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Pesticide application and water quality in Doho and Kibimba rice irrigation schemes, eastern Uganda

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ABSTRACT

The number and amount of agrochemicals used has increased dramatically world over and their toxic nature has raised concern about environmental impact and effects on human health. Considering that agriculture is a major source of income in most developing countries, crop damage from pest infestation is of great concern to many farmers. These farmers are therefore motivated to apply pesticides. However, runoff from such farmlands unintendedly contaminates the water sources thereby causing harm to aquatic life and contaminates drinking water. This study was carried out at Doho and Kibimba irrigation schemes, which are the two commercial paddy rice growing areas in Uganda. The aim of this study was to investigate the effect of pesticide application on water quality in these two schemes and assess community awareness of the dangers of pesticide application. A cross sectional research design was used to collect data. A total of 60 samples (30 from each site) on physicochemical characteristics were collected in situ using standard equipment. 200 local community members (100 from each scheme) were randomly selected while on the farm and interviewed. Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS) program, version 20. Results showed that there were significant spatial differences in all the physical chemical properties of water in Doho Rice Scheme (P<0.05), while significant spatial variations were recorded for only pH, temperature at Kibimba rice scheme (P<0.05). Independent t-test results showed that water pH, temperature and turbidity varied significantly between Doho and Kibimba (P<0.05). Herbicides such as rocket, Diazine, Cypermatrine glyphosate were being used by famers with rocket frequently used at Doho while glyphosate was the only one used at Kibimba. Majority of the farm workers at Kibimba (96.9%) reported to have always used protective devices when handling pesticides and the reverse was true for farm workers at Doho despite the training on pesticide usage. The study therefore recommends regular water quality monitoring and sensitization of farmworkers on the dangers of improper pesticide use.

Keywords: Doho and Kibimba rice irrigation schemes, Pesticides - Environmental aspects – Eastern Uganda, Pesticides - Risk mitigation – Eastern Uganda, Agricultural pollution – Eastern Uganda

Introduction

High population growth combined with an increasing rice demand have led to an intensification of rice production. High yield in rice production are achieved by a combination of the introduction of high-yielding, short-duration varieties in association with a wider use of agrochemicals, particularly pesticides which are applied to mitigate or destroy pests.

Concerns about the health and environmental effects of pesticides have increased over the past years (Govinda, 2014). While the use of pesticides in agriculture provides benefits, it also has negative impacts (Flores *et al*., 2011). Pesticides residues result in serious problems not only in the cultivated soils where they are applied, but also in the crops that systemically retain part of these residues, in non-target organisms, and finally in surface and underground water, through runoff and seepage of agricultural drainage (CIA, 2014, Mokhele, 2011).

Since agriculture is a major source of income in most developing world economies like Uganda agricultural pests are a serious concern to farmers because they can cause significant reductions in farm yields and incomes (FAO, 2011). As a result, pesticides are heavily used in attempts to mitigate this problem. The WHO Guidelines for drinking Water (2011), recently emphasized the importance of protecting drinking water in the developing world from chemicals, especially pesticides from agricultural runoff. With widespread lack of understanding about the hazards caused by pesticide use, and deficient water treatment systems, the problem of pesticide misuse and consequent environmental degradation in the developing world seems imminent (Ibitayo, 2006).

Rice has progressively become a main cash crop in Uganda with the collapse of the cotton industry. Paddy rice is the dominant production system of rice worldwide, where fields are temporarily flooded. In Uganda, Paddy rice is intensively grown at Doho and Kibimba Rice schemes that are in Eastern Uganda, in addition to other smaller farms scattered across the country. Given the fast growing nature of the rice industry in Uganda, a study on the perceptions of pesticide use, especially pesticide risks to human health, is very important and necessary because it provides information on the effects of farmers' decisions on the amount and methods of pesticide usage (Ntow *et al*., 2006).

The study therefore aimed to investigate the effect of pesticide application on water quality and examine farmworkers perception of environmental and health effects of the pesticides in Doho and Kibimba Rice Schemes. It was aimed to generate information on pesticides contamination levels to enable appropriate mitigation measures to be applied.

Literature Review

The Pesticide situation in Uganda

The majority of Uganda's population works either directly or indirectly in the agricultural sectors. Country-wide, most agricultural activity takes place on farms averaging 0.9 ha, although average farm size varies by region and has been declining over the years (Uganda, 2007). Figures on pesticide use are not readily available, and where available, they are mostly rough estimates. Reasons for this situation are varied: It is costly to establish active ingredients used, as most chemicals are mixed into concoctions to provide a formulation known only to the applicator; many chemicals are stored for long periods such that any inventory estimation would be inaccurate; and the illegal trade and sale of banned pesticides mentioned earlier means that that portion of the market is not documented. Missing information about pesticide use in most cases translates into under-estimates.

However, even if these low usage rates are correct, handling and storage procedures may be more important factors when attempting to estimate numbers affected by pesticide exposure at household and national levels. Open pesticide containers can be found stored in kitchens, as well as in market places. Used empty containers are sometimes used as measuring devices for food and other items in homes, markets and on farms. In fact used containers were given out to farm workers on large estate farms as a work incentive (although this practice is declining due to recent environmental awareness and education about possible dangers). Forty four pesticides are currently registered for use in Uganda (Kegley & Orme, 2007). However, many more find their way into the country and into farm shops, farms and eventually into the environment.
Effects of pesticides on water quality

The selection of water quality assessment parameters depend on the needs and objectives of the assessment (Shukla *et al.*, 2006). Primary parameters such as temperature, pH and dissolved oxygen are essential as they influence reactions in water and the later important for sustaining aquatic life (Brouwer & De Blois, 2008). Other parameters are selected based on the needs of the water quality assessment. Generally, rice fields show a wide variation of water parameters such as temperature, pH, dissolved oxygen, conductivity, nitrate and phosphate (Gillion *et al.*, 2007). This study focused on Water pH, temperature, conductivity and turbidity. Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms. The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment (Tanajura & Belyaev, 2009). Furthermore, turbidity can be used to determine water quality since its directly influenced by the amount of suspended and particulate matter in water (Nalya, 2019). Electro conductivity is an essential parameter in assessing the suitability of water for human consumption since its increased concentration in water indicates presence of foreign inputs (free ions and chemical substances) (Sidabutar, 2017).

Knowledge on environmental and health effect of pesticides and Precautionary practices of farm workers
Farmers are often exposed to increased health risks through the mixing, application, and disposal of pesticides. This exposure can lead to pesticide poisoning causing short- and/or long-term health effects. In 2011, the WHO estimated that 1 million cases of pesticide poisoning were reported annually which resulted from farm use; approximately 200,000 (20.0%) of these cases resulted in death (McCauley *et al.*, 2006). The causes of death are often attributed to improper handling and management of pesticides by farmers who lack adequate knowledge of the common guidelines for safe use of pesticides, including use of personal protective equipment (PPE).

A knowledge and practice (KAP) analysis conducted at Pondicherry, India discloses that, while 70% of respondent‘s perceived effect of pesticide spraying on human health, only 40% were aware that pesticide spraying affects the environment. Two thirds of the respondents (62%) were aware that pesticide enters the body through nose and affects lungs. Awareness on other modes of entry was less. Majority (76%) of them were aware of training programs conducted by government agriculture department on pest management. About 42% of farmers had good knowledge regarding pesticide. Between 40% and 70% of respondents was not using any protective equipment during pesticide spraying. Around 68% of farmers indiscriminately disposed empty containers while 48% buried the leftover pesticides. Significant association ($p<0.05$) was observed between knowledge of the farmers and their practices related to pesticides (Manoj *et al.*, 2013).

In a study to determine the potential health effects of pesticides use in Lesotho Mokhele (2011), found that many farmers had no training on pesticide use due to low formal education. These less educated farmers are unlikely to comprehend information and therefore end up misusing pesticides. A pesticide safety knowledge test was developed to assess farmer‘s knowledge related to pesticide safety at two districts of southern Punjab Pakistan. More educated and adult respondents performed better than younger and illiterate. Similarly large land holder scored higher than small land holders, indicating their more access to information and extension (Muhammad *et al*., 2009).

Empirical studies on pesticide spraying practices and the effects of pesticides on farmers' health in developing countries have been documented in Asia (El-Zaemey *et al*., 2013), in Africa (Ngowi *et al*., 2007) and Latin America (Arcury *et al*., 2006). Other experimental studies calculate Personal Dermal Exposure (PDE) using tracers, such as fluorescent tracers, one comparing exposure as a function of the nozzle on the backpack sprayer for potato farmers in Colombia (Lesmes-Fabian *et al*., 2012). A study conducted by Govinda (2014), among Nepal rice paddy farmers using paraquat and 2,4-D found that wind speed had the largest effect on inhalation and PDE was extremely negatively correlated with the amount of personal protective equipment worn.

Recent research has shown that pesticides may also have negative impacts on public health. Studies have demonstrated acutely toxic effects at high doses, as well as chronic effects at low levels of exposure (García-Santos *et al*., 2011). While investigating the attitudes of Egyptian farmers on the use of pesticides Ibitayo (2006), saw the need of finding ways of communicating hazards of agricultural pesticide use to the end-users through training and participation in education of safe use of pesticides.

Several studies have recognized that pesticide safety education does not prevent much of the serious exposure that causes illness or death; such exposure usually results from working conditions, which are not likely to be under laborers control. Worker education programs and safe work practices have been emphasized as key components in the regulatory strategy towards pesticide protection for workers (Meena *et al*., 2008).

Ntow *et al*. (2006), surveyed 137 farmers to analyze farmers' perceptions of pesticide usage in vegetable cultivation in Ghana, the study established that various inappropriate practices in the handling and use of pesticides caused possible poisoning symptoms among those farmers who generally did not wear protective clothing. Younger farmers were the most pesticides-effected group and well-targeted training programs related to the safe use of pesticides was recommended (Ntow *et al*., 2006). The study conducted by Waichman *et al*. (2007), discovered that the information displayed on product labels was not effective in promoting protective and safe measures for farmers in Brazil, while (Ngowi *et al*. (2007), investigation show that vegetable farmers in Tanzania were lack of appropriate knowledge on safe handling and use of pesticides. Oo *et al*. (2012), found although almost all farmers in Inlay Lake of Myanmar had known the negative impact of pesticides on their health, only 86.9 of them always used protective things during pesticide spraying.

More information from qualitative analysis of field study carried out by El-Zaemey *et al*. (2013), shows that 59% of farm workers and stockholders are not using personal protective equipment (PPE). It is the clothing and devices that are worn to protect the human body from contact with pesticide or pesticide residue, which indicates overalls or protective suits, foot wear, gloves, aprons, respirator, eye wear and head gears.

Waichman *et al.* (2007), conducted a study on pesticide applications in cocoa farms and found out that generally, farmers do not wear any protective materials at all, no matter what pesticide is being applied. Farmers scarcely follow precautionary measures as they are found eating, smoking or drinking in-between spraying activities. The left over pesticides and empty containers are not properly disposed as the containers are sometimes washed and used for domestic purposes.

A study of Yemeni women living farming communities show that the vast majority have sprayed banned pesticides and without personal protective equipment and some have done so while pregnant (El-Zaemey *et al.*, 2013). Additionally, women are typically washing the clothes with pesticide residues on them and caring for the children. A study potentially linking parental exposures to pesticides and childhood Leukemia in Costa Rica found that fathers working with picloram, benomyl, and paraquat had a positive correlation with risk of childhood Leukemia, though more studies are needed to link the two (Monge *et al.*, 2007).

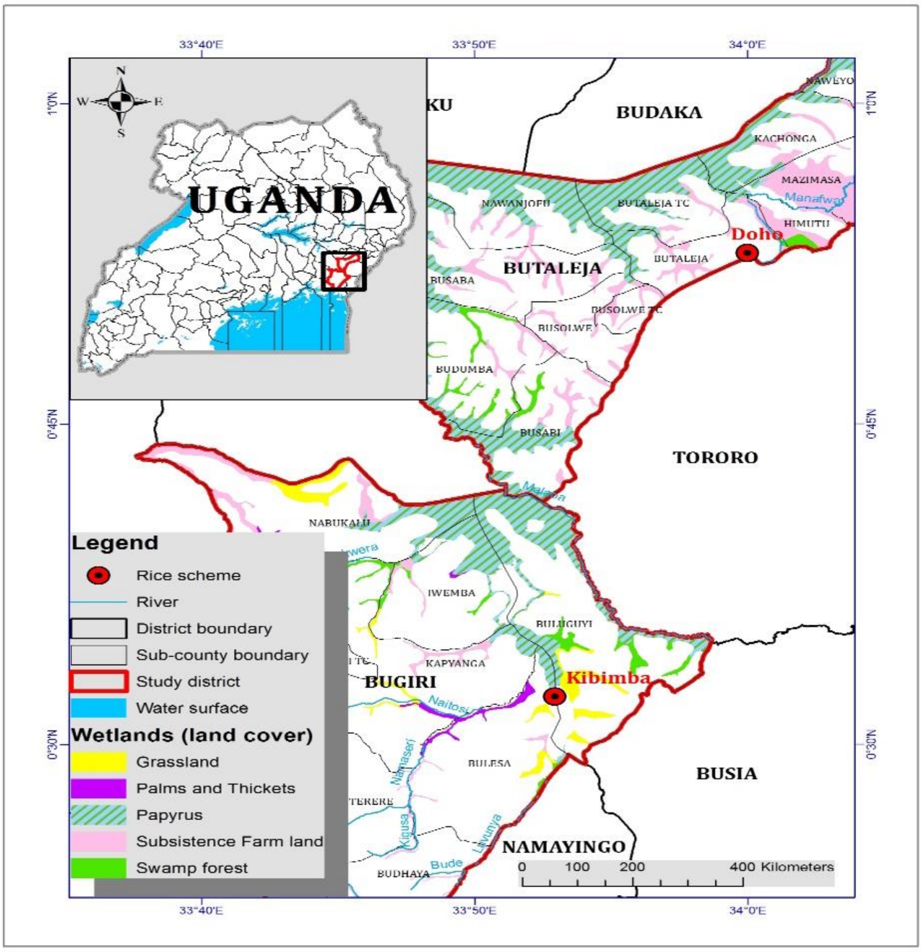
Dasgupta *et al.* (2007), in a study in Bangladesh found that almost half of the farmers overused pesticides and majority never took any precaution when handling them. This was attributed to poor formal training on the safe use of pesticides especially in developing countries, Uganda inclusive.

Materials and Methods

Study site

Doho Rice Scheme is located on longitudes 34o 02'E and latitudes 0o 50'N on the right bank of river Manafa in Mazimasa and Kachonga sub-counties of Butaleja District while Kibimba Rice Scheme lies between longitudes 33o 10'E and 34o 0'E and latitudes 0o 06'N and 1o 12'N. (Figure 1). These paddy rice irrigation schemes have almost similar infrastructure but differ in terms of management style. Large-scale rice cultivation began at Kibimba in 1966 and then Doho in 1976. Doho rice scheme covers an area of about 850 ha of irrigated rice fields, with about 3800 farmers participating on plot sizes ranging from 0.2 to 0.4 ha per farmer. Irrigation water for Doho comes from river Manafwa and this has been diverted to one main big dam from which a network of channels that supply water by gravity to the rice fields connect. There is minimal use of agricultural chemicals and ploughing is entirely by hand or oxen. In contrast, Kibimba scheme occupies a total area of 1,039 ha and is under the management of Tilda Uganda Limited, which is a privately owned company. Tilda employees about 500 casual laborers who spend very long hours in the rice paddies, but also own small holder farms at their homes. Unlike Doho, agrochemicals are intensively used at Kibimba and ploughing is heavily mechanized. These sites were selected for this study because they are the only areas of well-established intensive irrigated paddy rice cultivation in Uganda. They are also government ventures, under the management of the Ministry of Agriculture, Animal industry and Fisheries whose primary interest is rice

Figure 1: Location of Doho and Kibimba paddy rice irrigation schemes in eastern



Data collection and Analysis methods

Determination of water physicochemical parameters

A cross sectional research design was used to collect data on physicochemical parameters of water. In situ measurements were from each site twice at a five days interval. These measurements were taken in such a way that five were taken from the point of entry of water into the rice scheme, middle of each rice scheme and at exit from each rice scheme giving a total of 30 samples per rice scheme. Potential hydrogen (pH) was determined using multi-meter 340i connected to the pH- probes C 98 07 10 21 VTV, electrical conductivity was measured using the conductivity probe TetraCON 3245 connected to the multimeter 340i, water temperature was determined using a portable WTW multi 340i pH/O2/Conductivity meter connected to an oxygen probe cellox 325 VTV, turbidity was determined using a turbidimeter HI 93 703 HANNA instrument (Brouwer & De Blois 2008)

Collection of data on farm workers perception on pesticide use

A total of 200 farm workers (100 from each of the rice schemes) were interviewed on aspects of knowledge, practices and precautionary measures taken regarding pesticide use. An interview schedule was developed based on the United States Environmental Protection Agency ‘s questions related to safe pesticide use (Kegley *et al.*, 2007).

Data analysis

All data were analyzed using the Statistical Package for Social Sciences (SPSS) program, version 20. Descriptive results were expressed as frequencies, percentages cross tabulation for categorical variables, and as means ± SD for continuous variables. Independent t-test were used to test for difference in physicochemical parameters of water between the two rice schemes., One-way ANOVA was used to test for spatial variation between different sampling points at both sites.

Results

Spatial variations in water quality parameters at Doho and Kibimba Rice Scheme

One sample Kolmogorov-Smirnov test for normality of data showed that all the variables were normally distributed ($p>0.05$) except for turbidity. Considering that data on physicochemical parameters were collected at three different parts of the rice scheme it was important to find out if there were any significant spatial variations in these parameters within the rice fields at these two sites. Results of One-way ANOVA showed spatial variation of all these water quality parameters within each of the rice fields separately (Table 1).

Table 1: One-way ANOVA test for water physicochemical parameters at Doho and Kibimba

Parameter	Site			
	Doho		Kibimba	
	F	Sig.	F	Sig.
Water pH	7.253	.003	3.614	.041
Temperature °C	5.333	.011	4.439	.022
Conductivity (FTU)	61.167	.000	1.895	.170
Turbidity (µS/cm)	3.479	.045	1.895	.170

All the physicochemical parameters of water varied significantly within Doho rice scheme, while only pH and temperature are the only ones that varied within Kibimba (Table 1). Water pH was neutral in Doho rice Scheme and acidic at Kibimba at all the 3 sampling points (Table 2). Mean variations were evident in conductivity and turbidity at both rice schemes.

Table 2: Mean ± SE of the water quality parameters at Doho and Kibimba

	Point of entry		Within the rice fields		Point of exit	
	Doho	Kibimba	Doho	Kibimba	Doho	Kibimba
Water quality variable	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
pH	7.48±.090	6.47±.056	7.05±.077	6.54±.057	7.18±.076	6.35±.031
Temperature oC	25.34±.274	25.29±.202	26.61±.305	25.90±.097	26.40±.309	25.58±.111
Conductivity (FTU)	157.87±.400	249.20±10.2	198.55±4.90	233.90±7.63	202.84±2.45	257.70±8.23
Turbidity (µS/cm)	92.92±4.21	27.65±1.63	77.89±7.43	32.33±2.38	74.18±3.44	31.76±1.32

Table 3: Independent t-test for variations in the physicochemical parameters at for Doho and Kibimba

Parameter	F value	Sig.
Water pH	14.039	.000
Temperature oC	27.698	.000
Conductivity (FTU)	3.489	.067
Turbidity (μS/cm)	16.500	.000

There were significant variations in all the water quality parameter between Doho and Kibimba (t-test, $p<0.05$) except Conductivity (Table 3). Water conductivity was higher at Kibimba than Doho and the reverse was true for turbidity. Water was warmer at Doho than Kibimba. (Table 2).

Knowledge of farmworkers on environmental and health effects of pesticide use in Doho and Kibimba

Demographic characteristics

A total of 200 (100 for each scheme) questionnaires were issued out to the respondents and out of these 94 were returned for Doho and 98 for Kibimba giving a response rate of 94% and 98% for Doho and Kibimba Rice Schemes, respectively. Majority of the respondents were males at both the sites (Table 4). Most respondents were aged between 20 to 39 years, 54 (57.4%) in Doho and 93 (94.9%) while the group with over 50 years of age had the least respondents. Many of the farmworkers at Kibimba had never attended in formal education with about 50% of those at Doho having done so.

Table 4: Demographic of the respondents

Doho			Kibimba	
	Frequency	Percent	Frequency	Percent
Gender				
Male	78	83.0	98.00	100.0
Female	16	17.0	00.00	100.0
Age				
20-29	24	25.5	49	50.0
30-39	30	31.9	44	44.9
40-49	24	25.5	5	5.1
50&above	16	17.0	00.0	0.0
Educational level				
None	38	40.4	59	60.2
Primary	45	47.9	31	31.6
Secondary	8	8.5	8	8.2
College/University	3	3.2	0	0.0

Pesticides used at Doho and Kibimba Rice Scheme

Slightly more than half 53 (56%) of the farmers at Doho Rice Scheme were found not use any pesticides. Nevertheless, (23%) commonly used Rocket pesticides, 14 (15%) used Diazine and only 5 (6%) used cypermethrin and none of the farmers on this scheme used glyphosate. On the contrary, glyphosate pesticide was the only pesticide used by farm workers at Kibimba rice scheme, and this was supported by 81 (83%) respondents (Table 5).

Table 5: Types of Pesticides used at Doho and Kibimba

Scheme	Glyphosate	Rocket	Diazine	Cypermethrin	None	Total
Doho	0	22	14	5	53	94
Kibimba	81	0	0	0	17	98
Total	81	22	14	5	70	192

Precautionary practices by farm workers

Majority of the farm workers at Kibimba (96.9%) reported that they always used protective devices when handling pesticides and the reverse was true for farm workers at Doho (Table 6). The most common precaution practices included wearing face masks and washing hands after pesticide application. Generally, the farm workers at the two rice schemes never read labels on the pesticides package.

Table 6: Precautionary practices by farm workers

Doho			Kibimba	
	Frequency	Percent	Frequency	Percent
Using protective device when handling pesticide				
Never	54	57.4	1	1.0
Sometimes	6	6.4	2	2.0
Always	34	36.2	95	96.9
Eating, drinking, or smoking while spraying pesticides				
Never	70	74.5	87	88.8
Sometimes	20	20.2	11	11.2
Always	5	5.3	0	0.0
Reading the labels on the pesticides package				
Never	57	60.6	79	80.6
Sometimes	4	4.3	15	15.3
Always	33	35.1	4	4.1
Wearing face masks				
Never	59	62.8	0	0.0
Sometimes	14	14.9	9	9.2
Always	21	22.3	89	90.8
Washing hands after pesticide application				
Never	15	16.0	5	5.1
Sometimes	28	29.8	21	21.4
Always	51	54.3	72	73.5

Training of farmworker on the risks and hazards associated to Pesticide use.

Findings revealed that farmers at both rice schemes have been trained on the safe use of pesticides and 68 (62%) of the respondents trained on pesticide usage had ever been told about the risk and hazards from pesticides, while 42 (38%) although trained on pesticide usage were ignorant about the risk and hazards from pesticides the risks and hazards associated to them. In addition, a reasonable number of farmworkers, 100 (52%) were unaware that pesticides contaminate sources of drinking water.

Discussion

Spatial variations in water quality parameters at Doho and Kibimba Rice Scheme

Physicochemical parameters of water varied at the point of entry, within the rice fields and the point of exit at both the rice schemes, although some were not significant. Because the primary goal of rice paddies is rice production, rice ecosystems are highly dynamic; their physical and chemical parameters and water levels change very quickly, and their biological communities develop rapidly (Bardgett, 2005). This rapid change, including the type of fertilizer used and the time of application could probably explain the cause of variation in these physicochemical parameters of water. Except for electrical conductivity, the results of this research demonstrate that after the water had irrigated the plants, there was a clear reduction of the concentration of the variables. The acidic nature (lower pH value) of water in Kibimba could be attributed to intensive use of glyphosate (Sharma *et al.*, 2000). Electrical conductivity of the water in the study areas was quite high. This finding is consistent with Brouwer & De Blois (2008), who recorded similar values of conductivity in a rice field in New South Wales in Australia. The higher values at Kibimba perhaps indicate the magnitude at which water in this rice Scheme is polluted, and thus posing a threat not only to the aquatic organisms, but to the farm workers as well (Atasoy *et al.*, 2006).

Demographic characteristics

Majority of the respondents were males at both the sites. These results seem to agree with a number of studies, for example Obopile (2008), Botswana; Dasgupta *et al.* (2007) in Bangladesh; (Ntow *et al.*, 2006) in Ghana that found that more men than women were involved in farm working.

Precautionary practices by farm workers

The use of protective devices when handling pesticides by some of the farm workers is a clear manifestation that they are aware of the dangers of pesticide use to human health. Meena *et al.* (2008), also reported similar situations in the case of Sri Lanka & (El-Zaemey *et al.*, 2013), in Yemen and Naidoo *et al.* (2010). The inability for farmers to read the labels on the herbicide packaging, and the lack of awareness that pesticides contaminate sources of drinking water is of serious concern. However, this could be because of their level of education.

Limitations

Data collection was done over a very short temporal variation in between the samples, with no consideration for seasonal variations. In addition, only physical characteristics of the water were used to measure water quality, therefore limiting the strength of the conclusions.

Conclusion

The acidic nature of water at Kibimba rice scheme at the point of exit from the farm suggests a potential threat if this water gets into the source of water for drinking for the communities within the catchment of the scheme given the deficient water treatment systems in Uganda. In addition, the lack of formal education among majority of the farm workers and adequate training on the use of pesticides, poses a threat to the health of farm workers because they cannot read and understand the information labels on the pesticides. There is therefore need for regular water quality monitoring and sensitization of farmworkers on the dangers of improper pesticide use.

Recommendations

The study therefore recommends regular water quality monitoring and sensitization of farmworkers on the dangers of improper pesticide use.

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