

Research Article

Analysis of Environmental and Health Risks Linked to the Use of Chemical Coating Products in the Commune of Tchaoudjo 1

Sassou Megnassan^{1,*} , Kwamivi Nyonuwoosro Segbeaya^{1,2} ,
Nitale Mbalikine Krou¹ , Baguibassa Matakouna¹ 

¹Department of Chemistry, University of Kara, Kara, Togo

²Department of Chemistry, University of Lomé, Lomé, Togo

Abstract

This innovative study assesses the environmental and health risks associated with the use of chemical coating products in the commune of Tchaoudjo 1 (Togo), a context marked by informality and the absence of strict regulations. It combines, in an unprecedented way, field surveys of artisans, chemical analyses of commonly used products (paints, varnishes, mastics, thinners) and a comparison with international standards. The results reveal a high use of solvent-based products containing volatile organic compounds (VOCs) and heavy metals (chromium, lead, mercury). Waste management is alarming: 100% of liquid residues are discharged into the open air and 85% of plastic waste is burned, promoting the dispersion of toxic pollutants. The study highlights previously poorly documented risks, such as the presence of hexavalent chromium (Cr^{6+}), a carcinogen, and the domestic storage of hazardous substances. Although measured concentrations generally remain below regulatory thresholds, their accumulation and persistence represent a serious threat. By filling a significant regional knowledge gap, this research provides essential baseline data for public policies, while highlighting the urgent need for regulatory, awareness-raising, and substitution measures.

Keywords

Chemicals, Coating, Informal Sector, Heavy Metals, Environment, Health

1. Introduction

In developing countries, the informal sector plays a central role in the local economy by creating jobs and providing goods and services accessible to a large part of the population [1]. However, the lack of a rigorous regulatory framework and effective control mechanisms makes this sector a major environmental and health issue. Among the most worrying problems is the uncontrolled use of coating chemicals,

commonly used in artisanal activities such as carpentry, painting, metalworking, and decoration. Coating products are designed to protect and improve the durability of surfaces. They are widely used in the construction, automotive, furniture, and handicraft sectors. Their effectiveness relies on complex formulations that often include volatile organic compounds (VOCs), pigments, and metal-based additives.

*Corresponding author: sassoumegnassan@gmail.com (Sassou Megnassan)

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Several studies have shown the toxicity, environmental persistence and bioaccumulative properties of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr) and mercury (Hg) [2, 3]. Other studies have shown that when these chemicals are handled, stored or disposed of improperly, they can contaminate soils and water sources, with significant risks to ecosystems and human health, particularly among workers chronically exposed without protection [4]. In urban settings in West Africa, and in Togo in particular, the majority of small workshops using these products operate informally. This regulatory vacuum promotes dangerous practices: insufficient awareness of risks, limited access to technical or health information, lack of safety standards and almost total absence of hazardous waste management [5]. Low-cost imported coating products, often not compliant with international health and environmental safety standards, are widely marketed and used without adequate monitoring. The commune of Tchaoudjo 1, located in the Central region of Togo, illustrates this situation. It concentrates many informal activities involving paints, varnishes and solvents in poorly regulated environments. Practices such as open-air storage, dumping of residues in sewers and the reuse of contaminated containers contribute to the gradual accumulation of pollutants in the natural environment [6]. The health consequences are equally alarming: respiratory problems, skin irritations, chronic poisoning, and even cancers linked to prolonged exposure to solvents and heavy metals [4]. These risks are aggravated by the widespread use of a young and untrained workforce and the rare use of personal protective equipment. Despite the growing magnitude of the problem, there is a notable lack of studies in Togo focusing on the chemical characterization of coatings used in the informal sector and their environmental and health impacts. This study fills this gap by combining field surveys, laboratory analyses, and regulatory comparisons an innovative approach rarely applied in the regional context. The objective is to analyze coating chemical management practices in the informal sector of Tchaoudjo 1 and to assess the associated environmental and public health risks, thus providing essential data to inform

local public policies and targeted prevention strategies.

2. Materials and Methods

2.1. Study Area

Created by Law No. 2017-008 of June 29, 2017, the commune of Tchaoudjo 1 is located in the Central Region of Togo. It is one of the four communes of the Tchaoudjo prefecture and is bordered by the neighboring communes of Tchaoudjo 2, 3, and 4, as well as the district of Tchamba to the east and Bassar to the west. With an area of 1,063.44 km², the commune combines urban and peri-urban areas. It is organized into five cantons (Sokodé Kpangalam, Tchalo, Kadambara, Kparatao), comprising 42 villages and 18 urban neighborhoods [7]. The concentration of artisanal activities using coating products (paint, varnish, solvents) makes it a fertile ground for studying environmental and health impacts in the informal sector.

2.2. Sampling

The study is based on a dual approach: a field survey of users and a laboratory analysis of coating products.

A semi-structured questionnaire was administered to a sample of 102 artisans operating in the five cantons of the municipality, including painters, carpenters, decorators, body repairers, and designers. The questionnaire collected data on the types of products used paints, solvents, varnish, etc., storage and handling methods, waste disposal practices, and perceptions of environmental and health risks associated with their activity. A GPRS system was used to locate the sites. Based on the most frequently used products, eight representative samples were selected for laboratory analysis. These included paints, varnishes, thinners, and sealants of various brands and colors (Table 1).

Table 1. Characteristics of the Coating Product Samples Analyzed.

No.	Description	Product Type	Brand	Color	Sample Volume (L)
1	Paint	Paint	CITROL	White	0.25
2	Paint	Paint	LEYLAC	Red	0.25
3	Paint	Paint	(Not specified)	Blue	0.25
4	Paint	Paint	SUPER SHINE	White	0.125
5	Varnish	Varnish	AZAR GLOSS	Reddish	0.25
6	Varnish	Varnish	SAVANA	Grey	0.25
7	Thinner	Thinner	AZARFIX	Colorless	0.25

No.	Description	Product Type	Brand	Color	Sample Volume (L)
8	Putty	Putty	EGC 50	White	0.125

Samples were collected directly from a local retail outlet, at room temperature, using newly arrived products. Sampling was carried out using 250 mL plastic tubes with airtight caps, previously washed with distilled water and dried to avoid contamination. These samples were then stored under appropriate conditions for analysis.



Figure 1. Sampling at the warehouse.

2.3. Analysis of Coating Products

Eight samples of coating products, including paints, varnishes, thinners, and sealants commonly used by Tchaoudjo 1 artisans, were collected and analyzed to determine their content of toxic trace metal elements (TMEs): lead (Pb), chromium (Cr), cadmium (Cd), and mercury (Hg). These analyses aimed to assess the environmental and health risks associated with their use. The samples first underwent microwave-assisted acid digestion (ETHOS UP model) according to a specific protocol. Approximately 0.25 g of each sample was treated with 9 mL of nitric acid (40%) and 3 mL of hydrofluoric acid (40%). The mixture was then

subjected to a stepwise temperature increase (up to 200 °C), followed by controlled cooling. A boric acid solution was added to neutralize the fluorinated residues, and then the volume was made up to 50 mL with ultrapure distilled water. The analysis was performed using inductively coupled plasma optical emission spectrometry (ICP-OES). This technique relies on the excitation of atoms in an argon plasma at over 6000 °C, resulting in the emission of photons characteristic of the elements present. The spectral lines obtained allow for the precise identification and quantification of the TMEs. The results were then compared to WHO and USEPA standards to assess potential toxicity levels. The data were analyzed using Excel software.

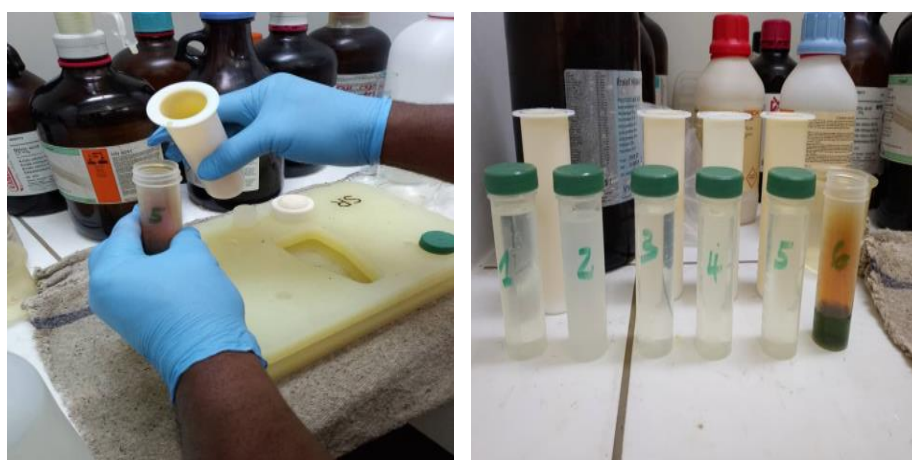


Figure 2. Sample preparation for mineralization.

3. Results and Discussion

3.1. Use and Management of Coating Chemicals

The survey results reveal a high prevalence of oil-based paints, used by 90% of craftspeople, compared to 26.47% for water-based paints. The latter are primarily used in the construction sector due to their low toxicity and ease of cleaning. Varnishes (70%), sealants (52%), thinners (50%), and glues (36%) are widely used by carpenters and sheet

metal workers. These products contain volatile organic compounds (VOCs), such as toluene, xylene, and styrene, known for their harmful effects on human health and their contribution to the formation of ground-level ozone [8, 9]. Chronic exposure to VOCs is also associated with an increased risk of cancer [10]. The local context of Tchaoudjo shows more acute exposure, due to poor ventilation and very limited use of personal protective equipment (PPE).

Table 2. Chemical use rates by category.

Product Type	Usage Rate (%)	Main Users
Oil-based paints	90.00	Artisans in general
Water-based paints	26.47	Mainly in the construction sector
Varnishes	70.00	Carpenters and sheet metal workers
Putties	52.00	Carpenters and sheet metal workers
Thinners	50.00	Carpenters and sheet metal workers
Glue	36.00	Carpenters and sheet metal workers

The surveyed artisans reported mainly using gasoline alone (33.33%) or mixed with thinners (49.02%), while thinner alone (3.92%) and the gasoline/water/thinner mixture (13.72%) were less common (Table 3). The use of

hydrocarbon-based solvents exposes workers to significant emissions of VOCs, especially in the absence of adequate ventilation and personal protective equipment [11].

Table 3. Distribution of solvents used for paint dilution.

Type of Solvent Used	Proportion (%)
Gasoline only	33.33 ± 1.2
Gasoline and thinner mixture	49.02 ± 2.1
Thinner only	3.92 ± 0.2
Gasoline/water/thinner mixture	13.72 ± 1.8

Concerning the application methods and associated risks, the results show that manual application is dominant (82%) in the building sector, while spraying (18%) is preferred in auto body workshops. Spraying, in particular, promotes the dispersion of fine particles and toxic vapors, thereby increasing inhalation exposure [10]. Studies show that this application method can increase VOC concentrations in ambient air by 2 to 5 times compared to brush application [3].

3.2. Coating Waste Management

3.2.1. Typology of Waste and Disposal Methods

Generated waste is of two types: liquid/pasty (paint sludge, used solvents) and solid (containers, brushes, residues). Metal containers account for 69.29%, compared to 30.71% for plastic ones (Table 4). This waste is often stored without precaution, posing a high risk of pollutant leaching especially

during the rainy season potentially contaminating soil and groundwater [12]. The complete lack of secure landfill or

hazardous waste treatment in Tchaoudjo represents a critical divergence from international best practices.

Table 4. Nature of empty containers found.

Type of Container	Percentage (%)
Metal	69.29 ± 3.2
Plastic	30.71 ± 2.1

The survey showed that 100% of pasty waste is dumped in the open air, while solid waste is either burned (85%) or reused (70%) depending on its nature (Table 5). Open-air burning of plastic waste releases carcinogenic substances such as dioxins and furans, in violation of the Stockholm Convention and UNEP recommendations (2020).

Table 5. Waste disposal methods by type.

Type of Waste	Main Disposal Method	Proportion (%)
Liquid/pasty	Open-air dumping	100
Solid (plastic)	Burning	85
Solid (metal)	Reuse / recovery	70

3.2.2. Storage Conditions and Risks Perception

In Tchaoudjo 1, coating products are primarily stored in workshops (70%), on construction sites (20%), and, more worryingly, at home (10%), particularly in the absence of dedicated storage areas. Field observations reveal disorganized storage practices, increasing the risk of chemical exposure and accidents. The domestic storage of chemicals reported by 10% of artisans is particularly alarming. This vulnerability factor has not been documented in previous similar African studies, making it a concerning local development.

Concerning the risk associated, the study reveals that 52% of artisans consider coating products to be hazardous, while

39% believe them to be harmless. This fragmented perception reflects a lack of training and awareness of chemical risks. These findings are consistent with those of [13, 14], which highlight how poor knowledge of risks contributes to unsafe handling of chemicals in developing countries.

3.3. Contamination by Trace Metal Elements (TMEs)

Physico-chemical analyses revealed the presence of several trace metal elements (Cd, Cr, Hg, Pb, Zn) in the samples analyzed (Tables 6, 7, 8, and 9).

Table 6. Trace metal elements in paints (mg/kg).

Element	N °1 Citrol White	N °2 Leylac Red	N °3 Leylac Blue	N °4 Super Shine	Average	Limit (mg/kg)
Cd	0.28	0.33	0.53	0.30	0.36 ± 0.10	100
Cr	34.20	47.29	89.98	35.96	51.36 ± 20.62	60
Hg	1.24	0.43	0.39	1.59	0.91 ± 0.37	60
Pb	6.89	2.71	4.26	5.49	4.84 ± 1.52	90
Zn	502.80	5.58	5.80	127.87	160.51 ± 110.30	1000

Table 7. Trace metal elements in varnishes (mg/kg).

Element	N °5 Azar Gloss	N °6 Savana	Average	Limit (mg/kg)
Cd	0.34	0.41	0.38 ± 0.03	100
Cr	1.65	36.88	19.27 ± 18.60	60
Hg	0.36	0.51	0.44 ± 0.10	60
Pb	9.18	1.95	5.57 ± 3.2	90
Zn	127.87	7.26	67.57 ± 48.24	1000

Table 8. Trace metal elements in thinner (mg/L).

Element	N °7 Azarfix	Average	Limit (mg/L)
Cd	0.13	0.13	0.1
Cr	4.18	4.18	1.0
Hg	0.19	0.19	0.01
Pb	1.61	1.61	0.2
Zn	1.44	1.44	-

Table 9. Trace metal elements in putty (mg/kg).

Element	N °8 EGC 50	Average	Limit (mg/kg)
Cd	0.58	0.58	100
Cr	145.30	145.30	60
Hg	0.40	0.40	60
Pb	5.84	5.84	90
Zn	17.37	17.37	1000

Physicochemical analyses revealed the presence of trace metals (Cd, Cr, Hg, Pb, Zn). Although most concentrations were below regulatory thresholds, some exceeded them (Cr in Leylac Blue and EGC 50, as well as all metals tested in Azarfix thinner). These results confirm observations from studies conducted in Southeast Asia [15], which link low-cost coating products to high levels of heavy metals. However, this study breaks new ground by directly linking products from the Togolese informal market to specific health standards and thresholds recommended by the WHO.

In paints, Cd, Hg, Pb, and Zn levels are generally below regulatory limits, except for Cr in Leylac Blue (89.98 mg/kg), which clearly exceeds the 60 mg/kg threshold. The high variability in Zn content indicates inconsistent formulations, suggesting a lack of quality control.

In varnishes, although Cd, Hg, and Pb levels are low, Cr reaches 36.88 mg/kg in Savana compared to just 1.65 mg/kg in Azar Gloss, showing brand-dependent differences. Zn is also high in Azar Gloss (127.87 mg/kg) but remains below the critical threshold.

The thinner Azarfix is the most alarming: all measured concentrations of Cd, Cr, Hg, and Pb exceed regulatory limits, particularly Cr (4.18 mg/L), Pb (1.61 mg/L), and Hg (0.19 mg/L). This suggests a high health risk, especially for unprotected professional users.

The EGC 50 putty also contains a very high Cr level (145.30 mg/kg), more than double the permitted limit. Although other metals remain below thresholds, their combined presence is concerning in chronic exposure contexts. Samples N°3 (Leylac Blue), No. 7 (Azarfix), and No. 8 (EGC 50) show Cr concentrations far above the norm. This is especially concerning if Cr is present as hexavalent chromium (Cr^{6+}), classified as a human carcinogen by IARC [16].

The lead concentration in sample N° 7 (1.61 mg/L) also exceeds standards, posing a risk of soil pollution. Even when under legal thresholds, cadmium and zinc remain problematic due to bioaccumulation and nephrotoxicity [17]. The high mercury content in the same sample (0.19 mg/L) increases both environmental and health risks.

These findings justify stricter regulatory controls, better product labeling, and increased user awareness about the dangers of handling these substances.

3.4. Cumulative Impacts on Health and the Environment

Heavy metals like lead and mercury are known to be toxic at very low doses. Lead is a proven neurotoxin, especially in children, even at blood levels below 5 $\mu\text{g}/\text{dL}$ [17]. Mercury disrupts neurological and immune development [18]. Hexavalent chromium ($\text{Cr}(\text{VI})$), identified in some paints, is classified as carcinogenic by IARC [16]. Moreover, environmental factors (rain, heat, UV radiation) accelerate the degradation of coatings and the release of metals into the environment [19]. These metals can contaminate water, air, and soil, contributing to diffuse pollution. Once released, they may be absorbed by living organisms, accumulate in tissues,

and move up the food chain, causing major ecotoxicological effects [20, 21]. Unlike most local studies that analyze chemicals in isolation, this research takes a cumulative approach that considers synergistic effects, combined toxicity, and bioaccumulation. Even at concentrations below legal thresholds, toxic effects from lead, mercury, and chromium (VI) can occur due to their persistence, accumulation in the environment, and prolonged exposure [8, 17]. The identification of hexavalent chromium (Cr^{6+}) as a potential carcinogen in coating products widely used in Tchaoudjo 1 constitutes a major public health warning signal, which has not yet been addressed by local authorities.

4. Conclusion

The management of coating chemicals in the informal sector of Tchaoudjo 1 presents both major challenges and opportunities for reducing environmental impacts. This study highlighted current practices, user perceptions, and the health and ecological implications of widespread use of paints and varnishes. Results show that most users, who are predominantly young and under-informed about environmental risks, primarily use oil-based paints and struggle with safe waste management. Improvised storage methods and improper disposal practices are major sources of pollution, pointing to the urgent need for educational and structural measures. Diverse perceptions of health and environmental hazards underscore the need for increased awareness and ongoing training to encourage responsible behavior. Achieving this requires building local capacity through targeted training, promoting eco-friendly alternatives to conventional paints, and improving waste collection and treatment systems. Ultimately, establishing proactive, sustainable, and inclusive management of coating products in the informal sector is essential to ensure a healthy environment, secure working conditions, and preserve the quality of life for the people of Tchaoudjo1 both now and for future generations.

Abbreviations

WHO	World Health Organization
USEPA	United States Environmental Protection Agency
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
VOCs	Volatile Organic Compounds
UNEP	United Nations Environment Programme

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Author Contributions

Sassou Megnassan: Conceptualization, Methodology, Software, Supervision

Kwamivi Nyonuwoosro Segbeaya: Supervision, Validation

Nitale Mbalikine Krou: Formal Analysis, Writing – original draft, Writing – review & editing

Baguibassa Matakouna: Formal Analysis, Investigation

Conflicts of Interest

The authors declare no conflicts of interest.

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