Chapter 2

Dose Response and Exposure Assessment of Household Hazardous Waste

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Additional information is available at the end of the chapter

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Abstract

This study was conducted to assess the risk of health hazards to employees working in local authorities in Malaysia especially workforce involved in waste management. Therefore, the four steps process of Health Risk Assessment has been identified, which include hazard identification, exposure assessment, dose response assessment and risk characterization. It was estimated approximately 22,388 tons of wastes generated every year in Malaysia and around 2.2 % out of that amount were consisting of hazardous household waste (HHW) with mean average generation for each person per day was around 0.02 kg. The waste generation is expected to increase 2 to 3 % per year and estimated to reach approximately 31 million of tones per day in the year 2020. In this study, the household hazardous wastes (HHW) were analyzed for their permissible dose level and the existing hazard level, hazard index and cancer index. Cancer Index for dermal exposure is found to be 5.8 × 10–^{7} mg/m^{3}, for Inhalation dust 1.4× ×10–^{1} mg/m^{3}, which falls under Low Risk and for Inhalation aerosol is 5 × ×10–^{2} mg/m^{3}, under Medium Risk. Extra care must be taken for the management of HHW as if it is improperly managed, it will fall into High Risk.

Keywords: Household Hazardous Waste, Hazard Index, Cancer Index

1. Solid waste and household hazardous wastes

1.1. Solid waste and household hazardous waste generation in Malaysia

Malaysia has undergone rather rapid urbanization since the beginning of the twentieth century and resulted in the development of more urban environment. Level of urbanization in Malaysia has increased from 26.8% in 1970 to 70.9% in 2010. Between 1970 and 2010, the urban population increased drastically by 557.5% or 16.5 million [1]. Modernization and progress has had their share of disadvantages, and one of the main aspects of concern is the pollution they are causing to human and environment. Increasing in the global population and the rising demand for food and other essentials such as household products lead to the increasing amount of waste being generated daily by each household and resulted in generation of more household hazardous wastes (HHW).

The total population of Malaysia in 2005 was only 25,048,000, and it increased gradually every year. Ministry of Housing and Local Government has reported that the estimated population of Malaysia in 2020 will be about 31,453,353 (**Table 1**). The increase in population will directly contribute to the increase in waste too.

Year	Population
2005	25,048,000
2010	27,642,193
2015	29,486,262
2020	31,453,353

Table 1. Population of Malaysia from year 2005–2020.

Municipal Solid Waste (MSW) generation had increased to 6.0 million tons in 1998, with an average of 0.5–0.8 kg per capita per day. Per capita waste generalization increased from 0.70 kg/person in 1990s to 1.2 kg/person in 2000, but in the recent past the range has increased to between 0.5 and 2.5 kg/person. The production of domestic and commercial waste in 2000 was 8.0 million tons/year [2]. The estimated solid waste generation in Malaysia in 2007 was approximately 24,000 tons per day (8.64 million tons/year) for a population of approximately 26 million people, and only 70% of waste produced per day were collected [3]. It is known that the greater the economic prosperity of any nation, the higher the rate of urbanization and consequently the greater will be the amount of solid waste produced, and Malaysia is one of such nations. Moreover, as the population of Malaysia increases, the generation of HHW will also increase, where approximately 31 million tons per day are estimated by the year 2020. Increase in residents will increase the generation of wastes from time to time. If no efforts are taken to reduce the generation of wastes, it will contribute to the increase in HHW at landfill. As a result, it will impact the workers and public negatively. It will also contribute to ground water contamination. In addition, if there is open burning at the landfill, it will also lead to air contamination.

Figure 1 shows the composition of solid waste in Malaysia, in which about 60% consist of domestic waste (DW), while 34% consist of other wastes (OW) such as industrial wastes, commercial waste and others; approximately 3.3% of total solid wastes consist of HHW.

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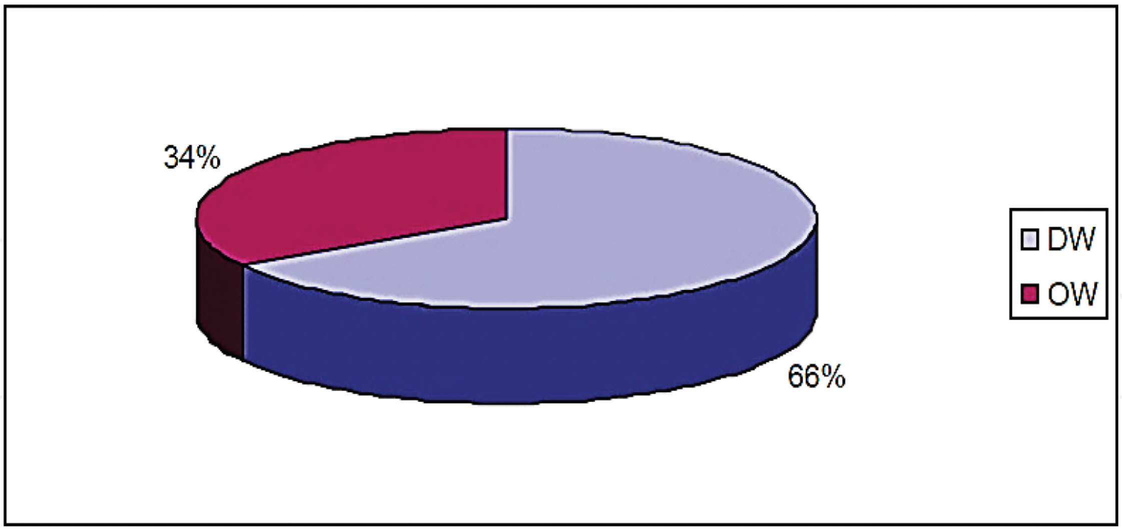

Figure 1. Percentage of domestic waste generated in Malaysia.

1.2. HHW composition in Malaysia

Determination of HHW composition was conducted at 40 local authorities in Malaysia. Results showed that a total of 9408 kg/day (0.02 kg/person/day) of HHW were generated. The category of cleaning products generated the highest portion of HHW of about 18%, followed by 16% of personal products, 12% of automotive products, 11% of fertilizers, 9% of paints and pesticides, 8% of lamps, 7% of stains and their removers, 6% of hobby products and batteries as the least generated HHW of about 5% (**Figures 2** and **3**).

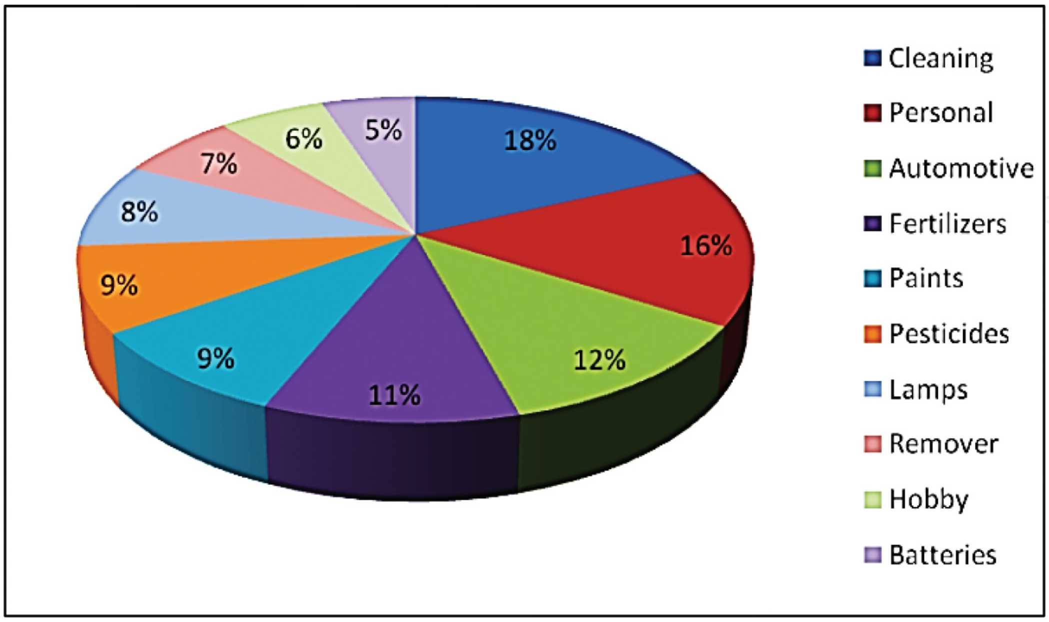

Figure 2. Composition of HHW (% by weight) generation at local authority in Malaysia.

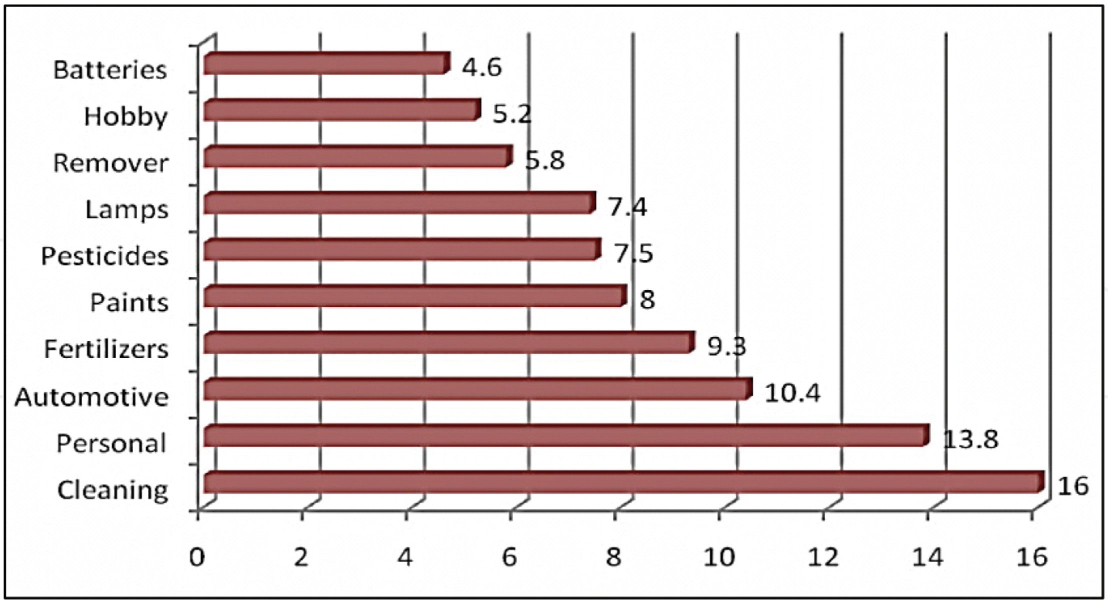

Figure 3. Composition of HHW (g/p/day) in Malaysia.

From the study, it can be seen that the utilization of personal products and cleaning products is high in Malaysia and in line with the era of globalization and modernization process where plenty of these materials are available in the market. In general, it can be said that all the houses are generating HHW and each individual produces approximately about 0.02kg of HHW per day, and it is expected to rise about 2–5% per year. Without the waste minimization measures; "3Rs" and especially HHW waste separation at home, this will increase the waste disposal in landfills and increase the risk of health hazards to workers handling HHW and subsequently increase the occurrence of pollution.

The average generation of household hazardous waste (HHW) in Malaysia is 0.02 kg/p/day. Thus, for a population of 27 million, HHW waste generated will be about 7.3kg/p/year. Pesticides and batteries perhaps showed a small percentage but it could still cause harm to human. They may contaminate underground water and have the potential for causing cancer if not properly managed at local level.

1.3. Estimation of total HHW generated in Malaysia by 2020

Improper management of HHW will result in increasing of waste generation from time to time and contribute to health problems and pollution.

As shown in **Table 2**, estimation of HHW generated in Malaysia is 865,753,484 tons per year in 2010 and is estimated to increase by about 985,119,016 tons per year in 2020. Results from this study showed that 823,492,800 tons of HHW were generated per year, where cleaning products were the highest contributor with the amount of 148,543,200 kg per year, as compared to personal products (128,793,600 kg per year), motor oil (93,974,400 kg per year), pesticides (79,466,400 kg per year), home maintenance (66,362,400 kg per year), fluorescent and menthol

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(61,214,400 kg per year), flea and tick control (58,687,200 kg per year), adhesive, glue and varnish (54,288,000 ton per year) and batteries (46,238,400 ton per year).

Year	Population (million)	Kg/p/day	Kg/pop/day	Ton/year
2005	25.05	0.09	2,179,176	784,503.36
2006	26.00	0.09	2,262,000	814,320.00
2010	27.64	0.09	2,404,870	865,753.48
2015	29.49	0.09	2,565,304	923,509.72
2020	31.45	0.09	2,736,441	985,119.01

Table 2. Total of HHW based on all categories generated in Malaysia from 2005 to 2020.

The generation of HHW has been continuously on the rise and in Malaysia its management has been a problem till today due to its rapid increases in the volume and composition [2]. Improper disposal of HHW will lead to the contamination and pollution of river and underground water. The chemicals contained in HHW are hazardous and have the potential to cause cancer in people.

This high generation of HHW in Malaysia is attributed to the rapid economic growth, population growth, developments of town and not forgetting the changing lifestyle that has been experienced in the recent past. If no action is taken to minimize waste in the early stages, it will harm the employees who are handling those waste materials that pollute our environment.

2. Dose response assessment

Garbage collection work is a major responsibility in all local authorities, and all types of waste, particularly domestic waste should be managed properly. Domestic waste contains HHW that need to be managed as efficiently as possible. Hazardous wastes at home are not subjected to the controlled scheduled waste according to the Environmental Quality Act, 1994, thus, the waste is directly disposed into the trash and then to the landfill. The absence of segregation at the source and landfill cause it to be potential water resources pollutant and direct exposure to workers. Improper management of HHW can directly expose the local authorities' workers to the above-mentioned hazard. Every employer must ensure that their employees are safe during the course of their duties as subjected in the provision of Occupational Safety and Health, 1994. Thus, to ensure the safety of workers, human health risk assessment should be conducted to identify the level of risk from HHW so that prevention and control measures can be applied and thus minimize the impact of health and safety of employees during the course of their duties.

Therefore, risk assessment for HHW must be conducted to estimate the increasing risk on health of human due to exposure to toxic substances. Four main steps involved in the process of assessing risks start from hazard identification, followed by exposure assessment, dose-response assessment and end with risk characterization [4] as shown in **Figure 4**.

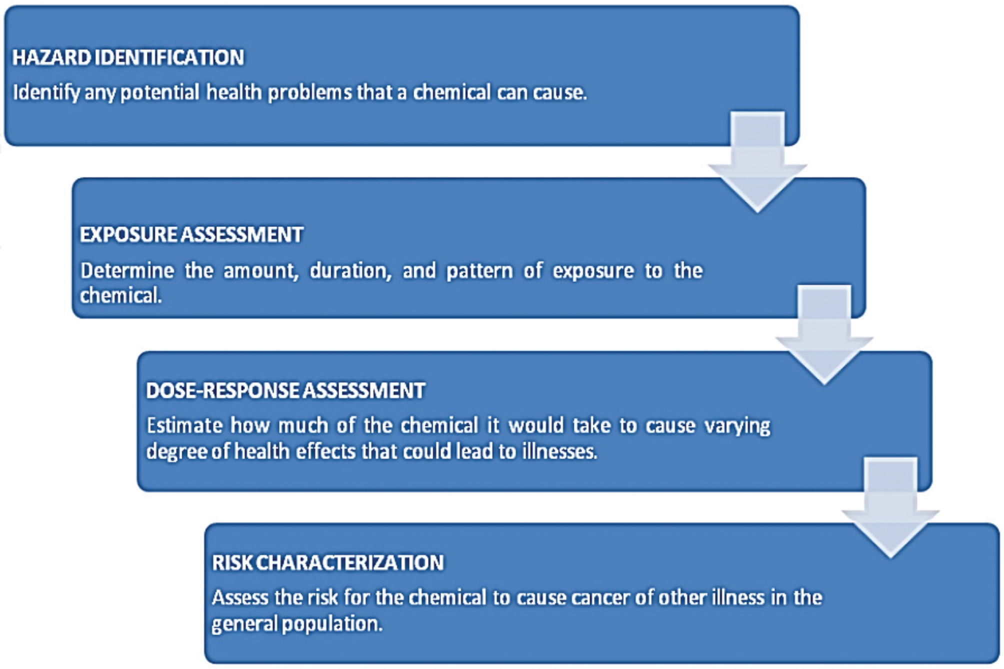

Figure 4. The four steps of risk assessment.

Similar to solid waste management, HHW waste management includes all the activities starting from generation to the final disposal and is defined as the control, generation, storage, collection, transfer and transportation, processing and disposal of solid waste consistent with the best practices with public health and environmental considerations.

Toxicity of the chemicals present in HHW need to be studied in order to provide guidance for the workforce involved directly in the waste management process. Thus, the toxicity studies can be done through dose response assessment. Dose response assessment describes the toxicity of the chemicals identified in HHW using models based on human (including clinical and epidemiologic approaches) and animal studies, and data-based reference by US EPA integrated risk information system (IRIS).

The exposure assessment identifies exposed populations and details on the type, level, duration and frequency of exposure. Typically, exposure assessment consists of a number of steps [5] which are:

i. Estimation of ambient air concentrations using air pollution monitor or other predictive air quality models, including analysis of spatial and temporal trends and distributions.

ii. Identification of any special group that may be at risk due to high exposure (due to proximity, diet, or other factors) or vulnerability (due to pre-existing disease or other factor) to the pollutants.

iii. Development of appropriate exposure assumptions, for example activity factors (e.g. time spent outdoors), location factors (mobility), uptake factors (breathing rates, absorption rates, etc.), and other factors that may affect exposure to pollutants for each group.

iv. Estimation of the number of exposed individual based on demographic and other data and validation of exposure analysis using monitoring or other means.

2.1. Empirical model of reference dose and exposure assessment of HHW

Referring to the provisions of the Occupational Safety and Health Act [6], the employer must take measures and precautions to prevent the employees from being exposed to safety and health hazards in their course of works. Thus, workers in local authorities involved in waste collection and disposal sites should be aware of the health hazards that exist so that they can be protected and reduce the risk of exposure to the HHW.

Workers and public have their right to know the requirement to inform particular group or individual on the health risk when exposed to HHW. Employers are required to assess chemicals contained in HHW or used in workplace and to make information regarding physical exposure and any associated risks of those agents to their employees.

Categories of HHW	(g/person/day)	(% by weight)
Cleaning	20.74	17
Personal	18.65	15
Automotive	15.62	13
Fertilizers	13.7	11
Paints	10.61	9
Pesticides	10.52	8
Lamps	10.4	8
Remover	9.09	7
Hobby	7.72	6
Batteries	7.36	6
Total	124.41	100

Table 3. Ranking of HHW generated based on categories at city council (% by weight).

The ranking of the generated HHW, based on categories at City Council, is shown in **Table 3**. It can be seen that the cleaning products generated about 21 g/p/day, personal products 19 g/p/day, automotive 16 g/p/day, fertilizers 14 g/p/day and the rest less than 11 g/p/day. These high utilization figures are due to income disparities, social economic and cultural life of the population of the developed and growing city. These developments were in line with the use of hazardous household products (HHP) growing every day in the market. Overall generated

HHW is 124 g/p/day. Therefore, these developments need to be addressed with the control measures in the management of solid waste and improve the management of HHW to ensure that the health of the workers is protected during the management of waste and the environment is not polluted by the HHW for the developed nation in 2020.

Moreover, it is important to highlight that, domestic wastes contain HHW and chemicals that can cause harm and affect health of human especially general workers who has direct contact with waste operations at dumping site or landfill. Therefore, an empirical model has been produced as given in Section 2.2 with different times and days of exposure at work equivalent with reference concentration (RfC) and reference dose (RfD) to serve as a guideline to employees or employers for minimization of health hazards. By knowing dose response of HHW to employees, preventive measures can be taken when carrying out these tasks.

2.2. Reference dose response of chemical contained in HHW

A dose-response relationship describes how the likelihood and severity of adverse health effects (the responses) are related to the amount and condition of exposure to an agent (the dose provided) [5]. Dose response assessments are determination of the relation between the magnitude of exposure and the probability of occurrence of the health effect in question [7–10]. It examines the relationship between the level of exposure and the resultant toxicity of the hazards. Therefore, establishment of a reference dose is an important aspect of the dose-response assessment. The RfD is the amount of the chemical, if received over a lifetime, that should not cause harmful effects. The RfD of a chemical is based on no observed adverse effect level (NOAEL) and lowest observable effect level (LOEAL) derived from a wide range of toxicity studies. The duration of exposure is important to consider. Varying durations of acute, short-term, intermediate-term and chronic are taken into account when formulating risk as a dose-response evaluation usually requires an extrapolation from the generally high doses administered to experimental animals, or exposures reported in occupational studies, to the exposures expected from human contact with the agent in the environment. There are many reasons for this. First, the possible mechanisms of all action for carcinogens are not fully understood [11, 12].

NOAEL is the highest exposure level at which no statistically or biologically significant increases are seen in the frequency or severity of adverse effect between the exposed population and its appropriate control population. In an experiment with several NOAELs, the regulatory focus is normally on the highest one, leading to the common usage of the term NOAEL as the highest experimentally determined dose without a statistically or biologically significant adverse effect. In cases where a NOAEL has not been demonstrated experimentally, the term LOAEL is used, which this is the lowest dose tested [2].

By referring to RfC and RfD for each classes of HHW as shown in **Table 4**, for class I, the mean RfC is found to be 0.05 mg/m^3 and RfD is 0.17 mg/kg/day; for class II, RfC is 0.036 mg/m^3, and RfD is 0.39 mg/kg/day; for class III, RfC is 0.0035 mg/m^3 and RfD is 0.017 mg/kg/day, for class IV, RfC is 0.002 mg/m^3, and RfD is 0004 mg/kg/day, while for class V, RfD is 0094 mg/ kg/day and for class VI, RfC is 0.02 mg/m^3 and RfD is 0.60 mg/kg/day.

Classes of HHW	Chemical contains	Reference dose		Mean	
		RfC mg/m³	RfD mg/kg/day	RfC mg/m³	RfD mg/kg/day
I	Ammonia	0.1	Na	0.05	0.17
	Acrylic acid	0.001	0.0005		
	Acetone	Na	0.9		
	Nitrobenzene	Na	0.0005		
	Potassium cyanide	Na	0.05		
	Sodium azide	Na	0.004		
II	Ammonia	0.1	Na	0.036	0.39
	Allylchloride	0.01	Na		
	Acetophenone	Na	0.1		
	Acetaldehyde	0.009	Na		
	Acetone	Na	0.9		
	Benzyl chloride	Na	0.17		
III	Acetonitrile	0.06	Na	0.0035	0.017
	Allylchloride	0.001	Na		
	Atrazine	Na	0.035		
	Warfrin	Na	0.0003		
IV	Benzene	Na	0.004	0.002	0.004
	Hydrogen sulphide	0.002	Na		
V	Furan	Na	0.001	0.0	0.094
	Toluene	Na	0.008		
	Xylenes	Na	0.2		
VI	Acetone	Na	0.9	0.02	**0.60**
	Aniline	0.001	Na		
	Acrylic acid		0.5		
	Allylchloride	0.001	Na		
	Acetonitrile	0.06	Na		
	Benzene	Na	0.004		
	Chloroform	Na	0.01		
	Ethylene glycol	Na	2		
Total				0.022 2.2E-2	0.21 2.1E-1

Table 4. Reference dose response of chemical contains in HHW.

These results indicated that the allowable HHW dose level for the RfC is 0.022 mg/m^3, while that for RfD is 0.21 mg/kg/day. Exposure exceeding the dose limits specified here will cause risks and health hazards to workers exposed to it.

Therefore, it is the responsibility of the employers to ensure that the allowable dose level of HHW is strictly followed so that the employees are not at risk of health hazards at workplace.

2.3. Toxicity factors of chemical contained in HHW

Table 5 shows the toxicity factors of chemicals contained in HHW. The level of oral exposure to benzene in HHW is allowed to be 0.000013 mg/kg/day while for Cadmium it is 0.001 mg/kg/day. These values are too small and require high prevention measures to avoid the materials contained in this HHW are accidentally swallowed.

Constituents	Oral CSF (mg/kg/day)	IUR* (μg/m^3)	Oral RfD(mg/kg/day)	Inhalation (μg/m^3)
Benzene	9.1	0.0026	0.000013	0.0455
Cadmium	NA	0.0018	0.001	0.02
Mercury	NA	NA	0.0003	1.05
Toluene	NA	NA	0.08	0.005
Xylene	NA	NA	0.2	100
Lead	0.0015	0.33	NA	NA

*IUR (Inhalation unit risk): US EPA (2005).

Table 5. Toxicity factors of chemical constituents in HHW.

Exposure by dermal	Direct skin contact
Formula for calculated average dose exposure to workers	[Fl*C*Kp*t*Sder*n]BW [0.1*10 mg/l*3.9 × 10^{-5} cm/h*0.617 h*1980 cm^2*10]/60
Workers (direct skin contact)	Direct skin contact for the exposure estimated, the terms are defined with following values for the calculation considering a worst-case scenario
Fl	Percentage weight factor of substance in product 10% (0.1) AISE
C	Product concentration in (mg/ml) 10 mg/ml AISE/HERA, 2002
Kp	Dermal penetration coefficient 3.9 ×10^{-5} cm/h Prottey,1975
t (0.5h)	Duration of exposure skin 10 min (0.167h) AISE, HERA, 2002
Sder	Surface area of exposure skin 1980 cm^2 TGD, 1996
n (30)	Product used frequency (tasks per day) 3 AISE, HERA, 2002
BW	Body weight 60 kg (TGD, 1996)
Formula for HHW (direct skin contact to workers)	[0.1 × 0.01%*3.9 × 10^{-5}*0.167*30* 1980]/60 3.8x10^{-6}/60 = 6.4 ×10^{-8} Exp sys = 6.4E-8 μg/kg/day
Average dose exposure Daily (ADD)	6.4 × 10^{-8} μg/kg/day

Table 6. Average exposure by dermal of HHW.

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2.4. Average dose exposure of HHW

To determine the level of exposure to skin where HHW is in direct skin contact, the estimations were made, as given in **Table 6**. The estimate obtained from the average daily exposure dose (ADD) is 6.4 × 10^{-8}μg/kg/day. Estimation was also made to determine the level of exposure to dust, as given in **Table 7** and the average daily exposure dose (ADD) obtained is 1.35 × 10^{-2} (0.0135) μg/kg/day. ADD obtained for exposure by inhalation for aerosol is found to be 5.6 × 10^{-3}μg/kg /day (**Table 8**).

Exposure by inhalation	**Dust**
Formula for calculated average dose exposure to workers	[Dp*P*n]/BW [0.27μg*0.1*3*]/60 kg
Workers (Exposure by inhalation)	Inhalation dust for the exposure estimated, the terms are defined with following values for the calculation considering a worst-case scenario
Dp	Dust per product/cup used 0.27μgdust per cup/product Van de Plassche et al. 1998
P	Powder detergent/product maximum level 10% 0.027 μg (AISE, 2002)
n (30)	Product used frequency (Tasks per day) 3 AISE, HERA, 2002
BW	Body Weight 60 kg (TGD, 1996)
Formula for HHW (Inhalation by dust to workers)	[0.27 μg*0.1*30]/60 0.0135 μg/kg/day Exp sys = 1.35E-2 μg/kg/day
Average dose exposure daily (ADD)	1.35 ×10^{-2} μg/kg/day

Table 7. Average exposures by inhalation (dust) of HHW.

Exposure by inhalation	**Inhalation (aerosol)**
Formula for calculated average dose exposure to workers	[Fl*C*Qinch*t*n*F7*F8]/BW [0.08*0.3 5 mg/m3*0.8 m3/h*0.17h*l]/60
Workers (exposure by inhalation)	Inhalation dust for the exposure estimated, the terms are defined **with** following values for the calculation considering a worst-case scenario
Fl	Percentage weight fraction of substance in product 8% AISE internal data, 2002
C	Product concentration in air 0.35mg/m^3 (P&G, 1974, 1978)
Q_{inh}	Ventilation rate 0.8m^3/h (TGD, 1996)
t (0.5h)	Duration of exposure skin 10 min (0.167h) AISE, HERA, 2002
n (30)	Product used frequency (tasks per day) 1 AISE, HERA, 2002
F7	Weight fraction of respirable particles 100% (1)
F8	Weight fraction absorbed or bioavailable 100% (1)
BW	Body weight 60 kg (TGD, 1996)
Formula for HHW (inhalation by dust to workers)	[0.08*0.35mg/m^{3*} × 0.8m^3/h*0.5h*30*l]/60 5.6 × 10^{-3} (0.0056) μg/kg/day Exp sys = 5.6E-3 μg/kg/day
Average dose exposure daily (ADD)	5.6 × 10^{-3} μg/kg/day

Table 8. Average exposures by inhalation (aerosol) of HHW.

From these results, it can be concluded that if the rate of exposure exceeds the given levels, it can cause health hazards to workers either through the skin or through ingested or inhaled substances containing dangerous materials from HHW. Therefore, it is essential for the employer to know the minimum level of exposure and educate the employees. However, the minimum dose is very small and it difficult to prevent the workers from being exposed to this level. Hence, protection at work is very important, which can be done by providing PPEs to employees, such as gloves, uniforms and so on. What is more important is the knowledge and awareness among employees on the hazards that exist around them when performing their tasks.

2.5. Hazard risk and cancer risk index of HHW

To make estimation of hazard and cancer risk index, it is important and necessary to obtain the value of ADD exposure and the RFC or RfD for the estimations as shown in **Tables 9** and **10**.

Hazard risk	**Hazard index = ADD/RfC or RfD**
ADD (exposure)	Average daily dose exposure
Calculated cancer risk	
Exposure by dermal	**Direct skin contact**
Average dose exposure daily (ADD)	6.4×10^{-8}μg/kg/day
Exposure by inhalation	**Dust**
Average dose exposure daily (ADD)	1.35×10^{-2} μg/kg/day
Exposure by inhalation	**Aerosol**
Average dose exposure daily (ADD)	5.6×10^{-3} μg/kg/day

Table 9. Value of ADD exposure for hazard risk.

Hazard risk (cancer)	**Hazard risk = LADD * CSF**
ADD (exposure)	Average daily dose exposure
Calculated hazard index (Cancei')	
Exposure by dermal	**Direct skin contact**
Average dose exposure daily (ADD)	6.4×10^{-8} μg/kg/day
Exposure by inhalation	**Dust**
Average dose exposure daily (ADD)	1.35×10^{-2} μg/kg/day
Exposure by inhalation	**Aerosol**
Average dose exposure daily (ADD)	5.6×10^{-3}μg/kg/day

Note: NOEAL*CSF = RfD or RfC (CSF = RfD of RfC/NOEAL).

Table 10. Value of AA exposure for cancer risk.

From these estimates, hazard risk index for HHW has been tabulated in **Table 11** for some of the materials contained in the HHW that affect the health of both exposed workers and the public. The total hazard risk index for HHW was found to be more than 1.

Constituents	Average dose exposure daily (ADD)	IUR (μg/m³)	Oral RfD (mg/kg/day)	Inhalation (μg/m³)	Hazard risk
Benzene	6.4×10^{-8} μg/kg/day **dermal exposure**	2.6E-03	1.3E-05	4.55E-02	**4.9E-03**
	5.6×10^{-3}μg/kg/day **Inhalation**	2.6E-03	1.3E-05	4.55E-02	**0.12 1.2E-01**
Cadmium	6.4×10^{-8} μg/kg/day **dermal exposure**	1.8E-03	1E-03	2E-02	**3.2E-5**
	5.6×10^{-3}μg/kg/day **Inhalation**	1.8E-03	1E-03	2E-02	**0.28 2.8E-01**
Mercury	6.4×10^{-8} μg/kg/day **Dermal exposure**	NA	3E-04	1.05	**2.1E-04**
	5.6×10^{-3} μg/kg/day **Inhalation**	NA	3E-04	1.05	**5.3E-03**
Toluene	6.4×10^{-8} μg/kg/day **dermal exposure**	NA	8E-02	5E+03	**8E-06**
	5.6×10^{-3} μg/kg/day **Inhalation**	NA	8E-02	5E+03	**1.12**
Xylene	6.4×10^{-3} μg/kg/day **Dermal exposure**	NA	0.2	100	**3.2E-07**
	5.6×10^{-3} μg/kg/day **Inhalation**	NA	0.2	100	**5.6E-05**
TOTAL					1.93

Table 11. Hazard risk index of HHW.

Constituents	Average dose exposure daily (ADD)	Oral CSF (mg/kg/day)	Hazard index
Benzene	6.4×10^{-8} μg/kg/day **Dermal**	9.1	**5.8E-07**
	1.35×10^{-2} μg/kg/day **Inhalation dust**	9.1	**0.12**
	5.6×10^{-3}μg/kg/day **Inhalation aerosol**	9.1	**0.05**
Lead	6.4×10^{-8}μg/kg/day **Dermal**	1.5E+03	**9.6E-11**
	1.35×10^{-2} μg/kg/day **Inhalation dust**	1.5E+03	**2.0E-02**
	5.6 $\times 10^{-3}$ μg/kg/day **Inhalation aerosol**	1.5E+03	**8.4E-06**

Table 12. Estimation of cancer risk of HHW.

The estimations for cancer index are shown in **Table 12**. For benzene, the cancer index was found to be 5.8×10^{-7} for exposure through the skin, 0.12 for dust inhalation exposure which is under low risk and 0.05 for aerosol inhalation exposure under medium risk, as well as for lead with hazard index of 9.6×10^{-11} for exposure through skin, 2.0×10^{-2} for dust inhalation and 8.4×10^{-6} for aerosol inhalation. The total cancer index was less than the value of 1. Risk for dermal are acceptable to workers, however, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded. Medium risk requires a planned approach to control the hazard and applied temporary measures, if required.

2.6. Summary of short-term (1-hour) references concentration (RfC)

Table 13 shows the materials contained in the HHW that can pose hazards in terms of employee safety. Exposure to these materials should be limited or avoided to minimize the risk that occurs during the tasks, especially for garbage collecting employees and workers at the landfill. Exposure that occurs even in the short term will cause health hazards and adverse effects on them.

Chemical	Exposure limit (1 hour) μg/m³	References	Exposure limit (24hour) μg/m³	References
Acetamide (solvent)	2.0×10^{-5} skin irritation	CalEPA (1999)	7.0×10^{-2}	CalEPA (1999)
Acetophenone (soaps, detergent, lotion and perfumes)	0.1 mg/kg/day	US EPA (1999)	4.1 mg/m³	US EPA (1999)
Allylchloride (varnish, perfume and insecticides)	3 mg/m³	US EPA (1999)	3.6mg/m³	US EPA (1999)
Calcium cyanamide (fertilizer, herbicide, fungicide and pesticides)	3 mg/m³	US EPA (1999)	3.6mg/m³	US EPA (1999)
Cadmium	1.36E-02 μg/m³	US EPA (2003)	3.00E+01 μg/m³	US EPA (2003)
Hg(Elemental Mercury), (bulb, batteries)	1.8	OEHHA (2001)	2.0	OMEE (1999)
Pb (lead oxide (paint))	1.5	AEP (2000)	2.0	OMEE (1999)

Table 13. Summary of short-term (1-hour) references concentration (RfC).

For materials found in solvents such as acetamide, exposure limit (1 hour) is 2.0×10^{-5} mg/m³ while for materials like allylchloride (varnish, perfume and insecticides); calcium cyanamide (fertilizer, herbicide, fungicide and pesticides), the permissible dose is 3 mg/m³. Exposure data should be communicated to employees and thus, safety and protection equipment and personal protective equipment can be provided by the employer and used solely by employees to reduce workplace accidents and health hazards.

For HHW, short-term exposure in an hour shall not exceed 2.0×10^{-5} mg/m³ (min exposure) to 3 mg/m³ (max exposure).

2.7. Summary of long-term (chronic) exposure limit for human receptors

Based on **Table 14**, the exposure limit for long-term exposure of the solvent through inhalation is 2.0×10^{-5} mg/m³ for RfC. While for soaps, detergent, lotion and perfumes RfD is

0.1 mg/kg/day. While fertilizers, herbicides, fungicides and pesticides are 0.5 mg/m^3 (RfC); varnish, perfume and insecticides are 0.001 mg/m^3 (RfC); the bulbs and batteries are 0.3 mg/m^3 (RfC); and for Pb (lead oxide (paint)) is 1.85 mg/kg/day (RfD), accordingly.

Chemical	Route	Units	Exposure limit		References
			Type	Value	
Acetamide (solvent)	Inhalation (Possible human carcinogen)	μg/m^3	RfC	2.0×10^{-5}	CalEPA (1999)
Acetophenone (soaps, detergent, lotion and perfumes)	Oral	mg/kg/day	RfD	0.1	US EPA,IRIS (1999)
Allylchloride (varnish, perfume and insecticides)	Inhalation	mg/m^3	RfC	0.001	US EPA,IRIS (1999)
Calcium cyanamide (fertilizer, herbicide, fungicide and pesticides)	Inhalation	mg/m^3	RfC	0.5	ACGIH (1999)
Hg (elemental mercury) (bulbs, batteries)	Inhalation	μg/m^3	RfC	0.3	US EPA, IRIS (2001)
Allylchloride(varnish, perfume and insecticides)	Inhalation	mg/m^3	RfC	0.001	US EPA (1999)
Pb(lead oxide (paint))	Oral inhalation	μg/kg bw/day	RfD	1.85	OMME (1999)

Table 14. Summary of long-term (chronic) exposure limit for human receptors.

Above values showed that the solvent material is highly sensitive and hazardous because the dose limit allowed has the smallest value compared to other hazardous materials, in which it can cause risk to health, followed by the bulbs, batteries and paint. Therefore, these materials should be given priority for a more orderly management in each local authority in Malaysia.

3. Conclusion

The increasing scale of economic activity, urbanization, industrialization, rising standard of living and population growth has led to a sharp increase in the quantity of the generated waste. It can be said that almost every household is producing hazardous wastes as HHW is a part of domestic waste. Moreover, many fail to realize that the ingredients of some of the products that they use in their daily routine in house contain hazardous substances. Generally, out of the total solid waste generated, 64.7% ended up in the garbage bin, 27% are disposed down the drain and 2.4% are burnt while remaining 20.2% are disposed of by other means such as burying [13]. Improper use, storage and disposal of hazardous household products can harm humans and contaminate the environment [14]. Therefore, extra care must be taken when disposing used hazardous products as it can harm sanitation workers if thrown in with regular trash. Exposure to chemicals contained in some of the waste products in our home can cause health problems where the effects can range from minor problems such as watery eyes and irritation to skin to more serious problems such as poisoning, burns or may even lead to cancer. The exposures can be through ingestion by swallowing the hazardous substances if it is accidentally transferred onto food or cigarettes, through inhalation by breathing dust or fumes or through contact with skin or eye.

Referring to the flow chart in **Figure 5**, the work process undertaken would contribute to the potential hazards of exposure to garbage collection workers and in landfills if HHW existed in the operation during the handling. HHW disposal directly into the public dustbin and no separation at source caused nearly 80% of HHW disposed in the trash and then to the landfill. This is repeated when each truck at least run the collection for two to three trips a day. This situation will increase the potential of chemical exposure to the employees.

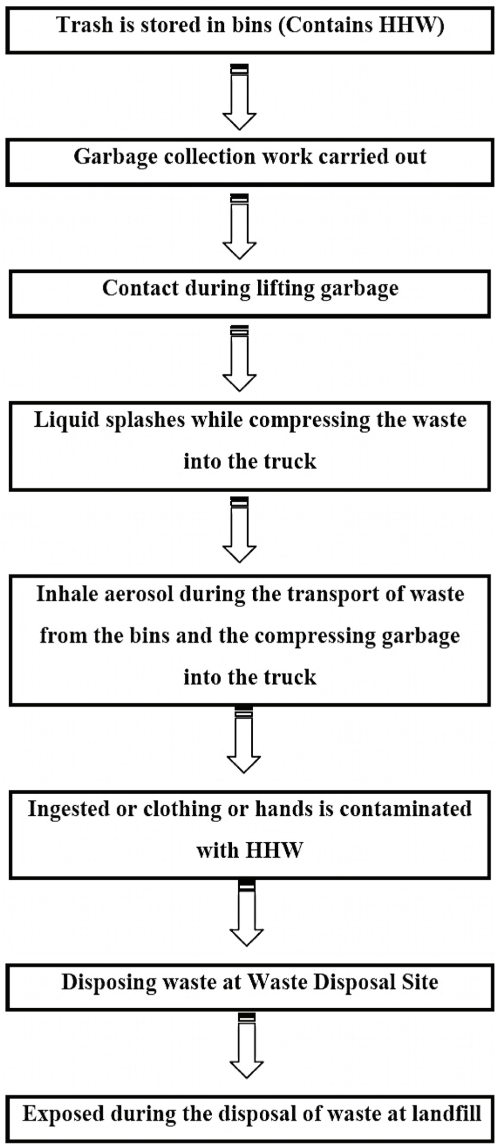

Figure 5. Work process flow of sanitary workers and disposal site.

The workers who do not practise health care and has no knowledge of the health hazards are more vulnerable and coupled with their lack of safety clothing such as gloves and safety helmets can hamper their safety and health.

In this case, employers must provide adequate training to staff regarding exposure to chemical hazards, toxic residues that affect the health and potentially cause cancer. The employers should provide adequate and appropriate personal protection equipment (PPE) to avoid direct exposure to workers during the work carried out. Preventive controls should also be done on a few trucks to transport the waste to prevent leakage of waste water from the garbage during operation and should provide covered and comfortable lorries for the workers.

Cases of accident and health can be prevented from occurring and recurring by adopting the concept of ergonomic principles in the management of solid waste, especially hazardous waste at home and steps like the separation at source is the best way to reduce exposure of workers to the HHW and prevent pollution in all local authorities in Malaysia.

4. Recommendation

The result from this study showed that HHW can affect humans. Hazardous household products most likely to contribute significantly to the input of hazardous substances were then identified as being the most problematic for the current waste management and disposal routes, namely paints, pesticides, arsenic treated wood and fluorescent lamps. Therefore the wastes must be properly managed. Separation of HHW at an early stage at home, such as separating HHW in separate plastic bags to reduce and minimize the waste dumping directly into public trash bin and eventually to the landfill must be practiced by all local authorities in Malaysia. A study on reviewing compliance with the provisions of OSHA, 1994 is necessary to ensure the implementation of the welfare, safety and health of employees in local authorities in Malaysia. Employees need to know the level of risk that exists in the workplace so that prevention and control measures can be carried out. Research also needs to be done for compliance with the labelling of hazardous products used at home in terms of their content of hazardous materials to serve as guidance and revisions for the consumers and facilitate local authorities in implementing the HHW collection program. The local authorities are proposed to play a more active role in the safety and security of workers with preventive measures; either by administrative or engineering and the usage of personal protective equipment among workers in local authorities should be strictly enforced, in an effort to improve and create a comfortable and safe workplace.

Therefore, the results of this study and recommendation can be used to increase and improve the management of solid waste in order to minimize health hazards and safety risks among workers, and surveillance. This chapter can be a guideline for proper management especially in HHW at local authorities in Malaysia.

Proper management of HHW will enhance the comfort of living and solve the problem of pollution of the earth and water resources that affect sources for drinking, and also overcome the air pollution due to open and uncontrolled burning. The contamination of groundwater due to improper disposal of HHW will continue if no concrete steps are taken by local authorities as well as the Ministry of Housing and Local Government to ensure that disposal sites are secure and proper management of waste is being practiced. Apart from that, human health risk assessment of HHW is important in determining the safety and health of employees and the public security and reduces the danger of existing risks. The contribution from proper management of HHW will make the management of solid waste more robust and ensure the comfort and health improved in line with community aspirations towards a developed nation by 2020.

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