Potential Pollutants Released From A Recycling Plant For Lead-acid Batteries And Their Health Impact In Malaysia: Result Of Air Modeling

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ABSTRACT: Battery recycling activity has become an important industry in many developing and developed countries. Using an air dispersion modeling results of one recycling plant, the study aims to determine the contents and their concentration in two simulated conditions, controlled and uncontrolled scenarios. For controlled modeling, all pollutants were within the permissible limits. However, in uncontrolled situation, Pb was found to be the major pollutants followed by As, Cd, PM_{10} and SO_2. In addition, the lifetime cancer risk was not exceeded the limit even though on uncontrolled emission simulation.

Keywords: Lead-acid battery, recycling plant, air modeling, As, Cd, PM_{10}, SO_2

INTRODUCTION

Recycling industries have become one of the major activities in Malaysia. It was due to the abundance present of wastes in the country. It comprises of various types of wastes, including lead-acid batteries that important to starting up any engines, either in small or big vehicles. Nevertheless, this type of waste management usually believed to contaminate the environment (Uzu et al., 2009; Paoleillo et al., 2007). In addition, it may also produce unnecessary health impacts (Dyosi 2008; de Freitas *et al.*, 2007). Not much information was available in this type of environmental concern, especially in Malaysia.

Using an air dispersion modeling results for controlled and uncontrolled emission of one battery recycling plant in the country, the study aims to identify the possible pollutants emitted from the stack and to determine the health risk based on their concentrations in both conditions.

METHODS AND MATERIAL

This is a comparison study between controlled and uncontrolled emission based on the air dispersion modeling done for a new proposed lead-acid battery recycling plant. The controlled emission was based on fully functioning of air filtration. The uncontrolled emission was a condition when there is a total failure of the air filtration system. The plant is going to produce about 48 tonnes of lead ingot per day. The prediction was based on EPA Industrial Source Complex (ISC3) Dispersion Models (1995) with consideration of several meteorological factors like surface wind speed, ambient temperature, and atmospheric stability. The Kuala Lumpur International Airport (KLIA) meteorological data for the year 2005 and 2006 were used. The health impact was divided into two categories, carcinogens and non-carcinogens substances. For non-carcinogens, the hazard indexes (HI) were calculated, meanwhile for carcinogen substances their lifetime cancer risk (LCR) were computed according to the USEPA (2009) guideline. For low health risks, HI should be less than one, and LCR should be less than 10^{-4} as being accepted worldwide.

RESULTS

There was a mixed of pollutants, non-carcinogen and carcinogen substances that potentially been released from a battery recycling facility (Table 1). Lead (Pb), particulate matter (PM_{10}), sulphur dioxides (SO_2), nitrogen oxides (NO_X) and zinc (Zn) were non-carcinogens that identified for this type of industry. Arsenic and cadmium are two carcinogens that potentially released during the recycling process.

In the controlled emission scenario, the study found that all pollutants were released within the acceptable limits. The main pollutants based on their proportion with the recommended limit were Pb (28%), As (21%) and PM_{10} (12%). And followed by SO_2, Cd, NO_x and Zn, 9.5%, 2.2%, 0.6%, and 0.02% respectively.

For the uncontrolled scenario, the modelling showed that metals were the majority make up of the pollutants. The highest proportion obtained was on Pb with 3800 times above the limit. Followed by As (2325%) and Cd (2222%). Others were PM_{10} (593%) and SO_2 (209%).

Substances like NOx and Zn increased but at a very low percentage, 0.6% and 0.4% respectively.

For the hazard index (HI), in the controlled emission situation, the indexes were less than one (Table 2). This signified that no excess of health risk to the surrounding residential areas. On the other hand, for the uncontrolled emission, Pb produced a HI value of 38.00 and followed by PM_{10} (5.93) and SO_2 (2.09). At this worst case scenario exposure, communities may experience shortness of breath, cough with phlegm, headache, dizziness, and delirious.

Both carcinogens showed the LCR of less than 10^{-4} for both controlled and uncontrolled conditions (Table 3). It will be no excess of cancer cases among the exposed communities for controlled and uncontrolled scenarios. This likewise implies that any recycling lead-acid battery industries with the total output of 48 metric tons per day will not pose any cancer risk to human at any circumstance. However, this was only comply if the failure was mitigated and stopped immediately or within few minutes.

DISCUSSION

The study found that the particular lead-acid battery recycling facility emitted certain amount of both non-carcinogens and carcinogens. PM10, Pb, Cd, As and Zn were the correct potential metal pollutants as mentioned by other studies (Pogrzeba *et al.*, 2015).

For the controlled condition, both health risk indicators (HI and LCR) were within the healthy range. Conversely, for uncontrolled scenario, non-carcinogen like Pb was found very high. The condition is supported by other studies that related high Pb emission with battery recycling activities (Akintunde *et al.*, 2015; Cao *et al.*, 2015; Kaushal *et al.*, 2013; Revich 1994; Sanders *et al.*, 2014).

The carcinogen like Cd was also found higher, among other similar industry in other countries (Akintunde *et al.*, 2015; Hellstrom *et al.*, 2007; Kaushal *et al.*, 2013; Taioli *et al.*, 1998). As was found to be among the major metals in the emission of battery recycling plant (Landrigan *et al.*, 1982). But, another study found that As is not an important pollutant for this kind of industry since its level was detected low (Jones 1984). This might due to the differences in battery contents. However, for both Cd and As, their LCR value were within the acceptable range.

CONCLUSION

The lead-acid battery recycling industry can be considered as safe for both controlled and uncontrolled emission scenarios will not pose any excess risk of human cancer. However, it might produce certain respiratory and neurological problems due to excessive Pb and PM_{10} in ambient air after few hours of exposure in uncontrolled emission condition.

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Table 1. Potential pollutants from a battery recycling plant during controlled and uncontrolled emission simulation

Pollutants	Ground Level Concentrations (μg/m³)		Recommended Malaysian Air Quality Limit (μg/m³)
	Controlled Emission	Uncontrolled Emission	
Lead (Pb)	0.42 (3-month)	57 (3-month)	1.5 (3 month)
Particulate matter 10μm (PM_{10})	18 (24-hr)	890 (24-hr)	150 (24 hr)
Sulphur dioxide (SO_2)	10 (24-hr)	220 (24-hr)	105 (24 hr)
Nitrogen oxides (NO_x)	2 (1 hr)	2 (1 hr)	320 (1 hr)
Zinc (Zn)	0.17 (1 hr)	4 (1 hr)	[a]1000
Arsenic (As)	0.0009 (1 hr)	0.1 (1 hr)	[b]4.3×10^{-3}
Cadmium (Cd)	0.00004 (1 hr)	0.04 (1 hr)	[c]1.8×10^{-3}

[a] Cal/OSHA
[b] Inhalation unit risk (IRIS 2007)
[c] Inhalation unit risk (IRIS 2008)

Table 2. Hazard index of pollutants for controlled and uncontrolled scenario

Pollutants	Hazard Index	
	Controlled Emission	Uncontrolled Emission
Lead (Pb)	0.28	38
Particulate matter 10μm (PM_{10})	0.12	5.93
Sulphur dioxide (SO_2)	0.09	2.09
Nitrogen oxides (NO_x)	0.006	0.006
Zinc (Zn)	0.0002	0.004

Table 3. Lifetime cancer risk for controlled and uncontrolled scenario

Pollutants	Lifetime cancer risk	
	Controlled Emission	Uncontrolled Emission
Arsenic (As)	3.9×10^{-6}	4.3×10^{-4}
Cadmium (Cd)	7.2×10^{-8}	7.2×10^{-5}

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