether they were recurrent.

<table>
<thead>
<tr>
<th>Disease condition (Respondents)</th>
<th>Subtotal, respondent categories</th>
<th>Response</th>
<th>Short-term exposure ≤ 3 months n (%)</th>
<th>Long-term exposure ≥ 5 years n (%)</th>
<th>p value</th>
<th>Recurrent conditions (variable)</th>
<th>Response</th>
<th>Short-term exposure ≤ 3 months n (%)</th>
<th>Long-term exposure ≥ 5 years n (%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral neurologic (n=155)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Neurologic (n=11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>147 No</td>
<td>95 (64.6)</td>
<td>52 (35.4)</td>
<td></td>
<td>0.024</td>
<td>No</td>
<td>1 (33.3)</td>
<td>2 (66.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Yes</td>
<td>2 (25.0)</td>
<td>6 (75.0)</td>
<td></td>
<td></td>
<td>Yes</td>
<td>3 (37.5)</td>
<td>5 (62.5)</td>
<td></td>
<td>0.046</td>
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<tr>
<td>Sight (n=154)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Sight (n=24)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>130 No</td>
<td>85 (65.4)</td>
<td>45 (34.6)</td>
<td></td>
<td>0.155</td>
<td>No</td>
<td>8 (88.9)</td>
<td>1 (11.1)</td>
<td></td>
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<td></td>
<td>24 Yes</td>
<td>12 (50)</td>
<td>12 (50)</td>
<td></td>
<td></td>
<td>Yes</td>
<td>3 (20.0)</td>
<td>12 (80.0)</td>
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<td>0.001</td>
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<td>Skin (n=154)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Skin (n=27)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>127 No</td>
<td>81 (63.8)</td>
<td>46 (36.2)</td>
<td></td>
<td></td>
<td>No</td>
<td>11 (68.7)</td>
<td>5 (31.3)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>27 Yes</td>
<td>15 (55.6)</td>
<td>12 (44.4)</td>
<td></td>
<td>0.537</td>
<td>Yes</td>
<td>3 (27.3)</td>
<td>8 (72.7)</td>
<td></td>
<td>0.045</td>
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<td>Heart (n=1550)</td>
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<td></td>
<td></td>
<td>Heart (n=9)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>147 No</td>
<td>94 (64.0)</td>
<td>53 (36.1)</td>
<td></td>
<td></td>
<td>No</td>
<td>2 (100)</td>
<td>0 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Yes</td>
<td>3 (37.5)</td>
<td>5 (62.5)</td>
<td></td>
<td>0.132</td>
<td>Yes</td>
<td>2 (28.6)</td>
<td>5 (71.4)</td>
<td></td>
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</tr>
<tr>
<td>Respiratory (n=155)</td>
<td></td>
<td></td>
<td></td>
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<td>Respiratory (n=44)</td>
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<td></td>
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<tr>
<td></td>
<td>109 No</td>
<td>62 (56.9)</td>
<td>47 (43.1)</td>
<td></td>
<td></td>
<td>No</td>
<td>15 (79.0)</td>
<td>4 (21.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>46 Yes</td>
<td>35 (76.1)</td>
<td>11 (23.9)</td>
<td></td>
<td>0.024</td>
<td>Yes</td>
<td>18 (72.0)</td>
<td>7 (28.0)</td>
<td></td>
<td>0.139</td>
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<tr>
<td>Sexual health (n=154)</td>
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<td></td>
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<td>Sexual health dysfunction (n=154)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>146 No</td>
<td>97 (66.4)</td>
<td>49 (33.6)</td>
<td>&lt; 0.001</td>
<td></td>
<td>NA</td>
<td>97 (66.4)</td>
<td>49 (33.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Yes</td>
<td>0 (0)</td>
<td>8 (100)</td>
<td></td>
<td></td>
<td>Impotence</td>
<td>0 (0)</td>
<td>4 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If the condition is long-term (at least 3 months), If Yes, how long do you have this problem till now? (n=122)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Loss of libido</td>
<td>0 (0)</td>
<td>4 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>111 No</td>
<td>69 (62.2)</td>
<td>42 (37.8)</td>
<td></td>
<td></td>
<td>NA</td>
<td>97 (66.4)</td>
<td>49 (33.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 Yes</td>
<td>2 (18.2)</td>
<td>9 (81.8)</td>
<td></td>
<td>0.005</td>
<td>Impotence</td>
<td>0 (0)</td>
<td>4 (100)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pearson chi² and Exact tests applied accordingly, significant/different at p=0.05, where NA=Not applicable.
problems among the long-term exposed may be explained by adaptation and tolerance. Salameh et al. [40] showed that inhalation of pesticides induced irritation of the airways causing acute mucosal hyperactivity. However, individuals undergoing chronic exposure to the same irritants may develop tolerance by desensitizing the airways [41,42]. This could further be explained by cross-desensitization of reactive irritants to each other's ability to initiate respiratory defensive responses [42]. For example, rats chronically exposed to formaldehyde vapours developed reduced respiratory responses to subsequent exposures to acetaldehyde, and vice versa [43]. A suggested explanation for this phenomenon is that sensory neurons contain a single reactive irritant receptor site. Once this receptor site is saturated through exposure to an irritating chemical, it is rendered unresponsive to subsequent exposures by the same, or other, irritants [42].

The present study showed that exposure to modern pesticides including endosulfan for several years is associated with sexual health problems expressed in form of impotence and loss of libido. These findings are in line with previous reports [14,44] in which individuals that were regularly exposed to carbamates and endosulfan reported reproductive and erectile dysfunction. In addition, Burnett [45] in his review reports increased erectile dysfunction and loss of libido in men exposed to a variety pesticides [46,47].

In a British study, impaired erectile function in four farm workers, who had used pesticides for over a 1-year [48] was documented. Pesticides including OPs were identified as harmful agents and it was suggested that these chemicals disrupted testosterone metabolism [49]. An interesting observation was that all four men recovered upon each other's ability to initiate respiratory defensive responses [42]. For example, rats chronically exposed to formaldehyde vapours developed reduced respiratory responses to subsequent exposures to acetaldehyde, and vice versa [43]. A suggested explanation for this phenomenon is that sensory neurons contain a single reactive irritant receptor site. Once this receptor site is saturated through exposure to an irritating chemical, it is rendered unresponsive to subsequent exposures by the same, or other, irritants [42].

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improvements during this time period.

Several limitations of the present study should be noted. Because of limited resources, we had to restrict the present number of participants. The use of self-report data to assess disease condition may be inaccurate because the study participants might report what they believe reflects positively on their own abilities, knowledge or opinions. Another question is whether subjects are able to accurately recall past experiences. Furthermore, a cross sectional study design upon which these results are based is relatively weak in establishing causal effect relationship, hence weak evidence for causality. A detailed well designed study may disclose additional and more important biological information. However, despite the study limitations, the data obtained in the present study suggest association between increased risk of various disease conditions and long-term exposure compared to short-term. Furthermore, the observation of high levels of respiratory and skin problems among both long-term and short-term exposed sprayers, suggest increased risk of this disease conditions regardless of exposure time.

Conclusions
Safe pesticide use and handling including use protective measures were limited in the study area. In addition, unsafe practice with pesticides increases exposure risk and the occurrence of self-reported adverse effect. The higher levels of self-reported adverse health effects are observed among long-term compared to short-term exposed individuals. Chronic exposure to pesticides is more harmful to human health as compared to short-term exposure. Although the present study was typically focusing on sprayers in rural setting of Tanzania it applies to all exposed to pesticides including consumers of the farm produces and family members of farm workers. The data obtained in the present study will assist in new hypothesis formulation and new studies aiming to address more accurately the causality between unprotected pesticide use and adverse health effects among people at risk.

Competing Interests
We declare that, there are neither financial nor non-financial competing interests.

Acknowledgements
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References
Biomonitoring of organophosphate exposure of pesticide sprayers and comparison of exposure levels with other population groups in Thessaly (Greece). Occup Environ Med; 71: 126-133.


