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Respiratory and non-respiratory symptoms associated with pesticide management practices among farmers in Ghana's most important vegetable hub

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Abstract The data presented here are from the Offinso North District Farm Health Study (ONFAHS), a population-based cross-sectional study among vegetable farmers in Ghana. The paper addresses knowledge, pesticide handling practices, and protective measures related to pesticide use by self-reported symptoms for 310 adult farmers who completed a comprehensive questionnaire on pesticide management practices and health. In addition, an inventory was prepared using information supplied by pesticide sellers/dealers in this district. We report that cough and wheezing (but not breathlessness) are positively associated with stirring pesticide preparations with bare hands/drinking water while mixing/applying pesticides, and stirring pesticide

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preparations with bare hands/drinking water/smoking cigarettes while mixing/applying pesticides. There is a significant exposure-response association between the number of precautionary measures practiced while handling pesticides and cough and wheezing but not with breathlessness. We also found unsafe practices to be associated with sexual dysfunction, nervousness, and lack of concentration. The results also suggest a negative association between practice of any precautionary measure when mixing/applying pesticides and sexual dysfunction, nervousness, and lack of concentration. We found that in spite of the fact that farmers have adequate knowledge about the environment and health effects of pesticides, several unhygienic practices are in widespread use, indicating that knowledge is not necessarily always translated in action. Further action is necessary to promote the safe use of pesticides and to replace existing poor management practices among these and other farmers in Ghana.

Keywords Farms · Ghana · Pesticide handling · Safety · Vegetable farmers · Symptoms

Introduction

Synthetic pesticides are efficacious and have contributed substantially to achieving higher crop yields in developed and developing countries (Tago et al. 2014). As a result, synthetic pesticides are widely applied by vegetable farmers in low- and middle-income countries (LMIC) to control plant and insect infestations to help optimize crop yield (Williamson et al. 2008). Deficiencies in the way in which these pesticides are used (preparation for use, application, disposal of unused pesticide and pesticide containers) are linked to the degree of hazard to farmers. Practices including storage of pesticides at home or beside foodstuffs (Karunamoorthi et al. 2011), mixing pesticides with the hands, tasting pesticide mixtures to determine pesticide strength, blowing the nozzle of a knapsack sprayer with the mouth to clear, and the use of old pesticide containers to store water and food are potential sources of unintended pesticide exposure to farmers (Khan and Damalas 2015; Gesesew et al. 2016). Other sources of unintended exposure to pesticides include spills and splashes and direct spray as a result of faulty or missing protective equipment (Negatu et al. 2016). Several studies have also linked knowledge, attitude, and behavior to the risk of pesticide exposure, but results are mixed (Fan et al. 2015). Whereas some studies have shown that good knowledge and favorable attitudes toward pesticide use do not always translate into good pesticide management practices (e.g., Mohanty et al. 2013; Jors et al. 2014; Bagheri et al. 2018; Kongtip et al. 2018), others have shown otherwise (e.g., Fan et al. 2015; Yuantari et al. 2015). Achieving a low grade on a knowledge score or moderate on a personal hygiene score is associated with symptoms related to the central nervous and gastrointestinal systems and abnormal decreased cholinesterase (ChE) levels in Iranian farmers (Sharafi et al. 2018). Among farmers in Tanzania, Iran, Kuwait, and China, lack of knowledge about the risk associated with pesticide use and lack of training were related to irritation of the eyes, skin, throat, and nose, as well as headache and flu-like symptoms (Wang et al. 2017; Bagheri et al. 2018). Improper use, management, and/or disposal of pesticides contributed significantly to pesticide poisoning among Ethiopian (Karunamoorthi et al. 2012; Gesesew et al. 2016), Ugandan (Oesterlund et al. 2014), and Pakistani farmers (Khan and Damalasn 2015). Yassin et al. (2002) assessed knowledge, attitude, practice, and toxicity symptoms associated with pesticide use among farm workers in the Gaza Strip. Farmers were aware of the protective measures to use during pesticide application, but virtually none of them took the necessary precautions. The prevalence of self-reported toxicity symptoms was associated with mixing of pesticides and using high concentrations of these toxic chemicals. A high degree of self-reported toxicity symptoms was found among farmers who returned to sprayed fields within 1 h after applying pesticides.

In Ghana, changes in consumer taste, yield, and the demand for vegetables, particularly to feed the growing urban population has increased the use of synthetic pesticides to manage and control diseases affecting vegetables (Dinham 2003). A large proportion of vegetable farmers in Ghana have minimal education and lack literacy necessary for understanding safe handling and management of pesticide practices described on product labels (Ntow 2001). Many of the pesticides they apply to their crops are classified as Class II (moderately hazardous) by the World Health Organization (WHO) although a few others are WHO Class III (slightly hazardous). Some farmers continue to apply persistent or very toxic banned pesticides, including aldrin, dieldrin, endosulfan, lindane, DDT, and methyl bromide and these chemicals have been identified in human fluids, vegetables, and the environment (Fosu-Mensah et al. 2016; Quansah et al. 2016; Darko and Acquaah 2008; Bruce-Vanderpuije et al. 2019). So while farmers have openly embraced the use of pesticides, few have the knowledge to properly handle these toxic chemicals. Consequently, understanding farmers' knowledge and behavior regarding pesticide management practices is critical to attenuating both environmental contamination and public health problems in Ghana. An inventory of pesticides for specific vegetables used by farmers in the most important vegetable growing areas in Ghana is also lacking.

The present study builds on previous work regarding the knowledge and practices associated with pesticide use in Ghana by Ntow et al. (2006). This paper focuses on handling practices and protective measures related to pesticide use and self-reported symptoms in a cohort of vegetable farmers in the Offinso North Farm Health Study (ONFAHS) in Ghana. Offinso North is one of the most important vegetable growing hubs in Ghana and is the closest to the largest vegetable market in Ghana (Ntow et al. 2001).

Methods

Study setting

The subjects for this study are participants in the ongoing Offinso North District Farm Health Study (ONFAHS). The Offinso North District is about 95 km north-west of the Ashanti region. It is a major vegetable farming community in Ghana, cultivating tomatoes, okro, pepper, as well as garden eggs. The district lies in the transitional zone of Ghana which has two (2) rainfall seasons. The major rainfall season occurs from April to July, with a shorter dry season in August. The minor rainfall season runs from September through October. A detailed description of the study area is reported elsewhere (Quansah et al. 2016). The district is divided into 3 geographical zones by agriculture extension services to facilitate their operations. Each zone is normally overseen by agriculture extension officers who provide technical support to the farmers. Each zone includes a major farming community and surrounding villages. The zonal communities are Akumadan, Nkenkenso, and Afrancho. The population of the Offinso North district is 25,000 of whom about 85% are directly involved in farming. Farmers in the Offinso North district are known to use pesticides or are exposed to pesticides more than any other farming communities in Ghana (Ntow et al. 2001; Quansah et al. 2016).

Study design and participants

The ONFAHS is a population-based cross-sectional study divided into 2 phases. The objective of phase I is to understand pesticide handling and management practices, pesticide exposure experience, and disease burden among farmers, their spouses, and their children under 5 years of age. Data collection in phase I applied a convenient sampling framework over a period of 3 months, from May to July 2016. Participants completed a comprehensive questionnaire about their work. In addition, samples of vegetables, plant parts, soil, and urine were collected from each geographical zone and sent to a Ghana Standards Authority laboratory for analysis.

To begin, the research team had a meeting with community elders, the Offinso North District Director for Agricultural Extension Services, a representative from the office of the Municipal Chief Executive, local farmers' representatives and local agricultural extension officers (total of 15 individuals). The relevance of the project and the overall goal of ONFAHS (i.e., phases 1 and 2) were explained to them. Permission to carry out the project in these communities was received from the Ghana Health Services Review Board. Following this meeting, a second meeting was organized with the 6 local agriculture extension officers who were to serve as research assistants on the project. In this meeting, a detailed plan and timelines for the project were discussed. We provided training on how to (i) conduct interviews, (ii) administer questionnaires, (iii) observe research ethics, (iv) keep records of forms and questionnaires, and (v) observe quality control issues relating to sampling and sampling storage to these team members. Each of the agriculture extension officers was provided an honorarium of $ 70.00 (USD).

Because farmers in the community leave home for their farm early in the morning (around 06:00), we applied a convenient sampling strategy. Trained agricultural extension officers in each geographical zone invited households to take part in the study after its objectives were explained to them. Selection of households was based on a priori eligibility criteria which included: (i) presence of a man and/or a woman who is above 18 years of age in the household; (ii) the man and/or the woman reside permanently in the study area and at least one of them is a father or mother; (iv) both the man and/or the woman have a biological child who is below 5 years of age; and (v) the man and/or the woman is willing to follow the study protocol and complete the study. In a household where there is more than one family, we randomly selected one family who met our eligibility criteria. A family is defined here as parents and a child. In all, data were obtained for 930 individuals including 310 children under 5 years of age and their parents in 310 households. The current analysis included questionnaire data of 310 adults who indicated that they were farmers. Informed consent was obtained from parents and informed assent for children was obtained from parents on behalf of the children.

Data collection

Parents were interviewed with a 50-min slightly modified version of a questionnaire used in previous studies (LaVerda et al. 2015; Quansah et al. 2016) by trained local agricultural extension officers. Questions on sociodemographic factors included age, marital status, gender, cooking fuel type, and level of education. The questionnaire captured information on lifestyle factors including questions about alcohol drinking and smoking. Questions were also asked about pesticide hygiene practices including whether or not the farmer changes into clean clothes after mixing/applying pesticides; in the event of a pesticide spill on clothes, whether or not the farmer changes into new clothes immediately; whether or not the farmer works with the same pair of gloves over and over again; whether or not the farmer mixes pesticides with bare hands; and whether or not the farmer eats/drinks/smokes while applying pesticides. There were also questions on precautionary measures taken by a farmer, such as the use and type of protective equipment used (boots, hat, dust mask, full face shield, and/or chemical resistant gloves). Questions were also asked about individual farmer's knowledge about the potential adverse effects of pesticides on their health and the environment. Questions included whether or not the farmer thinks pesticide use/exposure has an adverse effect on health; whether or not the farmer is aware that pesticide(s) residues in produce could affect consumer's health; and whether or not the farmer is aware that pesticides could have a detrimental effect on the components of the ecosystem, such as soil and aquatic vertebrates and invertebrates. Questions about respiratory conditions and ailments were added, including whether or not individuals experienced coughing, wheezing, and breathlessness during or shortly after handling pesticides. With respect to respiratory symptoms, farmers also were asked whether they had ever experienced coughing, wheezing, and breathlessness. Non-respiratory symptom questions included sexual performance in males, general body pain, and decreased concentration.

Determinants of interest

The main determinants of interest included (i) indulgence in any unhygienic practice(s) while mixing/applying pesticides; (ii) any precautionary measures used while mixing/applying pesticides; and (iii) any knowledge on the effects of pesticides on human health and the environment. Indicator variables were included to measure (iv) a hygiene practices score (defined as indulgence in > 3 unhygienic practices while mixing/applying pesticides; inclusion of 1 or 2 unhygienic practices while mixing/applying vs practices of good personal hygiene while mixing/applying pesticides; and (v) a safety practices score (defined as taking 1 safety precaution while mixing/applying pesticides, taking 2 safety precautions while mixing/applying pesticides, or taking no (0) safety precaution while mixing/applying pesticides vs taking 3 or more safety precautions while mixing/applying pesticides). We also considered mixing pesticides with bare hands, eating while mixing/applying pesticides, drinking while mixing/applying pesticides, and smoking while mixing/applying pesticides because these were considered important exposure pathways associated with our outcomes of interest.

Health outcomes

The main health outcomes are self-reported respiratory and non-respiratory symptoms. Respiratory symptoms include cough, wheezing, and breathlessness 2 weeks prior to the study, while non-respiratory symptoms included sexual impotence, depression, general body weakness, and decreased mental concentration.

Confounders

Potential confounders include gender, age, marital status, cooking fuel type, and zone of community.

Selection of these variables was based on literature and their significant association with the outcomes of interest at $p < 0.05$.

Statistical analysis

We computed proportions for categorical variables. First, we applied generalized linear models (SAS PROC GENMOD) with binomial distribution and log link function to assess the potential association between any personal hygiene practices and any precautionary measures adopted while mixing/applying pesticides and each of the health outcomes (Barros and Hirakata 2003; Zhang and Yu 1998). We constructed separate models for each determinant of interest to test for the association with cough, wheezing, or breathlessness. Second, we assessed the potential exposure-response relationships between the hygiene practices score and the safety practices score and respiratory and non-respiratory symptoms, and we also tested for trend. We controlled for potential confounders. The relationship between knowledge of the environment and health effects of pesticides with our outcomes of interest was indirect and we did not explore this association. Prevalence ratio (PR) was the effect measure (Quansah et al. 2016; Zoccheti et al. 1997). The analysis was performed with the SAS statistical software package (SAS, version 9.3, SAS Institute, Cary, NC).

Results

Characteristics of study population

The mean age of the study population was 44.4 years (standard deviation = 7.5 years). The characteristics of the study population of farmers are listed in Table 1.

The majority of the farmers were males (74.5%), married/cohabitating (85.5%), had never been to school (58.4%), use high-pollution fuels such as wood for cooking at home (93.4%), drink alcohol (74.5%) or smoke cigarettes (83.9 %), farm on land with size below 6 acres (35.2%), have worked as a farmer for less than 12 years (26.8%) or up to 17 years (25.8%), and earned an average annual income below (32.6%) GHS 4500 ($ 1021 USD).

Table 1 Sociodemographic characteristics of study population in the Offinso North Farm Health study (ONFAHS) (n = 310)

Characteristics of study population	*n*	%
Gender		
Male	231	74.5
Female	79	25.5
Age		
≤ 30	15	4.8
30–40	75	24.2
40–50	167	53.9
≥ 50	53	17.1
Marital status		
Married/cohabiting	265	85.5
Single/separated/divorced/widowed	45	14.5
Cooking fuel type		
High-pollution fuel (e.g., wood, cow dung)	290	93.6
Medium-pollution fuel (e.g., stacking of wood/charcoal and LPG)	11	3.4
Low-pollution fuel (e.g., LPG)	9	3.0
Level of education		
Have not attended any school	181	58.4
JHS/middle school/primary school	110	35.5
SHS/secondary school/vocational or technical education	19	6.1
Smoking habit		
Never smoked	23	7.4
Past smoker	27	8.7
Current smoker	260	83.9
Drinking habit		
Never drank	31	10.0
Past drinker	48	15.5
Current drinker	231	74.5
Work shift		
Full-time	214	69.5
Part-time	94	30.5
Missing	2	
Size of land farmed (acres)		
≤ 6	109	35.2
6–9	52	16.8
9–12	54	17.4
≥ 12	95	30.6
Duration of employment (year)		
< 12	83	26.8
12–17	80	25.8
17–22	72	23.3
> 22	75	24.1

Table 1 (continued)

Characteristics of study population	*n*	%
Average annual income (GHS)		
≤ 4500	101	32.6
4500–6500	64	20.7
6500–15000	81	26.1
≥ 15000	64	20.6
Zonal communities		
Akumadan	150	61.3
Nkenkenso	95	30.7
Afrancho	65	21.0

Nature and scope of pesticides used by farmers

The nature and scope (chemical family, category, active ingredient) of the pesticides represented on the market in the study area are shown in Table 2.

The chemical family indicates more than 20 broad groups some of which are a combination of two distinct groups. There are about five pesticide categories (insecticides, fungicides, nematicides, herbicides, surfactants/additives). Regarding hazard classes, most of the pesticides were either in WHO Class II (moderately hazardous) or Class III (slightly hazardous). The oral acute LD_{50} of a Class II pesticide is 50–2000 mg/kg, and that of a Class III pesticide is greater than 2000 mg/kg (WHO 2009).

Personal hygiene, protective measures, and knowledge of the health and environmental effects of pesticides among farmers

Most farmers drank water (89.4%), smoked cigarettes (74.2%), or ate (64.8%) while mixing/applying pesticides and did not change into new clothes after applying/mixing pesticides (98.4%), did not change into new clothes after spilling pesticides on their clothes (89.4%), or worked with the same glove(s) all the time (73.9%) (Table 3).

We also solicited information from farmers about protective measures taken while handling pesticides and the majority, about 48.4% indicated wearing boots, 51.6% using a hat, whereas very few used a full-face shield (1.0%) or disposable outer clothing (2.3%). Most of the farmers surveyed were also aware that pesticides can remain in the soil for extended periods of time (62.8%) and can affect the natural environment (62.6%). About one-quarter (24.8%) knew that pesticides can adversely affect human health, 21.5 % of the farmers knew that pesticides can affect fish and other species in water bodies and 23.4% knew that residues of pesticides in vegetables can affect consumer health (Table 3).

The knowledge of farmers regarding the use of protective measures to protect against the adverse effects of handling pesticides is shown in Table 4. Farmers who were aware of the environmental and health effects of pesticides were more likely to wear boots ($p < 0.001$) and use hats ($p = 0.0047$) compared to those who had no awareness of these factors.

Prevalence of respiratory and non-respiratory symptoms

The most common respiratory symptoms among farmers were chronic wheezing (38.7%) and chronic cough (36.8%) (Table 5).

With respect to non-respiratory symptoms, general body weakness was common (82.9%). Farmers also reported symptoms of nervousness (27.7%), sexual dysfunction (21.0%), and loss of concentration (12.6%) (Table 5).

Association between personal hygiene practices and respiratory and non-respiratory symptoms among farmers

Farmers who indulged in any of the personal unhygienic practices that were evaluated were at risk of coughing (Prevalence ratio (PR) = 2.12, 95% CI 1.61–2.80) and wheezing (2.38, 1.15–4.91), but not breathlessness. Farmers who stirred pesticides with bare hands were at risk of cough (1.96, 1.32–2.90) and wheezing (2.01, 1.05–4.13), but not breathlessness. Those who stirred pesticides with bare hands/and drank water while handling pesticides were also at risk of cough (2.50, 1.30–4.80) and wheezing (3.51, 1.44–8.60), but not breathlessness. Stirring pesticides with bare hands and eating food and drinking water while handling pesticides increased the risk of cough (2.20, 1.67–2.89) and wheezing (2.87, 1.35–6.07), but not breathlessness. Stirring pesticides with bare hands and drinking water and smoking while handling pesticides were associated with cough (3.22, 2.54–4.08) and wheezing (3.66, 1.32–10.02), but not breathlessness. We observed an apparent positive association between the number of unhygienic practices used by a farmer and the risk of respiratory symptoms but these associations were not statistically significant (Table 6).

Table 2 Active ingredient, chemical class, trade name, and poundage of pesticides sold in the Offinso North District

Chemical family	Active ingredient	Trade name	Hazard class, WHO	Poundage sold in Ghana in 2018	Poundage imported to Ghana in 2018
Insecticides					
Avermectins (AV)	Abamectin	Mektrin 1.8EC	II	Unknown	Unknown
	Abamectin	Bomee EC	II	Unknown	Unknown
	Emamectin benzoate	Attack 1.9EC	II	Unknown	Unknown
	Emamectin benzoate	Control 5WDG	II	Unknown	Unknown
	Emamectin benzoate	Ema 1.9EC	II	Unknown	Unknown
	Emamectin benzoate	Protect 1.9EC	II	Unknown	Unknown
Carbamates	Carbofuran	Carbodan	II	Unknown	Unknown
	Carbofuran	Furadan 3G	II	Unknown	Unknown
Chitin synthesis inhibitor	Novaluron	Rimon 10EC	III	Unknown	Unknown
Neonicotinoids (NEO)	Acetamiprid	Buffalo Supa	III	Unknown	Unknown
	Acetamiprid	Golan 20SP	III	Unknown	Unknown
	Imidacloprid	Condifor Super	II	Unknown	Unknown
	Imidacloprid	Consider Super	II	Unknown	Unknown
	Imidacloprid	Dimiprid	II	Unknown	Unknown
	Imidacloprid	Punto	II	Unknown	Unknown
	Thiamethoxam	Devaxam	II	Unknown	Unknown
	Thiamethoxam	Wonderes	II	Unknown	Unknown
Organophosphates (OP)	Chlorpyrifos	D-Ban Super 48EC	II	Unknown	Unknown
	Chlorpyrifos-ethyl	Actforce 48EC	II	Unknown	Unknown
	Chlorpyrifos-ethyl	Chlorpyrifos	II	Unknown	Unknown
	Diazinon	Conti-Zol 5	II	Unknown	Unknown
	Diazinon	Diazol 50EW	II	Unknown	Unknown
	Dimethoate	Agro-Thoate 40EC	II	Unknown	Unknown
Oxadiazine	Indoxacarb	Aventall 300WG	III	Unknown	Unknown
Phenylpyrazole	Fipronil	Fipro 50EC	II	Unknown	Unknown
Polysaccharide	Maltodextrin	Eradicoat	III	Unknown	Unknown
Pyrethroids (PYR)	Alpha-Cypermethrin	Alphaccp	II	Unknown	Unknown
	Cypermethrin	Caweprethrin	II	Unknown	Unknown
	Deltamethrin	Decis 100EC	II	Unknown	Unknown
	Fenvalerate	Frankofen	II	Unknown	Unknown
	Lambda-Cyhalothrin	Aweradlamp	III	Unknown	Unknown
Quinolizidine Alkaloid	Oxymatrine	Levo 2.4SL	III	Unknown	Unknown
Tetramic acid derivative (keto-enol)	Spirotetramat	Movento 100SC	III	Unknown	Unknown
Bio-insecticides					
Microbial	*Peris rapae Granulosis* Virus + *Bacillus thuringiensis*	Bypel	II	Unknown	Unknown

Table 2 (continued)

Chemical family	Active ingredient	Trade name	Hazard class, WHO	Poundage sold in Ghana in 2018	Poundage imported to Ghana in 2018
	Spinosad (*Saccharopolyspora spinosa*)	Success Appat	U (unlikely to present acute hazard in normal use)	Unknown	Unknown
Combination insecticides					
AV + NEO	Emamectin benzoate Imidacloprid	Dean 62EC	II	Unknown	Unknown
NEO + PYR	Acetamiprid Cypermethrin	Chemaprid 88EC	II	Unknown	Unknown
NEO + PYR	Acetamiprid Lambda-Cyhalothrin	Blast	IV	Unknown	Unknown
NEO + PYR	Acetamiprid Lambda-Cyhalothrin	K-Optimal EC	II	Unknown	Unknown
NEO + PYR	Thiamethoxam Lambda-Cyhalothrin	Efforia 15EC	II	Unknown	Unknown
OP + PYR	Chlorpyrifos Lambda-Cyhalothrin	KD 415EC	II	Unknown	Unknown
OP + PYR	Cypermethrin Dimethoate	Cymethoate Super	II	Unknown	Unknown
Fungicides					
ß-Methoxyacrylates (BMA)	Azoxystrobin	Skyrobin	III	Unknown	Unknown
Carbamates	Carbendazim	Goldazin 500SC	III	Unknown	Unknown
Dithiocarbamate (DTC)	Mancozeb	Agrithane	III	Unknown	Unknown
	Mancozeb	Benco 80 WP	III	Unknown	Unknown
	Mancozeb	Dihane M45 WP	III	Unknown	Unknown
	Mancozeb	Foko Super	III	Unknown	Unknown
	Mancozeb	Ivory 80 W	III	Unknown	Unknown
	Mancozeb	Kilazeb	III	Unknown	Unknown
	Mancozeb	Suncozeb	III	Unknown	Unknown
	Maneb	Kenmaneb	III	Unknown	Unknown
	Propineb	Atracol 70 WP	III	Unknown	Unknown
Inorganic copper (ICu)	Copper oxychloride	Curenox 50WP	III	Unknown	Unknown
Organophosphate (OP)	Fosetyl-aluminum	Athlete	III	Unknown	Unknown
Phthalimides	Captan	Merpan 50WR	III	Unknown	Unknown
	Folpet	Folpan 50WP	III	Unknown	Unknown
Combination fungicides					
Acylaniline (AcA) + DTC	Metalaxyl Mancozeb	Mancozan	III	Unknown	Unknown
AcA + DTC	Metalaxyl Mancozeb	Victory	III	Unknown	Unknown
Azole BMA	Tebuconazole Trifloxystrobin	Navito 300SC	III	Unknown	Unknown
Bordeaux mixture	Cuprous sulfate Calcium hydroxide	Caldo Bordeles Valles 20WP	III	Unknown	Unknown

Table 2 (continued)

Chemical family	Active ingredient	Trade name	Hazard class, WHO	Poundage sold in Ghana in 2018	Poundage imported to Ghana in 2018
Chlorothalonil + Morpholine	Chlorothalonil Dimethomorph	Sphinx Star	III	Unknown	Unknown
DTC + ICu	Mancozeb Metallic copper	Cuprofix 30 Disperse	II	Unknown	Unknown
Herbicides					
Dinitroaniline	Pendimethalin	Pendigan	II	Unknown	Unknown
Imidazolinone	Imazethapyr	Vezir	III	Unknown	Unknown
Phosphonoglycine	Glyphosate	Adom 48SI	III	Unknown	Unknown
Pyrimidinedione	Saflufenacil	Heat 76WG	III	Unknown	Unknown
Quaternary nitrogen	Paraquat dichloride	Canquat Super SL	II	Unknown	Unknown
Pyrimidinyl Sulfonylurea	Nicosulfuron	Nicocal	III	Unknown	Unknown
Combination herbicides					
Nitrophenyl ether + phosphonoglycine	Oxyfluoren Glyphosate	Zoomer 390SC	III	Unknown	Unknown
Chloroacetanilide + triazine Chlorotriazine	Acetochlor Atrazine Terbutylazine	Ballistic	IV	Unknown	Unknown
Surfactants (modified)					
Polyether-modified Trisiloxane	Polyether-polymethylsiloxane Copolymer	Break-Thru S240	U	Unknown	Unknown

Indulgence in any unhygienic practice while mixing/applying pesticides on the farm was associated with sexual performance dysfunction (3.93, 1.94–7.97), nervousness (5.79, 3.02–11.12), and decreased mental concentration (11.45, 3.48–36.63) but the effect estimates of the last two conditions were imprecise. The different combinations of stirring pesticides with bare hands, drinking or eating or smoking while mixing/applying pesticides and indicator variables were not associated with any non-respiratory symptoms (Table 7).

Association between protective measures and respiratory and non-respiratory symptoms among farmers

Failure to apply any protective measures while mixing/applying pesticides was associated with cough (1.38, 1.01–1.87), wheezing (3.26, 2.10–5.01), and breathlessness (2.19, 0.99–5.22). There was decreasing risk of cough (p for trend < 0.0001) and wheezing (p for trend < 0.0001) with increasing number of protective measures used by a farmer while mixing/applying pesticides. The PRs for farmers taking 2 safety precautions while mixing/applying pesticides; 1 safety precaution while mixing/applying pesticides; and no safety precautions while mixing/applying pesticides vs farmers taking > 3 safety precautions while mixing/applying pesticides were 1.35 (1.01–1.34), 1.83 (0.99–3.39), and 3.11 (1.02–7.01), respectively for chronic cough; and 3.26 (2.10–5.06), 5.31 (3.14–5.51), and 7.12 (4.10–23.01), respectively for wheezing (Table 6). Failure to use any protective measure while mixing/applying pesticides was associated with sexual dysfunction (3.93, 1.94–7.97), nervousness (5.79, 3.02–11.12), and lack of mental concentration (11.45, 3.48–37.63) but the effect estimates of the latter two were imprecise. Trend was observed for the relation between the number of precautionary measures taken while mixing/applying pesticides and non-respiratory symptoms, but none of the effect estimates was precise (Table 7).

Discussions

Main findings

This study investigated handling practices and protective measures related to pesticide use and self-reported symptoms in a cohort of vegetable farmers in the Offinso North

Table 3 Hygiene practices, protective measures, and farmers' knowledge on environmental and health effects of pesticides in the Offinso North Farm Health study (ONFAHS) (*n* = 310)

	Yes *n* (%)	No *n* (%)
Personal hygiene		
Did not change clothes after applying and mixing pesticides?	305 (98.4)	5 (1.6)
Did not change clothes after spilling pesticides on your clothes?	277 (89.4)	33 (10.6)
Work with the same gloves all the time?	229 (73.9)	81 (26.1)
Mix pesticides with bare hands?	289 (93.2)	21 (6.8)
Eat while spraying pesticide?	201 (64.8)	109 (35.2)
Drink while spraying pesticide?	277 (89.4)	33 (10.6)
Smoke while spraying pesticide?	230 (74.2)	80 (25.8)
Protective measure		
Use boots?	150 (48.4)	160 (51.6)
Use hat?	160 (51.6)	150 (48.4)
Use cartridge respirator gas mask?	11 (3.6)	299 (96.4)
Use dust mask?	15 (4.8)	295 (95.2)
Use full face shield?	3 (1.0)	307 (99.0)
Use chemically resistant gloves	20 (6.5)	290 (93.5)
Use disposable outer clothing	7 (2.3)	303 (97.7)
Knowledge of the environmental and health effects of pesticides		
Pesticides affect human health	74 (24.8)	225 (75.2)
Pesticide residues affect consumer health	70 (23.4)	229 (76.6)
Pesticides affect soil	60 (20.3)	236 (79.7)
Pesticides affect fish and other animals in rivers	64 (21.5)	234 (78.5)
Pesticides remain in the soil for a long time	184 (62.8)	109 (37.2)
Pesticides affect natural environment	186 (62.6)	111 (37.4)

Farm Health Study (ONFAHS) in Ghana. All the indicators of unhygienic and safety practices were associated with cough and wheezing, but not breathlessness. The primary findings from this study among vegetable farmers in Ghana show that the use of any unhygienic practice for mixing/applying pesticides is positively associated with cough and wheezing, but not breathlessness, and that the greater the number of these unhygienic practices used, the greater the harm. Stirring pesticides with bare hands/drinking water only while mixing/applying pesticides and stirring pesticides with bare hands/drinking water/smoking cigarettes while mixing/applying pesticides are positively associated with coughing and wheezing, but not with breathlessness. We found a significant exposure-response association of the number of precautionary measures undertaken while handling pesticides with coughing and wheezing, but not with breathlessness. Indulgence in any unhygienic practice is associated with sexual dysfunction, nervousness, and decreased mental concentration. Combination of specific unhygienic practices such as stirring pesticides with bare hands, drinking water while mixing/applying pesticides, eating while mixing/applying pesticides, and smoking while mixing/applying pesticides are not associated with any of our non-respiratory symptoms. There was suggestive evidence of association between the use of any precautionary measure when mixing/applying pesticides and sexual dysfunction, nervousness, and decreased concentration. Most of the pesticides identified for distribution in the study area are in WHO hazard Class II (moderately hazardous) or Class III (slightly hazardous) (WHO 2009).

Validity issues

Our study has several strengths. The results are derived from a population-based cross-sectional study in 4 vegetable-intensive farming communities and their surrounding villages, thus, minimizing selection bias. We

Table 4 Knowledge of farmers about health and environmental effects of pesticides and protective measures applied in the Offinso North Farm Health Study (ONFAHS) (n = 310)

Protective measures used	No knowledge n (%)	High knowledge n (%)	p value
Boots			
Yes	25 (21.6)	125 (64.4)	< 0.001
No	91 (78.4)	69 (35.6)	
Hat			
Yes	53 (45.7)	107 (55.2)	0.1066
No	63 (54.3)	87 (44.8)	
Respirator			
Yes	3 (2.6)	8 (4.1)	0.5460
No	113 (97.4)	186 (95.9)	
Dust mask			
Yes	2 (1.2)	13 (6.7)	0.056
No	114 (98.8)	181 (93.3)	
Full-face shield			
Yes	1 (0.8)	2 (1.0)	0.4416
No	115 (99.2)	192 (99.0)	
Gloves			
Yes	2 (1.2)	12 (6.2)	0.9883
No	114 (98.8)	182 (93.8)	
Use disposable clothes			
Yes	2 (1.7)	18 (9.3)	0.0047)
No	114 (98.3)	176 (90.7)	
Goggle use			
Yes	1 (0.9)	6 (3.1)	0.2630
No	115 (99.1)	188 (96.9)	

Table 5 Prevalence of respiratory and non-respiratory symptoms among farmers in the Offinso North Farm Health Study (ONFAHS) (n = 310)

Symptoms	n	%
Respiratory		
Chronic cough	114	36.8
Breathlessness	30	9.7
Wheezing	120	38.7
Non-respiratory		
Sexual weakness	65	21.0
General body weakness	257	82.9
Nervousness	86	27.7
Loss of concentration	39	12.6
Depression	37	11.9

also adapted a questionnaire successfully used in previous studies (Quansah et al. 2016) and controlled for potential confounders. In addition, the study was strongly supported by the participating communities which resulted in a high participation rate. When considering the importance of this study several limitations must also be noted. A selection bias may have occurred in this study because of the sampling method (i.e., convenient sampling) used. The farmers leave home for their farms very early in the morning and it was not possible to apply a probabilistic sampling technique here. Even though, the interviews were carried out by trained interviewers, we cannot guarantee their stringency or homogeneity. In addition, many of the symptoms reported by participants may be due to factors other than exposure to pesticides such as prolonged exposure to sunlight; exposure to elevated temperatures associated with a hot

Table 6 Associations between unhygienic practices, use of personal protective equipment (PPE), and knowledge of environmental and health effects of pesticides and respiratory symptoms in the Offinso North Farm Health Study (ONFAHS) ($n = 310$)

	Coughing		Breathlessness		Wheezing	
	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*
Indulgence in any unhygienic practices						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.28 (1.76–2.97)	2.12 (1.61–2.80)	1.94 (0.66–1.34)	1.91 (0.63–1.30)	2.31 (1.18–4.54)	2.38 (1.15–4.91)
Mixing pesticide with bare hands only						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.85 (1.19–2.87)	1.96 (1.32–2.90)	0.99 (0.49–2.00)	0.99 (0.49–2.00)	1.97 (1.02–4.01)	2.01 (1.05–4.13)
Mixing pesticide with bare hands and drinking water only						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.47 (1.95–3.14)	2.50 (1.30–4.80)	1.49 (0.14–1.71)	1.46 (0.11–1.89)	3.35 (1.16–9.66)	3.51 (1.44–8.60)
Mix pesticide with bare hand, eat food/drink water while spraying only						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.15 (1.61–2.88)	2.20 (1.67–2.89)	1.62 (0.33–2.15)	1.75 (0.38–2.65)	1.97 (1.02–4.01)	2.87 (1.35–6.07)
Mixing pesticide with bare hands, drinking water and smoking cigarette only						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.68 (1.78–4.02)	3.22 (2.54–4.08)	1.13 (0.05–1.34)	1.15 (0.06–1.40)	3.16 (1.54–6.50)	3.66 (1.32–10.02)
Hygiene practices score						
Practice of good hygiene while mixing/applying pesticides	1.00	1.00	1.00	1.00	1.00	1.00
Inclusion of 1 or 2 unhygienic practices while mixing/applying pesticides	1.13 (0.83–1.54)	1.09 (0.76–1.56)	1.22 (0.68–2.18)	1.16 (0.64–2.09)	2.28 (1.00–5.19)	2.17 (0.82–5.77)
Inclusion of ≥3 unhygienic practices while mixing/applying pesticides	1.29 (0.70–2.38)	1.19 (0.58–2.44)	1.49 (0.47–4.73)	1.34 (0.41–4.38)	5.18 (0.99–26.99)	4.71(0.67–33.27)
p for trend	< 0.0001	< 0.0001	0.8122	0.8802	0.0010	0.0007
Practice of any safety precaution when handling pesticides						
Yes	1.00	1.00	1.00	1.00	1.00	1.00
No	1.49 (1.11–2.01)	1.38 (1.01–1.87)	3.21 (2.07–4.97)	3.26 (2.10–5.01)	2.27 (1.02–5.06)	2.19 (0.99–5.22)
Safety practices score						
Taken more than 3 safety precautions while mixing/applying pesticide	1.00	1.00	1.00	1.00	1.00	1.00
Take 2 safety precautions while mixing/applying pesticide	1.49 (1.11–2.01)	1.35 (1.01–1.34)	2.27 (1.02–5.06)	2.06 (0.98–4.68)	3.21 (2.07–4.97)	3.26 (2.10–5.06)
Taken 1 safety precautions while mixing/applying pesticide	2.22 (1.22–4.04)	1.83 (0.99–3.39)	5.16 (1.04–10.21)	4.36 (0.82–14.68)	5.23 (3.11–7.89)	5.31 (3.14–5.51)
Taken no safety precautions while mixing/applying pesticide	4.01 (1.34–6.11)	3.11 (1.02–7.01)	9.01 (3.22–22.39)	8.78 (0.77–16.42)	7.28 (4.28–24.70)	7.12 (4.10–23.01)
p for trend	< 0.0001	< 0.0001	0.0785	0.1393	< 0.0001	< 0.0001

*Adjusted for gender, age, marital status, cooking fuel type, and zonal community

climate; and other diseases. Symptoms reported by farmers are those that occurred 2 weeks prior to our study. However, the fact that these symptoms have been widely reported in farmers using pesticides in different climatic conditions suggests a probable association with use and exposure to pesticides. Again, non-respiratory symptoms are outcomes usually related to chronic pesticide exposures. These outcomes may also be related to existing health conditions such as diabetes, hypertension, anxiety, or neurological trauma and none of these were controlled for in our analysis. However, the farmers in these communities have long been known to be exposed to higher levels of pesticide than any other farming community in Ghana (Ntow 2001; Ntow et al. 2006, 2008; Quansah et al. 2016) and thus, the observed association between pesticide use and non-respiratory symptoms reported in this study may be real.

Comparison of our findings with previous studies

Although no published epidemiological studies have examined the relationship between pesticide exposures with or without personal hygiene or protective measures and respiratory and non-respiratory symptoms among farmers in Ghana, few studies elsewhere have reported on these issues (Ntow et al. 2006). In the current study, a majority of farmers had considerable knowledge of the potential impacts of pesticides on human health and environmental health but unhygienic practices such as stirring pesticides with bare hands, eating while mixing/applying pesticides, smoking while mixing/applying pesticides, inability of farmers to shower and change into new clothes immediately after spilling pesticides on clothes, and using the same pair of gloves repeatedly were common. Our findings on pesticide handling practices are consistent with those of previous studies in Africa (Oesterlund et al. 2014; Gesesew et al. 2016; Negatu et al. 2016; Abadi 2018; Bondori et al. 2018; Rezaei et al. 2018). Also, similar to the current findings, some studies have shown that despite farmers' good knowledge and favorable attitudes toward pesticide use, these are not reflected in their day-to-day farming practices (Fan et al. 2015; Yuantari et al. 2015). On the other hand, Gesesew et al. (2016) and others (e.g., Abadi 2018; Bondori et al. 2018; Rezaei et al. 2018) have linked poor pesticide management practices to farmers' poor knowledge of the harmful effects of pesticide use. The fact stands that farmers in developing countries lack information on pesticides and their safe methods of use. Moreover, agriculture extension officers lacked the necessary training to educate farmers on the safe use of pesticides (Ntow et al. 2006; Bagheri et al. 2018; Bondori et al. 2018).

We also observed that the farmers who participated in our study do not use appropriate protective measures such as gas respirators, dust masks, face shields, chemically resistant gloves, and disposable outer clothes required for safety in their work. Our results corroborated published studies of Oesterlund et al. (2014) and Ntow et al. (2006) who demonstrated that Ugandan and Ghanaian farmers used ordinary clothing, including boots and long-sleeved t-shirts when spraying pesticides. The reasons for this behavior may include lack of appropriate training due to high illiteracy among farmers which compromises their ability to understand instructions, labels, and safety procedures. Perhaps, the farmers are so poor they cannot afford to purchase personal protective equipment (PPE) such as gas respirators, dust masks, face shields, chemically resistant gloves, and disposable outer clothes that are required for the safe handling of hazardous pesticides.

The classification of pesticides by WHO is based upon their acute toxicity and relative risk to human and environmental health. It is assumed in this classification system that pesticide preparations with an oral LD_{50} of 2000 mg/kg or less for solids and 3000 mg/kg or less for liquids, or a dermal LD_{50} for solids and liquids of 4000 and 6000 mg/kg or less, respectively, presents a low risk in exposed populations so long as adequate precautions are taken in the use, distribution, application, and disposal of these toxic products. Normally, it is the final products that are classified. However, in some cases, it is only the active ingredients that are classified. In these cases, the toxicity of solvents and other non-pesticide products (emulsifiers, surfactants, preservatives) included in the final product. Thus, classification of a pesticide formulation into one of the higher hazard classes may be essential if a toxic non-pesticide chemical is present in the product of commerce.

Another focus of our study was to examine the relationship between the number of unhygienic practices typically used by these vegetable farmers and the prevalence of respiratory and non-respiratory symptoms. To the best of our knowledge, this is the first study to have tested this association among vegetable farmers in Africa. We noted that coughing and wheezing are positively associated with unhygienic practices in handling of pesticides, but breathlessness is not. We further evaluated the relationship between specific personal unhygienic practices such as stirring pesticides with bare hands and drinking water or eating food or smoking cigarettes and respiratory and non-respiratory symptoms. We observed that stirring pesticide with bare hands led to 96% excess risk for cough whereas stirring pesticides with bare hands plus drinking water while mixing/applying pesticides led to 150% excess risk for cough. Moreover, stirring pesticide during product

Table 7 Associations between unhygienic practices, use of personal protective equipment (PPE) and knowledge of environmental and health effects of pesticides and non-respiratory symptoms in the Offinso North Farm Health Study (ONFAHS) ($n = 310$)

	Sexual weakness		General body pains		Nervousness		Lack of concentration	
	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*
Indulgence in any unhygienic practice								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	3.85 (2.00–7.40))	3.93 (1.94–7.97)	0.89 (0.77–1.03)	0.90 (0.66–1.24)	5.73 (3.17–10.36)	5.79 (3.02–11.12)	10.69 (3.35–34.08)	11.45 (3.48–37.63)
Mixing pesticide with bare hands only								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.76 (0.58–4.80)	2.74 (0.25–6.01)	0.83 (0.58–1.20)	0.82 (0.42–1.59)	2.02 (1.18–3.47)	1.83 (0.84–4.00)	1.90 (0.67–5.38)	1.81 (0.55–5.94)
Mixing pesticide with bare hands and drinking water while spraying pesticide only								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.32 (0.49–3.54)	1.27 (0.40–4.07)	0.65 (0.38–1.12)	0.64 (0.29–1.44)	2.79 (1.85–4.20)	2.30 (1.09–4.88)	1.47 (0.40–5.33)	1.40 (0.33–5.84)
Mix pesticide with bare hand/eat food/drink water while spraying only								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.77 (1.04–3.02)	1.73 (0.90–3.33)	0.77 (0.60–1.00)	0.76 (0.49–1.20)	1.27 (0.76–2.14)	1.20 (0.63–2.28)	1.90 (0.91–3.95)	1.84 (0.80–4.20)
Mixing pesticide with bare hands, drinking water, and smoking cigarette only								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.13 (1.03–1.25)	1.12 (0.82–1.53)	1.30 (0.88–1.93)	1.09 (0.64–1.84)	2.48 (0.39–4.42)	2.75 (0.34–5.65)	2.08 (0.39–4.42)	2.05 (0.34–5.65)
Hygiene practices score								
Practice of good hygiene practices while mixing/applying pesticide	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Inclusion of 1 or 2 unhygienic practices while mixing/applying pesticide	1.52 (0.72–3.19)	1.50 (0.71–3.15	1.06 (0.82–1.38)	1.06 (0.82–1.37	0.81 (0.39–1.70	0.79 (0.38–1.61)	0.81 (0.19–3.52)	0.80 (0.19–3.47)
Inclusion of ≥ 3 unhygienic practices while mixing/applying pesticide	2.30 (0.52–10.19)	2.25 (0.51–9.94)	1.13 (0.67–1.89)	1.13 (0.68–1.89)	0.66 (0.15–2.91)	0.62 (0.15–2.61)	0.66 (0.04–12.39)	0.65 (0.03–12.07)
p for trend	0.0575	0.0730	0.0029	0.0020	0.0003	0.0009	0.9265	0.9220
Practice of any safety precaution when handling pesticides								
Yes	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No								

Table 7 (continued)

	Sexual weakness		General body pains		Nervousness		Lack of concentration	
	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*	Crude PR	Adjusted PR*
	3.85 (2.00–7.40)	3.93 (1.94–7.97)	0.82 (0.73–0.92)	1.17 (0.90–1.51)	5.73 (3.17–10.36)	5.79 (3.02–11.12)	10.69 (3.35–34.08)	11.45 (3.48–37.63)
Safety practices score								
Taken more than 3 safety precautions while mixing/applying pesticide	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Take 2 safety precautions while mixing/applying pesticide	3.85 (2.00–7.40)	3.92 (2.03–7.55)			5.73 (3.17–10.36)	3.50 (2.21–5.56)	10.69 (3.35–34.08)	11.42 (3.59–36.40)
Taken 1 safety precautions while mixing/applying pesticide	5.76 (3.31–10.96)	6.13 (3.41–12.92)					0.11 (0.02–0.57)	
Taken no safety precautions while mixing/applying pesticide	14.81 (4.01–54.70)	15.33 (4.12–56.99)			32.07 (10.06–167.37)	12.28 (4.88–30.94)	114.27 (11.24–1161.60)	1306.12.86–1329.60)
p for trend	< 0.0001	< 0.0001	0.1111	0.1310	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Any knowledge on environmental and health effects of pesticide								
Yes	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No	2.72 (1.80–4.10)	2.40 (1.43–4.03)	0.91 (0.78–1.05)	0.93 (0.67–1.30)	2.61 (1.87–3.64	2.43 (1.54–3.86)	1.89 (1.02–3.49)	1.74 (0.86–3.52)

*Adjusted for gender, age, marital status, cooking fuel type, and zonal community preparation with bare hands and drinking water or eating food and smoking while mixing/applying pesticides led to 222% excess risk for cough. Similarly, stirring pesticides with bare hands resulted in 101% excess risk for wheezing; stirring pesticides with bare hands and drinking water while mixing/applying pesticides resulted in 251% excess risk for wheezing; and stirring pesticides with bare hands and drinking water/eating foods and smoking resulted in 266% excess risk for wheezing. Poor pesticide management practices are associated with self-reported symptoms of headache, vomiting, nausea, sneezing, diarrhea (Karunamoorthi et al. 2012; Marisa da Silva et al. 2016), burning sensation in the eyes/face, weakness and dizziness (Negatu et al. 2016; Yassi et al. 2006), and symptoms of pesticide poisoning (Jors et al. 2014). On the other hand, a study by Oesterlund et al. (2014) did not find any association between pesticide management practices and self-reported symptoms among 317 Ugandan farmers.

We tested the hypothesis that the number of protective measures utilized by a vegetable farmer handling pesticides in Ghana is a predictor for decreased prevalence of respiratory and non-respiratory symptoms. The results of this analysis showed that application of < 3 safety precautions when spraying/applying pesticides increased the risk of coughing and wheezing in an exposure-response manner although the associations with the non-respiratory symptoms evaluated are inconclusive. This finding is similar to that of Jors et al. (2014) who reported between 415 and 1288% excess risk for general symptoms in 114 male farmers in Bolivia who used fewer than 3 precautionary measures while handling pesticides.

Our findings have significant public health implications for farmers, medical personnel, agriculture extension officers, and environmental officers in developing countries where improper pesticide management practices are widespread and pesticides banned, which are more toxic and/or more persistent in the environment are still used. Our findings clearly demonstrate the need to enforce laws and regulations regarding the use of banned pesticides in the country. There is also the need to educate and promote the use of protective measures to minimize exposure and reduce consequent health problems of farmers during the handling, application, and disposal of pesticides. Alternative integrated natural, biological, and physical methods of pest control should be advocated wherever possible to control pests, decrease exposures to dangerous chemicals, and reduce risk of degradation of the environment.

Conclusions

Our study demonstrated that although many farmers have adequate knowledge on the potential adverse effects of pesticide use on human health and the environment, several unhygienic practices are common and widespread. Very few farmers applied any safety precautions while handling pesticides. Unhygienic practices for pesticide handling are associated with increased incidence of coughing and wheezing. Safety precautions are related to coughing and wheezing in an exposure-response manner, the more precautions used the lower the incidence of these endpoints. Future studies are needed to provide understanding of the motivation for these poor management practices among the farmers. Also, as we were unable to determine the amounts of various pesticides annually imported and used in Ghana, it is recommended that governments develop an economical method to track pesticide use and safe disposal.

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