

# COMPOSITION AND SOURCE DETERMINATION OF HEAVY METALS (HM) IN PARTICLES IN SELECTED PRIMARY SCHOOLS IN PAHANG

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## ARTICLE HISTORY

## ABSTRACT

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*Composition and concentrations of air pollutants in particles have been shown to have a correlation with differences in mortality counts in different parts of the world. These particles are also able to deteriorate health especially the respiratory system and may lead to mortality. Toxic metals in these particles are associated with respiratory diseases and lung cancer in school children. The effects of HM toxicity are more severe to the schoolchildren as their immune system is not fully developed yet. Thus, this study aims to analyse the HM composition in particles collected inside the classroom during the school days (occupied) and the weekends (vacant), and to determine pattern of HM concentration from particles based on different location backgrounds (residential, industrial and rural). In order to achieve these objectives, the following samplings were done. The particles were simultaneously collected using GilAir-5 air pump sampler (Sensidyne, USA) inside and outside the classrooms. The sampling was done for a minimum of 8 hours. The exposed Mixed Cellulose Ester (MCE) membrane filters (0.8 µm, 37 mm) were digested following the International Standard Test Method (ASTM) for Determination of Elements in Airborne Particulate Matter by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The compositions of metals in particles were determined using ICP-MS NexION™ 300× (PerkinElmer, USA). From the result obtained, concentrations of Al, Zn and Pb inside the classrooms were higher compared to the other elements like Cr, Mg, Cd and Cu. Meanwhile, HM concentration detected in the industrial site was higher compared to the residential and rural sites.*

**Keywords:** heavy metals; particles; ICP-MS; school children

## 1. INTRODUCTION

Exposure to ambient air pollutants may lead to pulmonary diseases (Liu et al., 2009). Other than pulmonary diseases, studies have found that the complex mixture of air pollutants like various gases including hydrocarbon and HM in air can also elevate the respiratory diseases (Mathew, Goyal, Taneja, & Arora, 2014). This is because toxic HM in air are able to damage the cells in the body. This damage is due to oxidative stress from the toxic HM (Morton Lippmann, 2000). However, some metals are naturally exist in the body and are vital to

health. For example, Fe prevents anaemia and Zn is a cofactor in more than 100 enzymes reactions in the body. These metals are beneficial to the body in trace amount, not in high concentration which these metals become toxic. In contrast with HM (trace metals which have density of at least five times of water) are difficult to metabolize. HM has a relatively high density and is toxic or poisonous even at low concentration (Lenntech Water Treatment and Air Purification, 2004). This HM can accumulate in the cells and tissue. Due to this bioaccumulation, cellular function can be interrupted and DNA will be damaged. It has been shown that humans' health will be affected if HM continue bioaccumulated in the body (Hewitt & Jackson, 2008). For children the effects of HM are worse than adults because they have higher haemoglobin sensitivity to HM than adults (Chisolm, O'Hara, & United States. Office for Maternal and Child Health, 1982).

Nowadays, children spend 6 to 8 hours at the school especially in classrooms throughout the year except during the school holidays. As recent studies suggest the presence of HM trace on airborne pollutants found both indoors and outdoors (Latif, Baharudin, Nor, & Mokhtar, 2011; Yang Razali, 2015) of the school classrooms. This is alarming because children are considered as one of the most sensitive population subgroups. This is because they have proportionally a higher dose of respirable suspended particulate matter (RSP) could be received into their lungs compared to adults. Due to this reason, they have greater fractional deposition with each breath and/or larger minute ventilation relative to lung size (Zeman, 1998). Subsequently, children's rate of inhalation of toxins such as HM also increased (Stosic et al., 2006).

Early studies done by Diapouli, Chaloulakou, and Koutrakis (2013) found that the pollutants inside classrooms were mainly originated from an infiltration of outdoor sources. The examples outdoor sources are such as soil dust, traffic and industrial emissions. Furthermore, a lot of studies have concluded that the level of air pollutants in classrooms is directly proportional to the levels of air pollutants outside school buildings (Mohamad, Latif, & Khan, 2016). Therefore, this study aims to analyse the HM composition in the particles collected inside the classroom and to determine the effect of location to the HM concentration in order to see either the location affect the HM concentration or not.

## **2. EXPERIMENTAL**

### ***2.1 Sampling Sites Description***

Three primary schools' classrooms were selected for this study. Each primary school has different background characteristic such as residential, industrial and rural area. This study was done indoor and outdoor the classrooms. It is worth taking note that all selected schools are public school. Thus the classrooms' design is likely the same. The classrooms are naturally ventilated with similar numbers of doors and windows. Besides, numbers of schoolchildren in each classroom are more than 30 but not exceeding 40 pupils as per regulated by Malaysian Ministry of Education.

Table 1: The Description of the Traffic Nearby the Selected Primary Schools

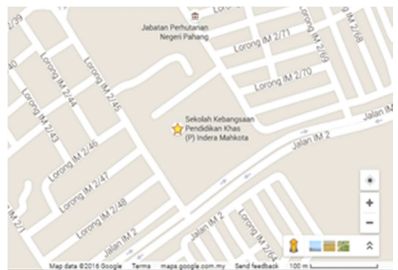
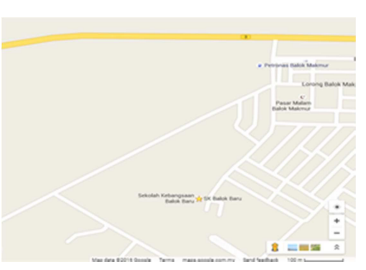
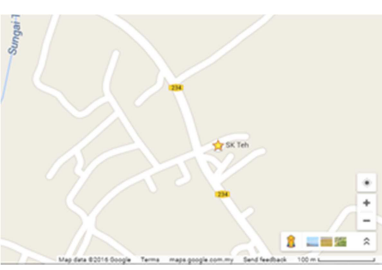
Sampling sites	Distance from main road	*Numbers of vehicle during the peak hour	*Numbers of vehicle for the 16hrs traffic	Land uses
SKIM	600m	2997 (5-6pm)	36899	Residential
SKBB	600m	6084 (5-6pm)	65582	Industrial
SKT	230m	1202 (9-10am)	14690	Rural

Table 2: Traffic Composition (%) at Sampling Areas\*

Sampling sites	Cars & taxi	Vans & utilities	Medium lorries	Heavy Lorries	Buses	Motorcycle
SKIM	74	8.8	2	0.4	0.7	14.1
SKBB	53.9	17.4	13.1	6.5	0.3	8.7
SKT	43.6	16.1	13.6	5	0.8	20.8

\*The traffic load volume was obtained from RTVM 2014, Bahagian Perancang Jalan, Kementerian Kerja Raya Malaysia.

Table 3: The Map of the Sampling Sites Shows the Nearby Road

		
SKIM	SKBB	SKT

## 2.2 Sampling Particles

Sampling was carried out on 8h basis, starting from the students entered the classroom and extended after the schoolchildren finished their school. A total of 12 replicates were obtained during the sampling (4 replicates each sample site). The samples were collected in indoor and outdoor of the selected classrooms. The sampling was done from May to August (during the south west (SW) monsoon), as this study focus only on HM levels during this monsoon. Apart from the sampling during SW monsoon, the sampling was also done during north east (NE) monsoon. Even though the sampling was done for 6 months' period for both monsoons, this paper focuses only for one season. Moreover if the sampling needs to be extended, more advance and durable device is needed to be used rather than personal air sampler (like the one used in this study).

The particles were collected on mixed cellulose ester (MCE) (0.8  $\mu$ m, 37 mm) filters using personal air sampling pumps GilAir-5 (Sensidyne, USA) at a flow rate of 4 l/min. This flow rate is according to National Institute of Occupational Safety and Health (NIOSH) Manual of Analytical Methods (NMAM) 7300. Prior from sampling, MCE filters were put in the

desiccator for 24 hours to make sure the filter is dry. The filters were weight before they were placed in filters' cassette. After sampling, the filters were weight one more time.

In this study, other IAQ parameters were also been determined. Discussion on IAQ parameters like PM10, CO<sub>2</sub>, CO and temperature were described in (Hazrin et al., 2016).

### **2.3 HM Analysis Using (ICP-MS)**

The MCE filters exposed to the environment were digested according to the guidelines provided by the International Standard Test Method (ASTM) for Determination of Elements in Airborne Particulate Matter by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Before the HM analysis, MCE filters were digested using microwave digester with model Preekem WX6000. After that the composition of the HM was analysed using the ICP-MS NexION™ 300X (PerkinElmer, USA).

## **3. RESULTS AND DISCUSSION**

### **3.1 HM Concentrations Between Locations**

According to the present study, the distribution of HM concentrations outdoor and indoor the classrooms was varied between locations. This is mainly because the surrounding activities proximate the school area. Below are the HM concentrations outdoor and indoor according to the HM concentrations abundance

SKIM: Al > Zn > Mg > Pb > Cr > Cu > Cd > Ag > As

SKBB: Al > Zn > Mg > Cu > Pb > Cr > Cd > Ag > As

SKT: Al > Zn > Cr > Mg > Pb > Ag > Cu > Cd > As

The HM concentrations pattern shows almost the same trend where Al, Zn, Mg and Pb are the highest. This trend was found might be due to the vehicular activities in nearby areas. The finding is consistent with findings of past studies by Basha et al. (2010). In his study he found that automobile emissions, leakage of fuels and lubricating oils, car abrasion, chrome plating of vehicle parts and traffic flows are the major sources of the higher metal contents in the surrounding areas.

Referring to the Figure 1, concentrations of Al were the highest compared to the other HM. The Al concentration in SKT was the highest 901.40ppb in indoor and 6.10ppb for outdoor. The high concentration of Al indoor might be due to the art materials inside the classroom and also the windows' grill made from Al. It appeared that in the classroom, the art project using cans and foil were placed at the back of the classroom. In SKIM (residential area) the concentration of Al is higher in indoor and outdoor compared to SKBB (industrial area). SKIM located nearer to the main road compared to SKBB. Perhaps this is might be due to the distance between the main road and the school. For SKBB, this school is located near the main road for bauxite transportation to the Kuantan Port. Al found in particles collected inside the schools might be originated from this activity since bauxite has variable composition especially aluminium oxides and aluminium hydroxides.

It has been suggested by Chithra and Nagendra (2012) the concentration of Al might be raised from geological material such as soil and road dust. Thus this factor explains the high concentration of Al. Similarly with Zn and Pb, SKT recorded highest concentration of these metals. This finding was in agreement with previous study by Vosniakos et al. (2011) that found that road transportation was the main source of Zn and Pb. While Zn was originated from tires and Pb was from petrol. From this study, the outdoor concentrations of Pb of classrooms in SKIM and SKBB show high value of Pb compared to the indoor of classrooms. This is might be due to incomplete combustion of fuel. When the schools are located near to the main roads which have high density of traffic, then it is expected that the Pb concentration is elevated (Latif et al., 2011). Therefore, these findings suggest that different backgrounds and activities between schools were also factors which influenced the amount of HM in the classrooms.

Moreover, the concentration of Mg for indoor classrooms in SKBB and SKT are lower than outdoor classrooms. Studies suggested that the source of Mg is from resuspended dust from surrounding such as factories nearby the school (Basha et al., 2010).

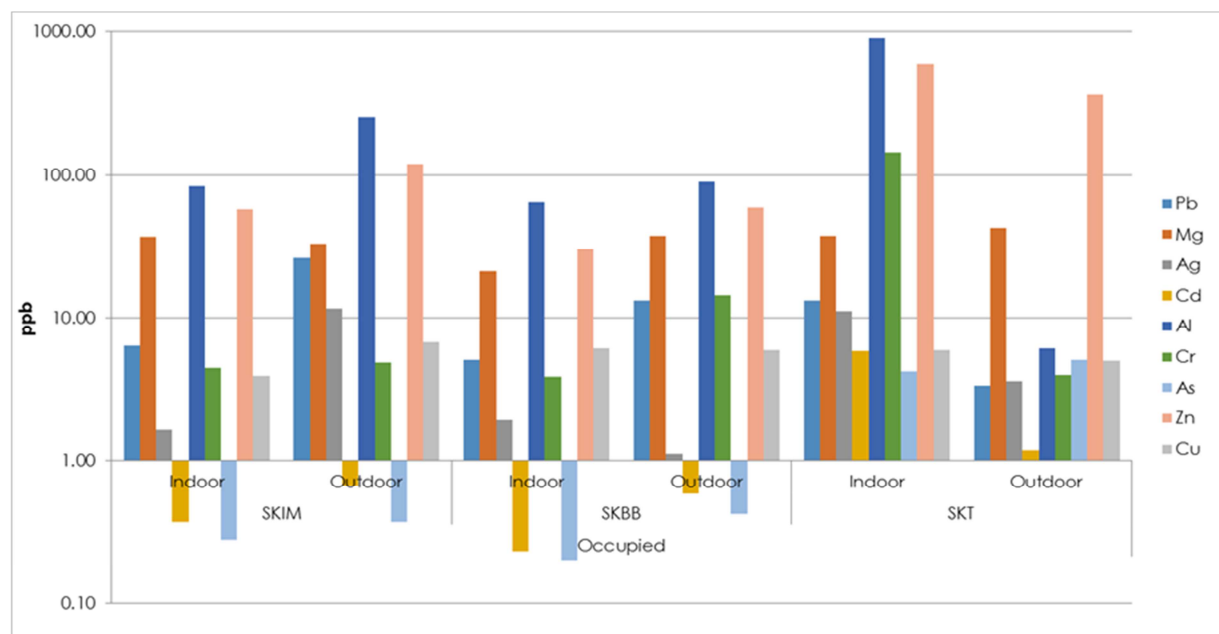


Figure 1: The Concentration of HM in All Indoor and Outdoor Sites During Occupied Period.

### 3.2 HM Concentration Inside the Classrooms

There are many factors influencing the concentration of HM inside the classrooms. As highlighted by (Stosic et al., 2006), air pollutants inside the building can be categorized into four primary classes. The air pollutants can be originated from combustion products; semi-volatile and volatile organic compounds released by building materials, furniture, and chemical products; soil gas pollutants; and pollutants generated by biological processes. In this study, the HM is mainly from the outdoor sources such as vehicular emissions.

In this study, Al was found indoor in high concentration. According to Darus, Nasir, Sumari, Ismail, and Omar (2012), Al was produced by friction. Then Al was transported by wind blow that associated with street dust. Thus the soil or street dusts were the main contributor in of concentration of Al inside the classrooms.

From Table 1 and Table 2, it can be seen that even though SKIM and SKBB are having the same distance from main road (600m), but the traffic composition are different. This could explain the traffic fleet influences to some of the HM elements found in the samples. Specific HM such as Pb, Al, Zn and Mg might normally derived from vehicle combustion, plate tyre breaks and soil dust resuspension due to higher number of car fleet within high contaminated area such SKBB. This is also proven in Table 2, to show the higher number of heavy lorries nearby SKBB (6.5% traffic composition) followed by medium lorries and high load vehicles such vans. Nevertheless, besides outdoor elements - there's no doubt to say indoor factors and building occupancy is the biggest possibility factor to contribute such elemental exposure.

Apart from the distance between the school and the main road, HM concentration found in indoor classroom also influenced by the movement of students going in and out of the classroom (Darus et al., 2012). Also, the type of ventilation affected the concentration of HM in the classroom. Open windows and doors for example, are the possible pathways of HM entering the classroom (Yang, Sohn, Kim, Son, & Park, 2009). In Malaysian public schools, all the windows and doors are open during the school days. A study by Sofian and Ismail (2011) suggested that the open windows are the air pollutants pathway to the classroom. He found that highest concentrations of particles collected indoor were near the classroom window where the outdoor air flows in.

### ***3.3 Effects of HM Towards Children***

Previous studies found that by inhalation of airborne pollutants may cause asthma and acute respiratory infection (ARI) among children (Carrer, Maroni, Alcini, & Cavallo, 2001). Considering this factor, it is worth to provide the children good air quality. Furthermore, in comparison to adult, children have higher ventilatory rates per minute (400mL/min/kg in newborns compared to 150mL/min/kg in adults) therefore children inhale more toxins and have higher risk. Plus with the higher ventilator rate, active children inhale more than inactive children (for example children who are calm and sleeping) (Stosic et al., 2006). The evidence suggested that due to this breathing behaviour, respirable particles and fibres are easily exposed to the children's pulmonary system if not filtered in the upper airway (Fenske et al., 1990). HM in particles enter the children body either through inhalation or ingestion. Once HM entered, the effects of bioaccumulation of HM in the body can be fatal. Below are the examples of effects of HM towards human's body.

Cd and Pb are known to be biotoxic even at very low concentration. These metals can block essential functional groups, displace essential metals ions and modify the active confirmation of biological molecules. As a result, metabolic and enzyme activities in the body will be inhibited (Tamrakar & Shakya, 2011). On top of that, a small quantity of Pb may affect IQ and behaviour, resulting in poor school performance of the children (Lanphear et al., 2005). Like Cd and Pb, Cr also is nonessential metals. Previous study reported that high concentrations of Cr may cause respiratory problems and a lower ability to fight disease.

Other than the said illnesses and diseases, Cr also may cause birth defects, sterility and cancer (Honeyman & Santschi, 1988).

#### 4. CONCLUSION

Even though HM might be originated from outdoor and indoor classrooms, this study found that the major influence of HM was from outside the classrooms. This is because, the elevated metal (Al, Zn, Mg and Pb) levels found in the particles collected were mostly related to anthropogenic sources (industrial activities, vehicular emission, and oil combustion). HM might enter the classrooms through the open windows and doors. However, it is worth to take note that the occupancy and activities of the occupants also influence the concentration of HM inside the classrooms.

Since the HM found in the particles may cause long term effects to the school children, proper actions need to be taken to avoid the risk of the effects of HM bioaccumulation. Hence, author would like to suggest doing a suitable cleaning and housekeeping inside the classrooms.

Furthermore, proper attention should be done in future monitoring studies especially in the schools that are located near the heavy traffic routes. Other organic pollutants such as the carcinogenic chemicals polycyclic aromatic hydrocarbon should be included in the future monitoring studies at the school areas.

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