

ORIGINAL ARTICLE

Health Risks Associated with Household Product Use Patterns in Urban and Rural Communities

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ABSTRACT

Introduction: Household products are essential for hygiene and convenience but often contain hazardous chemicals such as volatile organic compounds, disinfectants, and endocrine disruptors. While occupational chemical exposures are systematically regulated, domestic exposures remain largely overlooked in public health frameworks. This study assessed and compared the health risks associated with household product use among rural and urban communities in Selangor, Malaysia. **Methods:** A comparative cross-sectional study was conducted between July and December 2024. Data were collected through structured questionnaires, product inventories, and direct observation. Hazard identification was conducted using regulatory hazard classifications. Exposure and risk characterization were performed using a semi-qualitative Chemical Health Risk Assessment (CHRA) approach, which combines hazard severity and exposure potential to generate risk scores for inhalation and dermal exposure pathways. **Results:** Rural households demonstrated significantly higher inhalation risks for cleaning agents and laundry products (mean = 2.60 vs. 1.64, $p < 0.001$) and higher dermal risks for detergents and multipurpose cleaners ($p < 0.05$). These elevated risks were associated with frequent use of concentrated products, handwashing practices, and limited protective measures. Urban households, although showing lower acute exposure scores, reported a greater diversity of products containing carcinogenic, mutagenic, and endocrine-disrupting chemicals. **Conclusion:** Household environments in Malaysia function as unregulated spaces of chemical exposure. Rural households face acute risks from concentrated cleaners, while urban households experience chronic risks from diverse low-dose exposures. These findings highlight a hidden public health gap and underscore the need for policy actions by integrating of household chemical safety into national public health policies.

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INTRODUCTION

Household products play a central role in maintaining hygiene, sanitation, and convenience in daily life. However, many of these products contain chemical constituents that pose potential health hazards, ranging from immediate irritation of the skin, eyes and respiratory tract to long-term outcomes such as endocrine disruption, reproductive toxicity, and carcinogenicity (1). Active ingredients including chlorine-based disinfectants, ammonia, volatile organic compounds (VOCs), phthalates, and synthetic fragrances are of particular concern (2,3). Evidence indicates that these substances can enter the human body through inhalation, dermal absorption (4), and in some cases accidental ingestion,

making household environments a significant yet often overlooked source of chemical exposure.

Despite the established toxicological profiles of many of these substances, the health risks associated with household products remain underappreciated in both research and policy (5). Much of the existing literature evaluates individual products rather than their specific chemical components, neglecting the reality of cumulative chemical exposure (1). In practice, individuals are exposed repeatedly to the same hazardous compounds across multiple products, such as laundry detergents, air fresheners, disinfectant, and pesticides. While each product may contain permissible concentrations, the combined exposure substantially increases the potential for adverse health effects (5). This cumulative and chronic exposure scenario is rarely accounted for in risk assessments, leaving a critical knowledge gap in understanding the full burden of household chemical use.

While global evidence increasingly recognizes household environments as an important source of chemical exposure, research in Malaysia remains limited. Household products commonly used in Malaysian homes, including cleaning agents, disinfectants, air fresheners, and pesticides, often contain hazardous chemical constituents such as volatile organic compounds, chlorine-based compounds, and synthetic fragrances. However, national regulatory frameworks primarily focus on product labeling and classification rather than evaluating cumulative exposure from multiple products used within domestic environments. As a result, household chemical exposure remains largely invisible within Malaysian public health and environmental health discourse.

Patterns of household product use further complicate risk profiles and vary considerably across sociodemographic and geographic contexts (6). Urban households tend to use a wider array of commercial cleaning agents and fragranced products, leading to chronic low-dose exposures in enclosed or poorly ventilated spaces (7). Conversely, rural households frequently depend on a smaller set of concentrated multipurpose products, such as bleach or pesticides, which heighten acute risks, particularly in settings with inadequate ventilation and limited use of protective measures (8). These contrasting usage patterns underscore the need for context-specific risk assessments that account for both acute and chronic hazards.

In Malaysia, the regulation of household products is fragmented across multiple agencies, with oversight varying depending on whether the product is classified as a pharmaceutical, cosmetic, pesticide, or industrial chemical. While current frameworks address labelling and basic safety standards, they do not adequately consider cumulative exposures or differences in use across communities. As a result, a significant gap persists between workplace chemical safety, where systematic risk assessments are mandated under the Occupational Safety and Health (Use and Standards of Exposure of Chemical Hazardous to Health) Regulations 2000 and the unregulated household environment (9), where similar or even higher exposures may occur without protective measures. This regulatory blind spot represents a pressing public health concern, particularly in low and middle-income country contexts where chemical literacy and access to safer alternatives may be limited.

This study seeks to address these gaps by assessing the health risks associated with patterns of household product use among urban and rural communities in Selangor, Malaysia, specifically, it investigates the types of products used, characterises the associated health hazards, and compare the aggregated health risks between communities. Findings from this preliminary investigation aim to generate evidence that informs

regulatory reform, strengthen consumer protection, and advanced public awareness of chemical safety in domestic environments, by doing so this study contributes to a more comprehensive understanding of household chemical exposures and their implications for environmental and occupational health.

MATERIALS AND METHODS

Study Design and Setting

This was a cross-sectional study aims to evaluate chemical health risks associated with household product use among urban and rural communities in Selangor, Malaysia. Data collection was conducted between July and December 2024. Urban respondents were recruited from Kuala Lumpur, the federal capital and the most developed metropolitan area, while rural respondents were drawn from Hulu Langat, a district comprising traditional villages and indigenous settlements. These two locations were selected to capture contrasting sociodemographic and environmental contexts relevant to exposure patterns.

Study Population and Sampling

A total of 50 respondents (25 urban, 25 rural) were recruited through stratified random sampling from household lists provided by local community committees (Jawatankuasa Perwakilan Penduduk and Jawatankuasa Kemajuan dan Keselamatan Kampung). Inclusion criteria comprised adults aged 18–60 years, residents of the study area for at least 12 months, and individuals directly responsible for purchasing and handling household products. Exclusion criteria were pre-existing chronic skin diseases, history of chemotherapy or radiation exposure, pregnancy, and age above 60 years. Sample size was calculated using the two-group comparison formula described by Lemeshow et al. (1990), with parameters informed by a previous survey (He et al., 2018). Assuming 80% power and a 95% confidence level, and accounting for a 20% non-response rate, the final sample size was determined to be 50 respondents.

Data Collection

Primary data were obtained through face-to-face interviews using a structured questionnaire and a household product inventory checklist. The questionnaire collected sociodemographic data and detailed information on household product usage, including type of product, frequency and duration of use, amount used, and ventilation conditions. Household products were cross-verified through direct observation and photographic documentation, where consent was provided, to ensure accuracy of self-reported data.

Health Hazard and Exposure Assessment

Chemical hazard identification was conducted by screening the listed product ingredients against safety data sheets (SDS) obtained from product manufacturers

and supplier websites. Where SDS were not readily available or ingredient information required further verification, chemical hazard information was cross-referenced with publicly available chemical safety databases, including PubChem (National Center for Biotechnology Information, USA). Hazard classifications were interpreted in accordance with the Globally Harmonized System (GHS), as adopted under the Occupational Safety and Health (Classification, Labelling and Safety Data Sheet of Hazardous Chemicals) Regulations (CLASS), 2013.

Exposure assessment was carried out following the semi-qualitative methodology outlined in the Chemical Health Risk Assessment (CHRA) Manual, 3rd Edition (DOSH, 2018). This approach evaluates health risk by integrating hazard severity and exposure potential. Inhalation exposure was assessed by considering factors such as frequency and duration of product use, physical form of the product (e.g., liquid, aerosol, or powder), degree of chemical release during use, proximity to the breathing zone, and ventilation conditions within the household environment. Dermal exposure assessment considered the likelihood of direct skin contact during product handling, as well as the frequency and duration of contact during routine cleaning or laundry activities. As this study applied a semi-qualitative risk assessment approach, quantitative exposure dose calculations were not performed. Instead, the overall health risk was determined using the CHRA risk scoring system. The risk characterization was determined by combining the hazard rating (HR) and exposure rating (ER), where the overall health risk score is expressed as:

Health Risk = Hazard Rating (HR) x Exposure Rating (ER)

The resulting scores for both inhalation and dermal exposure pathways were subsequently categorized into risk levels in accordance with the CHRA Manual. The resulting risk scores were then aggregated and compared across urban and rural households.

For each household, risk scores were calculated for individual products based on the CHRA framework. These scores were subsequently aggregated by product category and exposure route (inhalation and dermal) to obtain an overall risk score representing the cumulative household exposure profile. The aggregated scores were then used for comparison between urban and rural households.

Quality Assurance

Several measures were implemented to ensure methodological rigor. A pilot study involving 20% of the intended sample was conducted to test the questionnaire, household product checklist, and logistic procedures. Feedback from the pilot informed refinements to question phrasing, product categorization, and interview flow.

Besides, all research assistants underwent structured training to minimize inter-observer variability during data collection. Standardized protocols were followed, and field notes and photographic records were maintained to support data validity. Furthermore, chemical hazard classification was independently verified by a registered Chemical Health Risk Assessor recognized by the Department of Occupational Safety and Health (DOSH), Malaysia. These steps ensured both internal consistency and compliance with recognized occupational health assessment standards.

Ethical Approval

The study received ethical clearance from the Ethics Committee for Research Involving Human Subjects, Universiti Putra Malaysia (JKEUPM) under approval number JKEUPM-2024-404.

Statistical Analysis

Data were analyzed using SPSS version 24.0 (IBM Corp., Armonk, NY). Descriptive statistics were applied to summarize sociodemographic characteristics, product usage patterns, and exposure levels. Data normality was assessed using the Shapiro-Wilk test and visual inspection of histograms prior to inferential analysis. Independent t-tests were used to compare mean aggregated household risk scores, derived from the combined CHRA risk scores of individual household products, between urban and rural groups; while chi-square tests were applied to categorical variables such as dermal exposure prevalence. Effect sizes (Cohen's d) were calculated to quantify the magnitude of difference between groups. A significance level of $p < 0.05$ was adopted for all analyses.

RESULTS

Sociodemographic Characteristics of Respondents

Of the 50 respondents, rural participants were predominantly female (84%), while the urban group was mostly male (72%). Rural households were generally older, with nearly half aged 36–45 years (48%), whereas urban respondents were younger, with 40% aged 19–29 years. Ethnic distribution showed rural communities were mainly Malay (60%) and Orang Asli/others (36%), while urban respondents were largely Chinese (52%) and Malay (40%). Educational attainment was lower in rural areas, where 12% had no formal education and 48% only secondary education. In contrast, 56% of urban participants had tertiary-level qualifications (undergraduate or postgraduate). Most respondents were married with children in both groups, though this was more pronounced in rural areas (84% vs. 48% urban). Income distribution reflected socioeconomic disparities: 68% of rural households earned below RM3,000, while urban households reported higher earnings, with 28% earning RM3,000–4,999 and 12% earning above RM11,000.

Table I: Sociodemographic Characteristics of Respondents from Rural and Urban Communities in Selangor, Malaysia (N = 50). This table summarizes the distribution of respondents according to gender, age group, ethnicity, education level, marital status, and monthly household income for rural and urban communities. Values are presented as frequency (n) and percentage (%).

n (%)		Rural	Urban
		n (%)	
Gender	Male	4 (16%)	18 (72%)
	Female	21 (84%)	7 (28%)
Age	19-29	4 (16%)	10 (40%)
	30-35	6 (24%)	7 (28%)
	36-45	12 (48%)	4 (16%)
	46-60	3 (12%)	4 (16%)
Ethnic	Malay	15 (60%)	10 (40%)
	Chinese	1 (4%)	13 (52%)
	Others	9 (36%)	2 (8%)
Education	No educational back-ground	3 (12%)	0
	Primary education	4 (16%)	0
	Secondary education	12 (48%)	2 (8%)
	Foundation/Matriculation/ Diploma/ STPM	5 (20%)	9 (36%)
	Undergraduate	1 (4%)	11 (44%)
	Postgraduate	xx (xx)	3 (12%)
Marital Status	Single	4 (16%)	13 (52%)
	Married with children	21 (84%)	12 (48%)
Income	Below RM1000	10 (40%)	1 (4%)
	RM1000- 2999	7 (28%)	8 (32%)
	RM3000-4999	5 (20%)	7 (28%)
	RM5000-6999	2 (8%)	3 (12%)
	RM7000-8999	1 (4%)	2 (8%)
	RM9000-10999	0	1 (4%)
	RM11000 and above	0	3 (12%)

Household Product Usage Patterns

The types of household products reported varied considerably between rural and urban communities as tabulated in **Table II**.

Cleaning agents were common in both groups, though patterns diverged. Rural households relied heavily on dishwashing agents (80%) and all-purpose cleaners (36%), while urban households more often used bathroom/toilet cleaners (60%), floor cleaners (36%), and glass cleaners (24%). Laundry and fabric care products were nearly universal, but usage was higher in rural households, particularly for detergents (92%), fabric softeners (52%), and bleaching agents (40%), compared to lower use in urban areas (44%, 32%, and 20%).

Specialised household products showed stronger uptake in urban households. Insecticides were more prevalent in urban settings (56% vs. 32% rural), while polishing agents were reported only by urban households (8%).

Table II. Types of household products used among rural and urban communities in Selangor, Malaysia (N = 50). This table presents the distribution of household product categories reported by respondents, including cleaning agents, laundry and fabric care products, specialised household products, and personal hygiene or safe cleaning products. Values are expressed as frequency (n) and percentage (%).

n (%)		Rural	Urban
		n (%)	
Cleaning Agents	Floor cleaner	2 (8.0%)	9 (36%)
	All-purpose cleaner	9 (36%)	4 (16%)
	Glass cleaner	0 (0%)	6 (24%)
	Metal cleaner	2 (8%)	1 (4%)
	Dishwashing agent	20 (80%)	14 (56%)
	Bathroom and toilet cleaner	3 (12%)	15 (60%)
	Drain cleaner	0 (0%)	0 (0%)
	Grease remover	0 (0%)	0 (0%)
Laundry and Fabric Care	Laundry detergent	23 (92%)	11 (44%)
	Fabric Softener	13 (52%)	8 (32%)
	Bleaching agent	10 (40%)	5 (20%)
Specialised Household Product	Air freshener	6 (24%)	7 (28%)
	Deodoriser	6 (24%)	1 (4%)
	Insecticides	8 (32%)	14 (56%)
	Herbicides	0 (0%)	0 (0%)
	WD-40	1 (4%)	1 (4%)
	Paint thinner	0 (0%)	0 (0%)
	Polishing agent	0 (0%)	2 (8%)
	Colour spray	0 (0%)	0 (0%)
Personal Hygiene and Safe Cleaning	Hand Sanitizer	2 (8%)	9 (36%)
	Vinegar	2 (8%)	0 (0%)
	Baking powder	2 (8%)	1 (4%)

Air fresheners were used at similar rates (24% rural vs. 28% urban), but deodorisers were more common in rural homes (24% vs. 4%). Personal hygiene and safe cleaning products also differed. Hand sanitizers were reported more often in urban households (36% vs. 8%), whereas traditional substitutes such as vinegar and baking powder were more common in rural households (8% each).

Health Hazards of Household Products

The hazard identification analysis confirmed that household products in both rural and urban communities contained ingredients associated with systemic, inhalation, dermal, and ocular health risks as summarized in **Table III**.

Systemic effects. Products classified with carcinogenic, mutagenic, and reproductive toxicity (CMR) hazards were present in both groups. While both rural and urban households reported carcinogenic products (n=2 each), urban households showed greater diversity of systemic

hazards, including products suspected of causing cancer (n=4), genetic defects (n=2), and fertility damage (n=4), compared to rural households (n=2, 0, and 2, respectively). Notably, repeated organ toxicity (STOT-RE, Cat. 2) was only identified in urban households (n=4).

Table III: Health hazard classification of household products used in rural and urban communities in Selangor, Malaysia (N = 50). The table presents the number of household products containing ingredients associated with specific health hazards according to the Globally Harmonized System (GHS) hazard statements. Hazards are categorized into systemic effects, local immediate inhalation effects, and local immediate dermal effects. Values indicate the number of products identified within rural and urban households. H3XX = GHS hazard statement codes indicating specific health hazards.

		No. of Product	
	Health Hazard (H3XX)	Rural household	Urban household
Systemic effects	May cause cancer (Carcinogenicity, Cat. 1B)	2	2
	Suspected of causing cancer (Carcinogenicity, Cat. 2)	2	4
	Suspected of causing genetic defects (Mutagenicity, Cat. 2)	0	2
	Suspected of damaging fertility (Reproductive toxicity, Cat. 2)	2	4
	Causes damage to organ through single exposure (H370)	2	2
	May cause damage to organ through single exposure (H371)	2	2
	Causes damage to organ through repeated exposure (H372)	4	2
	May cause damage to organ through repeated exposure (H373)	0	4
Local immediate effects (inhalation)	Fatal if inhaled (H330)	4	8
	Toxic if inhaled (H331)	4	4
	Harmful if inhaled (H332)	2	8
	May cause allergies or asthma symptoms (H334)	0	2
Local and immediate effects (Dermal)	Respiratory irritation (H335)	4	8
	Narcotic effect (H336)	4	8
	Fatal if contact via dermal (skin or eye) (H310)	6	2
	Toxic if contact via dermal (skin or eye) (H311)	4	8
	Harmful if contact via dermal (skin or eye) (H312)	2	4
	Cause severe skin burns dan damage (H314)	12	15
	Cause skin irritation (H315)	12	22
	Causes severe eye burns and damage (H318)	16	20
	Cause eye irritation (H319)	14	18
	May cause allergic skin reaction (H317)	6	18

Local and immediate inhalation effects. Acute inhalation risks were observed in both settings, though more frequent in urban households. Four rural products and eight urban products were classified as “fatal if inhaled” (Cat. 1). Both groups reported equal numbers of toxic inhalants (n=4), but urban households reported more products harmful if inhaled (n=8 vs. 2 rural). Respiratory sensitisation was only present in urban households (n=2), while respiratory irritants were twice as common in urban homes (n=8 vs. 4 rural).

Local and immediate dermal and ocular effects. Hazards related to skin and eye contact were widespread in both groups, but consistently higher in urban households. Products associated with severe skin burns were reported in 15 urban households versus 12 rural, while severe eye damage (Cat. 1) was linked to 20 urban products compared to 16 rural. Similarly, eye irritation (Cat. 2) was more frequent in urban households (n=18 vs. 14). Allergic skin reactions were three times higher in urban households (n=18) than in rural (n=6).

Inhalation Health Risks of Household Products

Inhalation risk assessment revealed significant differences between rural and urban households (**Table IV**). Rural households demonstrated higher inhalation risks from cleaning agents (mean = 2.08 ± 0.91) compared to urban households (1.96 ± 0.58 , $p = 0.043$). The largest disparity was observed for laundry and fabric care products, where rural households recorded substantially higher mean scores (2.60 ± 0.71) and a greater proportion of products classified as high risk, compared to urban households (1.64 ± 0.72 , $p < 0.001$). For specialised household products, no significant difference was found between rural (1.68 ± 0.74) and urban (1.52 ± 0.65) households ($p = 0.418$). However, when all categories were aggregated, the overall inhalation risk was significantly greater among rural households (2.15 ± 0.90) compared to urban households (1.68 ± 0.68 , $p < 0.001$).

Dermal Health Risks of Household Products

Dermal exposure risks were generally higher among rural households compared to urban households (**Table V**). Cleaning agents posed significantly greater dermal risks in rural households (mean = 2.03 ± 0.42) than in urban households (1.78 ± 0.55 , $p = 0.032$). Similarly, laundry and fabric care products showed higher dermal risk scores in rural households (2.23 ± 0.53) compared to urban (2.01 ± 0.68 , $p = 0.046$).

For specialised household products, no significant difference was observed between rural (2.24 ± 0.56) and urban (1.95 ± 0.74) households ($p = 0.186$). When aggregated across all categories, total dermal risk scores remained higher in rural households (2.21 ± 0.48) compared to urban (2.09 ± 0.64), though the difference was not statistically significant ($p = 0.148$).

Table IV: Aggregated Health Risks (Inhalation) by Household Products among Rural and Urban Communities (N=50). This table presents the distribution of household products according to inhalation risk levels (low, moderate, and high) based on the semi-qualitative Chemical Health Risk Assessment (CHRA) methodology. Risk scores were derived by combining hazard ratings and exposure ratings for each product category. Mean risk scores ($\pm$ SD) represent the aggregated inhalation risk for each household product category among rural and urban respondents. Independent t-tests were used to compare mean risk scores between groups. * $p < 0.05$; ** $p < 0.001$.

Household products	Group	Household Risk Levels (Inhalation)			Mean (SD)	p-value
		No. of ingredients in the household products used				
		Low	Moderate	High		
Cleaning agent	Rural	10	1	14	2.08 (0.91)	0.043*
	Urban	5	17	3	1.96 (0.58)	
Laundry and fabric care	Rural	3	4	18	2.60 (0.71)	<0.001**
	Urban	13	8	4	1.64 (0.72)	
Specialized household product	Rural	13	7	5	1.68 (0.74)	0.418
	Urban	15	8	2	1.52 (0.65)	
Total household Product	Rural	26	12	37	2.15 (0.90)	<0.001**
	Urban	33	33	9	1.68 (0.68)	

* p -value is significant at 0.05 level

** p -value is significant at 0.001 level

Table V: Aggregated Health Risks (Dermal) by Household Products among Rural and Urban Communities (N=50). This table presents the distribution of household products according to dermal exposure risk levels (low, moderate, and high) based on the semi-qualitative Chemical Health Risk Assessment (CHRA) methodology. Risk scores were derived by integrating hazard ratings and exposure ratings for each product category. Mean risk scores are expressed as mean $\pm$ standard deviation (SD) for rural and urban households. Independent t-tests were used to compare mean dermal risk scores between groups. * $p < 0.05$; ** $p < 0.001$.

Household products	Group	Household Risk Levels (Dermal)			Mean (SD)	p-value
		No. of ingredients in the household products used				
		Low	Moderate	High		
Cleaning agent	Rural	2	27	6	2.03 (0.42)	0.032*
	Urban	16	29	29	1.78 (0.55)	
Laundry and fabric care	Rural	2	27	11	2.23 (0.53)	0.046*
	Urban	9	20	9	2.01 (0.68)	
Specialized household product	Rural	1	11	5	2.24 (0.56)	0.186
	Urban	7	7	7	1.95 (0.74)	
Total household Product	Rural	5	65	22	2.21 (0.48)	0.148
	Urban	32	56	45	2.09 (0.64)	

* p -value is significant at 0.05 level

** p -value is significant at 0.001 level

DISCUSSION

This study demonstrates that household chemical exposures, though routine and normalized in daily life, represent a neglected yet significant public health issue. Using hazard identification and semi-quantitative risk assessment, we show that households in Selangor, both rural and urban are routinely exposed to products containing carcinogens, respiratory irritants, endocrine disruptors, and dermal sensitizers. The risks differ in nature across settings: rural households experience higher acute inhalation and dermal hazards, while urban households face a broader burden of chronic systemic risks. Together, these findings highlight a hidden exposure landscape that remains largely overlooked by current regulations and public health systems, despite being embedded in environments where people spend most of their time. This study underscores the urgent need for a paradigm shift in how household chemical exposures are perceived and managed, moving beyond

individual product safety towards a comprehensive assessment of cumulative and chronic risks (10-11).

The findings of this study are broadly consistent with global evidence indicating that household environments represent an important yet under-recognized source of chemical exposure. Previous studies in Europe, North America, and East Asia have reported that routine use of cleaning agents, disinfectants, air fresheners, and pesticides contributes to inhalation and dermal exposure to VOCs, surfactants, and other hazardous chemicals in indoor environments (6,7,14). Similar to these studies, our results demonstrate that household product use is associated with measurable exposure risks through everyday domestic activities. However, the Malaysian context introduces additional dimensions shaped by socioeconomic disparities, product accessibility, and differences in household practices between rural and urban communities. In particular, reliance on concentrated multipurpose cleaning products in rural

areas and the widespread use of diverse commercial products in urban households create distinct exposure pathways that may not be fully captured in studies conducted in higher-income countries.

To our knowledge, few studies have systematically assessed health risks associated with household product use patterns using a structured risk assessment framework. Most existing studies have focused primarily on indoor air pollutants, chemical emissions from individual products, or biomonitoring of exposure markers, rather than evaluating cumulative health risks arising from routine household product use. In the Malaysian context, research examining household chemical exposure has remained limited, particularly with respect to comparing risk profiles between rural and urban communities. By applying a semi-qualitative risk assessment framework adapted from the CHRA methodology, this study provides one of the first attempts to characterize household chemical risks associated with everyday product use patterns in Malaysia. This approach offers a practical framework for identifying potential exposure hotspots in domestic environments and may support future research and policy development related to household chemical safety.

Sociodemographic Determinants of Exposure

The sociodemographic difference observed in this study are not incidental but central to understanding exposure risks. Rural respondents were largely women of lower education and income, while urban respondents were more male, better educated and economically advantaged. These disparities shape not only what products are used, but also how they are handled. Rural women, for instance, often carry the dual role of homemakers and cleaners, exposing themselves daily to concentrated detergents, bleach, and disinfectants through handwashing and domestic tasks, often without gloves or ventilation. These exposures remain invisible in health surveillance systems, which do not capture chemical hazards in domestic spaces (12).

This gendered and socioeconomic dimension of exposure parallels global findings: women in low-income or rural households face disproportionate risks from domestic chemicals, with evidence linking such exposures to respiratory illness, reproductive health effects, and dermatitis (13). Yet, these risks remain hidden because household spaces are not conceptualized as exposure sites within public health frameworks.

Household Product Use Patterns

Household product use patterns in this study highlight how everyday practices normalize exposure to hazardous chemicals. Rural households relied on a narrow set of (11,14) multipurpose products, detergents, dishwashing agents, and all-purpose cleaners that were used frequently and in bulk. Urban households, by contrast, reported broader product diversity such as,

bathroom cleaners, insecticides, air fresheners which reflecting consumer market penetration and lifestyle demands.

Both patterns generate health risks. For instance, rural households face acute hazards from repeated handling of concentrated products in confined or poorly ventilated spaces; while urban households accumulate chronic risks from multiple low-dose exposures, particularly to VOCs, phthalates and fragrance chemicals. The contrast is striking: one community faces intensity-driven acute risks, while the other faces diversity-driven chronic risks. Yet both operate in the same blind spot—domestic environments where chemical risk is unregulated (6,15).

Hazard Identification and Health Risk Profiles

Hazard identification confirmed that dangerous chemicals are embedded in household products. Products classified as carcinogenic (Cat. 1B), mutagenic, and reproductive toxicants were identified across both rural and urban homes. Urban households reported more products linked to systemic hazards, such as suspected cancer and fertility impairment, while rural households reported more acute hazards, including products “fatal if inhaled” (5,16,17). This dual burden exposes the inadequacy of assessing consumer product safety in isolation. Regulatory systems evaluate each product category separately, but the cumulative and overlapping presence of systemic and acute hazards across households is invisible to regulators (1,6,14,16). This is the hidden crisis: exposures are not extraordinary, but ordinary which built into laundry, cleaning, and disinfecting routines.

Inhalation and Dermal Risks: A Hidden Divide Between Rural and Urban Households

Our analysis of inhalation and dermal risks (Tables IV and V) exposes a critical divide between rural and urban households that reflects deeper inequities in access, knowledge, and consumer choice.

Rural Households: Acute Risks from Concentrated Exposures

Rural households showed significantly higher inhalation risks from laundry and fabric care products (mean = 2.60 vs. 1.64 in urban, $p < 0.001$) and higher dermal risks from cleaning agents and detergents ($p < 0.05$). Several factors may explain this pattern.

First, product availability and affordability influence usage patterns. Rural households tend to rely on multipurpose detergents, bleach, and disinfectants because these products are widely available in local shops, relatively inexpensive, and often perceived as “strong” or highly effective cleaning agents. Safer alternatives, such as eco-labeled or low-VOC formulations, may be less accessible or more costly, limiting substitution. Second, differences in knowledge and risk perception may also contribute to higher exposure. Lower education levels

can reduce awareness of chemical hazards, hazard labelling, and safe-use practices (18,1). In this study, rural respondents rarely reported using protective measures such as gloves, masks, or adequate ventilation during cleaning activities, often perceiving these tasks as routine domestic chores rather than potential chemical exposure events. Third, the context in which cleaning activities occur may further intensify exposure. Activities such as handwashing clothes or scrubbing household surfaces frequently take place in confined spaces without mechanical ventilation, which may increase exposure to chlorine vapors, VOCs, and surfactant aerosols.

From a public health perspective, these practices create acute risk pathways that may lead to respiratory irritation, asthma exacerbation, dermatitis, and eye injuries. Women, who are often the primary handlers of household cleaning products, may therefore face disproportionate risks, with potential implications for reproductive and respiratory health. Children may also be indirectly exposed through passive inhalation and secondary dermal contact Within the household environment.

Urban Households: Chronic Risks from Product Diversity

Urban households recorded lower acute inhalation and dermal risks but demonstrated broader exposure to systemic hazards due to the use of a wider range of specialized household products. Several factors may contribute to this pattern. First, consumer culture and product availability play an important role. Urban residents typically have greater access to a wide variety of branded cleaning agents, air fresheners, and insecticides that are frequently marketed as “hygienic” or “modern”. Although these products may individually contain lower concentrations of hazardous chemicals compared to multipurpose cleaners, their combined and repeated use can introduce multiple low-dose chemical exposures within indoor environment (4, 20,21).

Lifestyle and housing characteristics may further influence these exposure patterns. Urban residents commonly live in high-rise apartments or compact housing units where indoor air exchange may be limited, allowing VOCs, phthalates, and fragrance chemicals from multiple products to accumulate indoors (22,24). In contrast, rural houses may benefit from greater natural ventilation due to larger openings and detached housing structures, although this advantage may vary depending on building design and household practices. These structural differences can influence how household chemicals disperse and accumulate within indoor environments.

In addition, perceptions of product safety may shape usage behaviors. Many urban consumers interpret fragrance, disinfectant claims, or “eco-friendly” labels as indicators of safety, which may encourage more

frequent or excessive product use without recognition of cumulative chemical exposures (23). From a public health perspective, such practices may contribute to chronic exposure pathways, including endocrine disruption associated with phthalates, neurodevelopmental risks in children linked to pesticide residues, allergic dermatitis caused by preservatives, and potential carcinogenicity from repeated low-level VOC exposure. Although these risks may not manifest immediately, their long-term accumulation may contribute to the broader burden of chronic disease.

The Hidden Epidemic of Domestic Chemical Exposure

The divergence between acute rural risks and chronic urban risks demonstrates that household chemical exposures are not uniform but are socially determined. In rural communities, exposures are shaped by affordability and necessity, with heavy reliance on concentrated, multipurpose chemicals because they are inexpensive and widely accessible. Such practices lead to short-term, high-intensity health effects, including asthma attacks, chemical burns, and skin rashes, which place immediate strain on local healthcare systems. By contrast, in urban settings, exposures are driven by consumer choice and lifestyle, characterized by frequent use of multiple specialized products marketed as safe but applied within enclosed spaces. These exposures contribute to long-term, low-dose health outcomes, such as endocrine disruption, reproductive toxicity, and cancers, which accumulate silently and add to the chronic disease burden.

These findings suggest that Malaysian households function as unregulated micro-workplaces, where cleaning and laundering replicate occupational chemical exposures but without the protections of ventilation standards, hazard communication, or personal protective equipment. For rural women, this means the daily inhalation of detergent and bleach fumes during handwashing tasks; for urban families, it is the continual inhalation of volatile organic compounds (VOCs) from air fresheners in poorly ventilated apartments. Both forms of exposure remain invisible to current health surveillance systems, yet both contribute to avoidable respiratory, dermatological, reproductive, and systemic health risks.

From a public health perspective, this duality highlights why domestic chemical exposure represents a hidden crisis. It is embedded within normative household hygiene practices, which renders the risks underestimated or ignored. The burden falls disproportionately on women and children, who are the primary users or passive recipients of these exposures in domestic environments. Moreover, household settings are excluded from occupational and environmental health regulations, leaving them unmonitored despite exposures comparable to, or greater than those encountered in workplaces. While the risk profiles

manifest differently across rural and urban communities, such that acute, high-intensity exposures in rural households and chronic, low-dose exposures in urban ones, they collectively contribute to Malaysia's growing burden of respiratory disease, dermatological disorders, endocrine dysfunction, and cancer.

CONCLUSION

This preliminary study demonstrates that household chemical exposures represent an existing but hidden public health problems in Malaysia. Rural households face disproportionately higher acute inhalation and dermal risks due to heavy reliance on concentrated multipurpose products, limited access to safer alternatives, and inadequate protective practices. In contrast, urban households encounter chronic, low-dose exposures from a wider array of specialized products, exacerbated by enclosed living environments and consumer perceptions of safety. These differences are not incidental but reflect broader socio-economic disparities, where affordability, access, and knowledge shape patterns of use, thereby creating distinct pathways of risks.

What emerges is the recognition that households function as unregulated micro-workplaces, where cleaning and laundering replicate occupational chemical exposures but without the safeguards mandated in formal workplaces. Yet, unlike occupational exposures, domestic exposures remain absent from national regulatory frameworks and health surveillance systems. This regulatory blind spot not only perpetuates inequities between rural and urban communities but also allows preventable health risks to accumulate silently, adding to the burden of respiratory illness, dermatological conditions, endocrine disorders, and cancers.

Closing this gap requires a paradigm shift in chemical safety governance: one that integrates households into the broader environmental and occupational health agenda. This includes harmonizing hazard communication across all consumer products, mandating clearer labeling of hazardous ingredients, and embedding household exposures within public health monitoring and education initiatives. Particular attention must be given to women and children in lower-income rural households, who bear the heaviest exposure burden yet have the least resources to mitigate risks.

Limitations and Future Directions

As a preliminary study, the findings are constrained by a modest sample size (N = 50) and reliance on self-reported usage, which may be subject to recall bias. Risk characterization was based on semi-qualitative methods and did not include direct exposure measurements. Future research should expand on these findings through larger, multi-site studies across different Malaysian states to better capture regional variations in household

product use. In addition, environmental monitoring of indoor pollutants and biomonitoring of exposure markers among household members would provide more robust evidence of actual exposure pathways. Further research should also explore behavioural and policy interventions, including consumer awareness, safer product substitution, and improved hazard communication, to reduce household chemical risks. Such work will be critical in developing a comprehensive national profile of household chemical exposure and informing evidence-based public health and regulatory strategies.

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