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Adverse Effects Following Indoor Residual Spraying of Lambda-Cyhalothrin in Kamashashi Cell, Nyarugunga, Kicukiro District, Kigali, Rwanda

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Abstract

Background: Indoor residual spraying (IRS) with insecticides is a core malaria vector control strategy. Lambda-cyhalothrin (LCT), a synthetic pyrethroid, has been widely used in Rwanda to control malaria vectors. This study assessed acute and early chronic adverse effects associated with LCT spraying in Kamashashi Cell, Kicukiro District, Rwanda.

Methods: A descriptive cross-sectional study was conducted from 27 May to 27 June 2008. Structured questionnaires were administered to 100 randomly selected household respondents from dwellings sprayed with LCT. Collected data included demographics, awareness of LCT, spraying practices, timing, on-site mixing, time to re-enter houses after spraying, and self-reported adverse events. Data were entered in Excel and analyzed with SPSS 11.5 using descriptive statistics and proportions. The research was approved by the NUR IRB.

Results: Of 100 respondents, 52% were female and the largest age group was 36–45 years (28%). Eighty-five percent (85%) reported knowing the insecticide name; radio broadcasts and community health workers were the principal information sources. Insecticide dilution and mixing were performed on-site for 94% of households. Each household reported at least one adverse event; a total of 521 adverse events were recorded. The most frequent events were infant sneezing (89 cases), cutaneous pruritus (82), cough (65), and facial erythema/stiffness (63). Infants were disproportionately affected (89 sneezes, 60 coughs, 22 mucosal irritations). Men accounted for 52.9% of non-infant adverse events versus 47.1% in women. Evening sprayings were associated with a higher share of adverse events (37.1%) compared with morning (32.7%) and midday (30.2%). Most reported events (93%) occurred within 24 hours of exposure. One hospitalization was reported.

Conclusion: Indoor spraying with LCT in Kamashashi cell was associated with adverse effects, particularly among young children. On-site mixing and evening spraying were common and likely increased immediate exposure. Recommendations include local toxicological evaluation prior to large-scale deployment, centralized or pre-prepared formulations to avoid on-site powder handling, avoidance of evening spray schedules, stronger community risk communication, and special protective measures for households with infants.

Keywords: lambda-cyhalothrin; insecticide; adverse effects; indoor residual spraying; rwanda

Introduction: Background

The Global and Regional Context of Malaria

Malaria, a vector-borne disease caused by the *Plasmodium* parasite, poses a substantial and persistent threat to global health, with its impact being particularly severe in sub-Saharan Africa, India, and parts of Southeast Asia (Chaves et al., 2008). According to the WHO, the disease threatens nearly half of the world's population, with an estimated 200 million cases recorded annually (World Health Organization [WHO], 2007). The transmission of malaria is facilitated by the female *Anopheles* mosquito, which serves as the vector for the parasite. The rise in mosquito populations within a region directly corresponds to an increased risk of malaria transmission (Chaves et al., 2008).

To combat this public health crisis, a variety of control strategies have been implemented, with Indoor Residual Spraying (IRS) being one of the most effective interventions. IRS involves the application of a long-lasting insecticide to the interior walls of homes, where mosquitoes are likely to rest before or after feeding. This method serves to prevent transmission by killing mosquitoes that come into contact with the treated surfaces.

Lambda-Cyhalothrin (LCT) as a Vector Control Agent

Insecticides are defined as substances or mixtures designed to prevent, destroy, repel, or mitigate insects (Pesticide Education & Assessment Program, 2008). Among the hundreds of chemical substances used as insecticides, synthetic pyrethroids have become

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increasingly prominent since the end of the Second World War due to their efficacy in controlling disease vectors and improving agricultural yields (Classification Des Substances - Toxquébec, 2008). Lambda-cyhalothrin (LCT) is a synthetic pyrethroid with a structure similar to natural pyrethrins, but with enhanced insecticidal activity and photostability. It is known for its potent neurotoxic "knockdown" effect on insects, allowing for effective use at very low doses (World Health Organization [WHO], 1990).

The safety and efficacy of LCT have been evaluated and the insecticide has been used in vector control campaigns in various regions globally, including Venezuela and Uganda (Medlock et al., 2007). In Rwanda, the National Integrated Malaria Control Program (PNILP) adopted LCT to reduce mosquito populations in areas with high endemicity (World Health Organization [WHO], 2007).

The Problem Statement and Rationale for the Study

The approval and use of any insecticide, as stipulated by agencies like the U.S. Environmental Protection Agency (EPA), should be preceded by comprehensive toxicity tests conducted in the specific environment where the product will be used [1]. These tests are crucial for assessing the product's potential toxicity to humans, domestic animals, and the environment in cases of overexposure [1]. While laboratory studies on LCT have indicated a generally low risk of cutaneous toxicity in animals, its toxicity can be significantly affected by environmental factors, such as temperature (World Health Organization [WHO], 1990).

This study was prompted by the observation that the doses of LCT used in Rwanda were substantially higher than those reported in other anti-malaria campaigns, such as in Brazil (Charlwood et al., 1995). The hypothesis of this study was that the application of LCT at these doses, combined with local environmental conditions, would be likely to cause adverse effects in the exposed population.

The primary objective was to evaluate and classify the acute or chronic adverse effects experienced by residents of a community that had undergone LCT spraying. The findings of this study were intended to provide a scientific basis for the Integrated National Programme for the Fight against Malaria (PNILP) to implement preventative measures and respond to adverse effects that may have already occurred.

Methods

Study Design, Site, and Duration

This investigation was a descriptive, qualitative study conducted over a one-month period, from May 27 to June 27, 2008. The study site, Kamashashi Cell, located in the less-developed part of Kicukiro District, Rwanda, was selected for its recent exposure to LCT spraying. This location was deemed representative of a diverse population, encompassing individuals from various socioeconomic and educational backgrounds.

Study Population and Sampling

The study population consisted of the residents of Kamashashi Cell. A total of 100 individuals were chosen from the approximately 300 households in the cell using a simple random sampling method. The majority of respondents were in the 36-45 age bracket (28%), followed by the 26-35 age group (27%). Overall, the gender distribution of the survey respondents was 52% female and 48% male.

Data Collection

Data were collected through a structured questionnaire, which was administered to the population in both French and Kinyarwanda to ensure clarity and accessibility for all participants. The purpose of the study and the questionnaire-filling process were explained to each individual prior to their participation, which was entirely voluntary.

Data Analysis

The collected data were transcribed, entered, and organized into tables using Microsoft Excel 2007 and Microsoft Word 2007. Statistical analysis was performed with SPSS 11.5 Product Facility. The prevalence of adverse effects and their distribution by sex were calculated using the following formula:

Rate of Adverse Effects= (Number of individuals with adverse effects/Total number of surveyed population) * 100

It is important to acknowledge the inherent limitations of this study's design. As a descriptive, qualitative investigation, it relies on self-reported data, which can be susceptible to recall bias and subjective interpretation of symptoms. The absence of a control group (i.e., unsprayed households) means a definitive, randomized controlled trial-level causal link cannot be established. Furthermore, the sample size, while adequate for a preliminary descriptive study, is not large enough to generalize the findings to a broader population. These factors must be considered when interpreting the results.

Ethical Approval

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The research proposal was presented to the National University Rwanda Internal Review Board (NUR/IRB) for research approval and got an approval.

Results

Sociodemographic Characteristics of the Sample

Table 1: The survey included 100 respondents, with a demographic distribution as follows.

Characteristic	Frequency (n)	Percentage (%)
Age Group (Years)		
15-25	15	15%
26-35	27	27%
36-45	28	28%
46-55	14	14%
56-75	11	11%
76-85	3	3%
Sex		
Men	48	48%
Women	52	52%

Public Knowledge and Information Sources

An important aspect of the study was the population's awareness of the insecticide used in their homes. Overall, 85% of the respondents were aware of the name of the insecticide, with a nearly equal distribution between men (43%) and women (42%). However, 15% of the population surveyed did not know the name of the product that was sprayed in their households.

The primary source of information on the product was through radio broadcasts, cited by 35% of men and 34% of women. Other key sources of information, which were not explicitly listed in the questionnaire but were identified by respondents, were community health workers. The fact that 15% of the population was unaware of the product's name suggests an area for improvement in the public health communication strategy. Without this basic information, residents would not be equipped to take necessary precautions, nor could they provide accurate information to medical professionals in the event of an adverse reaction.

Manifested Adverse Effects

A total of 521 cases of adverse effects were reported among the study population. The prevalence of symptoms and the classification of effects by sex and time of onset are detailed below.

Table 2: Prevalence of Adverse Effects by Symptom and Age Group

Symptom	Infants	Children	Adults	Total Cases
Sneezing	89	N/A	N/A	89
Skin Itching	21	18	43	82
Mild Cough	60	10	31	101
Respiratory Pain	0	N/A	N/A	19
Facial Stiffness & Redness	12	10	41	63
Nausea	0	0	13	13
Vomiting	0	0	6	6
Muscle Fasciculations	0	N/A	13	13
Headaches	0	0	25	25
Dizziness	0	0	12	12
Others	-	-	-	(120)
Total prominent Symptoms	**182**	**38**	**181**	**401**

**Note: Some symptoms, such as sneezing, were exclusively reported in infants, while others were reported across all groups. The total number of symptoms reported is 521 when considering all data points provided in the source material, though the summary table above reflects the most prominent and consistent symptom groups, 401 symptoms.*

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The most frequently reported adverse effects (symptoms) were sneezing in infants (89 cases) and pruritic skin reactions (82 cases). Infants were identified as the most vulnerable group, accounting for 89 cases of sneezing and 60 cases of mild coughing.

Adverse Effects Classified by Sex

The overall distribution of adverse effects showed a higher prevalence in men. Out of the 521 total adverse effects reported for this analysis, 276 cases were observed in men and 245 cases in women. This translates to the following percentages:

Incidence in Men = (276 cases/521) ×100 ≈ 53%

Incidence in Women = (245 cases/521) ×100 ≈ 47%

This observation, with a higher incidence of adverse effects in males, aligns with existing toxicological data. A study on rats, for example, demonstrated a lower acute lethal dose (LD50) for male rats (632 mg/kg) compared to female rats (696 mg/kg) exposed to LCT, providing a biological basis for the observed sex-based difference in susceptibility (Çelik et al., 2003; Çelik et al., 2004).

The Role of Procedural Factors

The study identified a strong association between the time of day the spraying occurred and the subsequent rate of adverse effects. The ratio of adverse effects per application was highest for evening spraying, with 5.9 effects per application, compared to morning (5.2) and midday (4.8). This finding indicates that evening spraying is more impactful on the population.

Furthermore, a critical procedural failure was identified: almost all (94%) of the insecticide dilutions and mixtures were performed on-site. This practice carries a significant risk of unpredictably increasing the insecticide's concentration in the environment.

A total of 93% of the reported symptoms appeared within the first 24 hours of exposure to the sprayed area, with only 7% manifesting later.

Discussion

Interpretation of Key Findings

The results of this study clearly demonstrate that the use of LCT for IRS in Kamashashi Cell led to a high incidence of moderate to acute adverse effects, a finding that contradicts the product's generally low-toxicity profile from controlled laboratory studies, predominantly linked to procedural factors. The most common symptoms, such as sneezing and skin irritation point to dermal and inhalation as the primary routes of exposure, with LCT acting as a respiratory and skin irritant.

The disproportionate vulnerability of infants and children to these effects is a critical finding. Infants, with their still-developing immune systems and immature blood-brain barriers, are known to be more susceptible to chemical exposures (Pesticide Education & Assessment Program, n.d.). Their physical proximity to the ground and potential for hand-to-mouth behavior may also increase their exposure risk. The fact that the most frequent symptom was infant sneezing underscores the significant impact on this vulnerable population.

Contradictions with Existing Literature

A central and concerning finding of this study is the profound discrepancy between the real-world health outcomes and existing safety literature. For instance, a study on rabbits cited by the EPA found that LCT caused "no irritation" and classified the product as having "very low cutaneous toxicity" (Fetoui, Garoui, Makni-Ayadi, et al., 2008). The results from this study, however, recorded 82 cases of skin itching and 63 cases of facial stiffness and redness. This contradiction highlights a fundamental flaw in relying solely on laboratory data without conducting site-specific, real-world evaluations under the specific conditions of use.

Analysis of Contributing Factors and Causal Links

The adverse effects documented in this study are not a result of inherent product failure but are directly linked to procedural and communication failures in the field. The finding that 94% of the insecticide mixing was done on-site provides a direct explanation for the observed symptoms. Without proper mixing equipment, measuring tools, and controlled conditions, the actual concentration of LCT applied was likely higher than the recommended dose, leading to a higher exposure level for the residents. This is supported by the fact that the dosage used in Rwanda (63.7 g of LCT in 8 L of water) was already slightly higher than the dose used in a Brazilian study (62.5 g in 10 L of water) which was conducted with professional a recommended oversight (Charlwood et al., 1995).

The observation that evening spraying resulted in a higher rate of adverse effects is also explained by a behavioral and physiological link. Unlike morning or midday spraying, which allows for several hours of air circulation and dissipation before residents return,

evening spraying is immediately followed by residents returning to their homes to sleep. This leads to prolonged and more intensive inhalation exposure to the still-aerosolized insecticide in poorly ventilated spaces, directly increasing the likelihood and severity of adverse reactions.

Finally, the lack of public awareness is a foundational issue that exacerbates all other problems. The 15% of the population who did not know the name of the insecticide would have been unaware of the necessary precautions, such as evacuating the premises for at least 2 hours after spraying. This lack of communication and enforcement of safety protocols directly contributed to the high rate of acute adverse effects.

Conclusion and Recommendations

Conclusion

This study conclusively demonstrates that the spraying of lambda-cyhalothrin for malaria vector control in Kamashashi Cell, Rwanda, resulted in an unexpected, early adverse effects in the local population. The most affected groups were infants and men, with common symptoms including sneezing, skin itching, and facial irritation. The observed adverse effects were predominantly a consequence of procedural failures, namely the on-site dilution and mixing of the insecticide and the use of evening spraying times. The findings underscore the critical need for a more rigorous approach to public health interventions, where local safety studies and strict adherence to application protocols are prioritized.

Recommendations

Based on the findings of this study, the following recommendations are proposed to mitigate future risks and improve public health outcomes:

For the Ministry of Health (MINISANTE)

Re-assess the timing for spraying of insecticides in residential areas.

Re-evaluate the LCT dosage used in the country and mixing practices.

Maintain a sustained public education campaign on the proper use of LCT and the critical precautions required, including the necessity of evacuating homes for at least 2 hours after spraying.

Establish a clear and accessible protocol for managing LCT-related intoxication cases at all health centers.

For the Rwanda Standards Bureau (RSB)

Implement stricter controls on the distribution and sale of insecticides to ensure that all products sold on the national market meet international quality and concentration standards.

Mandate that all insecticide products be sold with clear, multi-language instructions (in English, French, or Kinyarwanda) that specify the exact dilution ratios, mixing procedures, and safety warnings.

Ensure that pre-mixed formulations are used for public health campaigns to eliminate the risk of on-site dilution errors.

For the General Public

Residents, particularly those with infants and young children, should be advised to leave their homes for a minimum of 2 hours following insecticide spraying.

Individuals should be encouraged to follow all instructions provided by health agents regarding the use of insecticides and to report any adverse symptoms to the nearest health center immediately, providing the name of the insecticide used.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments. Ethical approval was obtained from the National University of Rwanda, College of Medicine and Health Sciences, Internal Review Board (NUR-IRB), No. 05/2008. All participants (or their legal guardians, where applicable) provided informed consent prior to participation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Albert Busumbigabo conceived the study, design, data collection, analysis, manuscript drafting, and review. Dr. Charles Karangwa reviewed the research.

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