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KNOWLEDGE AND PRACTICES OF STANDARD USE OF CHEMICAL PESTICIDES AND HAZARDOUS EXPOSURE AMONG FARMERS IN THE NYIRAGONGO HEALTH ZONE, NORTH KIVU, DRC

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ABSTRACT

The Pesticides are mainly used in agriculture According to the FAO, 4,600,000 tonnes of pesticides are sprayed into the environment each year, or 146 kg of pesticides per second. Every year, 3 million people are poisoned by pesticides worldwide. Developing countries represent a quarter of the use of pesticides in the world, but record 99% of deaths caused by these same pesticides. The Food and Agriculture Organization of the United Nations (FAO) recommends good management practices pesticides that can minimize potential health risks for farmers and other users in public hygiene. However, in the Nyiragongo health zone, in North Kivu, thousands of farmers are victims of respiratory poisoning caused by chemical pesticides. The objective of this study, therefore, was to examine the knowledge and practices of standard use of chemical pesticides and hazardous exposure among farmers in the Nyiragongo health zone in North Kivu, DRC. The study was guided by the theory of planned behavior. The study used a retrospective matched case-control design targeting 183,988 farmers in the Nyiragongo health zone from which a sample of 302 farmers selected using. Data was collected using a questionnaire, and analyzed using descriptive and inferential statistics. The study established that knowledge and practices on standards were significantly associated with harmful exposure to chemical pesticides among farmers in the Nyiragongo health zone. The study therefore recommends the development of robust regulatory frameworks that will enable policy actors to carry out urgent multidimensional interventions, such as raising awareness and training policy implementers and farmers on chemical pesticides.

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INTRODUCTION

The term pesticide is derived from the English "Pest", (pests) and the suffix - cide (to kill), pesticide brings together all the substances which are used to prevent, control or eliminate organisms considered undesirable, whether plant , animals, fungi or bacteria. Mainly used in agriculture, we then speak of phytosanitary or phytopharmaceutical products and are classified by type of use: herbicides, insecticides, fungicides, nematicides (against nematodes) and rodenticides (Tebila, 2020). According to the FAO, 4,600,000 tonnes of pesticides are sprayed into the environment each year, or 146 kg of pesticides per second. Developing countries represent a quarter of the use of pesticides in the world, but record 99% of deaths caused by these same pesticides (Planetoscope, 2023). Every year, 3 million people are poisoned by pesticides worldwide. According to the WHO, between 20,000 and 200,000 deaths are due to pesticides each year, especially in developing countries where around a third of the pesticides used do not meet international quality standards (Planetscope, 2023). The International Code of Conduct for the Distribution and Use of Pesticides, adopted in 1985 by the Conference of the Food and Agriculture Organization of the United Nations (FAO) and revised in 2002, recommends good management practices pesticides that can minimize potential health risks for farmers and other users in public hygiene (FAO, 2017). The use of pesticides has increased due to their widespread application in agricultural and environmental pest control. Many agricultural activities pose serious pesticide exposure risks, such as preparing land for cultivation, storing, mixing, preparing and spraying pesticides, and loading and cleaning spray equipment. Adverse exposure to pesticides can lead to acute and chronic health problems, including temporary acute effects such as eye irritation and excessive salivation, as well as chronic diseases such as cancer and reproductive and developmental disorders. Others have reported adverse health effects, such as dermatitis, asthma, effects on peripheral nerves, chronic neurobehavioral disorders, motor dysfunction, burning sensations in the eyes/face, skin irritation, headache, dizziness and respiratory effects. The WHO (2023) estimates the number of poisonings worldwide at 1,000,000 and the resulting deaths at 20,000. Farmers in developing countries are the most disproportionally by the products banned for use in industrialized countries are still sold in these countries (WHO, 2023). Several studies have reported an increased risk of respiratory problems, such as asthma and chronic bronchitis, among agricultural workers. Exposure to pesticides has been associated with an increased risk of respiratory symptoms in agricultural activities. Workers are typically exposed to a wide range of different chemicals. Contact with these substances is not limited to the application of the product, but also occurs during the preparation of the product, when carrying hoses, washing contaminated clothing and administering the treatment to livestock (Mamane *et al.,* 2015).

A study involving a large cohort of approximately 20,000 pesticide applicators in the United States, demonstrated the association between agricultural activities with pesticides and the occurrence of wheezing in the previous year. A historical cohort of Australian farm workers involved in tick control showed that occupational exposure to insecticides was associated with lower asthma mortality rates and higher prevalence of atopic diseases among the survivors (Jucy, 2022). According to previous studies, factors contributing to morbidity and mortality related to pesticide exposure included insufficient knowledge, non-use or inappropriate use of PPE, inappropriate storage of pesticides at home, poor attitude negative towards pesticides and inappropriate practices. For instance, in the mountainous region of southern Brazil (Serra Gaúcha), an estimated 95% of farms use some kind of pesticide and at least three out of four agricultural workers are regularly exposed to pesticides. It is also estimated that only half of these workers use protective masks (face shields) when working with these products (Jucy, 2020). Also, in September 2001, around 500 farmers working in cotton fields in India died from heavy exposure to the pesticides they were spreading. To protect themselves, they only covered their mouth and nose with a piece of cloth (AFP July 31, 2002).

The context of the current study is Nyiragongo Health Zone in Nord Kivu Province in the Democratic Republic of Congo. North Kivu is a province bordering Lake Kivu in the eastern Democratic Republic of the Congo. Its capital is Goma. The 2020 population was estimated to be 8,147,400. North Kivu borders the provinces of Ituri to the north, Tshopo to the northwest, Maniema to the southwest, and South Kivu to the south. The area is complex theatre of disasters ranging from episodic volcanic eruptions, outbreaks of epidemic diseases such as cholera an ebola and is also a malaria endemic area. It is also an area of high policy instability characterized by perennial armed conflict between the government and the rebels. Before the last volcanic eruption in 2021, 1,149,300 people were living in the Nyiragongo health zone, north of Goma city, before the crisis. 49.1% were men and 50.9% women. As per the 2017 census, 72.9% of the population were living on less than 1 USD per day and the human development index in the zone was 0,440 (ReliefWeb, 2021).

Problem: Majority of the population in the Nyiragongo health zone are peasant farmers and mostly practice market gardening. Pesticides form a major farm input in the area with many farmers in the area being observed as continually pesticides to boost their crop production practices. Many farmers in the area are victims of several repeated symptoms that cause respiratory diseases, thus weakening their health and consequently affecting their level of agricultural productivity. The respiratory diseases also present as acute and chronic and can have severe consequences including morbidity and mortality if left untreated. According to the Central Office of the Nyiragongo Health Zone (BCZ/NYIRAGONGO), many farmers coming to consult different health centers present with acute respiratory symptoms (persistent cough, shortness of breath, fever, cold, difficulty breathing and rhinitis) and others are already suffering from asthma, bronchitis which have been linked to hazardous exposure to the chemical pesticides. However, their knowledge of the pesticides and their handling practices together with their link to hazardous exposure had not been previously established in extant literature carried out in the DRC such as SOS FAIM (2021) and Balasha *et al*., (2023). This, therefore, prompted the present study to examine the knowledge and practices of standard use of chemical pesticides and hazardous exposure among farmers in the Nyiragongo health zone in North Kivu, DRC.

Objective: The objective of this study, therefore, was to examine the knowledge and practices of standard use of chemical pesticides and hazardous exposure among farmers in the Nyiragongo health zone in North Kivu, DRC.

LITERATURE REVIEW

Theory of Planned Behaviour: The Theory of Planned Behavior (TPB) is a psychological theory that links beliefs to behavior. It was proposed by Icek Ajzen (1991). The theory holds that three fundamental elements, namely attitude, subjective norms and perceived behavioral control, together shape an individual's behavioral intentions. In turn, a tenet of the TPB is that behavioral intention is the most proximal determinant of human social behavior. The theory of planned behavior links knowledge and attitude toward behavior, subjective norms, and perceived behavioral control to behavioral intentions and actions (Haileamlak, 2018; Anuar *et al*., 2020). However, it is also possible for external factors to directly force or prevent behaviors, regardless of intention, depending on the degree to which a behavior is actually controlled by the individual and the degree to which perceived behavioral control is an accurate measure of control actual behavior. The TPB has been applied to the study of relationships among beliefs, attitudes, behavioral intentions, and behaviors in various human domains. These areas include, but are not limited to, advertising, public relations, advertising campaigns, healthcare, sports management, consumer and household finance, and sustainability, among others. Several studies have shown that, compared to TRA, TPB better predicts health-related behavioral intention (Ajzen, 2015; Albarracin, Johnson, Fishbein, & Muellerleile, 2001; Sheeran & Taylor, 1999). However, the theory of planned behavior has not been used in studies on malaria prevention in North Kivu, eastern DRC. Given that disease prevention is largely determined by behavioral intention, the theory of planned behavior was useful in guiding the present study on how: knowledge and attitudes towards chemical pesticides; subjective norms such as social pressures, as well as the perceived expectations of others and the value the individual places on these expectations influence hazardous exposure to chemical pesticides among farmers in the Nyiragongo health zone in North Kivu, DRC.

Knowledge and standard use practices and hazardous exposure to chemical pesticides: Chemical pesticides are manufactured to work effectively within certain parameters and standards. Knowledge and application of pesticides within prescribed standards is therefore important for farmers if they want to get the most out of pesticides and also avoid harmful exposures that can lead to disease or injury. In this section we look into the; Correct wearing of personal protective equipment, Compliance with required doses when mixing chemical pesticides, Non-use of expired pesticides in agriculture, Body washing and cleaning of clothes after spraying, Correctly following manufacturer's instructions on product labels, Spraying chemical pesticides in non-windy weather, and Good management of pesticide containers or packaging.

Correct wearing of personal protective equipment: Having correct knowledge and attitudes regarding pesticide protection and safe practices, such as effective use of PPE, and understanding manufacturers' labels are important for correct handling of pesticides by farmers. Generally, PPE such as masks, gloves, boots, helmets and long-sleeved clothing are used as protective equipment during the preparation and spraying of pesticides. According to the standards set out in the International Code of Conduct for the Distribution and Use of Chemical Pesticides, pesticides whose handling and application require the use of personal protective equipment that is uncomfortable, expensive or difficult to obtain, must be avoided, particularly by small farmers in tropical climates. Preference should be given to pesticides requiring inexpensive protective equipment and application materials, as well as procedures appropriate to the conditions under which the pesticides are to be handled and used (FAO, 2002). However, the gap between farmers' knowledge and practices, particularly regarding the use of pesticides, has been highlighted by several researchers.

Globally, the use of pesticides is increasing day by day, but the use of personal protective equipment (PPE) in developing countries remains low and farmers are directly exposed to chemicals that cause health problems (Patrick, 2021). Studies associated with knowledge, attitudes and behaviors regarding the use of pesticides have been carried out in some countries. They revealed that many farmers still behave riskily and some do not use personal protective equipment when spraying. Studies conducted on the knowledge and use of pesticides in several developing countries have shown that agricultural practices are often dangerous and can lead to health problems and environmental risks. Inappropriate use of pesticides is still widespread in many regions, leading to a number of negative impacts. An experimental study by Van (2021) comparing different types of gloves determined that nitrile gloves would provide better protection than polyvinyl chloride (PVC) gloves against a permethrin-based pesticide. Houbraken *et al* (2016) state that the importance of using personal protective equipment (PPE) when handling pesticides is recognized by agricultural workers. However, not everyone wears safety equipment. Gesesew *et al.* (2016) found that even though farmers are aware of the adverse effects of pesticides on human health, they continue to neglect the use of PPE when using them. A study by Taghdisi *et al.* (2019) revealed that although knowledge significantly affects the practice of safe pesticide use, the lack of "know- how" still exists among Iranian farmers; the study found that this gap is due to the cost and difficulty of taking protective measures.

Aye, Jirapongsuwan, and Siri (2023) carried out a cross-sectional study of pesticide safety behaviors and associated factors among 195 cabbage growers in Kalaw Township, Myanmar. In total, 72.1% of farmers had a low level of safety behaviors. Goggles and masks were rarely used before and during pesticide application. All farmers have suffered adverse health effects after using pesticides. Attitudes towards pesticide poisoning; support from family, colleagues, and health care providers; and availability of personal protective equipment were significantly associated with safety behaviors. Miyittah *et al.* (2022) studied farmers' knowledge, attitudes towards pesticide use, storage/disposal, exposure risks and health symptoms in one of eight cocoa-producing regions of Ghana. The study found that a considerable proportion, more than a third of farmers, used the bush as a place to store pesticides, 17% of farmers stored chemicals in their living room, 3% of farmers stored chemicals in their kitchen, 15% in their food reserve and 4% in the pet store. Use of personal protective equipment (PPE) was positively associated with advice obtained from agrochemical stores and extension services as sources of information on PPE use. Female farmers were less likely to use PPE. The study also found that farmers in certain geographic areas were significantly less likely to use PPE.

Compliance with required doses when mixing chemical pesticides: According to the international standard, exposure to pesticides can occur during transportation, mixing, loading or application of chemicals, during cleaning or repair of equipment or when returning to treated fields. Factors affecting the level of exposure include the type of activity (e.g., application, mixing, loading, or harvesting), method of application (For example: air blast, rear airbag, aerial spray, spray manual or ground application), pesticide formulation (For example: diluted spray). , aerosol). or dust), application rate (For example: weight of active ingredient/acre), and work and personal hygiene habits (For example: putting on clean clothes/washing hands or taking a bath/shower after using the pesticide, frequency of medical visits). The challenge is to integrate these exposure modifiers into an estimate of the intensity of pesticide exposure (Mustafa, 2002). According to Son *et al.,* (2021), some farmers have poor phytosanitary practices such as poor choice of pesticides, non-compliance with prescribed doses, non-compliance with recommended protection and hygiene rules during treatments., as well as poor crop management. empty packaging. Overdose of chemical pesticides is an important factor in farmers' exposure when mixing chemical pesticides. This includes workers handling pesticides, from preparation of the pesticide to application, workers responsible for cleaning pesticide handling systems, as well as those near the premises where disinfection procedures are carried out. Many researchers, including those in this study, suggest that an increase in environmental pollutants like pesticides could be the cause (Tarmor *et al.,* 2020). In the DRC, regarding the use of chemical pesticides, farmers buy repackaged pesticides, sometimes in 100 ml bottles without labels, in very small quantities. They do not know the specific pests to control, nor the concentration and formulation of the product, nor the dose to use, and often do not protect themselves by wearing protective equipment during treatment. The safety period of 2 to 3 weeks before harvesting treated vegetables is not always respected (Chimanga, 2018).

Non-use of expired pesticides in agriculture: According to the standard, once a pesticide has passed its expiration date, a disposal procedure must be initiated in accordance with international standards for the disposal of hazardous materials. The same goes for out-of-use equipment which must be removed from storage, decontaminated and dismantled so as not to be used for other purposes (Senamayake, 2007). Furthermore, according to the standards of pesticide use, due to the dangers posed by obsolete pesticide stocks and the high cost of their safe and environmentally acceptable disposal, the solution to the problem lies in preventive measures based on adequate planning and implementation of phytosanitary treatment operations (Sungur, 2020). Lekei *et al.* (2014) established that poor pesticide use practices, such as lack of disposal management and use of PPE, are common among farmers, even when they have a good level of knowledge about the potential dangers of pesticides.

Body washing and cleaning of clothes after spraying: Farmers should properly clean their bodies and clean up their habits after finishing spraying chemical pesticides on plants (Williams, 2016). Additionally, protective clothing and equipment should be washed daily with soap and water, separately from other clothing. Protective clothing must always be impeccably maintained and periodic checks must be carried out to verify that there are no tears or wear in the fabric which could lead to contamination of the epidermis. Gloves should be given special attention and should be replaced as soon as they become torn or show signs of wear. After use, they must be rinsed with plenty of water before others. At the end of each working day, they must be washed outside and inside (PAN-Mali, 2012). Several studies have shown that hand washing almost completely eliminates pesticides. Handwashing was one of the strategies used to reduce pesticide exposure among agricultural workers in most studies. A study on pesticide use on agricultural farms in Ethiopia by Gesesew *et al.* (2016) found that sprayers agreed with recommendations to wash if pesticides were splashed on their bodies, but did not seem convinced of the benefit of going to a center to receive further treatment. A few thought that working with pesticides should not be a problem at all, while the vast majority considered careful handling to be more important than using PPE.According to a study carried out by Mushagalusa (2021) in South Kivu, the results also showed that most isolated farmers did not protect themselves when applying pesticides. The main reason respondents gave for not wearing protective equipment was lack of money to buy PPE. The same reason was given by urban farmers in Togo and Lubumbashi, where Mushagalusa et al., (2019) also discussed the neglect of hygiene practices, i.e. washing the body, or at least the hands after treatment. This negligence, combined with observed negligence, such as eating and smoking during treatment, significantly increases the risks of poisoning, burns and, in extreme cases, can lead to death (Mushagalusa *et al.,* 2021).

Correctly following manufacturer's instructions on product labels: Many farmers expose themselves to the dangers of chemical pesticides due to their lack of knowledge of the quality of the products they wish to use in agriculture. The information label is usually stuck directly on the container, but an additional information label can also be affixed in a sealed plastic envelope. It is the responsibility of the manufacturer, formulator, importer or exporter to affix the label required by national pesticide legislation. The label should be in the appropriate local language(s). The quality of information on chemical labels varies widely, particularly regarding prevention and control measures (WHO, 2020). All pesticides must be used in accordance with the provisions of the Pesticide Management Code and the manufacturer's instructions on the product label. In the event of a discrepancy between a label instruction and a provision of the Pesticide Management Code, the more restrictive rule applies (Afshari *et al.,* 2021).

Spraying chemical pesticides in non-windy weather: When farmers spray, pesticides come into contact with the atmosphere during their application through the phenomena of volatilization, photolysis with atmospheric hydrogen oxide and the effect of wind (drift). The term "volatilization" brings together all the physicochemical processes of transfer of compounds from the soil or plants to the atmosphere. This is one of the main causes of pesticide leakage outside the target area, especially when treatments target the soil surface or that of plants. The transfer of pesticides into the air varies depending on the nature of the product, methods of use, the nature of the soil, and climatology (Pesto, 2020). Therefore, when spraying pesticides, the direction and movement of spraying are considered important as they prevent direct contact of the pesticide during spraying. A study by Pesto (2023), however, found that the majority of farmers considered wind direction when spraying, and 39.5% of them moved in the direction opposite to the direction of the pesticide when spraying. Studies have shown that farmers who spray chemical insecticides in windy weather have a high probability of inhaling a large amount of chemical pesticides and thus causing acute respiratory poisoning. Respiratory diseases represent a major health problem for agricultural workers. An increase in the frequency of respiratory manifestations is associated with exposure to pesticides. Recent studies have identified a number of respiratory symptoms associated with occupational exposure to pesticides. Respiratory pathologies in people exposed to pesticides and the association between bronchial asthma and occupational exposure to pesticides have been well documented, mainly in agricultural occupations (Tarbre *et al.,* 2020).

Good management of pesticide containers or packaging: According to the standards set by the WHO and FAO, empty containers, packaging and receptacles that have contained pesticides must not be reused, but recovered and recycled. It is therefore recommended to return the containers to the supplier and, if this is not possible, it is preferable to clean them three times before crushing them and burying them in a site studied and provided for this purpose. The management of empty containers must be done at two levels: those coming directly from the manufacturer must be returned and the others prepared for orderly reuse (Ministry, 2021). Furthermore, in accordance with international pesticide regulations, governments must take necessary regulatory measures to prohibit the repackaging or transfer of any pesticide into containers used for food or beverages and apply severe penalties to effectively discourage these practices. In addition, governments must commit to ensuring that pesticides are sold and purchased by reputable traders, preferably affiliated with a recognized trade association (FAO, 2002). A study carried out among farmers in Mali showed that the country is full of resellers and window dressers whose control poses problems for the services responsible for regulation and control. In fact, many of them do not meet the profiles required by the profession. Empty pesticide packaging is used to store, preserve and transport beverages (including water, milk, etc.) as well as foods such as porridge and oil (Moustafa, 2022). In the DRC, empty packaging is generally thrown into nature in an anarchic manner (either buried in the ground or burned), or is reused for other purposes (water collection, food preservation, etc.), thus putting endangering the lives of populations and the environment (Ministry, Idem). Other farmers in the Democratic Republic of Congo use containers, packaging and empty containers that have contained categories of chemical pesticides which should not be reused, but recovered and recycled.

METHODOLOGY

Context of the study area: This study was carried out in the Nyiragongo health zone, North Kivu Province in the Democratic Republic of Congo. Agricultural activities constitute the economic pillar of the Nyiragongo health zone where more than 85% of households practice agriculture and livestock breeding. Nyiragongo health zone was chosen for this study due to the high prevalence of respiratory diseases in recent years compared to other health zones in the region, and these have been linked to the hazardous application chemical pesticides.

Study design: According to a 2023 report from the Health Information System (SNIS) of the Nyiragongo health zone, respiratory diseases have a prevalence of 8% among farmers in the area. The prevalence of respiratory diseases recorded in the Nyiragongo health zone justifies the choice of the retrospective case-control study design. The case-control study is retrospective because it begins with an outcome and then returns to examining exposures.The case-control study was used to see if exposure is linked to a certain outcome (i.e. recurrent respiratory illness). In this study, the cases therefore included farmers using chemical pesticides who had contracted respiratory diseases, while the control group was composed of farmers using chemical pesticides who had not previously contracted respiratory diseases. Exposure included farmers who inhaled, handled, stayed for a long time in hazardous agrochemicals, while non-exposures included farmers who had not been exposed to hazardous agrochemicals. The researcher had reason to believe that exposure to hazardous chemical pesticides was influenced by the farmers' knowledge and practices regarding the application of chemical pesticides in the region.

Population studied: This study targeted farmers in the Nyiragongo health zone who use chemical pesticides, estimated today at 183,988 farmers. The study included area farmers aged 18 and over because they are responsible for their choices. This included actual farm owners and farmers who are actively involved in daily agricultural activities on their land. The study focused only on farmers actively involved in purchasing and applying chemical pesticides on their farms. This research targeted farmers in the Nyiragongo health zone who had contracted respiratory diseases (cases) and those who had not contracted respiratory diseases (control zone). Exposure was defined as farmers who had prolonged exposures and inhalation of pesticide vapors (exposed) and those who did not have prolonged exposures and inhalation of pesticide vapors (unexposed). The inclusion criteria for the cases and control were; being a farmer from the Nyiragongo Health Zone, having ever used chemical pesticides, resident in the Nyiragongo Health Zone, being an adult, over 18 years old, having contracted a respiratory symptom or illness for the cases, and not reported in people with respiratory illnesses for the control. The exclusion criteria for the cases and the control were; being a farmer from another health zone in North Kivu, farmers who do not use chemical pesticides in Nyiragongo Health Zone, farmers under 18 years of age, and an undeclared case in a health facility in the Nyiragongo health zone. The study also targeted the regulatory actors involved in the implementation of the chemical pesticide control policy in the North Kivu province. These included actors involved in different services in the implementation of the chemical pesticide control policy at the provincial level, namely: The Congolese Control Office (OCC), National Service for Fertilizers and Associated Inputs (SENAFIC), Directorate of Plant Production and Protection (DPPV), Animal and Plant Quarantine Service (SQUAV), National Agricultural Extension Service (SNVa), National Institute for the Study of Agronomic Research (INERA), National Sanitation Program (PNA), Provincial Environment Division (DPE), Provincial Health Division (DPS), Civil protection, Peasant organizations of Nyiragongo farmers, Central Health Zone Office (BCZ), Rural development (DR), and Trade.

Determination of sample size: For this case-control study, the sample size was determined among farmers (cases and controls) for the quantitative approach. But also at the level of the actors involved in the implementation of chemical pesticide control policies for the qualitative approach.To determine the sample size for the two groups (cases and controls) of the retrospective case-control study, the study used the formula proposed by *Charan and Biswas* (2013) as follows:

$$n = \frac{r+1}{r}\frac{(P^*)(1-P^*)\left(Z_\beta + Z_{\alpha/2}\right)^2}{(P_1 - P_2)^2}$$

Or;

r = Control/case ratio, 1 for an equal number of cases and controls
P* = Average proportion exposed = proportion of cases exposed + proportion of controls exposed/2
Z_β = standard normal variable for power = for 80% power, it is 0.84 and for 95% value, it is 1.96.
$Z_{a/2}$ = standard normal variable for significance level as mentioned in the previous section.
$P_1 - P_2$ = Effect size or different proportion expected based on previous studies.
P_1 is the control proportion which is taken as 19% from the calculation of P_1 using the odds ratio formula.
P_2 is the proportion of cases retained at 8% in the study of the Health Information System (SNIS).

Substitution into the above formula yielded a sample size of 151 cases which was then matched with 151 controls using gender as a matching criteria. Qualitative data was collected from 14 state structures responsible for implementing chemical pesticide control policies who were the key informants on pesticide policy monitoring and regulation in the North Kivu Province.

Sampling technique: According to the Health Information System (SNIS) of the Nyiragongo health zone, respiratory diseases have a prevalence of 8% among farmers. Since most of these farmers were diagnosed at some point with respiratory diseases in public health facilities in the region, it was possible to access their data and thus be able to trace them. Their medical records at health facilities in their respective health zones provided the necessary contact details as well as socio-demographic information of the farmers. Systematic random sampling was, therefore, used to select farmers who were diagnosed with respiratory diseases and match them with control group farmers. This ensured that inclusivity and proportionality in sampling was done across all the health zones. Using the farmers' contact information at the hospital, initial contacts were made with the farmers by the researcher where the study's purpose was explained and the inclusion criteria of the farmers in the study was determined. After these were determined, the researcher located physically the first farmer in his farm in Kiziba health zone. After interviewing the first farmer, the researcher was also able to locate other farmers who met the inclusion criteria for controls and cases group in the Kiziba health zone. The process was repeated in other health zones in the area as well. For the policy actors, the study used convenience sampling where individuals were interviewed in different structures or organizations based on their availability.

Data Collection Instruments: The study used two approaches: quantitative and qualitative, and each approach had its specific tools: for the quantitative approach, the *survey questionnaire* was used to facilitate data collection of cases and controls (farmers) in the Nyiragongo health zone. For the qualitative approach, *the interview guide* was used to collect data from key informants in different targeted structures.

Data analysis methods: For the quantitative approach the control cases used two types of analysis, namely univariate analysis and bivariate analysis. Univariate analysis involved frequencies, percentages, means, standard deviations.Bivariate analysis regression approach was used to evaluate the relationship between the dependent and independent variables, the Odds ratio (OR) was subsequently calculated and allowed us to measure the association between the factors of exposure of farmers to chemical pesticides and the respiratory diseases that this exposure causes. For the qualitative approach, the data analysis was carried out at two levels; content analysis and theme analysis.

RESULTS

Knowledge of the standard of use and hazardous exposure to chemical pesticides: The results summarized in Table 1. Table 1 shows there were some significant differences in practices between cases and controls regarding the knowledge of farmers when handling chemical pesticides.

Training farmers on proper wearing of personal protective equipment (PPE): The majority of farmers (N=279) had not received training on the correct wearing of PPE before using chemical

Table 1 Level of knowledge of farmers on the standards for the use of chemical pesticides

		Case	Controls	Chi square	P-value
Have you already been trained in the correct use of PPE before using	Yes	4	19	10.589a	0.001
chemical pesticides?	No	147	132		
In your opinion, what is your level of	Low (0 – 49%)	139	134	8.344a	0.015
knowledge consists of wearing PPE	Average (50 - 59%)	11	7		
correctly?	High (60 – 100%)	1	ten		
Have you ever been trained on dosing	Yes	19	31	3.451a	0.063
chemical pesticides?	No	132	120		
Do you know the exact dose of	Yes	60	47	2.446a	0.118
pesticide you use to spray plants?	No	91	104		
Do you know the procedure to identify the dosage of the pesticide you are using?	Yes	37	45	1.071a	0.301
On the label?	No	114	106		
In your opinion, what is your level of	Low (0 – 49%)	112	110	3.925a	0.141
knowledge of chemical dosage	Average (50 - 59%)	13	6		
pesticides?	High (60 – 100%)	26	35		
How much do you rate your knowledge on the importance of body washing and cleaning?	Low (0 – 49%)	137	143	9.344a	0.009
clothing after handling and spraying chemicals	Average (50 - 59%)	4	0		
pesticides?	High (60 – 100%)	10	2		
At what level do you estimate your knowledge in	Low (0 – 49%)	133	128	.706a	0.703
the importance of following instructions before	Average (50 - 59%)	7	9		
handle chemical pesticides?	High (60 – 100%)	11	14		
Do you know the ideal time to spray	Yes	57	75	4.360a	0.037
chemical pesticides?	No	94	76		
What do you think you know about	Low (0 – 49%)	106	91	5.327a	0.070
the ideal time to spray chemical pesticides?	Average (50 - 59%)	31	33		
	High (60 – 100%)	14	27		
Do you have knowledge on proper disposal of pesticide containers/packaging	Yes	12	20	2.237a	0.135
after use?	No	139	131		
At what level do you estimate your	Low (0 – 49%)	133	122	4.241a	0.120
knowledge of chemical management	Average (50 - 59%)	14	18		
pesticide containers/packaging?	High (60 – 100%)	4	11		

pesticides and the differences between the two groups were significant (p=0.001≤0.05). Along the same lines, more farmers in the control group (N = 10) than in the case group (N = 1) reported that their level of knowledge on the correct wearing of PPE was above 60% and that the differences were significant (p = 0.015 ≤ 0.05).

Knowledge of dosages of chemical pesticides: Most farmers indicated that they had not been trained on pesticide dosages. However, among the few farmers (N=50) who reported receiving training, more control group farmers (N=31) than case group farmers (N=19) reported receiving training on pesticide dosages, however, the difference in access to training between the two groups was not significant (p = 0.063). Most farmers in the case group (N = 60) compared to farmers in the control group (N = 47), however, indicated that they knew the exact dosages of chemical pesticides, although the differences in knowledge were not significant (p = 0.118). Additionally, most farmers (N=222) reported that their knowledge level on chemical dosage was less than 40%. However, among those who claimed to have more than 60% knowledge of pesticide dosages, there were more farmers in the control group (N = 35) than in the case group (N = 26), the difference was not also not significant (p = 0.141).

the control group (N = 75) than farmers in the case group (N = 57) indicated that they knew the ideal time for spraying pesticides and the difference was significant (p = 0.037). In terms of levels of knowledge of spraying schedules, more farmers in the case group (N=106) than in the control group (N=91) admitted that they knew less than 40%, while a greater Many farmers in the control group (N = 60) than the case group (N = 45) indicated that they knew more than 50%, although the difference was not significant (p = 0.070).

Knowledge on body washing and cleaning of clothes after handling chemical pesticides: The results also indicate that farmers' knowledge on the importance of washing the body and cleaning clothes after handling and spraying chemical pesticides was significant in both groups (p = 0.009 ≤ 0.05), the group of case being more informed on this aspect than the control group.

Good practices for disposing of chemical pesticide packaging: Most farmers admitted that they did not know the proper methods of disposing of pesticide containers/packaging after use (N=270). However, this result was not significant in both the case group and the control group (p = 0.135).

Table 2. Practices of farmers on the standards for the use of chemical pesticides

			Case	Controls	Chi square	P-value
Are you used to wearing personal protective equipment?						
		Yes	7	16	3.812a	0.050
		No	144	135		
If yes, under what circumstances do you wear personal protective equipment?						
		When mixing or dosing pesticides	4	14	4,000a	0.046
		While spraying pesticides	7	15	.273a	0.602
		During pesticide transportation	1	7	2.344a	0.126
		During pesticide storage	3	14	6.454a	0.011
What is the current status of the personal protective equipment you wear?						
		Good (new, clean)	3	ten	26.211a	0.000
		Average (acceptable)	7	34		
		Bad (torn, dirty, etc.)	141	107		
What is the main unit you use to measure chemical pesticides?						
		A beer cap	27	34	13.818a	0.003
		A cup	20	27		
		A 0.5 liter plastic bottle	10	26		
		Random dosing	34	17		
Do you have the habit of washing your body and cleaning your clothes properly after handling and finishing the spray pesticides chemicals?						
		Yes	63	76	2.253a	0.133
		No	88	75		
If so, how often do you do it?						
		Regularly	9	25	6.921a	0.031
		Rarely	37	38		
		Very rarely	17	13		
Otherwise, why don't you clean your body and clothes properly?						
		Lack of water to wash and clean clothes	19	10	4.263a	0.234
		Lack of soaps	18	10		
		Insufficiency of alternative clothing	13	15		
		Not important	38	40		
Otherwise, why don't you follow the directions on the label of the chemical pesticides you use?						
		I don't know how to read and write	2	52	89.965a	0.000
		The instructions are written in French	1	13		
		Instructions are written in English	31	36		
		Instructions are written in another foreign language	94	30		
If so, when is the ideal time to spray chemical pesticides that do not expose the user to the dangers of the chemical pesticides?						
		Early in the morning	12	20	7.320a	0.062
		The evening	23	34		
		During strong wind	13	5		
		Under a blazing sun	9	16		
Are you correctly following all label directions for the pesticides you use?						
		Yes	23	39	5.196a	0.023
		No	128	112		
Do you often buy and use pesticides that no longer have a label?						
		Yes	129	112	5.937a	0.015
		No	22	39		

Knowledge on ideal time to for spraying chemical pesticides: Most farmers indicated that they did not know the ideal spraying time (N = 170) than those who indicated that they did (N = 132). Among those who indicated that they knew the ideal spraying time, more farmers in

Additionally, most farmers (N=255) indicated that they knew less than 40% of the proper methods for disposing of pesticide containers/ packaging after use.

Practices on the standard of use and hazardous exposure to chemical pesticides: The results summarized in Table 2. Table 2 shows the practices used by farmers when handling chemical pesticides. There were some significant variations in practices between cases and controls.

Farmers practice on proper wearing of personal protective equipment (PPE): Majority of farmers (N=279) were not accustomed to wearing personal protective equipment and the differences between the two groups were significant (p=0.05), with more farmers in the control group than in the group of cases reporting that they regularly wore personal protective equipment. When asked under what circumstances they wore personal protective equipment, respondents indicated that it was when mixing or dosing pesticides ($p = 0.046 \leq 0.05$) and during pesticide storage ($p = 0.011 \leq 0.05$) and the differences between cases and controls were significant, with more farmers in the control group (N = 50) than in the case group (N = 15), indicating that they carried PPE at different times. There is some evidence that the current state of personal protective equipment worn by farmers was one of the reasons why they were not regularly wearing PPE. Most farmers reported that their PPE was "bad (torn, dirty, etc.)", with farmers in the case group having their PPE in poor condition compared to farmers in the control group, and the difference was significant (p = 0.000).

Knowledge of dosages of chemical pesticides: In terms of calculating dosages, most farmers used a beer cap (N = 61), a cup (N = 47), a 0.5 litres plastic bottle (N = 36) and a dosage random (N = 51). However, more farmers in the control group tended to adopt a beer cap as a dosing measure (N=34), while most farmers in the case group preferred random dosing (N=34) and the difference in dosing measurement preferences between the two groups was significant (p = 0.003).

Body washing and cleaning of clothes after handling and spraying chemical pesticides: More cases group farmers (N = 88) than control group farmers (N = 75) did not have the habit of washing their bodies and cleaning their clothes properly after handling and finishing spraying the chemical pesticides. However, there was a significant difference (p = 0.031) between control group farmers (N = 25) and cases group farmers (N = 9) who regularly washed their bodies and clothes after handling the chemical pesticides. Most of those who did not have the habit of washing their bodies and clothes after handling the pesticides felt that it was not important.

Practice of following the manufacturer's instructions on the labels: Most farmers did not correctly follow all label instructions for the pesticides they used (N=240), and fewer farmers in the case group (N=23) than in the control group (N = 39) correctly followed all label instructions (p = 0.023). ≤ 0.05). Most farmers indicated that label instructions being written in another foreign language (N=124) was the main reason they did not follow all label instructions correctly. Farmers then indicated that the instructions on the labels were written in English (N = 67). Illiteracy was also cited by most farmers as one of the reasons why they did not follow the instructions on the labels of the chemical pesticides they used (N = 54). However, it appears that fewer farmers have difficulty following the instructions on labels written in French (N = 14). Variations in these reasons for not correctly following all instructions on pesticide labels were significant between groups (p = 0.000). Additionally, most farmers indicated that they often purchase and use pesticides that no longer have labels, with more farmers in the case group (N=129) than in the control group (N=119) agreeing with the proposition ($p = 0.015 \leq 0.05$). The majority of farmers (N=261) also indicated that their level of knowledge about the importance of following instructions before handling chemical pesticides was very low, less than 40%.

Spraying chemical pesticides during non-windy time: Also, regarding the ideal time to spray chemical pesticides that does not expose the user to the dangers of chemical pesticides, there were no significant differences ($p = 0.062 > 0.05$) between the cases and the control groups. However, most farmers preferred to spray the chemicals in the evening (N=57), while a relatively small number of farmers sprayed the pesticides during windy hours (N=18), with a larger number of farmers in the case group tending to spray pesticides (wrongly) at windy hours (N = 13) than the farmers in the control group (N = 5). Finally, significant differences were also observed in farmers' knowledge of the ideal time to spray chemical pesticides ($p = 0.037 \leq 0.05$) between the two groups, with more farmers in the control group (N = 75) knowing the time of spraying than those in the control group the case group (N = 57).

DISCUSSION

The results revealed that the majority of farmers in both the case and control groups did not receive training on the correct wearing of PPE before using chemical pesticides. As a result, very few farmers (mainly in the control group) reported that their knowledge level on correctly wearing PPE was above 60%. This indicates that there was no effective program to educate farmers in the region, despite the risks posed to them by chemical pesticides. The results are therefore consistent with those of Aye, Jirapongsuwan and Siri (2023), whose study in Myanmar found that the majority of farmers had low levels of safety behaviors. The findings also agree with Abong'o et al., (2014) who found that the general knowledge among farmers about chemicals risks, safety, and chronic illnesses was low in the River Nyando catchment, Kenya. This result contrasts with that of a similar study carried out in Benin by Hinson *et al.,* (2015) which revealed that the level of knowledge of farmers on pesticides was high since more than 75% of farmers had been trained in more than an opportunity on the use of pesticides of pesticides. The results also do not agree with those of Pasiani *et al.* (2012), whose study in Brazil found that almost all farmers recognized that pesticides were potentially harmful to their health. However, very few farmers in Nyirangongo region knew about PPE and they probably obtained this knowledge/training from vendors. This is therefore consistent with Miyittah *et al.* (2022) whose study in Ghana established that the use of PPE was positively associated with advice obtained from agrochemical stores.

The results further revealed that the majority of farmers were not accustomed to wearing PPE, although more farmers in the control group than the case group reported that they regularly wore PPE. Among those who regularly wore PPE, this appeared to occur primarily when mixing or dosing pesticides and during pesticide storage. These results are consistent with Pasiani *et al.* (2012), who found that more than half of people rarely or never used personal protective devices (PPD). Aye *et al* (2023) also found that Myamar cabbage growers rarely used goggles and masks before and during pesticide applications. However, the results also contrast with those of Hinson *et al.* (2015) who established that all farmers in their study in Benin wore their PPE when handling pesticides. However, in the case of Nyirangongo farmers, the reasons for the misuse of PPE when handling pesticides go beyond training and knowledge and relate to the condition of the PPE worn by farmers. Most farmers reported that their PPE was "bad (torn, dirty.)", with farmers in the case group having their PPE in poor condition compared to farmers in the control group. With the results also indicating that more than 80% of farmers had a monthly income of US$100 or less, it is possible that most farmers were not able to meet the costs of acquisition, replacement or replacement proper maintenance of their PPE. Aye *et al.* (2023) did, however, establish a significant link between attitudes toward pesticide poisoning; support from family, colleagues, and health care providers; and availability of personal protective equipment with safety behaviors among farmers.

The present study also found that most farmers did not correctly follow all instructions on the label of the pesticides they used, and that fewer farmers in the case group than in the control group correctly followed all instructions on the label. This finding is in agreement with Emeribe *et al.* (2023) who found that the majority of farmers in Edo Central, Edo State, Nigeria, did not read pesticide labels before use, especially those who had no formal education or education basic and those with less than 5 years of experience. This is consistent with the current study, which also reveals that illiteracy was also cited by most farmers as one of the reasons why they did not follow the instructions on the labels of the chemical pesticides they used. However, the reasons for inability or choice not to read labels varied between the two studies, Emeribe *et al.* (2023) found that the reasons for not reading labels were reliance on other farmers' success stories and lack of label clarity. However, in the present study, most farmers indicated that label instructions being written in another foreign language, including English, was the main reason why they did not follow all label instructions correctly. However, it appears that fewer farmers have difficulty following instructions on labels written in French since the DRC is officially a French-speaking country. The results also indicate that farmers' knowledge on the importance of washing the body and cleaning clothes after handling and spraying chemical pesticides was significant in both groups, with the case group being more knowledgeable on this aspect than the a group of witnesses. Finally, significant differences were also observed in farmers' knowledge of the ideal time to spray chemical pesticides between the two groups, with more farmers in the control group knowing the timing of spraying than those in the case group. Overall, the results suggest that there was little farmer knowledge about standards for chemical pesticide use in the Nyiragongo health zone, North Kivu.

Most farmers admitted that they did not know the proper methods of disposing of pesticide containers/packaging after use. Thus, most discarded the containers in their residences or in the fields, while some even used them as containers to store water and foodstuffs. This could be attributed to the lack of a clear program or policy framework guiding disposal practices. The results are therefore in agreement with Pasiani *et al.* (2012) who found similar disposal practices among Brazilian farmers where empty containers were found distributed around the planting areas of those who reported handing over the empty pesticide containers to the government program, indicating that best practices are not fully applied by these farmers. The results also support those of Recena *et al.* (2006) who found that more than half of farmers stored empty containers at home in Brazil. Bigatão (2009), however, reported that a third of farmers burned or buried pesticide containers. However, the results do not agree with those of Miyittah *et al.* (2022), whose pesticide exposure risk assessment among cocoa farmers in the Western region of Ghana found that a considerable proportion of farmers used the bush as a pesticide storage facility, while other farmers stored chemicals in their kitchens, in their food storage and in the pet store. However, consistent with the present study, Miyittah *et al.* (2022) found that a number of farmers stored chemicals in their living rooms. Most farmers did not know how to use PPEs and had poor knowledge of the application of pesticides. This was dues to a host of factors including the lack of training, lack of PPEs, language used in the pesticides and illiteracy. Imperatively, with weak policy controls it was difficult to expect any meaningful knowledge and practice of safe use of pesticides among the farmers. A case in point is when pesticides come in labels and instructions written in foreign languages, which should not be the case in the first place, increases the probability that the pesticides will be mishandled by the farmers. Further, the fact that most of the banned pesticides found their way in the area and were sold in the black market meant that they were stripped of their labelling by the vendors and sold to farmers on mutual trust basis. This could explain the finding that farmers relied on the vendors instructions on how to apply the pesticides.

CONCLUSIONS

The results show that there are differences in farmers' knowledge about the standards for the use of chemical pesticides in the Nyiragongo health zone, North Kivu. However, the difference was only significant in certain aspects while it was due to chance in some cases. Overall, the results suggest that there was little knowledge and practice on chemical pesticide use standards among farmers in the Nyiragongo health zone, North Kivu. The study, therefore, concludes that levels of knowledge of chemical pesticides and associated practices were very low among farmers in the Nyiragongo health zone, North Kivu. Furthermore, there are significant differences in farmers' knowledge about the standards for the use of chemical pesticides. However, the difference in knowledge was only significant in some aspects, while it was due to chance in some cases. More farmers in the control group than the cases had received training on the correct wearing of PPE before using chemical pesticides and the differences between the two groups were significant.

Recommendations

The study makes the following recommendations arising from the findings and conclusions:

1) ***To the Government of the Democratic Republic of Congo:***

- The study recommends that farmers in the area be regularly made aware of the use of chemical pesticides, particularly toxic ones, and their methods of use. It is imperative that farmers be discouraged from purchasing and using banned pesticides, even in the absence of meaningful regulations on the control of chemical pesticides in the region.

2) ***To state services (OCC, IPAEL, DPPV, SNV, SQUAV, IPS, DPS, etc.)***

- Public health authorities in the region should develop a program to educate farmers about the toxicity of chemical pesticides and the health measures farmers should take after using the chemicals and especially when they begin to develop certain symptoms.
- Popularize existing international and national regulations among organizations that supervise farmers in different agricultural zones in the North Kivu Province;
- The study recommends to the Ministry of Agriculture to develop the technical support program for farmers in the production of organic pesticides which do not have harmful effects on human health and the environment;

3) ***To farmers in the Nyiragongo health zone***

- Avoid handling chemical pesticides without any personal protection measures to prevent any recurrent respiratory poisoning
- The study recommends that farmers in the region should be regularly informed about the use of chemical pesticides, especially toxic chemicals and their methods of use. Critically, even in the absence of meaningful regulations on the control of chemical pesticides in the region, farmers should be discouraged from purchasing and using banned pesticides;

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