ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

Socio-Demographic Predictors of Hazardous Chemical Pesticides Vulnerability in Farming Communities of Nyiragongo Health Zone, North Kivu, DR Congo

Aksanti Bahizire Philippe[1*]; Kasereka Syauswa[2]; Charles-Lwanga Bandima Apalanginda[3]; John P. Hawuory[4]; Mumbere Kilumbiro Serges[5]; Yemba Baruani Ahuka A.[6]

[1;2;3;4;5;6]Université Des Martyrs Du Congo /UNIM RDC

Corresponding Author: Aksanti Bahizire Philippe[1*]

Publication Date: 2026/04/11

Abstract: Pesticides are chemicals designed to control organisms considered harmful, and play a central role in modern agriculture, enabling farmers to protect crops from insects, weeds, fungi, and rodents. However, while these substances boost productivity, they can pose serious health risks when misused. In the Democratic Republic of Congo (DRC), and particularly in the Nyiragongo Health Zone of North Kivu Province, pesticide use is pervasive. Despite regulatory frameworks, banned and highly hazardous chemicals, such as Dichlorvos, DDT, and Thiodan, remain widely available through informal trade networks and continually expose farmers and their households to significant risks of adverse exposure and illnesses. The objective of this study, therefore, was to determine the relationship between socio-demographic characteristics of farmers and adverse /hazardous exposure to chemical pesticides in the Nyiragongo health zone in North Kivu, DRCongo. 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 farmers in the Nyiragongo Health Zone are disproportionately exposed to chemical pesticides, with socio-demographic factors such as age, monthly income, and years of residence significantly influencing their vulnerability. Older farmers and long-term residents face higher risks due to cumulative exposure, while farmers with lower incomes are less able to afford protective equipment, exacerbating their susceptibility to respiratory illnesses. Although gender, education, and marital status did not show statistically significant associations.The study therefore recommends that farmers should be provided with regular, context-specific training on safe pesticide handling, application, and storage. Provincial and national authorities should develop and enforce stricter regulations on pesticide distribution, labeling, and usage, ensuring hazardous products are restricted and safe alternatives promoted.

Keywords: *Socio-Demographic Characteristics, Banned Pesticides, Respiratory Disease, Harmful Exposure, Case-Control.*

How to Cite: Aksanti Bahizire Philippe; Kasereka Syauswa; Charles-Lwanga Bandima Apalanginda; John P. Hawuory; Mumbere Kilumbiro Serges; Yemba Baruani Ahuka A. (2026) Socio Demographic Predictors of Hazardous Chemical Pesticides Vulnerability in Farming Communities of Nyiragongo Health Zone, North Kivu, DR Congo. *International Journal of Innovative Science and Research Technology*, 11(1), 3832-3841. https://doi.org/10.38124/ijisrt/26jan568

I. INTRODUCTION

Pesticides are chemicals designed to control organisms considered harmful, and play a central role in modern agriculture, enabling farmers to protect crops from insects, weeds, fungi, and rodents (Tebila, 2020). Pesticides 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. However, while these substances boost productivity, they can pose serious health risks when misused. Globally, millions of people are poisoned by pesticides every year, with developing countries bearing the heaviest burden despite representing only a quarter of global pesticide use (Planetoscope, 2023). In these regions, a

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

significant proportion of products fail to meet international safety standards, contributing to tens of thousands of preventable deaths annually (WHO, 2023). 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 (Planetoscope, 2023). The widespread availability and daily use of pesticides make exposure an occupational reality for millions of farmers, particularly those working in smallholder and family-run farms.

Exposure to pesticides occurs in multiple ways, including preparing, mixing, and applying chemicals, handling contaminated equipment, or even storing and disposing of containers. The health consequences of these exposures can range from acute symptoms such as eye irritation, headaches, and dizziness, to long-term chronic conditions including respiratory diseases, neurobehavioral disorders, cancer, and reproductive complications (Mamane et al., 2015; Nordgren & Bailey, 2016). Children and other vulnerable household members are often at risk due to contamination in homes and water sources. In many low-resource settings, farmers' protective measures are minimal—often limited to makeshift coverings—and unsafe disposal practices, such as repurposing pesticide containers for food or water, further amplify the hazards.

In the Democratic Republic of Congo, and particularly in the Nyiragongo Health Zone of North Kivu Province, pesticide use is pervasive. Most residents are smallholder farmers relying on market gardening for subsistence and income. Despite existing laws regulating chemical inputs, banned or highly hazardous pesticides such as Dichlorvos, DDT, and Thiodan remain widely accessible due to informal trade networks and weak enforcement (SOS FAIM, 2021; Eye, 2020). Reports from local health centers indicate that farmers frequently present with acute respiratory symptoms, including persistent cough, shortness of breath, and rhinitis, as well as chronic conditions like asthma and bronchitis, linked to unsafe pesticide handling. The consequences extend beyond health, affecting farmers' productivity, livelihoods, and household well-being.

While many studies have described pesticide-related health risks, less attention has been paid to the socio-demographic factors that shape farmers' vulnerability. Age, education, gender, and household responsibilities can influence knowledge, attitudes, and practices around pesticide use, ultimately affecting exposure levels and health outcomes. Understanding these factors is essential to designing interventions that protect the most vulnerable farmers, reduce preventable illnesses, and promote safer agricultural practices. This study, therefore, examines the socio-demographic predictors of hazardous pesticide exposure in the Nyiragongo Health Zone, seeking to inform policies and programs that enhance the health and resilience of local farming communities.

- *Problem*

Farmers should cultivate crops safely, balancing productivity with their health and well-being. Chemical pesticides, when applied correctly, can protect crops, enhance yields, and sustain livelihoods without endangering human health. Safe pesticide management entails proper training, consistent use of personal protective equipment (PPE), adherence to recommended doses, and compliance with national and international regulations that restrict hazardous substances. In this context, farmers would understand the risks, minimize exposure, and prevent respiratory and other chronic illnesses linked to chemical pesticides, contributing to healthier communities and sustainable agricultural development. However, currently, every year, 3 million people are poisoned by pesticides worldwide, majority of them being farmers who are almost always in direct contact with the pesticides. 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). 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 Nyiragongo Health Zone, North Kivu Province, Democratic Republic of Congo (DRC), home to over 1.1 million people, is dominated by smallholder market gardeners who rely heavily on pesticides to boost production. Despite regulatory frameworks, banned and highly hazardous chemicals, such as Dichlorvos, DDT, and Thiodan, remain widely available through informal trade networks (SOS FAIM, 2021; Eye, 2020). Health facility records indicate that farmers frequently suffer acute respiratory symptoms, including persistent cough, rhinitis, wheezing, and chronic conditions such as asthma and bronchitis. Globally, respiratory diseases affect 12–22% of farmers, with women often at higher risk due to their participation in agricultural labor (Faria et al., 2005; Zhang et al., 2011). Children under five and adults over fifty are especially vulnerable, yet most farmworkers aged 15–50 face prolonged exposure that increases their risk of preventable illnesses (WHO, 2021).

Several socio-demographic factors exacerbate this vulnerability. Low education levels, high illiteracy, limited training, poverty, and inadequate PPE use amplify farmers' exposure to hazardous chemicals (MARCS, 2018; Lusenga, 2017; Bars et al., 2022). Despite decades of research on pesticide-related health risks, few studies have explored how socio-demographic characteristics, age, gender, education, income, marital status, and years in farming, predict hazardous exposure, particularly in conflict-affected and resource-limited settings like North Kivu. Weak policy enforcement, poor monitoring of banned substances, and insufficient awareness perpetuate unsafe practices, leaving farmers at risk and threatening both health and productivity.

Addressing these gaps is urgent and directly aligns with Sustainable Development Goal 3, Target 3.1, which emphasizes reducing preventable deaths and promoting healthy lives for all, particularly infants and mothers. Understanding socio-demographic predictors of hazardous pesticide exposure can guide targeted interventions, strengthen occupational safety, improve policy implementation, and reduce preventable respiratory illnesses

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

among farmers. This study seeks to provide actionable evidence to protect vulnerable farming communities in Nyiragongo Health Zone, ensuring that agricultural productivity does not come at the cost of health and human development.

➢ *Objective*

The objective of the study was to determine the relationship between socio-demographic characteristics of farmers and adverse /hazardous exposure to chemical pesticides in the Nyiragongo health zone in North Kivu, DR Congo.

II. LITERATURE REVIEW

➢ *Socio-Demographic Characteristics of Farmers and Exposure to Harmful Pesticides*

- *Age of Farmers*

Farming has long been recognized as a high-risk occupation, with workers historically experiencing elevated rates of respiratory illnesses due to exposure to hay, grains, and livestock. Interestingly, recent evidence suggests that some farmers may develop a degree of resilience to allergies and asthma from early and continuous on-farm exposure (Hoppin et al., 2014). In modern agricultural settings, individuals aged 15 to 50 are the main workforce exposed to pesticides. However, the most vulnerable groups, according to the World Health Organization (WHO) and UNICEF, are children under five and adults over 50, who often suffer the worst health outcomes from pesticide exposure (WHO, 2021).

Research indicates that all age groups are at risk of pesticide-related illnesses. Damalas (2022) emphasizes that no one is immune to the harmful effects of chemical pesticides during agricultural activities, while Beyene et al. (2016) found significant respiratory problems in relatively young workers (average age 27) even after only four years of exposure. These findings underscore the need for strict occupational health interventions. Moreover, age may influence farmers' knowledge and use of protective measures: some studies suggest older workers have less awareness, whereas others argue that education and training level can offset age-related differences (Hassen et al., 2011; Kumari & Reddy, 2013; Mohsen et al., 2016).

- *Gender of Farmers*

Gender plays a critical role in pesticide exposure and health risks. Globally, women often face higher exposure than men, even though men typically handle pesticide application (Mubushar et al., 2019; Knzi et al., 2021). In some regions, such as South Kivu in the DRC, women make up the majority of farmers (68%) and are regularly exposed to harmful chemicals (Domique, 2023). In other contexts, men dominate farming tasks, such as vegetable production, but women still face substantial exposure due to secondary contact during weeding, harvesting, or post-application tasks (Gains, 2019). Studies in China and Europe confirm that women in agriculture experience higher rates of chronic bronchitis and other respiratory illnesses linked to pesticide use, highlighting the intersection of occupational roles and health vulnerabilities (Zhang et al., 2011; Tual et al., 2013; Faria et al., 2005). Observational studies in Mali also show that women often neglect protective measures during pesticide preparation and application, increasing their risk of long-term respiratory and systemic health effects (Hercberg, 2020).

- *Education, Income, and Knowledge*

Education strongly influences farmers' awareness and safe use of pesticides. Low literacy and limited formal training hinder comprehension of instructions, leading to improper handling and increased exposure (MARCS, 2018; Tarnagda et al., 2017). Farmers with at least primary or secondary education demonstrate better awareness of health and environmental risks (Sabran & Abbas, 2021; Gaber & Abdel Latif, 2012). Language barriers further exacerbate the problem, as many pesticide labels are written in foreign languages, leaving smallholder farmers dependent on informal guidance (Balasha & Kesonga, 2019; Arcury et al., 2010; Hachimou et al., 2018). Studies across Nigeria, Cameroon, and the DRC reveal that the majority of market gardeners receive no formal training, relying instead on inherited knowledge from predecessors, leaving them vulnerable to chemical exposure (Gains et al., 2019; Bars et al., 2022; Gutierrez-Jara et al., 2020).

Economic constraints significantly affect farmers' ability to adopt protective measures. Low-income farmers often cannot afford PPE, increasing exposure to respiratory, skin, eye, and neurological conditions (Lusenga, 2017; Azur, 2020). Income is another crucial factor. Low-income farmers often cannot afford personal protective equipment (PPE) such as gloves, masks, and coveralls, which increases their exposure to respiratory, skin, and neurological disorders (Lusenga, 2017; Azur, 2020). Years of residency in farming areas further contribute to cumulative exposure, with long-term contact with pesticides linked to chronic illnesses, including cancer, reproductive damage, and impaired lung function (Damalas & Koutroubas, 2016; Cha et al., 2012; Hernández et al., 2008).

- *Marital Status, and Residency*

Marital status appears less predictive of exposure, as both married and single farmers face similar risks (Blandin, 2021; Jayaraj, 2016). Similarly, years of residency in farming areas contribute to cumulative exposure, with long-term pesticide use associated with chronic health effects, including cancer, reproductive system damage, and impaired respiratory function (Damalas & Koutroubas, 2016; Cha et al., 2012; Hernández et al., 2008).

- *Religion and Cultural Practices*

Religious affiliation does not appear to limit pesticide use. Farmers of all major religions—including Catholicism, Protestantism, Buddhism, and Hinduism—regularly rely on chemical pesticides for subsistence and commercial agriculture. Consequently, all religious groups are susceptible to pesticide-related health hazards (Gesesew et al., 2020; Amide, 2021).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

➢ *Exposure to Pesticides and Respiratory Health*

Occupational exposure to pesticides remains a major threat to farmers' health. Inhalation of pesticide aerosols, dust, and vapors allows toxic compounds to penetrate the respiratory tract and bloodstream, leading to acute symptoms such as coughing, wheezing, eye irritation, and shortness of breath, and chronic conditions including asthma, chronic bronchitis, and COPD (Beyene et al., 2016; Clarine, 2022; Maddah et al., 2020). Exposure is particularly severe during fumigation or application in confined spaces such as greenhouses and silos. The physicochemical properties of pesticides, particle size, volatility, and lipophilicity, affect absorption into lung tissue and systemic circulation (Farila et al., 2005; YAP, 2020).

Epidemiological evidence consistently links pesticide exposure to increased respiratory morbidity among farmers. Cohort studies in the United States, Australia, and Europe report higher asthma prevalence, chronic bronchitis, and atopic diseases among agricultural workers (Baldi et al., 2013; WHO, 2022; Stoecklin et al., 2015). In the eastern DRC, highly hazardous pesticides such as dichlorvos 77% EC and abamectin are widely used, despite bans in the European Union and Sahel regions. Dichlorvos, a highly volatile compound, is particularly dangerous via inhalation, emphasizing the urgent need for stricter safety training, regulatory enforcement, and protective practices in farming communities (Rabiou, 2019).

III. METHODOLOGY

➢ *Context of the Study Area*

This study was conducted in the Nyiragongo Health Zone, North Kivu Province, Democratic Republic of Congo. Agriculture forms the backbone of the local economy, with over 85% of households engaged in crop cultivation and livestock rearing. The Nyiragongo Health Zone was specifically selected due to the observed high prevalence of respiratory diseases in recent years, which have been associated with the widespread and often hazardous use of chemical pesticides in farming practices.

➢ *Study Design*

According to the 2023 Health Information System (SNIS) report for Nyiragongo, the prevalence of respiratory diseases among farmers is 8%. Given this context, a retrospective case-control study design was employed. Case-control studies are appropriate for assessing the relationship between exposure and outcomes, beginning with an outcome (respiratory illness) and looking retrospectively at potential exposures (pesticide use).

In this study, cases were defined as farmers who use chemical pesticides and had a documented history of respiratory diseases, while controls were farmers using pesticides but without a history of respiratory illness. Exposure was defined as prolonged handling, inhalation, or presence in environments with hazardous pesticides, whereas non-exposure referred to limited or no contact with these substances. The study further hypothesized that exposure was influenced by farmers' knowledge and practices regarding pesticide handling.

➢ *Study Population*

The study population included farmers aged 18 years and older who were actively engaged in farming activities and the application of chemical pesticides. The total estimated population of such farmers in Nyiragongo Health Zone is 183,988. Participants were classified into two groups: those who had experienced respiratory illnesses (cases) and those who had not (controls).

Inclusion criteria were: (i) being a farmer residing in Nyiragongo, (ii) having ever used chemical pesticides, (iii) aged 18 years or older, and (iv) for cases, having a documented respiratory illness; for controls, absence of respiratory illness. Exclusion criteria included: (i) farmers from other health zones, (ii) farmers who do not use chemical pesticides, (iii) individuals under 18 years of age, and (iv) cases not officially recorded in health facilities within the Nyiragongo Health Zone.

Additionally, the study included regulatory actors involved in pesticide control policy implementation in North Kivu Province. Key informants included representatives from 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 Agronomic Research (INERA), Provincial Environment Division (DPE), Provincial Health Division (DPS), Civil Protection, peasant organizations, Central Health Zone Office (BCZ), Rural Development (DR), and trade authorities.

➢ *Determination of Sample Size*

For the quantitative component, the sample size for the case-control study was calculated using the formula proposed by Charan and Biswas (2013):

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

Where:

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).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

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.

➢ *Sampling Technique*

For farmers, systematic random sampling was applied using medical records from health facilities to identify cases with respiratory illnesses. These records provided contact information and socio-demographic data. Initial contact was made to explain the study and confirm eligibility. Farmers were then physically visited on their farms, and the process was repeated for both cases and matched controls across different health zones.

For key informants in policy and regulatory institutions, convenience sampling was used based on availability and willingness to participate.

➢ *Data Collection Instruments*

Data were collected using two complementary approaches:

- Quantitative approach: A structured survey questionnaire was administered to cases and controls to collect information on socio-demographics, pesticide exposure, and health outcomes.
- Qualitative approach: A semi-structured interview guide was used to collect data from key informants regarding pesticide policy implementation, monitoring, and regulatory challenges.

➢ *Data Analysis Methods*

Quantitative data were analyzed using univariate and bivariate methods. Univariate analysis included frequencies, percentages, means, and standard deviations to describe the study population. Bivariate analysis involved logistic regression to examine associations between pesticide exposure and respiratory illnesses, with odds ratios (ORs) calculated to quantify the strength of these associations.

Qualitative data were analyzed using content and thematic analysis, allowing patterns, themes, and key insights to emerge regarding pesticide policy implementation and regulatory challenges in the North Kivu Province.

IV. RESULTS

The study aimed to determine the demographic characteristics of the respondents, as they are considered categorical variables that provide basic insight about the respondents. The results are discussed below.

➢ *Distribution of Respondents According to Socio-Demographic Characteristics*

The socio-demographic information of the respondents taken into account in the study was: age group of the respondents, gender, highest level of education they achieved, religious denomination, monthly income, marital status, number of years of residence in the area and whether they smoked tobacco products . The results on this subject are summarized in Table 1.

Table 1 Socio-Demographic Information of Respondents

Variable	Category	Frequency	Percentage (%)	Mean	S. Dev
Age	18 - 29	43	14.3	46.42	15.113
	30 - 39	56	18.5		
	40 - 49	88	29.1		
	50 - 59	49	16.4		
	60 - 69	41	13.5		
	70 years and over	25	8.2		
Gender	Male	138	45.7		
	Feminine	164	54.3		
Religious denomination	Catholic	83	27.5	2.05	0.932
	Protestant	163	54		
	Muslim	15	5		
	Traditional faiths -Kimbanguist	41	13.6		
Level of education	University level	6	2	3.35	0.841
	Secondary level	54	17.9		
	Primary level	69	22.8		
	No education level/illiterate	173	57.3		
Monthly income	Less than $50 per month	114	37.7	374	169
	$51 to $100 per month	130	43		
	$101 to $200 per month	42	13.9		
	More than $200 per month	16	5.3		
Marital status	Married	77	25.5	3.21	1,434
	Bachelor	20	6.6		
	Divorce	3	1		
	Civil union	168	55.6		
	Widower	34	11.3		

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

Number of years of	Less than 5 years old	53	17.5	3	1.191
residence	Five to ten years	55	18.2		
	Eleven to twenty years	34	11.3		
	More than twenty years	160	53		

Table 1 presents the socio-demographic profile of farmers in the Nyiragongo Health Zone. The majority of respondents (61.9%) were aged between 18 and 49 years, with a mean age of 46.42 years (SD = 15.11). This indicates that most farmers are middle-aged, suggesting they possess substantial practical experience in agriculture, which may influence both their farming practices and their potential exposure to chemical pesticides. Notably, the inclusion of farmers over 50 years old (24.6%) highlights the continued engagement of older populations in farming activities, who may be more vulnerable to the long-term health effects of pesticide exposure due to age-related physiological changes.

Gender distribution showed that women constituted 54.3% of respondents, slightly outnumbering men (45.7%). This reflects broader demographic trends in developing countries, where women contribute significantly to the agricultural labor force (FAO, 2011b) and often play key roles in crop cultivation, pesticide application, and post-harvest management (Doss, 2011). Religious affiliation was predominantly Protestant (54%), followed by Catholic (27.5%), with smaller proportions adhering to traditional faiths (13.6%) or Islam (5%). These religious affiliations may influence community practices, social norms, and adoption of agricultural innovations.

Educational attainment among respondents was generally low: 57.3% reported no formal education, 22.8% completed primary education, 17.9% secondary education, and only 2% had university-level education. This is significantly lower than the national literacy rate in the DRC, which stands at 80.54% overall (UNESCO, 2023), suggesting structural and contextual barriers to formal education in North Kivu. Low literacy likely limits farmers' ability to comprehend pesticide instructions, implement safety measures, or adopt modern agricultural practices, thereby increasing the risk of harmful chemical exposure.

Regarding economic status, the majority of farmers earned between $51 and $100 per month (43%), while 37.7% earned less than $50. Such limited income suggests that subsistence farming predominates and may constrain farmers' ability to purchase protective equipment, invest in safer farming practices, or diversify livelihoods, thus increasing vulnerability to pesticide-related health risks. Marital status data revealed that 55.6% were in civil unions and 25.5% married, while most respondents (53%) had resided in the health zone for over 20 years. Long-term residency implies sustained exposure to local agricultural practices, environmental conditions, and potentially hazardous chemicals, reinforcing the importance of understanding socio-demographic factors when assessing occupational health risks in this population.

Collectively, these findings highlight that the farmer population in Nyiragongo is predominantly middle-aged, female, poorly educated, and economically constrained, characteristics that may intersect to influence both exposure patterns to chemical pesticides and susceptibility to associated respiratory and systemic health outcomes. This socio-demographic context provides essential insight for designing targeted interventions, training programs, and policy measures to reduce occupational health risks in the region.

- *Socio-Demographic (Individual) Characteristics and Harmful Exposure to Chemical Pesticides*

The socio-demographic characteristics of farmers in Nyiragongo Health Zone were also studied in terms of adverse exposure to chemical pesticides, with adverse exposure to chemical pesticides measured by inhalation of chemical particles during chemical pesticide spraying. The results are summarized in Table 2.

Table 2 Socio-Demographic Characteristics and Harmful Exposure to Chemical Pesticides

Variable	Category	Case	Controls	Totals	Chi square	P-value
Age	18 - 29	13	22	35	78.866a	0.036
	30 - 39	24	26	50		
	40 - 49	45	36	81		
	50 - 59	24	22	46		
	60 - 69	25	14	39		
	70 years and over	18	6	24		
Gender	Male	70	53	123	1.162	0.281
	Female	79	73	152		
Religion	Catholics	45	32	77	0.941	0.815
	Protestants	77	71	148		
	Muslims	8	6	14		
	Others)	19	17	36		
Level of education	University level	2	2	4	6.711a	0.082
	Secondary level	22	26	48		

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

	Primary level	28	33	61		
	No education level/illiterate	97	65	162		
Monthly income	Less than $50 per month	67	40	107	17.002a	0.002
	$51 to $100 per month	60	56	116		
	$101 to $200 per month	18	19	37		
	More than $200 per month	4	11	15		
Marital status	Bride	38	35	73	2.228a	0.527
	Bachelor	ten	6	16		
	Divorce	0	1	1		
	civil union	81	72	153		
	Widower	20	12	32		
Years of residence	Less than 5 years old	14	30	44	8.104a	0.044
	Five to ten years	22	26	48		
	Eleven to twenty years	ten	23	33		
	More than twenty years	103	47	150		

Table 2 presents the relationship between farmers' socio-demographic characteristics and their harmful exposure to chemical pesticides, measured through inhalation of chemical particles during pesticide application.

Age showed a statistically significant association with harmful exposure ($\chi^2 = 78.866$, $p = 0.036$). Farmers aged 40–49 years recorded the highest number of cases (45), followed by those aged 60–69 years (25 cases). Younger farmers (18–29 years) and older farmers (70 years and above) also had substantial exposure. This indicates that middle-aged farmers, who typically play the most active role in pesticide application, are disproportionately exposed to chemical pesticides, while older farmers may be more susceptible to adverse health effects due to cumulative exposure over time.

Gender did not show a statistically significant relationship with harmful pesticide exposure ($\chi^2 = 1.162$, $p = 0.281$), although slightly more women (79) than men (70) were recorded as cases. This suggests that both men and women are actively involved in pesticide application in this context, reflecting the predominance of women in agricultural labor in the Nyiragongo Health Zone.

Religious affiliation was not significantly associated with harmful exposure ($\chi^2 = 0.941$, $p = 0.815$), indicating that cultural or religious factors did not substantially influence pesticide handling practices in this population.

Level of education showed a near-significant association with harmful exposure ($\chi^2 = 6.711$, $p = 0.082$), with the highest cases among farmers with no formal education (97 cases). This highlights that illiteracy and low educational attainment may limit farmers' understanding of safe pesticide practices, increasing the risk of harmful exposure. Farmers with secondary or university education had fewer cases, suggesting that education may play a protective role in reducing exposure through knowledge of safe handling and protective measures.

Monthly income was strongly associated with harmful pesticide exposure ($\chi^2 = 17.002$, $p = 0.002$). Farmers earning less than $50 per month had the highest number of cases (67), followed by those earning $51–100 (60 cases). Low income likely constrains the ability to purchase personal protective equipment (PPE) or access safer alternatives, increasing vulnerability to chemical exposure. Farmers earning more than $200 per month recorded fewer cases, reflecting better access to resources and protective measures.

Marital status was not significantly associated with harmful exposure ($\chi^2 = 2.228$, $p = 0.527$), suggesting that family responsibilities or household composition did not directly influence pesticide handling behaviors.

Years of residence in the health zone were significantly associated with harmful exposure ($\chi^2 = 8.104$, $p = 0.044$). Farmers residing in the area for more than twenty years had the highest exposure (103 cases), suggesting that long-term residence correlates with cumulative exposure to pesticides. Conversely, newer residents (<5 years) had fewer cases, potentially due to less involvement in intensive agricultural activities.

Overall, the findings indicate that age, income, and years of residence are significant socio-demographic determinants of harmful pesticide exposure among farmers in Nyiragongo. Middle-aged, long-term residents with low income are the most vulnerable groups. Educational attainment also appears to influence exposure risk, highlighting the critical role of training and awareness programs in mitigating pesticide-related health hazards. These insights are essential for designing targeted interventions to reduce occupational health risks among farmers, particularly in resource-limited settings.

- *Odds Ratio of Farmer Socio-Demographic Characteristics and Adverse Exposure*

To establish how socio-demographic characteristics of farmers were associated with the risk of adverse exposure, the odds ratio was calculated, and the results summarized in Table 3.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

Table 3 Odds Ratio of Socio-Demographic Characteristics and Adverse Exposure

Variables	Wald	Sig.	Exp(B)	95% CI for EXP(B)	
				Lower	Superior
Age	1.119	0.041	1.019	0.984	1,056
Gender	0.514	0.473	0.731	0.311	1,721
Religion	0.579	0.447	0.851	0.562	1,289
Education	0.852	0.356	1,257	0.774	2.042
Monthly income	2,592	0.047	0.916	0.945	1,778
Marital status	0.944	0.331	0.849	0.611	1,181
Years of residence	3,273	0.030	1,399	0.972	2.012
Constant	0	0.999	1.7E+17		

The logistic regression model assessing the relationship between farmers' socio-demographic characteristics and adverse exposure to chemical pesticides in Table 3was statistically significant ($\chi^2(8) = 35.769$, $p < 0.0021$), indicating a strong fit. The model explained 10.2% of the variance in adverse exposure (Nagelkerke R^2) and correctly classified 91.1% of cases, suggesting a robust predictive capacity for identifying at-risk farmers.

Age was significantly associated with adverse exposure (Wald = 1.119, p = 0.041), with an odds ratio (Exp(B)) of 1.019 (95% CI: 0.984–1.056). This indicates that with each additional year of age, the likelihood of harmful pesticide exposure slightly increases. This finding aligns with previous results showing middle-aged and older farmers are disproportionately exposed, likely due to their extensive involvement in pesticide application and accumulated years of exposure.

Gender was not significantly associated with exposure (Wald = 0.514, p = 0.473; Exp(B) = 0.731, 95% CI: 0.311–1.721), reinforcing the conclusion that both men and women are actively involved in pesticide application in Nyiragongo, and gender alone does not determine risk.

Religion also showed no significant association (Wald = 0.579, p = 0.447; Exp(B) = 0.851, 95% CI: 0.562–1.289), suggesting that religious affiliation does not significantly influence farmers' pesticide handling behaviors or exposure levels.

Education level was not a significant predictor (Wald = 0.852, p = 0.356; Exp(B) = 1.257, 95% CI: 0.774–2.042), although farmers with formal education had a slightly higher odds ratio, possibly reflecting better awareness and selective reporting of exposure events.

Monthly income was significantly associated with exposure (Wald = 2.592, p = 0.047; Exp(B) = 0.916, 95% CI: 0.945–1.778). Farmers with higher incomes were slightly less likely to experience adverse exposure, likely because they can afford personal protective equipment (PPE) or safer pesticide alternatives.

Marital status was not significantly associated with exposure (Wald = 0.944, p = 0.331; Exp(B) = 0.849, 95% CI: 0.611–1.181), indicating household composition has minimal effect on pesticide handling behaviors.

Years of residence were significantly associated with exposure (Wald = 3.273, p = 0.030; Exp(B) = 1.399, 95% CI: 0.972–2.012), showing that farmers residing longer in the Nyiragongo Health Zone are more likely to experience harmful exposure. This reflects cumulative risk from repeated and prolonged pesticide handling over the years.

The analysis indicates that age, monthly income, and years of residence are significant socio-demographic predictors of adverse exposure to chemical pesticides among farmers in Nyiragongo. Older farmers, long-term residents, and those with lower income are particularly vulnerable. These findings underscore the importance of targeted interventions, including education on safe pesticide handling, provision of affordable protective equipment, and focused monitoring of long-term residents.

V. DISCUSSIONS

The socio-demographic profile of farmers in the Nyiragongo Health Zone aligns in several respects with previous literature on pesticide exposure among smallholder farmers in low- and middle-income countries. The predominance of middle-aged farmers (61.9% aged 18–49, mean age 46.42 years) corroborates findings from Beyene et al. (2016) and Damalas (2022), who observed that active pesticide applicators typically fall within the 18–50-year range. Furthermore, the study's identification of higher exposure among middle-aged and older farmers resonates with WHO (2021) observations that older adults may experience cumulative toxic effects due to prolonged exposure. This also aligns with Hassen et al. (2011), who showed that age influences both exposure patterns and knowledge of safe pesticide use. Conversely, the finding contrasts with Kumari and Reddy (2013), who found no significant effect of age on knowledge and practices, suggesting that contextual factors, including education and local agricultural norms, may modulate age-related exposure risks.

Gender distribution in Nyiragongo, slightly more women (54.3%) than men, reflects regional patterns where women participate significantly in agricultural labor (Doss, 2011; FAO, 2011b). While gender was not statistically significant for harmful exposure in this study, the literature reports mixed findings. Globally, studies indicate that women may face higher exposure due to their central role in cultivation and pesticide application (Knzi et al., 2021; Zhang

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

et al., 2011), though in other contexts, men dominate direct pesticide handling (Gains, 2019). Thus, the Nyiragongo findings agree with studies showing active involvement of both sexes, highlighting context-specific labor patterns that influence exposure.

Educational attainment in this population was low, with 57.3% having no formal education. This is consistent with prior studies in North Kivu and other sub-Saharan contexts (Bars et al., 2022; Gutierrez-Jara et al., 2020), where low literacy limits comprehension of pesticide labels, safe handling instructions, and adoption of protective measures (Emeribe et al., 2023; Tarnagda et al., 2017). The near-significant association between education and exposure observed in Nyiragongo reinforces the protective effect of literacy and formal training reported by Sabran and Abbas (2021) and Gaber and Abdel Latif (2012). These findings emphasize the need for literacy-sensitive training programs to mitigate pesticide-related risks.

Income emerged as a strong determinant of harmful exposure, with lower-income farmers (<$50/month) experiencing the highest exposure. This aligns with Lusenga (2017) and Azur (2020), who noted that poverty limits the ability to acquire personal protective equipment (PPE) and safer alternatives, thus increasing vulnerability. The protective effect of higher income observed in the Nyiragongo study corroborates these findings and underscores the socio-economic dimension of occupational health risks.

Marital status was not significantly associated with exposure, consistent with existing literature (Blandin, 2021; Jayaraj, 2016), indicating that household composition does not substantially alter pesticide handling practices. Similarly, religious affiliation showed no significant influence, supporting studies showing that chemical pesticide use transcends faith-based norms (Gesesew et al., 2020; Amide, 2021).

Years of residence in the farming area were significantly associated with harmful exposure, reflecting cumulative risk from long-term pesticide handling, which aligns with findings by Damalas and Koutroubas (2016), Cha et al. (2012), and Hernández et al. (2008). These studies demonstrate that chronic exposure over decades increases the likelihood of adverse respiratory and systemic effects, consistent with the Nyiragongo findings.

The logistic regression results reinforce these associations. Age, monthly income, and years of residence were significant predictors of adverse exposure, confirming trends in the literature on cumulative exposure, socio-economic constraints, and demographic risk factors (Beyene et al., 2016; Lusenga, 2017; WHO, 2021). Education and gender, while not significant predictors in this study, are reported elsewhere as influential under certain contextual conditions (Zhang et al., 2011; Sabran & Abbas, 2021), suggesting that their effects may be moderated by local practices, awareness campaigns, or access to resources.

Collectively, the study findings support the broader literature that socio-demographic characteristics, including age, income, and duration of residence, play crucial roles in shaping farmers' risk of exposure to chemical pesticides. They also highlight that interventions must consider local labor patterns, literacy levels, and long-term exposure histories to effectively reduce occupational health risks in resource-limited agricultural settings.

VI. CONCLUSIONS AND RECOMMENDATIONS

The study highlights that farmers in the Nyiragongo Health Zone are disproportionately exposed to chemical pesticides, with socio-demographic factors such as age, monthly income, and years of residence significantly influencing their vulnerability. Older farmers and long-term residents face higher risks due to cumulative exposure, while farmers with lower incomes are less able to afford protective equipment, exacerbating their susceptibility to respiratory illnesses. Although gender, education, and marital status did not show statistically significant associations, the predominance of illiteracy among farmers remains a concern, limiting their ability to understand safety instructions and adopt protective practices. These findings underscore that pesticide exposure is not only a function of individual behavior but also of structural and economic constraints that shape agricultural practices in the region. Urgent interventions are therefore needed to reduce occupational hazards, improve awareness, and strengthen protective measures to safeguard the health of farmers. Addressing these gaps aligns with Sustainable Development Goal 3, particularly Target 3.9, which aims to reduce illnesses and deaths caused by hazardous chemicals.

The study, therefore, makes the following recommendations arising from the findings and conclusions:Farmers should be provided with regular, context-specific training on safe pesticide handling, application, and storage. Extension services must prioritize distributing affordable personal protective equipment and promote practical risk-reduction strategies tailored to long-term and older farmers to minimize inhalation and dermal exposure during routine agricultural activities.

Provincial and national authorities should develop and enforce stricter regulations on pesticide distribution, labeling, and usage, ensuring hazardous products are restricted and safe alternatives promoted. Policies should also support farmer access to protective equipment, monitor long-term exposure, and implement community-based awareness programs targeting high-risk groups, fostering compliance and reducing the burden of pesticide-related respiratory illnesses in Nyiragongo.

REFERENCES

[1]. Armand GL (2020). Dangerous pesticides are readily available in developing countries, publication of the World Health Organization and the Food and

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jan568

Agriculture Organization of the United Nations, May 10: 125p

[2]. Asita, O. A., & Makhalemele, R. (2009). Genotoxic effects of dithane, malathion and garden ripcord on onion root tip cells. *African Journal of Food, Agriculture, Nutrition and Development*, *9*(5).

[3]. Balasha, A. M., Munyahali, W., Kulumbu, J. T., Okwe, A. N., Fyama, J. N. M., Lenge, E. K., & Tambwe, A. N. (2023). Understanding farmers' perception of climate change and adaptation practices in the marshlands of South Kivu, Democratic Republic of Congo. *Climate Risk Management*, *39*, 100469

[4]. Cedergreen, N., Dalhoff, K., Li, D., Gottardi, M., & Kretschmann, A. C. (2017). Can toxicokinetic and toxicodynamic modeling be used to understand and predict synergistic interactions between chemicals?. *Environmental science & technology*, *51*(24), 14379-14389.

[5]. Damalas, C. A., & Eleftherohorinos, I. G. (2011). Pesticide exposure, safety issues, and risk assessment indicators. *International journal of environmental research and public health*, *8*(5), 1402-1419.

[6]. Fosu-Mensah, B. Y., Okoffo, E. D., & Mensah, M. (2022). Assessment of farmers' knowledge and pesticides management in cocoa production in Ghana. *International Journal of Advanced and Applied Sciences*, *9*(3), 100-110.

[7]. Costa Lima R, Victora CG, Menezes AM, Barros FC (2003). Do risk factors for childhood infections and malnutrition protect against asthma? A study of Brazilian adolescents. Am J Public Health: 58-64

[8]. Eye, C.J. (2021). *Congo under the influence of banned pesticides, Democratic Republic of Congo – Pesticides, Vol 5, Kinshasa Gombe,* December 16: 11 -13

[9]. FAO (2002), International Code of Conduct on the Distribution and Use of Pesticides (Revised), ISBN 92-5-204914-2

[10]. FAO (2018). International guidelines on pesticides, co-publication with WHO , Geneva: 42

[11]. Gains K K , PAN JG, Lazare BY , Chantal AD , Roland NS (2019), Phytosanitary practices in peri-urban agriculture and contamination of foodstuffs by pesticides : the case of market gardeners in Port-Bouët (Abidjan) , publication date 31/ 07/2019, http://www.m.elewa.org/JAPS , accessed June 12, 2023

[12]. International Agency for Research on Cancer (2015), New pesticides recognized as carcinogenic by the WHO, Geneva, March 23, 36p

[13]. Isabelle BA (2021), Pesticides and health, health and environment, Vol 1, Edition Armand Collin: p5

[14]. Klaassen, C. D., Watkins, J. B., Casarett, L. J., & Doull, J. (2015). Casarett & Doull's essentials of toxicology. *(No Title)*.

[15]. Kumar, D., Sinha, S.N., Rajendra, S. and Sharma, K. (2023). Assessment of farmers' exposure to pesticides and risk of noncommunicable diseases: a biomonitoring study. *Total Environmental Science* , *891* , 164429.

[16]. Le Bars, M., Maïga, A., Sacko, M., & Koïta, O. (2022). Current Research in Environmental Sustainability. *Current Research in Environmental Sustainability*, *4*, 100188.

[17]. Lyn, R.F. (2017), The use of herbicides in agriculture and its consequences on human health and the environment, Rabat, 1st agricultural course , instructors: 24

[18]. Najam, L., & Alam, T. (2023). Occurrence, distribution, and fate of emerging persistent organic pollutants (POPs) in the environment. In *Emerging contaminants and plants: interactions, adaptations and remediation technologies* (pp. 135-161). Cham: Springer International Publishing.

[19]. Nayak, P., & Solanki, H. (2021). Pesticides and Indian agriculture—a review. *Int J Res Granthaalayah*, *9*(5), 250-263.

[20]. Sadasivaiah, S., Tozan, Y., & Breman, J. G. (2007). Dichlorodiphenyltrichloroethane (DDT) for indoor residual spraying in Africa: how can it be used for malaria control?. *Defining and Defeating the Intolerable Burden of Malaria III: Progress and Perspectives: Supplement to Volume 77 (6) of American Journal of Tropical Medicine and Hygiene*.

[21]. Tebila, J.M. (2020). *Integrated pesticide management in Africa,* World Health Organization, Vol1, Geneva: 51

[22]. Van, D.N. (2021). *The essentials on the illicit pesticide trade*, Geneva, Vol 7, ISBN, 56p

[23]. Williams MK, Barr DB (2016). An intervention to reduce residential exposure to insecticides during pregnancy in an inner-city cohort. Environ Health, November;114(11):13

[24]. World Bank (2013), Stockpiles of Obsolete Pesticides: A Strategic Legacy for the African Environment, New York: USA: 23 -25

[25]. World Health Organization (2016), Glyphosate, *the most used pesticide in the world, considered dangerous by the World Health Organization,* published on 03/08 at 5:25 p.m.

[26]. World Health Organization (2019), *Pesticide use in agriculture and implications for public health* . No. 7, Geneva: 41.

[27]. World Health Organization (2021), *Congo plagued by banned pesticides,* Publication Jos Faim (PJF), December 16: 84