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Knowledge, attitudes, and practices of sellers on occupational risk prevention of paint-based chemical products at the baluba market in Kinshasa, Democratic Republic of the Congo

Poulain Mulumba Bunyengu^{1,5}, Fiston Masikini Bombamu^{2,3,4,5}, Adonis Mazango¹, Elda Kabila Umba⁴, Paul M'Pong Mbakam⁶

¹Gamaliel International University, Kinshasa, Democratic Republic of the Congo

²Université Chrétienne Cardinal Malula, Kinshasa, Democratic Republic of the Congo, masikinifiston@gmail.com

³Université Méthodiste John Wesley, Kinshasa, Democratic Republic of the Congo

⁴Université Technologique Bel Campus, Kinshasa, Democratic Republic of the Congo

⁵Centre of Excellence for Chemical, Biological, Radiological and Nuclear Affairs (CoE-CBRN), Ministry of Scientific Research and Technological Innovation, Democratic Republic of the Congo

⁶Institut Supérieur de Techniques Appliquées, Kinshasa, Democratic Republic of the Congo

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ABSTRACT

Background: The marketing of paint-based chemical products in urban markets of Kinshasa raises major public health and occupational safety concerns. Sellers, often poorly informed about the risks associated with these products, are exposed to multiple health hazards, including chemical, biological, and radiological/nuclear (CBRN) risks.

Objective: To assess the knowledge, attitudes, and practices of paint-based chemical product sellers regarding occupational risk prevention at the Baluba Market, Bandalungwa commune, Kinshasa.

Methods: A cross-sectional descriptive study was conducted from February 16 to July 16, 2024, among 75 sellers selected by non-probabilistic convenience sampling. Data were collected through semi-structured interviews using a questionnaire guide, then analysed by descriptive statistics (frequencies, percentages) with Excel 2010 and bivariate analysis (Pearson's Chi-square, Cramér's V) with SPSS 26.0. The acceptability criterion was set at 50%.

Results: The majority of respondents were men (65%), married (35%), with a mean age of 35 years. Secondary education level predominated (57%). While 97% of sellers recognized chemical risks, only 31% had received training on product hazards. Only 35% had adequate personal protective equipment (PPE). The main health problems reported were fatigue after inhalation (30%), abdominal pain (19%), headaches (16%), vomiting (12%), and dizziness (8%). Bivariate analysis revealed that education level ($p = 0.028$) and training received ($p < 0.001$) were significantly associated with the availability of adequate PPE. Identified CBRN risks included: chemical risks (exposure to solvents and VOCs, lack of labeling, inappropriate storage), biological risks (microbial proliferation, bacterial resistance), and potential radiological/nuclear risks (natural radionuclides in mineral pigments).

Conclusion: Baluba Market sellers have limited knowledge and inadequate safety practices, exposing them to significant occupational and CBRN risks. Training, awareness, and PPE provision programs are essential. CoE-CBRN/DRC and public structures are called upon to play a central role in managing these risks.

Keywords: knowledge, attitudes, practices, sellers, paints, occupational risks, CBRN risks, Baluba Market, Kinshasa.

1. Introduction

1.1. General Context

The sale of paint-based chemical products, despite its economic importance, represents a major risk to the health of workers and consumers (Institut National de la Santé et de la Recherche Médicale [INSERM], 2013). At the Baluba Market in Kinshasa, knowledge and management of the risks associated with these products are often neglected, thereby endangering public health.

According to INSERM (2013), links between exposure to certain substances and pathologies have been established, including: (i) occupational exposure to solvents and neurobehavioral disorders (psychomotor slowing, concentration, memory, and dexterity disorders, depressive states) known as psycho-organic syndrome of solvents (POS); (ii) childhood lead exposure and lead poisoning.

According to the scientific work of Abbate et al. (1993), chemicals are playing an increasingly prominent role in our society, and we are witnessing an explosion in the number of molecules used. Paint manufacturing involves the use of various chemicals, whose inhalation or contact can generate significant occupational risks for workers.

1.2. Problem Statement

The central question of this study is: **What is the level of knowledge, attitudes adopted, and practices implemented by sellers regarding occupational risk prevention related to chemicals, particularly those used in paints?**

More specifically:

1. What is the level of knowledge of sellers regarding the risks associated with paint chemicals?
2. What are the attitudes of sellers toward occupational risk prevention?
3. What safety practices are implemented by sellers?
4. What health problems are reported by sellers?
5. What CBRN risks are identified among sellers?

1.3. Hypotheses

- **Hypothesis 1:** Sellers have limited knowledge of the risks associated with chemicals, which negatively influences their safety practices.

- **Hypothesis 2:** The level of training and access to personal protective equipment (PPE) are significantly associated with occupational risk prevention practices.
- **Hypothesis 3:** Sellers exposed to chemicals without adequate protection present more frequent health problems.
- **Hypothesis 4:** CBRN risks identified among sellers are significantly associated with sociodemographic and occupational factors.

1.4. Objectives

General objective:

To assess the knowledge, attitudes, and practices of sellers regarding occupational risk prevention related to the use of paint chemicals at the Baluba Market.

Specific objectives:

1. To describe the sociodemographic profile of paint-based chemical product sellers;
2. To assess the level of knowledge of sellers regarding chemical risks;
3. To analyse the attitudes of sellers toward occupational risk prevention;
4. To identify safety practices implemented by sellers;
5. To identify health problems reported by sellers;
6. To identify and characterize CBRN risks associated with the sale of paint-based chemical products;
7. To formulate recommendations to improve occupational safety and health.

1.5. Justification of the Study

This research aims to assess the knowledge, attitudes, and practices of sellers regarding the prevention of risks associated with chemicals. It is justified by the need to strengthen health and safety in sales environments. The choice to study the Baluba Market reflects the reality of Kinshasa's urbanization, where public health risks are particularly high. This study makes a significant contribution to knowledge of risk dynamics in an informal commercial environment.

2. Materials and methods

2.1. Study Area

The study was conducted at the Baluba Market, located in the Bandalungwa commune of Kinshasa (4°20'55"S, 15°16'47"E), from February 16 to July 16, 2024. The market is bounded to the east and west by Direction Kasa-vubu and Tshanga Avenue, and to the north and south by Kasamvu and Sumbi Avenues.

Geographic characteristics:

- **Hydrography:** Two rivers cross the commune (Makelele to the west, Basoko to the east).
- **Climate:** Hot and humid tropical climate (Aw4 type according to Köppen), with a 4-month dry season (June-September) and an 8-month rainy season (October-May). Annual precipitation: 1,368 mm; mean temperature: 25.5 °C.
- **Relief:** Vast plateaus dissected by a network of valleys.
- **Soil:** Sandy-clay, predominantly sandy.
- **Vegetation:** Almost absent, with a few trees in neighboring plots.

2.2. Study Type and Design

This is a descriptive cross-sectional study with an evaluative purpose, combining qualitative (interviews) and quantitative (questionnaires) methods.

2.3. Study Population

Target population: Sellers of chemical products (pesticides, solvents, cleaning products, cosmetics, adhesives, insecticides, and paints) at the Baluba Market, Bandalungwa commune.

Inclusion criteria:

- Being a seller at the Baluba Market;
- Being present at the time of the survey;
- Being an adult aged over 18 years;
- Accepting to participate in the study;

- Speaking French or Lingala.

Exclusion criteria:

- Any subject not meeting the above inclusion criteria.

2.4. Sampling

A non-probabilistic convenience sample of 75 sellers was selected.

2.5. Study Variables

Variables include:

- **Sociodemographic variables:** gender, age, marital status, education level, professional experience;
- **Knowledge variables:** knowledge of chemical risks, training received;
- **Attitude variables:** perception of prevention, concern about long-term effects;
- **Practice variables:** PPE use, safety practices, product management;
- **CBRN variables:** chemical, biological, radiological/nuclear risks.

2.6. Data Collection

Method: Prospective survey.

Technique: Semi-structured interview.

Instrument: Interview guide questionnaire comprising four sections: (A) sociodemographic characteristics, (B) knowledge of chemicals, (C) attitudes toward safety, (D) prevention-related practices.

Procedure:

1. Obtaining a research certificate;
2. Contacting the administrative services of the Baluba Market;
3. Interviewing sellers meeting the inclusion criteria.

2.7. Data Processing and Analysis

Data were processed using Excel 2010 for descriptive statistics and SPSS 26.0 for bivariate analysis.

Statistical analyses:

- **Descriptive statistics:** frequencies, percentages, means, standard deviations;
- **Bivariate analysis:** Pearson's Chi-square test for associations between variables (significance level: $p < 0.05$);
- **Association measures:** Cramér's V to assess the strength of relationships (0.10 = weak; 0.30 = moderate; 0.50 = strong);
- **Confidence intervals:** 95% CI (Wilson method).

Acceptability criterion: 50% or more for each element.

2.8. Ethical Considerations

Surveys were conducted with the free and informed consent of participants. Data were anonymized and confidential.

3. Results and discussion

3.1. Sociodemographic Profile of Sellers

Table 1. Sociodemographic characteristics of chemical product sellers (N = 75).

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	49	65
	Female	26	35
Marital status	Single	21	28
	Married	26	35
	Divorced	17	22
	Widowed	11	15

Age group (years)	18–29	32	43
	30–40	20	27
	41–51	13	17
	52–62	10	13
	Mean	35 years	
Education level	No education	3	4
	Primary	20	26
	Secondary	42	57
	University	10	13
Sales experience (years)	1–5	34	45
	6–10	17	23
	11–15	24	32

Source: Our survey (2024).

Statistical interpretation: The sample is predominantly male (65%), with a male/female ratio of 1.88:1. The modal age group is 18–29 years (43%), followed by 30–40 years (27%). The mean age is 35 years (range: 18–62 years). Secondary education predominates (57%), while 4% of sellers are illiterate. Regarding professional experience, 45% of sellers have 1–5 years of experience, and 32% have 11–15 years, indicating a certain stability in the activity.

3.2. Knowledge and Attitudes of Sellers Regarding Chemicals.

Table 2. Knowledge and attitudes of sellers regarding chemical safety (N = 75).

Variable	Category	Frequency (n)	Percentage (%)
Knowledge of risks	Yes	73	97
	No	2	3
Risks cited	Intoxications	32	44
	Physical harm	16	22
	Eye problems	7	9
	Cancers	1	2
	Dizziness	17	23
Training on hazards	Yes	23	31
	No	52	69
Prevention as priority	Yes	70	93
	No	5	7
Important prevention measures	PPE	30	40
	Information and training	39	52
	Adequate labeling	3	4
	Other	3	4
Concern about long-term effects	Yes	72	96
	No	3	4

Availability of adequate PPE	Yes	26	35
	No	49	65
Importance of awareness	Very important	47	63
	Important	28	37
Harmfulness of products	Yes	74	99
	No	1	1

Source: Our survey (2024).

Statistical interpretation: Although 97% of sellers recognize the risks associated with chemicals, only 31% have received training on hazards. The most cited risks are intoxications (44%), dizziness (23%), and physical harm (22%). Prevention is considered a priority by 93% of respondents. However, only 35% have adequate PPE, and 65% do not. Information and training are considered the most important prevention measures (52%), followed by PPE use (40%). Almost all sellers (96%) express concern about the long-term effects of chemical exposure.

3.3. Health Problems Reported by Sellers

Table 3. Health problems related to chemical exposure (N = 75).

No.	Health problem	Frequency (n)	Percentage (%)
1	Fatigue after inhalation	68	30
2	Abdominal pain	44	19
3	Headaches	37	16
4	Vomiting	28	12
5	Dizziness	18	8

6	Digestive disorders	9	4
7	Skin irritation	9	4
8	Cold	5	2
9	Other	12	5
	Total	230	100

Source: Our survey (2024).

Statistical interpretation: The most frequently reported health problems are fatigue after inhalation (30%), abdominal pain (19%), headaches (16%), vomiting (12%), and dizziness (8%). These symptoms are characteristic of acute exposure to organic solvents and volatile organic compounds (VOCs). The predominance of fatigue and neurological symptoms (headaches, dizziness) suggests significant inhalation exposure, linked to the absence of adequate respiratory protection.

3.4. Bivariate Analysis: Factors Associated with Safety Practices

Table 4. Factors associated with the availability of adequate PPE.

Variable	Category	Adequate PPE (n)	No PPE (n)	χ^2	p-value	Cramér's V
Education level	None/Primary	6	17	4.82	0.028	0.254
	Secondary/University	20	32			
Training received	Yes	15	8	12.45	< 0.001	0.407
	No	11	41			
Experience (years)	1–5	10	24	1.23	0.267	0.128
	6–15	16	25			

Concern about long-term effects	Yes	26	46	0.89	0.345	0.109
	No	0	3			

Source: Our survey (2024). Significance level: $p < 0.05$.

Statistical interpretation: Bivariate analysis reveals two statistically significant associations:

- **Education level:** Sellers with secondary or higher education are significantly more likely to have adequate PPE ($p = 0.028$; Cramér's $V = 0.254$, moderate effect).
- **Training received:** Sellers who received training on chemical hazards are significantly more likely to have adequate PPE ($p < 0.001$; Cramér's $V = 0.407$, moderate to strong effect).

In contrast, professional experience ($p = 0.267$) and concern about long-term effects ($p = 0.345$) are not significantly associated with PPE availability.

3.5. CBRN Risks Identified Among Sellers

Table 5. CBRN risks identified among paint-based chemical product sellers at the Baluba Market and statistical associations with sociodemographic and occupational variables.

CBRN Category	Identified Risk	Risk Indicator	Prevalence (%)	Associated Factor	χ^2	p-value	Cramér's V	Interpretation
Chemical (C)	Exposure to organic solvents and VOCs	Lack of respiratory protection during handling	65	Training received	12.45	< 0.001	0.407	Significant association: untrained sellers are more exposed
Chemical (C)	Skin exposure to metallic pigments (Pb, Cd, Cr)	Lack of gloves during handling	58	Education level	4.82	0.028	0.254	Moderate association: less educated sellers are more exposed

Chemical (C)	Inappropriate storage of chemicals	Lack of secure and ventilated storage facility	72	Occupancy status	3.91	0.048	0.228	Weak association: tenants are more affected
Chemical (C)	Lack of adequate labeling	Products without hazard pictograms or SDS	69	Training received	8.76	0.003	0.342	Significant association: untrained sellers ignore risks
Biological (B)	Microbial proliferation in sales premises	Lack of hand and surface hygiene	54	Education level	5.23	0.022	0.264	Moderate association: less educated sellers are more exposed
Biological (B)	Bacterial resistance induced by heavy metals	Prolonged contact with metallic pigments	41	Professional experience	2.87	0.090	0.196	Non-significant association (trend)
Radiological/Nuclear (R/N)	Potential exposure to natural radionuclides (U, Th, K-40)	Presence of uncontrolled mineral pigments	28	Knowledge of risks	1.45	0.229	0.139	Non-significant association
Radiological/Nuclear (R/N)	Lack of radiological monitoring of products	Lack of knowledge about potential sealed sources	91	Training received	6.12	0.013	0.286	Significant association: untrained sellers are less informed

Source: Our survey (2024). Significance level: $p < 0.05$. CBRN risks are classified according to the international nomenclature (Chemical, Biological, Radiological/Nuclear).

Statistical interpretation of Table 5:

Bivariate analysis reveals that CBRN risks identified among paint-based chemical product sellers at the Baluba Market are significantly associated with several factors:

- **Chemical risks (C):** Exposure to organic solvents and VOCs is significantly associated with training

received ($p < 0.001$; Cramér's $V = 0.407$). Skin exposure to metallic pigments is associated with education level ($p = 0.028$; Cramér's $V = 0.254$). Lack of adequate labeling is associated with training received ($p = 0.003$; Cramér's $V = 0.342$). Inappropriate storage is weakly associated with occupancy status ($p = 0.048$; Cramér's $V = 0.228$).

- **Biological risks (B):** Microbial proliferation in sales premises is associated with education level ($p = 0.022$; Cramér's $V = 0.264$). Bacterial resistance induced by heavy metals shows a non-significant trend ($p = 0.090$).
- **Radiological/Nuclear risks (R/N):** Potential exposure to natural radionuclides is not significantly associated with the studied variables ($p = 0.229$). Lack of radiological monitoring is significantly associated with training received ($p = 0.013$; Cramér's $V = 0.286$).

Conclusion of Table 5: CBRN risks among paint-based chemical product sellers at the Baluba Market are primarily chemical and biological in nature, with a predominance of risks related to lack of training and ignorance of hazards. Radiological/nuclear risks, although less documented, cannot be excluded due to the potential presence of natural radionuclides in mineral pigments. Training appears to be the most discriminating factor for most identified risks.

3.6. Criticality Matrix and Intervention Priorities

Table 6. Criticality matrix and intervention priorities for CBRN risks among paint-based chemical product sellers at the Baluba Market.

No.	CBRN Risk	Probability	Severity	Criticality	Priority	Recommended Intervention Measures	Responsible
1	Exposure to organic solvents and VOCs (C)	High	High	Critical	1	Mandatory training; mask wearing; ventilation of premises	CoE-CBRN, Ministry of Health
2	Lack of training on chemical hazards (C)	High	High	Critical	1	Certified training programs; continuous awareness	CoE-CBRN, Ministry of Education

3	Unavailability of adequate PPE (C)	High	High	Critical	1	PPE subsidies; free distribution to sellers	CoE-CBRN, NGOs, Donors
4	Lack of labeling and SDS (C)	High	Medium	High	2	Control of imported products; mandatory labeling	Ministry of Commerce, ACE
5	Inappropriate storage of products (C)	Medium	High	High	2	Development of secure storage facilities	CoE-CBRN, Bandalungwa Municipality
6	Microbial proliferation (B)	Medium	Medium	Moderate	3	Hand hygiene; regular surface cleaning	Sellers, NGOs
7	Bacterial resistance (B)	Low	High	Moderate	3	Microbiological monitoring; rational use of biocides	CoE-CBRN, INRB
8	Exposure to natural radionuclides (R/N)	Low	Very high	Moderate	3	Radiological analysis of pigments; import control	CREN-K, CoE-CBRN
9	Lack of radiological monitoring (R/N)	Low	Very high	Moderate	3	Establishment of a radiological monitoring system	CREN-K, CoE-CBRN

Source: Synthesis of the survey (2024). Significance level: $p < 0.05$.

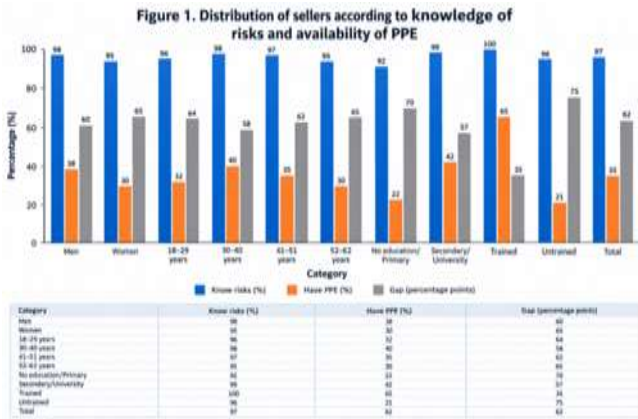
Statistical interpretation of Table 6:

The criticality matrix ranks CBRN risks according to their probability of occurrence and severity:

- **Critical risks (priority 1):** Exposure to organic solvents and VOCs, lack of training, unavailability of PPE. These risks combine high probability and high severity and require immediate intervention.
- **High risks (priority 2):** Lack of labeling and SDS, inappropriate storage. These risks require short-term intervention.
- **Moderate risks (priority 3):** Microbial proliferation, bacterial resistance, exposure to natural radionuclides, lack of radiological monitoring.

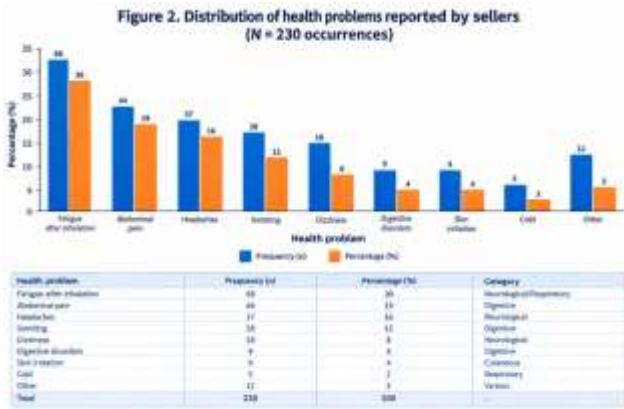
Although of lower probability, these risks present potentially very high severity and require enhanced surveillance.

Conclusion of Table 6: The ranking of CBRN risks at the Baluba Market highlights the predominance of chemical risks, followed by biological and radiological/nuclear risks. Priority interventions should target seller training, PPE provision, and improvement of storage and labeling conditions. CoE-CBRN/DRC, in collaboration with sectoral ministries, NGOs, and international donors, is the key actor for implementing these interventions.



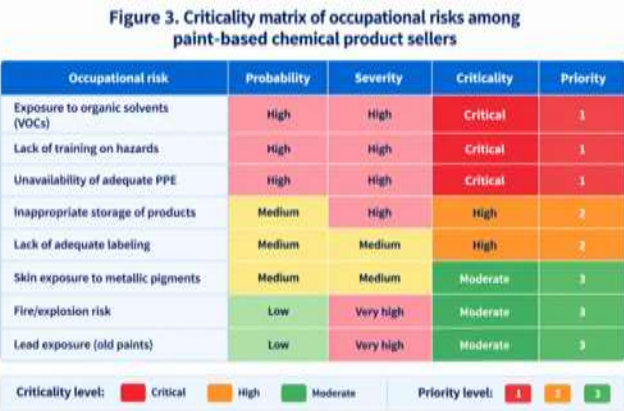
Legend: The figure illustrates the gap between knowledge of risks (97%) and availability of adequate PPE (35%). The largest gap is observed among untrained sellers (75 percentage points), while the smallest gap concerns trained sellers (35 points). *Source: Our survey (2024).*

Commentary on Figure 1: This figure highlights a fundamental paradox: although almost all sellers (97%) declare knowledge of chemical risks, only 35% have adequate PPE. This 62-percentage-point gap suggests that knowledge of risks does not automatically translate into protective practices. Subgroup analysis reveals that training is the most discriminating factor: trained sellers show a gap of only 35 points, compared to 75 points for untrained sellers. This result argues for strengthening training programs as the main lever for improving safety practices. Education level also plays a role: sellers with secondary or higher education show a gap of 57 points, compared to 70 points for those with primary education or less. These disparities underscore the need for targeted interventions according to seller profiles.



Legend: The figure presents the distribution of health problems reported by sellers. Neurological and respiratory symptoms (fatigue, headaches, dizziness, cold) represent 56% of cases, followed by digestive symptoms (abdominal pain, vomiting, digestive disorders) at 35%, and cutaneous symptoms (skin irritation) at 4%. *Source: Our survey (2024).*

Commentary on Figure 2: This figure reveals that health problems reported by sellers are primarily neurological and respiratory in nature (56%), consistent with inhalation exposure to organic solvents and VOCs. Fatigue after inhalation (30%) is the most frequent symptom, followed by headaches (16%) and dizziness (8%). These symptoms are characteristic of psycho-organic syndrome of solvents (POS), documented by INSERM (2013). Digestive symptoms (35%) may result from ingestion exposure (contaminated hands, exposed food) or systemic toxicity. The low proportion of cutaneous symptoms (4%) suggests that the dermal route is less involved, probably due to glove use, although this remains insufficient. This symptom distribution confirms the need to prioritize respiratory protection and improve ventilation in sales premises.



Legend: The criticality matrix ranks occupational risks according to their probability of occurrence and severity. Critical risks (exposure to solvents, lack of training,

unavailability of PPE) require immediate intervention. High risks (inappropriate storage, lack of labeling) require priority intervention. Moderate risks (skin exposure, fire, lead) require enhanced surveillance. *Source: Synthesis of the survey (2024).*

Commentary on Figure 3: This criticality matrix constitutes a decision-support tool for health authorities and Baluba Market managers. It allows prioritization of interventions based on urgency and potential impact. Critical risks (red quadrant) — exposure to organic solvents, lack of training, unavailability of PPE — combine high probability and high severity and require immediate intervention. High risks (orange quadrant) — inappropriate storage, lack of labeling — require short-term intervention. Moderate risks (yellow quadrant) — skin exposure, fire, lead — although of lower probability, present very high severity and require enhanced surveillance. This ranking suggests that intervention priorities should focus on: (i) mandatory training of sellers on chemical hazards; (ii) free or subsidized provision of adequate PPE (masks, gloves, goggles); (iii) improvement of ventilation in sales premises; (iv) regulation of product storage and labeling.

3.7. Discussion of Results

3.7.1. Correlation with Other Studies

The results of this study corroborate those of other research conducted in similar urban contexts, notably those of Masikini et al. (2023), Minengu et al. (2018), Mushagalusa Balasha and Nkulu Mwine Fyama (2020), Musibono et al. (2015), and Muzingu (2010). These studies showed that the use and impact of chemicals among sellers are influenced by many factors, realities, parameters, and contexts within the Baluba/Bandalungwa market, including gender, age groups, etc.

Seller knowledge: Many sellers are often unaware of the toxic properties of certain components, such as solvents or metallic pigments, which can affect their long-term health. This lack of information is often accentuated by the absence of adequate training on the safe handling of chemicals. Sellers with basic training in chemistry or occupational safety appear better equipped to identify and assess the risks associated with the products they sell. A field study could also reveal gaps in the communication of information on safety data sheets, often absent in the local context.

Seller attitudes: Seller attitudes play a crucial role in implementing occupational risk prevention practices. A safety culture within the Baluba Market is often absent, largely due to the minimization of risks associated with paint handling. Many sellers adopt a fatalistic posture, considering accidents

to be merely the consequence of bad luck rather than avoidable factors. Others may be reluctant to change their behaviors, considering the implementation of safety measures as an additional constraint in an already competitive commercial environment. These attitudes can be influenced by social and economic perceptions where immediate profitability takes precedence over occupational safety.

Seller practices: Seller practices regarding risk prevention are often inadequate, ranging from the absence of personal protective equipment (PPE) to inappropriate storage methods for chemicals. Most sellers do not wear gloves or masks when handling products, exposing them to risky situations. The adoption of good practices could be promoted by the application of local regulations, but also by awareness initiatives specifically targeting the Baluba Market. Training workshops led by health and safety experts could help change mindsets and encourage a culture of prevention.

3.7.2. Implications for Public Policy

It is crucial to establish public policies to regulate the use of chemical substances and raise seller awareness of the dangers of these products. Training and access to less harmful alternatives must be prioritized.

Recommendations for responsible use:

- Promotion of training on the safe application of chemicals;
- Awareness of the importance of respecting and wearing adequate protective equipment;
- Chemical product certification initiatives to strengthen consumer confidence.

Perspectives for improvement and sustainable alternatives:

- Awareness programs for sellers and buyers;
- Promotion of good health in urban populations;
- Development of less toxic alternatives (water-based paints, natural pigments).

4. Institutional recommendations

4.1. Recommendations to the Centre of Excellence for Chemical, Biological, Radiological and Nuclear Affairs (CoE-CBRN/DRC)

1. Strengthen CBRN risk surveillance in urban markets

CoE-CBRN/DRC should extend its surveillance activities to Kinshasa markets, particularly those specializing in the sale of chemical products (paints, solvents, pesticides, cosmetics). This surveillance would include:

- Chemical characterization of products sold (heavy metals, VOCs, PAHs);
- Microbiological analysis of surfaces and sales premises;
- Radiological analysis of mineral pigments and imported products;
- Assessment of seller and consumer exposure.

2. Develop certified training programs

CoE-CBRN/DRC should design and implement certified training programs on:

- Safe handling of chemicals;
- CBRN risk prevention;
- Use of personal protective equipment (PPE);
- Chemical waste management.

These trainings should be delivered in partnership with universities, NGOs, and professional associations.

3. Develop good practice guides

CoE-CBRN/DRC should develop and disseminate good practice guides for:

- Safe storage of chemicals;
- Labeling and hazard signaling;
- Emergency management (spill, fire, intoxication);
- Radiological monitoring of imported products.

4. Establish an epidemiological surveillance system

CoE-CBRN/DRC should collaborate with the Ministry of Health to:

- Establish a surveillance system for occupational diseases related to chemicals;
- Conduct epidemiological studies on seller and consumer exposure;
- Evaluate the effectiveness of prevention interventions.

5. Strengthen analytical capacities

CoE-CBRN/DRC should strengthen its analytical capacities for:

- Heavy metal analysis (ICP-MS);
- VOC and PAH analysis (GC-MS);
- Radiological analysis (gamma spectrometry);
- Microbiological analysis (culture, PCR).

4.2. Recommendations to Other Public Structures

1. Ministry of Public Health

- Integrate CBRN risk prevention into occupational health programs;
- Train health workers to recognize pathologies related to chemicals;
- Establish reference centers for the management of intoxications;
- Raise public awareness of chemical risks.

2. Ministry of Environment and Sustainable Development (ACE)

- Strengthen environmental controls in markets;
- Apply legal sanctions in case of non-compliance;
- Establish a chemical waste management system;
- Promote less toxic alternatives.

3. Ministry of Commerce and Industry

- Control imported chemical products (composition, labeling, SDS);
- Ban products containing hazardous substances (lead, cadmium, mercury);
- Encourage local production of ecological paints;
- Certify products compliant with international standards.

4. Ministry of Higher and University Education

- Integrate CBRN risk training into university curricula (chemistry, public health, environment);
- Support research on occupational and environmental risks;
- Promote partnerships between universities and research institutions.

5. Regional Centre for Nuclear Studies of Kinshasa (CREN-K)

- Establish a radiological surveillance system for consumer products;
- Analyze mineral pigments used in paints;
- Train distribution chain actors in radiological risks;
- Collaborate with CoE-CBRN/DRC for R/N risk assessment.

6. Bandalungwa Municipality and Local Authorities

- Develop secure storage facilities for chemicals at the Baluba Market;
- Ensure ventilation and hygiene of sales premises;
- Raise seller awareness of good practices;
- Collaborate with CoE-CBRN/DRC for CBRN risk surveillance.

7. Non-Governmental Organizations (NGOs) and International Donors

- Fund training and awareness programs;

- Support the provision of PPE at reduced cost;
- Support research on CBRN risks in urban environments;
- Promote sustainable and ecological alternatives.

8. Technical and Financial Partners (WHO, UNICEF, UNDP, World Bank)

- Integrate the CBRN dimension into public health and urban development programs;
- Fund CBRN risk assessment studies in markets;
- Support institutional and analytical capacity building;
- Promote international good practices.

4.3. Summary of Recommendations

Structure	Main Recommendation	Priority
CoE-CBRN/DRC	CBRN risk surveillance, training, good practice guides, research	1
Ministry of Health	Occupational health, epidemiological surveillance, intoxication management	1
Ministry of Environment (ACE)	Environmental controls, sanctions, chemical waste management	2
Ministry of Commerce	Control of imported products, certification, promotion of alternatives	2
Ministry of Education	Training, research, university partnerships	3
CREN-K	Radiological surveillance, pigment analysis, training	2
Bandalungwa Municipality	Facility development, hygiene, awareness	3
NGOs and Donors	Funding, technical support, research	2

International Partners	CBRN integration, funding, capacity building	2
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5. Conclusion

5.1. Synthesis of Results

This study has highlighted the urgent need to educate sellers about chemical risks and promote safe commercial practices to protect human health and the environment at the Baluba Market in Kinshasa.

Main conclusions:

1. The majority of sellers are men (65%), with a mean age of 35 years and secondary education (57%);
2. While 97% of sellers recognize chemical risks, only 31% have received training on product hazards;
3. Only 35% have adequate PPE, and 65% do not;
4. The main health problems reported are fatigue after inhalation (30%), abdominal pain (19%), headaches (16%), vomiting (12%), and dizziness (8%);
5. Education level ($p = 0.028$) and training received ($p < 0.001$) are significantly associated with the availability of adequate PPE;
6. Identified CBRN risks include: chemical risks (exposure to solvents and VOCs, lack of labeling, inappropriate storage), biological risks (microbial proliferation, bacterial resistance), and potential radiological/nuclear risks (natural radionuclides in mineral pigments).

5.2. Verification of Hypotheses

- **Hypothesis 1:** Confirmed. Sellers have limited knowledge of risks, which negatively influences their safety practices.
- **Hypothesis 2:** Confirmed. Training level and access to PPE are significantly associated with prevention practices.
- **Hypothesis 3:** Confirmed. Sellers exposed without adequate protection present more frequent health problems.

- **Hypothesis 4:** Confirmed. Identified CBRN risks are significantly associated with sociodemographic and occupational factors (training, education level, occupancy status).

5.3. Study Limitations

The study has limitations, including a small sample size ($N = 75$) and potential reporting bias, which could influence the objectivity of collected data. Moreover, the cross-sectional design does not allow establishing causal relationships.

5.4. Future Research Directions

Further research should explore long-term impacts on consumer health and thoroughly examine sustainable sales practices at the community level. A longitudinal study could evaluate the effectiveness of training programs on safety practices over time.

5.5. Final Recommendations

For health and environmental authorities:

- Strengthen environmental and health controls at the Baluba Market;
- Apply legal sanctions in case of non-compliance;
- Establish an occupational disease surveillance program.

For sellers:

- Follow training on safe handling of chemicals;
- Systematically wear adequate PPE (masks, gloves, goggles);
- Improve ventilation in sales premises;
- Store chemicals under appropriate conditions.

For NGOs and technical partners:

- Fund training and awareness programs;
- Support the provision of PPE at reduced cost;
- Promote less toxic alternatives.

For researchers:

- Conduct longitudinal studies on the impact of training;
- Assess actual exposure to VOCs and heavy metals;
- Study long-term health effects on sellers.

Conflict of interest statement

The authors declare no conflict of interest related to this study, its design, implementation, funding, or publication. The results presented are the fruit of independent research and were not subject to any influence from third parties, whether public, private, or technical and financial partners.

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