Environ Dev Sustain (2016) 18:1059–1079
DOI 10.1007/s10668-015-9686-2

The impact of farmers' participation in field trials in creating awareness and stimulating compliance with the World Health Organization's farm-based multiple-barrier approach

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Received: 5 November 2014 / Accepted: 20 June 2015 / Published online: 10 July 2015

Abstract The results of a study aimed as assessing the extent to which urban vegetable farmers' participation in field trials can impact on their awareness and engender compliance with the World Health Organization's farm-based multiple-barrier approach are presented in this paper. Both qualitative and quantitative approaches have been used in this paper. One hundred vegetable farmers and four vegetable farmers' associations in the Kumasi Metropolis in Ghana were covered. The individual farmers were grouped into two, namely: (1) participants and (2) non-participants of the farm-based multiple-barrier approach field trials. The results of the study show that participation in the field trials has statistically significant effects on farmers' awareness of the farm-based multiple-barrier approach. Compliance has, however, been undermined by the farmers' perception that the cost of compliance is more that the benefits. Policy tools that can address these constraints have been recommended in the paper.

Keywords World Health Organization · Farm-based multiple-barrier approach · Awareness and compliance

1 Introduction

The extent to which farmers' participation in field trials can impact on their awareness and compliance with the World Health Organization's (WHO's) farm-based multiple-barrier approach is assessed in this paper. The multiple-barrier approach is cost-effective means of

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mitigating the risk of infections associated with the use of low-quality water in unrestricted agriculture (Drechsel et al. 2014; Keraita et al. 2014). These risks result from the accidental ingestion of low quality water used for the irrigation and/or the consumption of raw-eaten vegetables produced from farms irrigated with low quality water which may contain pathogens. Previous studies (Amoah et al. 2005, 2007; Scheierling et al. 2010) identified excess amounts of pathogens (e.g. 10^{6-7} faecal coliform counts per 100 g weight) on the vegetables produced in the cities in Ghana. The risks of infections are similar in countries at the base of the sanitation ladder whose economies are primary in nature (Keraita et al. 2009). Consequently, about 12,000 disability-adjusted life years (DALYs) are lost in the cities in Ghana from the consumption of salads prepared with vegetables from these farms (Drechsel and Seidu 2011).

The WHO's multiple-barrier approach is based on the Hazard Analysis and Critical Control Points (HACCP) concept (Keraita et al. 2010). It entails several farm-based and post-farm risks reduction measures. The farm-based risks reduction interventions combine low-cost treatment and non-treatment options which include: (1) the three-tank system, (2) simple sedimentation and (3) simple filtration. Farmers are further required to adopt a combination of the following safe irrigation practices: (1) furrow irrigation, (2) low-cost drip irrigation, (3) reduction in splashing and (4) pathogen die-off (cessation of irrigation prior to harvest). These farm-based options, when combined with post-farm risks reduction measures, are cost-effective for the mitigation of the health risks associated with the use of low-quality water for farming ("Appendix").

The multiple-barrier approach was developed from studies[1] by the International Water Management Institute (IWMI) in partnership with the Kwame Nkrumah University of Science and Technology (KNUST) and University of Copenhagen. In these studies, some vegetable farmers and Agricultural Extension Agents (AEAs) in the Kumasi Metropolis in Ghana were involved in the process that led to the development of the multiple-barrier approach. The researchers developed a number of training materials (including videos, flip charts and policy briefs) which could be used to educate the participants not only on the relevance of the farm-based multiple-barrier approach but also its application (Abaidoo et al. 2009; Amoah et al. 2011; Keraita et al. 2008).

Compliance with the farm-based multiple-barrier approach will promote the safe use of low-quality water in unrestricted agriculture. Compliance is only possible if the farmers change their behaviours (Drechsel and Karg 2013). In their conceptual framework, Drechsel and Karg posit that behavioural change for the adoption of the safe irrigation practices is contingent upon four pillars, namely: (1) awareness creation, (2) incentives, (3) social marketing and (4) regulations (Drechsel and Karg 2013). Available literature indicates that the vegetable farmers in the cities in Ghana have limited awareness of the farm-based multiple-barrier approach. It was on the basis of this limited knowledge and, more importantly, the possible way forward to increasing awareness, that a section of the urban vegetable farmers in Kumasi in Ghana were involved in the farm-based risks reduction field trials. What remains unclear in the literature is the impact their participation in field trials can make on their awareness and compliance with the risks reduction measures. Clarity on this will inform policy makers in Ghana on the nature of extension strategies to apply given that several authors have recommended strategies such as workshops, farmer field schools and provision of teaching and learning materials as the way forward in promoting awareness (Drechsel and Karg 2013). Another grey area in the literature is the

[1] Entitled, "Safeguarding Public Health Concerns, Livelihoods and Productivity in Wastewater Irrigated Urban and Peri-urban Vegetable Farming".

replication effects of the field trials. Positive replication and catalytic effects will have implications for the use of field demonstrations as an effective approach to disseminating the risks reduction measures to a wider population.

In this study, the levels of awareness of the farm-based multiple-barrier approach between the farmers who participated in the farm-based risks reduction field trials (hereafter referred to as Category 1) and non-participants (also referred to as Category 2 farmers in the rest of the text) are compared. The impact of the farm-based field demonstrations on their irrigation practices is also assessed.

2 Overview of the WHO's multiple-barrier approach

The critical importance of water reuse within a water scarce world has been reported amply in the literature (Hamilton et al. 2007; Scheierling et al. 2010). Literature traces low-quality water reuse to the Minoans some 40 centuries ago (Angelakis et al. 2005). Sewerage farms were predominantly used for the disposal of low-quality water in Europe and the USA. Its reuse was also seen as a way of preventing surface water pollution in arid and semi-arid countries in the world. Its continued use was however undermined in later years by the numerous risks of infections that are known to be associated with low-quality water reuse.

The WHO, having recognised the significant contribution low-quality water reuse can make to global water management efforts, introduced guidelines in 1989 to promote its safe use in agriculture (WHO 1989). The guidelines emphasised the treatment of low-quality water to meet drinking water quality standards before its use even for irrigational purposes. For instance, it provided an upper limit of 1000 counts (10^3) per 100 mL for coliform count and less than one viable helminth egg count per litre in the water used for irrigation (Drechsel et al. 2014; Keraita et al. 2013). These strict treatment requirements were found to be beyond the means of many small holder farmers in many developing countries (Drechsel et al. 2008; Owusu et al. 2012). The need for cost-effective approaches to addressing the health and environmental risks associated with low-quality water reuse, particularly in developing countries, led to the introduction of the multiple-barrier approach in the 2006 edition of the WHO guidelines.

The multiple-barrier approach is a package of situation-specific safety interventions that reduce the disease burden even if they are not combined with conventional low-quality water treatment measures (Drechsel and Karg 2013). They focus on different entry points along the contamination pathways (i.e. from farm to fork) as depicted by Fig. 1 (Drechsel and Karg 2013; Drechsel et al. 2014; Keraita et al. 2014). These interventions been proven to be effective in mitigating the risks of infections associated with the use of low-quality water for irrigation in unrestricted agriculture ("Appendix"). Its cost-effectiveness makes it suitable for small holder farmers in many developing countries to adopt.

3 Study methodology

3.1 Description of the study area

The study was carried out in Kumasi in Ghana. It is the second largest but most populous city in Ghana with an estimated population of 2.7 million people as of 2015. The high

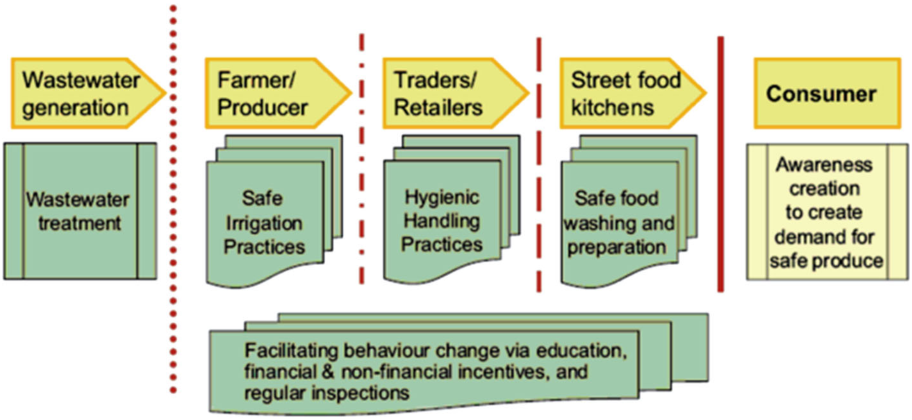

Fig. 1 Multiple-barrier approach for risk reduction (*Source* Amoah et al. 2011)

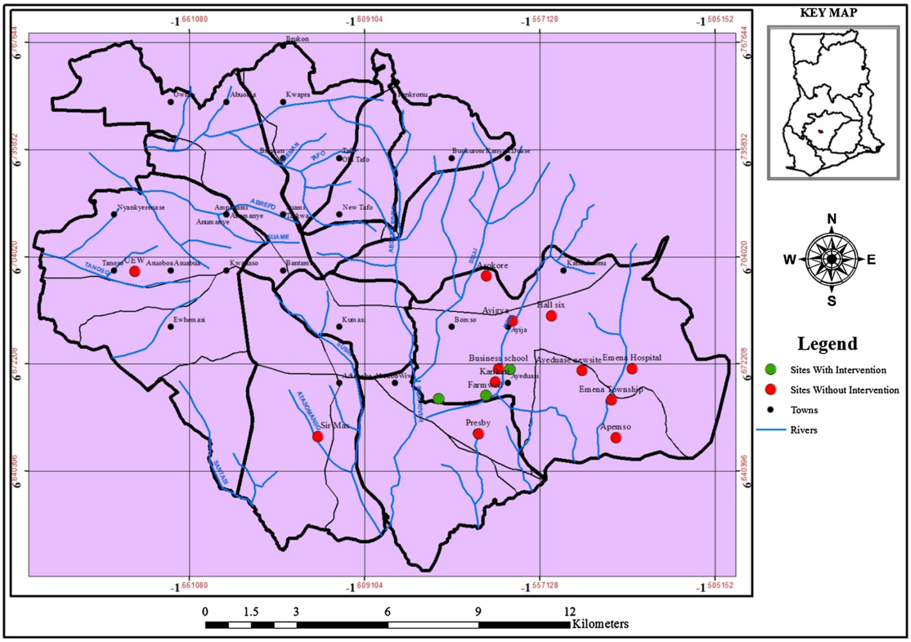

Fig. 2 Location of the vegetable farms within the Kumasi Metropolis

population has sustained the informal vegetable farming within and at the periphery of the city.

The lack of efficient transportation and refrigeration systems in rural Ghana further makes the city and its periphery (about 40 km radius from the city centre) the most attractive locations for the farmers who desire to farm in the proximity of market centres. Available data indicate that about 41 hectares, equivalent to 0.2 % of land in the city, is under informal agriculture (Obuobie et al. 2006). Like many African cities, the vegetable farms in Kumasi are located on marginal lands which are deemed not suitable for residential and commercial development. The vegetable farms are located along the banks of water bodies (Fig. 2). Amponsah et al. (2015) attribute this to the non-consideration of urban agriculture in urban land use planning. This is further evident in the absence of agricultural land use in Kumasi's structural plan (Fig. 3). The farmers depend on the water bodies for the supply of water for irrigation.

These water bodies have been heavily polluted by the discharge of untreated or partially-treated wastewater from households and firms in the city (Danquah et al. 2011; Keraita et al. 2010; Owusu et al. 2012; Qu et al. 2012; Scheierling et al. 2010). Consequently, the vegetables that are produced with the low-quality water have been found to carry excess amounts of pathogens (Amoah et al. 2005; Hamilton et al. 2007; Keraita et al. 2008; Rooijen et al. 2010). For instance, the faecal coliform levels found on some vegetables sampled by researchers at the farm gate in the city were 10^{6-7} faecal coliform counts per 100 g weight (Amoah et al. 2005, 2007; Scheierling et al. 2010).

The health risks associated with the use of low-quality water for irrigation are therefore enormous given that 500,000–800,000 people in the city patronise the raw-eaten vegetables (Drechsel et al. 2010).

3.2 Research design

The results of the study are based on a cross sectional survey of vegetable farmers in the Kumasi Metropolis. To enhance the validity of the conclusions, focus group discussions were held with some vegetable farmers' associations.

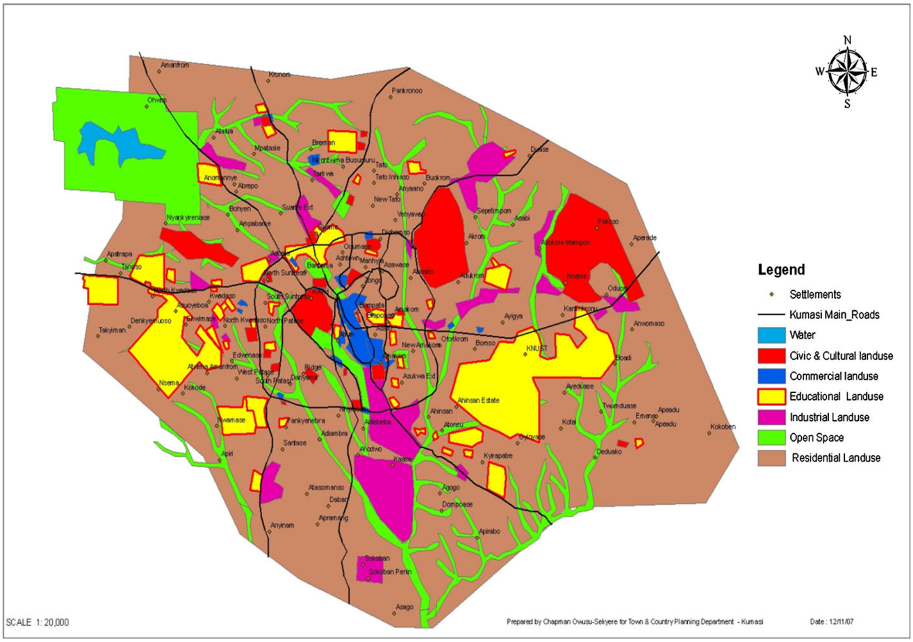

Fig. 3 Structure plan of Kumasi metropolitan area

3.2.1 Cross-sectional survey

Thirteen vegetable farm sites were identified from a meeting with the Metropolitan Agricultural Development Unit on 31st January, 2015 (Table 1). There were no records however on the number of farmers operating in these sites. The sites were then visited for purposes of enumerating the vegetable farm owners. The enumeration took place from 3rd to 24th February, 2014. The names of all the vegetable farm owners in the sites were recorded. Following Sudman's (1976) suggestion that a study should have a sample size of 100 if it involves a major group, 100 vegetable farmers were selected for interview using an interview schedule. The proportional allocation method was used to allocate the sample among the 13 vegetable producing sites.

3.2.2 Group discussions

Four group discussions were also held with four vegetable farmers associations. The associations were: the Farmwell Organic Vegetable Farmers' Association, Progressive Vegetable Growers' Association, Peace and Love Vegetable Farmers' Association and Frafra Vegetable Farmers' Association. Ten members each of these associations were drawn for separate interviews. A breakdown of the participants is as follows: three members in executive positions in each association (i.e. chairperson, secretary and treasurer) and seven members.

Table 1 Location of sampled vegetable farmers

Location name	Association	Number of farmers	Sample size
Gyinyase	Farmwell Organic Vegetable Farmers' Association	12	5
	Karikari farms: Progressive Vegetable Growers' Association	20	8
	Peace and Love Vegetable Farmers' Association	15	6
Ayeduase New site	*	34	14
Emena Hospital	*	14	6
Emena Township	*	17	7
KNUST College of Engineering	Frafra Vegetable Farmers' Association	18	7
KNUST Business School		15	6
KNUST Hall Six and Gaza	*	35	14
Ayigya-Tech-Kentinkrono	*	7	2
UEW, Kumasi Campus	*	20	8
Apemso	*	29	12
Presbyterian Girls Senior School	*	6	2
Sir max–Ahodwo	*	3	1
Asokore Mampong	*	4	2
Total		249	100

* No organised associations

The discussions were organised with the aid of an interview guide and were carried out to elicit information about the associations': (1) awareness of the farm-based risks reduction options, (2) compliance with the options, (3) reasons for compliance or otherwise and (4) measures used to reduce the health risks where the members of the associations were unaware of the farm-based risks reduction measures. The discussion was also aimed at identifying the factors that influence compliance and measures required to ensure compliance all from the associations' perspectives.

3.2.3 Direct observation

An observation checklist was prepared to guide the researchers' observation. It covered: (1) how farmers fetched water for irrigation (whether they stepped into the water while fetching, applied the treatment options such as simple sedimentation, simple filtration or three-tank system), (2) how the farmers' applied water to the vegetables (whether to the roots only or applied to all the parts of the vegetables) and (3) how harvesting was done (whether the produce makes contact with the soil). The data from the observation helped to verify the responses obtained from the individual farmers and groups.

3.3 Analytical methods

The IBM SPSS software version 21 was used to analyse the quantitative data. We split the data into two, namely (1) Category 1 farmers (defined as those who participated in the field trials) and (2) Category 2 farmers (also defined as those who were not part of the field trials). The approach enabled us to assess the impact of the field trials on farmers' awareness and compliance with the farm-based risks reduction measures. Each category's level of awareness of the farm-based risks reduction measures was measured follwing which a comparison was made between the two groups. A Chi-square test was performed to test the hypothesis that the level of awareness of each farm-based multiple-barrier approach is the same for Category 1 and Category 2 farmers. In other words, the null hypothesis is that there are no differences between the levels of awareness between the two categories of farmers. The null hypothesis was rejected if $p \leq 0.05$.

The vegetable farmers' perception about the quality of the water they used for irrigation was assessed by asking this categorical question, "do you consider that the water you use for irrigation poses any health risks to stakeholders including you?" Farmers' who perceived the irrigation water as unsafe were asked to indicate the extent to which they agreed that the water used for irrigation could lead to the occupation- and consumption-related risks (Table 2). This was after they had been asked to identify the health risks they associate with low-quality water reuse for irrigation.

4 Results and discussions

4.1 Characteristics of the urban vegetable farmers

Males dominate vegetable farming in Kumasi (Table 3). This result is consistent with those of Drechsel et al. (2006) and Owusu et al. (2012) which identified that urban vegetable farming in West Africa is dominated by males. It appears to be the preserve of actors

Table 2 Typologies of health risks

Type of risk	Health risks	Likert-type scale					
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Do not know
Occupational risks (contact)	Parasitic worms such as A. lumbricoides and hookworm infections						
	Bacterial and viral infections						
	Skin irritations (itching and blistering of the hands and feet)						
	Nail problems (such as koilonychias)						
Consumption-related risks	Mainly bacterial and viral infections such as cholera, typhoid, ETEC, hepatitis A, viral enteritis, which mainly cause diarrhoea						
	Parasitic worms such as *Ascaris*						

Source Health risks infections sourced from (Drechsel et al. 2010)

whose ages are within the economically active age group (which refers to the age cohorts from 15 to 64 years). The mean age of Category 1 farmers was 33 years and Category 2 farmers, 40 years. The labour-intensive nature of the economic activity may be the most plausible reason for the dominance of the economically active age group. The farm owners' formal educational levels were low for each category of vegetable farmers covered in the study (Table 3). This corroborates the works of (Arumugam et al. 2011; Busari et al. 2012; Owusu et al. 2012) which concluded that informal economic actors in many developing countries have low educational levels.

The data show that Category 1 farmers and Category 2 farmers had been engaged in vegetable farming for 11.3 and 11.7 years, respectively (Table 3). The results of the Levene's Test for Equality Variances (Table 3) indicate that the variances in the means of the two categories of vegetable farmers are not equal. Since the p value of the t test was <0.05, it was concluded based on the observed data that there is no significant difference between the levels of farming experiences (measured in years) between the two categories of farmers. The vegetable farmers' length of stay in the informal economy appears to support Sparks and Barnett's position that "employment in the informal sector is no longer a journey, but has become the destination of many" (Sparks and Barnett 2010). Previous studies have also identified that two out of every three urban vegetable farmers had no intentions of leaving the job even if they were offered regular salaried employment (Drechsel and Keraita 2014; Obuobie et al. 2006).

The results of the study indicate that most of the vegetable farms were located on public/government lands (Category 1 = 92 % and Category 2 = 64 %); a finding which is consistent with literature (see Danso et al. 2014; Keraita et al. 2014). Two main sources of water for irrigation were also identified. Approximately 70 % of them used water from shallow wells for irrigation. The remaining 30 % used water from open streams. These

Table 3 Characteristics of urban vegetable farmers

Group type	Demographic characteristics of farm owners						
	Sex						Age (in years)
	Male		Female		Total		
	N*	%	N	%	N	%	Mean
Category 1 farmers	26	92.9	2	7.1	28	100.0	33.4
Category 2 farmers	62	88.6	8	11.4	70	100.0	39.7

	Educational level		
	Level	Frequency	Percent
Category 1 farmers	None	7	25.0
	Primary	9	32.1
	JSS/JHS/middle school	10	35.7
	SSS/SHS/technical	1	3.6
	Tertiary	1	3.6
	Total	28	100.0
Category 2 farmers	None	23	32.9
	Primary	16	22.9
	JSS/JHS/middle school	24	34.3
	SSS/SHS/technical	7	10.0
	Total	70	100.0

Level of experience

Mean years of experience		Levene's Test for Equality Variances			*t* test for equality of means			
					t	Sig. (two-tailed)	Mean difference	Std. error difference
Category 1	11.32	Equal variances assumed	8.291	.005	−.277	.782	−.407	1.470
Category 2	11.73	Equal variances not assumed			−.338	.736	−.407	1.203

* Frequency

water sources have been found to be heavily polluted by the untreated or partially treated wastewater discharged into the environment by households and firms in the cities in Ghana (Akrong et al. 2012; Danquah et al. 2011; Drechsel and Keraita 2014; Owusu et al. 2012). The use of untreated low-quality water for irrigation therefore explains the high faecal coliform count (10^{6-7} faecal coliform counts per 100 g weight) found on vegetables sampled from some farm gates in Kumasi (Amoah et al. 2005, 2007; Scheierling et al. 2010).

The characterisation of the urban vegetable farmers has revealed that the Category 1 and Category 2 farmers exhibit similar characteristics in terms of their educational levels and years of experiences in farming. The other areas of similarity are their sources of irrigation

Table 4 Cross-analysis between category of farmers and perception about the quality of irrigation water

Category	Perception that water source poses health risks				Total	
	Yes		No			
	Frequency	%	Frequency	%	Frequency	%
Category 1	24	24.5	4	4.1	28	28.6
Category 2	61	62.2	9	9.2	70	71.4
Total	85	86.7	13	13.3	98	100.0

Chi-Square = 0.035 and p value = .851

water, land tenure systems and male dominance. On the basis of these similarities, the impact of the fields trails on their awareness and compliance with the farm-based multiple-barrier approach was assessed.

4.2 Farmers' perceptions about the quality of irrigation water

4.2.1 Perception about the quality of irrigation water

The survey data indicate that approximately 90 % of the vegetable farmers were aware that using low-quality water for irrigation in vegetable farming posed health risks to them and the other stakeholders along the contamination pathway (Table 4). The Chi-square test was used to assess whether the difference in the perception about the quality of the irrigation water was significant between Category 1 and Category 2 farmers. The evidence (Table 4) suggests that there is no significant difference between the two categories of farmers in terms of their perception about the quality of water used for irrigation. Generally, their perception about the health risks associated with the irrigation water was similar between the two categories of farmers. This can be explained by the recent media highlights of the health risks associated with low-quality water reuse. Many researchers have also organised workshops and field trials to expose the vegetable farmers to the nature of the health risks associated with low-quality water reuse (Abaidoo et al. 2009; Amoah et al. 2007; Drechsel et al. 2008; Owusu et al. 2012).

4.2.2 Farmers' knowledge of the kind of health risks

The survey data (Table 5) show that the vegetable farmers' knowledge of the kind of health risks associated with low-quality water use for irrigation purposes was generally low. Skin irritation and parasitic worms (both by contact and consumption) appeared to be the health risks most of the vegetable farmers could associate with low-quality water reuse. Their knowledge of the association between parasitic worms and skin irritations may have been the result of previous studies where the researchers de-wormed the vegetable farmers. The results show that more of the Category 1 farmers (i.e. participants of the filed trials) than Category 2 farmers (non-participants) associated the health risks considered in the study to low-quality water use for irrigation. Comprehension of all the health risks could have been undermined by their low formal educational levels. However, their perception about the health risks could be a catalyst for stimulating compliance with health risks reduction measures.

Table 5 Farmers' knowledge about known health risks associated with low-quality water use for irrigation

Category	Occupational health risks (parasitic worms such as A. lumbricoides and hookworm infections)			Occupational health risks (bacterial and viral infections)		
		Frequency	Percent		Frequency	Percent
Category 1	Do not know	10	41.7	Do not know	15	62.5
	Agree	10	41.7	Agree	5	20.8
	Strongly agree	4	16.7	Strongly agree	4	16.7
	Total	24	100.0	Total	24	100.0
Category 2	Do not know	45	75.0	Do not know	55	91.7
	Agree	15	25.0	Agree	5	8.3
	Total	60	100.0	Total	60	100.0
	Occupational health risks [skin irritations (itching and blistering of the hands and feet)]			Occupational health risks (such as koilonychias)		
		Frequency	Percent		Frequency	Percent
Category 1	Do not know	0	0.0	Do not know	13	54.2
	Agree	18	75.0	Agree	8	33.3
	Strongly agree	6	25.0	Strongly agree	3	12.5
	Total	24	100.0	Total	24	100.0
Category 2	Do not know	11	18.3	Do not know	52	86.7
	Agree	45	75.0	Agree	8	13.3
	Strongly agree	4	6.7	Strongly agree	0	0.0
	Total	60	100.0	Total	60	100.0
	Consumption-related risks (such as cholera, typhoid, ETEC, hepatitis A, viral enteritis, which mainly cause diarrhoea)			Consumption-related risks (parasitic worms such as Ascaris)		
		Frequency	Percent		Frequency	Percent
Category 1	Do not know	17	70.8	Do not know	8	33.3
	Agree	6	25.0	Agree	13	54.2
	Strongly agree	1	4.2	Strongly agree	3	12.5
	Total	24	100.0	Total	24	100.0
Category 2	Do not know	49	81.7	Do not know	42	70.0
	Agree	11	18.3	Agree	17	28.3
	Strongly agree	0	0.0	Strongly agree	1	1.7
	Total	60	100.0	Total	60	100.0

4.3 Current irrigation practices

At least seven out of every 10 urban vegetable farmers used shallow wells dug between 1 and 2 m away from streams for irrigation. The rest used mainly water from heavily polluted streams for irrigation. The water in the shallow wells and streams is heavily polluted (Akrong et al. 2012; Danquah et al. 2011; Drechsel and Keraita 2014; Owusu et al.

Fig. 4 The nature of plastic fitted at the outlets of the watering cans

2012). Almost all of them used the 15-L watering cans for irrigation. This is consistent with the literature on the irrigation practices of urban vegetable farmers in Ghana (Drechsel and Keraita 2014; Drechsel et al. 2006; Drecshel et al. 2014; Keraita et al. 2013).

It was observed that most of the vegetable farmers not only stepped in the water when fetching into their watering cans but also applied the water to the leaves of the vegetables. They explained that it is time-consuming to avoid contact with the leaves of spring onions and lettuce because of higher bed density. Generally, most of the Category 1 farmers covered the inlets of the watering cans with nets to prevent aquatic plants and animals from entering into the watering cans during irrigation. The practice has positive implications for "reduction in splashing" since the showers at the outlets of the watering cans were intact as of the time of the survey. Majority of the Category 2 farmers on the other hand had replaced the shower at the outlet of the watering cans with plastics (Fig. 4) to spread out the water during irrigation. The reason for replacing the shower was that the sediments in the water choked the outlets of the watering cans which made irrigation very difficult. Water however gushed out from these watering cans during irrigation. Although this practice prevents choking, it leads to splashing and could undermine the safety of the vegetables. The poor irrigation practices coupled with the use of heavily polluted water for irrigation may explain the presence of excess amounts of pathogens in the vegetables produced in the cities in Ghana.

Another common practice that was observed was that the vegetable farmers (both Category 1 and Category 2) sold their vegetables to market women, while the vegetables are still on the beds. It was therefore the responsibility of the vegetable sellers to harvest the crops directly from the beds. These sellers then requested the farmers to continue to irrigate even at the point of harvest in order to: (1) keep the vegetables fresh and (2) to loosen the soil to make harvesting easier. The sellers then harvested the crops, kept them on the beds (Fig. 5) and sometimes washed them with the surface water used for irrigation before transporting them to the markets. These practices have the tendency of compromising the safety of the vegetables even if farmers adopt safe irrigation practices. The implication is that risks reduction awareness programmes should adopt an integrated

Fig. 5 Harvested vegetables being kept on the bed

approach where vegetable sellers are introduced to safe harvesting practices instead of limiting them to the post-harvest multiple-barrier measures.

The foregoing implies that there is no clear distinction between the irrigation practices adopted by the two categories of farmers. Interviews with the farmers revealed that only 11 and 1 % of the farmers within Category 1 and Category 2, respectively, applied simple sedimentation. Similarly, while 43 % of the farmers within Category 1 adopted "reduction in splashing", only 4 % of their counterparts in Category 2 did same. There was no evidence of the application of simple filtration, three-tank system, furrow irrigation and the low-cost drip irrigation. Compliance with the WHO farm-based risks multiple-barrier approach is therefore low among both categories of farmers.

4.4 Awareness of WHO farm-based multiple-barrier approach

4.4.1 Individual vegetable farmers

The vegetable farmers' awareness of the WHO's farm-based multiple-barrier approaches was assessed given that the irrigation practices observed under Sect. 3.3 could undermine the safety of the vegetables. It was also intended to identify the factors that affect their compliance. The survey results indicate that Category 1 farmers appeared to be more aware of the farm-based risks reduction options than their counterparts on the second Category (Table 6). In assessing the likely impact of the field trials on their awareness, it was hypothesised that "the level of awareness of the farm-based multiple-barrier approach is the same for both Category 1 and Category 2 farmers" and this hypothesis was tested in a Chi-square test. The result shows that there is a significant difference in the levels of awareness of each farm-based risks reduction measures between Category 1 and Category 2 farmers (Table 6). Category 1 farmers seem to be more aware of the farm-based multiple-barrier approach than the Category 2 farmers. This indicates that the farmers'

Table 6 Vegetable farmers' awareness of farm-based multiple-barrier approach

Category	Three-tank system			Simple sedimentation		Simple filtration	
	Awareness	Frequency	Percent	Frequency	Percent	Frequency	Percent
Category 1	Yes	4	14.3	15	53.6	4	14.3
	No	24	85.7	13	46.4	24	85.7
	Total	28	100.0	28	100.0	28	100.0
Category 2	Yes	0	0	7	10.0	0	0
	No	70	100.0	63	90.0	70	100.0
	Total	70	100.0	70	100.0	70	100.0
	Furrow irrigation			Low-cost drip irrigation		Reduction in splashing	
	Awareness	Frequency	Percent	Frequency	Percent	Frequency	Percent
Category 1	Yes	15	53.6	18	64.3	15	53.6
	No	13	46.4	10	35.7	13	46.4
	Total	28	100.0	28	100.0	28	100.0
Category 2	Yes	5	7.1	3	4.3	8	11.4
	No	65	92.9	67	95.7	62	88.6
	Total	70	100.0	70	100.0	70	100.0
	Pathogen die-off						
	Awareness	Frequency	Percent				
Category 1	Yes	6	21.4				
	No	22	78.6				
	Total	28	100.0				
Category 2	Yes	1	1.4				
	No	69	98.6				
	Total	70	100.0				

Results of the Pearson Chi-square test

Three-tank system: Chi-square 10.424, $p = .001$

Simple filtration: Chi-square 10.426, $p = .001$

Pathogen die-off: Chi-square 12.062, $p = .001$

Low-cost drip irrigation: Chi-square 42.764, $p = .000$

Simple sedimentation: Chi-square 21.810, $p = .000$

Furrow irrigation: Chi-square 26.542, $p = .000$

Reduction in splashing: Chi-square 19.776, $p = .000$

participation in field demonstrations is an effective means of creating awareness about the farm-based multiple-barrier approach.

The field trials have had a positive catalytic and replication effect in terms of awareness creation among Category 2 farmers. This could be attributed to the sensitisation roles the vegetable farmers' associations and Agricultural Extension Agents have played in disseminating the results of the farm-based risks reduction field trials. The chairperson of the "Peace and Love Organic Vegetable Farmers Association" (Mr. Yeboah) with the support from an Agricultural Extension Agent (Mr. Acheampong) sensitised the Category 2 farmers in the city on the multiple-barrier approach. The motivation to disseminate the information, albeit informal, was their belief that compliance with the farm-based multiple-barrier approach would lead to increased demand for their produce. The leader is quoted as follows: "we told the vegetable farmers that there were some White men in town who would want to buy our produce for export. The condition was that we should adopt safer irrigation practices". We conclude therefore that farmers' participation in the trials of the farm-based multiple-barrier approaches has had significant impacts on their awareness of the approaches. The implication is that increased demand for their farm produce was a factor that could significantly lead to behavioural change on the part of the farmers in favour of safer irrigation practices.

4.4.2 Vegetable farmers' associations

The group discussions revealed that they were aware of the farm-based multiple-barrier approaches. The members were either directly involved in the field trials[2] or sensitised by their leadership who had participated in the field demonstrations.[3] A member of the Farmwell Organic Vegetable Growers' Association is quoted as follows: "Bernard Keraita and Philip Amoah from the International Water Management Institute (IWMI) taught us that we should: (1) not step in the water when fetching for irrigation, (2) not apply the water to the leaves, (3) stop irrigation days before harvest, (4) avoid contact between the harvested vegetables and the soil during harvesting and (5) not wash the vegetables with the water we use for irrigation". In addition to these five options, members of the Progressive Vegetable Farmers' Association disclosed that they were taught to cover the inlets of the watering cans with a net in order to prevent the shower at the outlet from choking. They explained that it is an effective means of reducing splashing during irrigation. The Frafra Vegetable Growers' Association members' awareness of the farm-based risks reduction measures underscores the positive catalytic and replication effects of the field trials. These farmers were not involved in the field trials, yet they were aware of these risks reduction measures.

The conclusion here is that awareness of the farm-based multiple-barrier approach does not guarantee their compliance. This is based on the observed irrigational practices (Sect. 4.3) which were contrary (except simple sedimentation and reduction in splashing) to the WHO's farm-based multiple-barrier approach. The proportions of the farmers who adopted simple sedimentation and reduction in splashing were very low.

4.5 Factors that affect compliance with the farm-based risks reduction measures

4.5.1 The perspectives of individual farmers

Several reasons were found to account for the vegetable farmers' non-compliance with the farm-based multiple-barrier approach (Table 7). Most of them considered the risks reduction options as "time-consuming" (in the case of three-tank system, simple sedimentation, simple filtration and reduction in splashing) and "expensive" (in the case of drip irrigation and simple filtration). The nature of the land (wetlands) makes furrow irrigation difficult to adopt. The farmers had no other options but to raise beds to prevent inundation of the fields in the wet season. They also explained that pathogen die-off

[2] Farmwell Organic Vegetables Farmers' Association, Peace and Love Organic Vegetable Farmers' Association and Progressive Vegetable Growers' Association.

[3] Frafra Vegetable Farmers' Association.

undermines the quality and value of the vegetables. These findings are consistent with those of Amoah et al. (2011) and Drechsel and Karg (2013).

4.5.2 The perspective of the vegetable farmers' associations

The members of the associations who were part of the group discussion explained that their members were not able to comply with the three-tank system and drip kit irrigation because they are costly. Osei-Adu (2015) identified that a farmer would spend between US$264.00 and US$3132.00 to install and use the three-tank system if s/he used between 2080 and 31,200 litres of water for irrigation a day. Similarly, he estimated that a farmer saves on the average US$68,541.48 for not complying with the drip kit irrigation system. The Theory of Rational Ignorance could partly explain the farmers decision not to adopt the on-farm multiple barrier approach. The theory's relevance to this study is that the farmers' adherence to the appropriate farming methods will be undermined by their perception that the cost of compliance is more that the benefits. Until the extra cost yields some immediate financial benefits, the farmers would not adhere to the farm-based multiple-barrier approach.

The decision to invest in these irrigation practices is further undermined by land tenure insecurity. As presented under Sect. 4.1, majority of the vegetable farms were located on

Table 7 Reasons for non-compliance with the farm-based multiple-barrier approach

Category	Reasons	N	%
Three-tank system			
Category 1	Time-consuming	4	100.0
Category 2	–	–	–
Simple filtration			
Category 1	Time-consuming	3	75.0
	Financial cost	1	25.0
Category 2	–	–	–
Low-cost drip irrigation			
Category 1	Financial cost	4	57.1
	Available kits not suitable	3	42.9
Category 2	Financial cost	2	100.0
Pathogen die-off			
Category 1	Reduction in quality of the produce	6	100.0
Category 2	–	–	–
Simple sedimentation			
Category 1	Time-consuming	6	75.0
	Other	2	25.0
Category 2	Other	1	100.0
Furrow irrigation			
Category 1	Land not suitable	13	86.7
	Waste of water	2	13.3
Category 2	Land not suitable	5	100.0
Reduction in splashing			
Category 1	Time-consuming	2	100.0
Category 2	Time-consuming	4	80.0
	Irrigation water poses no health risks	1	20.0

public/government lands. They would therefore not be willing to invest in these appropriate methods for fear of being evicted from the lands. Another reason for non-compliance with pathogen die-off was consumers' desire for fresh vegetables. One of the participants at the group discussions remarked that "it is not advisable to adopt these tedious and expensive farm-based risks reduction options if it will not translate into increased demand and cost for our produce. Any farmer who chooses not to comply with these measures will even benefit in terms of higher profits than those of us who comply". Consumers and vegetable sellers' preference for fresh-looking vegetables is a disincentive to complying with pathogen die-off (cessation). The quotation, which appears to reflect the perception of the farmers who participated in the farm-based multiple-barrier approach field trials, is consistent with the neoclassical theory. The theory posits that farmers will use inappropriate farming methods if the stream of returns from doing so is perceived to be higher than the cost of not doing so. Based on this, Wilson and Tisdell (2001) claim that farmers who may be using appropriate methods may be compelled to adopt unsustainable methods to avoid economic losses. The vegetable farmers in the Kumasi Metropolis have failed to comply with the risks reduction options because non-compliance is more rewarding than compliance. The implication is that awareness creation should target consumers whose preferences affect farmers' decision to comply with the farm-based multiple-barrier approach.

5 Conclusion and recommendations

The results of the study show that farmers' direct participation in field trials is an effective means of creating awareness about the farm-based risks reduction measures. The field trials could also have positive catalytic and replication effects especially where the teaching materials are made available to the participating farmers. Without incentives, awareness of the farm-based risks reduction measures will not necessarily lead to compliance. Improved marketing and land tenure security were the two most important incentives to stimulate compliance. We conclude, based on the extremely low level of compliance with the farm-based risks reduction measures that, raw vegetables produced from low-quality water irrigated farms in Kumasi will continue to pose a danger to the consuming public.

Based on the conclusion above, we recommend that the Ministry of Food and Agriculture (in this case the Ghana Irrigation Development Authority and District Agricultural Development Units) should commit funding to the dissemination of the farm-based multiple-barrier approaches. Farmers' awareness of these safe irrigation methods is the first but not the only step towards compliance. Compliance could then be stimulated through incentives and punishments. The first incentive should be land tenure security. The Ministry of Food and Agriculture should therefore collaborate with the Ministry of Local Government and Rural Development and Ministry of Land and Natural Resources to dedicate land in the cities and their peripheries for urban agricultural purposes. The open spaces along the surface water bodies appear to be the most feasible option to guaranteeing their access to land. The Metropolitan, Municipal and District Assemblies should protect their lands from residential, industrial and commercial land users. Cotonou and Seme-Kpodji in Benin, Bamako in Mali and Niamey in Niger (Drechsel et al. 2006) provide very useful lessons to Ghana and the rest of Africa on how land in the cities could be dedicated to urban agriculture. Land tenure security will incentivise farmers to invest in farming.

Another incentive to encourage compliance with the farm-based risks reduction options is improved marketing. We recommend the following policy tools: (1) credit (loans) and

(2) safety certificates given to compliant farmers. Vietnam offers very good lessons to guide the Ministry of Food and Agriculture in Ghana to operationalise these policy tools. In Vietnam, farmers who are applying safe irrigation methods are eligible for loans and safety certificates. These farmers have succeeded in eliminating intermediate actors in the food supply chain because they now have direct contact with buyers (hotels, guest houses, restaurants and households) (Drechsel and Karg 2013, 13). The consumers who are mainly middle income earners have began demanding that farmers adopt safe methods of production. In Ghana, the safety certificates could be issued by the Food and Drugs Authority working in collaboration with the Agricultural Development Units and Environmental Health Directorates under the various District Assemblies. They should be enabled to monitor the activities of vegetables farmers in the city.

The Ministry of Health and Ministry of Trade and Industry in Ghana should sensitise the public on the health risks associated with consuming vegetables from the farmers who do not observe the risks reduction measures. Consumers' preference for vegetables produced by farmers who adopt safe irrigation practices would lead to the desired increases in demand for the produce. This will be a major factor that will stimulate compliance with the farm-based risks reduction options.

Acknowledgments The authors are most grateful to the "Safe Water for Food Project (SaWaFo)" funded by Danida for supporting the study. We also acknowledge the immense contributions of Messrs Alfred Atimba, Michael Osei Asibey, Aminu Sulemana and Mathias Edetor. They supported us to collect data from the urban vegetable farmers.

Appendix

See Table 8.

Table 8 Health-protection control measures and associated pathogen reductions in irrigation water or on crop

Control measure	Pathogen reduction (log units)	Notes
A. Wastewater treatment	6–7	Reduction in pathogens depends on type and degree of treatment selected
B. On-farm options crop restriction (i.e. no food crops eaten uncooked)	6–7	Depends on (a) effectiveness of local enforcement of crop restriction and (b) comparative profit margin of the alternative crop(s)
On-farm treatment		
(a) Three-tank system	1–2	One pond is being filled by the farmer, one is settling, and the settled water from the third is being used for irrigation
(b) Simple sedimentation	0.5–1	Sedimentation for ~18 h
(c) Simple filtration	1–3	Value depends on filtration system used
Irrigation methods		
(a) Furrow irrigation	1–2	Crop density and yield may be reduced
(b) Low-cost drip irrigation	2–4	Reduction in 2-log units for low-growing crops and reduction in 4-log units for high-growing crops

Table 8 continued

Control measure	Pathogen reduction (log units)	Notes
(c) Reduction in splashing	1–2	Farmers trained to reduce splashing when watering cans are used (splashing adds contaminated soil particles onto crop surfaces which can be minimised)
(d) Pathogen die-off (cessation)	0.5–2 per day	Die-off between last irrigation and harvest (value depends on climate, crop type, etc.)
C. Post-harvest options at local markets		
Overnight storage in baskets	0.5–1	Selling produce after overnight storage in baskets (rather than overnight storage in sacks or selling fresh produce without overnight storage)
Production of preparation prior to sale	1–2	Washing salad crops, vegetables and fruits with clean water
	2–3	Washing salad crops, vegetables and fruits with running tap water
	1–3	Removing the outer leaves of cabbages, lettuce, etc.
D. In-kitchen produce-preparation options		
Application of disinfection.	2–3	Washing salad crops, vegetables and fruits with an appropriate disinfectant solution and rinsing with clean water
Peeling	2	Fruits, root crops
Cooking	5–6	Option depends on local diet and preference for cooked food

Source Amoah et al. (2011)

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