Assessment of trace elements concentration in road dust around the city of Kuala Lumpur

M I A Wahab\textsuperscript{1} and W M A A Razak\textsuperscript{1}
\textsuperscript{1}Centre of Health & Applied Sciences, Faculty of Health Sciences, Universiti Kebangsaan Malaysia
E-mail: ikram@ukm.edu.my

Abstract. This study aimed to assess the concentrations and health effect of heavy metals (Cd, Cu, Cr, Ni, Pb and Zn) in road dust of selected locations in the city of Kuala Lumpur. Sampling was conducted for three times at four locations namely Jalan Tun Razak, Jalan Raja Abdullah, Jalan TAR and Jalan Ayer Molek. The concentration of heavy metals in road dust was analyzed by using ICP-MS. The study found that Jalan TAR has the highest concentrations for the heavy metals Cd (0.23 ± 0.04 mg/kg), Cu (116.39 ± 38.77 mg/kg), Ni (83.29 ± 23.66 mg/kg), Pb (43.53 ± 7.00 mg/kg) and second highest for Cr (34.69 ± 3.57 mg/kg) and Zn (86.22 ± 23.07). The pollution level of heavy metals in road dust were assessed by Pollution Index and Pollution Load Index, showing that all locations are highly contaminated except Jalan Ayer Molek. Health risk assessment was determined to access the health effect of carcinogenic and non-carcinogenic to adults and children caused by exposure of heavy metals in road dust. Based on the integrated HI for children at all locations are more than 1. Indicating great chance of non-carcinogenic effects. All incremental lifetime cancer risk (ILTCR) values for adult and children at all locations are within acceptable limit. Traffic and activities that take place in these four locations are the sources of heavy metals. Jalan TAR which is loaded with commercial activities is the most polluted location followed by Jalan Raja Abdullah (commercial area), Jalan Tun Razak (highway area) and Jalan Ayer Molek (residential area).

1. Introduction
Kuala Lumpur is one of the fastest growing metropolitan areas in Southeast Asia, in terms of population and economy. Rapid urban and industrial growth has led to air pollution problems. One of the air pollutants that associated is dust emissions. Urbanization also lead to traffic problems which in turn contribute to road dust emissions [1].

Road dust is a soil material or dirt that becomes airborne, especially by the friction of tires traveling on unpaved roads and dust-covered paved roads [2]. Besides, it become airborne during dry and windy conditions, worsen by moving vehicles. Motor vehicles can be a source of road dust, thus contributing to the level of pollution in urban environments [3,4]. Road dust may accumulate heavy metals by deposition, impaction and interception. Sources of heavy metal can be from industrial emissions, the use of lubricating oils, car parts and erosion of building materials, road paints and concrete [5,6].

Common heavy metals released from vehicles are cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) [7,8].

According to T. Mehmood et al. [9] and C. Pagotto [10] heavy metals become bound to ground surfaces and dust. Thus increase in emissions and prolonged deposition can lead to enrichment, subsequently metal contamination occurs on the surface of the environment. M. Norouzi et al. [11]...
states metals such as Cu, Zn and Ni are necessary metals because they play an important role in biological systems, while some metals such as Cd and Pb are non-essential metals. Furthermore, Cd and Pb are relatively rare metal and have no important biological functions, instead are highly toxic to plants and animals [12,13]. Meanwhile chromium (VI) is highly toxic and carcinogenic to humans through inhalation exposure [14].

This study was conducted to assess the concentrations and health effect of heavy metals (Cd, Cu, Cr, Ni, Pb and Zn) in road dust of selected locations in the city of Kuala Lumpur as toxicities related to these heavy metals can result to major health problems to children and adults. The concentration of heavy metals determined were compared between study locations and further used in calculation of health risk assessment and pollution index.

2. Materials and methods

2.1. Study Area
Research was conducted in Kuala Lumpur. Kuala Lumpur is located at west of Peninsular Malaysia. The city covers an area of 243 km². Samples of road dust was taken from four streets that have different land use. Jalan Raja Abdullah (1.40 km in length) and Jalan TAR (1.90 km in length) are located in a commercial area with overcrowded traffic. Jalan Tun Razak is located in a busy highway area. While Jalan Ayer Molek is located in a residential area and was only used by the residents as the main route for daily use.

2.2. Sample Collection and Data Analysis
200 g road dust sample was collected using polyethylene brush and pan by manual sweeping (Yap et al. 2002). The road dust was then transferred into a sealable plastic bag. Collected samples were dried at 100 °C for 5 hours in a furnace [4] and sieved through a 2 mm sieve. 0.5 g of sieved road dust samples digested using 3 mL of 3:1:2 mixture of hydrochloric acid, HCl, nitric acid, HNO_3 and deionized water, H_2O at 95 °C for 1 hour [15]. This technique was taken and modified from NIOSH Method 7301 Aqua Regia digestion. The mixture is filtered with a sterile Minisart filter into a 100 mL flask. Then dilute up to 100 mL by adding deionized water. The solution were then stored in the refrigerator at 4 °C until the analysis was performed [16]. Furthermore, the analysis of six heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) in road dust samples was performed using ICP-MS instruments.

2.3. Health Risk Assessment
Population exposure of heavy metals in road dust can be calculated by health risk assessment model [17-19] via three pathways which are inhalation, dermal contact and ingestion. There are two types of health risk assessment (carcinogenic and non-carcinogenic) that was conducted for both age group, adult and children (Table 1 & 2). Initially, daily dose of exposure was calculated. Then hazard quotient (HQ) and hazard index (HI) were applied to assess the non-carcinogenic risk. Meanwhile for carcinogen, the incremental lifetime cancer risk (ILTCR) was calculated.

2.4. Assessment of Contamination Level
Each sampling location was assessed through the Pollution Index (PI) to determine the degree of heavy metal contamination by using model calculation by L. Hakanson [20] in equation 1. The four PI categories were defined below. Then based on the value of PI obtained, it was used to determine the Pollution Load Index (PLI) which proposed by D. Tomlinson et al. [21] to facilitate the comparison of quality between studied locations.

\[ PI = \frac{C_n}{C_b} \]  

\[ PLI = \left( PI_1 \times PI_2 \times PI_3 \times \ldots \times PI_n \right)^{1/n} \]
* PI ; < 1 : Low, 1 - 3 : Moderate, 3 - 6 : High, > 6 : Very high.

* PLI ; < 1 : Area is in good condition, 1 : Presence of pollutant at moderate level, > 1 : Degradation of area quality

**Table 1.** Exposure assessment for non-carcinogenic heavy metals.

| Calculation model |
|--------------------|
| $\text{ADD}_{\text{inh}} = \frac{C_{\text{dust}} \times \text{InhR} \times \text{EF} \times \text{ED}}{\text{AT}_{\text{necarc}} \times \text{BW} \times \text{PEF}}$ (3) |
| $\text{ADD}_{\text{der}} = \frac{C_{\text{dust}} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{AT}_{\text{necarc}} \times \text{BW}}$ (4) |
| $\text{ADD}_{\text{ing}} = \frac{C_{\text{dust}} \times \text{IngR} \times \text{EF} \times \text{ED} \times \text{CF} \times \text{AT}_{\text{necarc}} \times \text{BW} \times \text{AT}_{\text{carc}}}{\text{HQ} = \frac{\text{DD}_{\text{inh/der/ing}}}{\text{RfD}}}$ (6) |
| $\text{HI} = \sum \text{HQ}_{\text{inh/der/ing}}$ (7) |

$\text{ADD}_{\text{inh}} =$ average daily dose associated with inhalation exposure (mg/kg/day)

$\text{ADD}_{\text{der}} =$ average daily dose associated with dermal contact exposure (mg/kg/day)

$\text{ADD}_{\text{ing}} =$ average daily dose associated with ingestion exposure (mg/kg/day)

$\text{HQ} =$ hazard quotient

$\text{HI} =$ hazard index

(Source: 17,18)

**Table 2.** Exposure assessment for carcinogenic heavy metals.

| Calculation model |
|--------------------|
| $\text{LADD}_{\text{inh}} = \frac{C_{\text{dust}} \times \text{InhR} \times \text{EF} \times \text{ED}}{\text{AT}_{\text{carc}} \times \text{BW} \times \text{PEF}}$ (8) |
| $\text{LADD}_{\text{der}} = \frac{C_{\text{dust}} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{AT}_{\text{carc}} \times \text{BW}}$ (9) |
| $\text{LADD}_{\text{ing}} = \frac{C_{\text{dust}} \times \text{IngR} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{AT}_{\text{carc}} \times \text{BW}}$ (10) |
| $\text{ILTCR} = \text{LADD}_{\text{inh}} \times \text{CSF}_{\text{inh}}$ (11) |

$\text{LADD}_{\text{inh}} =$ lifetime average daily dose associated with inhalation exposure (mg/kg/day)

$\text{LADD}_{\text{der}} =$ lifetime average daily dose associated with dermal contact exposure (mg/kg/day)
LADD\textsubscript{ing} = lifetime average daily dose associated with ingestion exposure (mg/kg/day)
ILTCR = incremental lifetime cancer risk associated with inhalation exposure
CSF\textsubscript{inh} = cancer slope factor associated with inhalation

(Source: 18,19)

3. Results and discussion

3.1. Determination and Comparison of Heavy Metal Concentration Between Location

Determination of six heavy metal concentrations of cadmium, chromium, copper, nickel, lead and zinc in road dust samples around the city of Kuala Lumpur were carried out. The results showed that there are presence of heavy metals in road dust samples at all four study locations, Jalan Tun Razak, Jalan Raja Abdullah, Jalan TAR and Jalan Ayer Molek.

Overall, cadmium was recorded as the lowest compared to other heavy metals (Figure 1). This finding was supported by Y. Faiz et al. [4] found that low cadmium content compared to other metals studied in road dust. One-way ANOVA tests show a significant difference in cadmium concentration between Jalan TAR and Jalan Ayer Molek. This is because Jalan TAR has a higher traffic congestion than Jalan Ayer Molek. Thus, more traffic emissions are released. Cadmium is one of the component in diesel fuel, brake pads and car paints. In addition, cadmium was also contained in concrete surfaces. Thus, corrosion to these components will release cadmium.

The lowest reading for chromium concentration was recorded at Jalan Ayer Molek (Figure 2). This also led to significant differences in the concentration of chromium at Jalan Ayer Molek against Jalan Tun Razak, Jalan TAR and Jalan Raja Abdullah. This is attributed to the construction activity that took place during sampling at three locations (Jalan Tun Razak, Jalan TAR and Jalan Raja Abdullah). Construction activity can contribute to the increase in chromium concentration as cement contains chromium compounds. Chromium was also used in ink printing machines where there are commercial activities on Jalan TAR and Jalan Raja Abdullah.

In 2004, the WHO [22] stated that copper was used in electrical wiring, plumbing and building materials. Referring to the statement, there were construction activities during sampling at Jalan TAR and Jalan Raja Abdullah. There were also construction activities near Jalan Tun Razak. This can be attributed to the significant difference recorded for copper concentration at Jalan TAR and Jalan Ayer Molek (Figure 3). Among other factors that contribute to copper concentrations are the release of corrosion from manhole cover metal, emissions from engine parts, wear of tires and brake pads [23,24,3].

The lowest concentration of nickel was recorded at Jalan Tun Razak (Figure 4). Based on one-way ANOVA test, there was a significant difference between the nickel concentration at Jalan Tun Razak and Jalan TAR. Previous studies [25-27] suggested that high nickel presence was due to industrial processes, gas refineries and fuel combustion. According to previous researchers [28] nickel was also contained in car paint. It has been found that Jalan TAR has more diversity of transportations such as the presence of monorail and bus stations as compared to Jalan Tun Razak which only have limited types of vehicles such as cars and motorcycles. Among other reasons, this nickel content also may be contributed by the presence of small industries [29] such as automobile workshops found at Jalan TAR.

Malaysia, Singapore and some European countries have begun to stop the use of unleaded petrol by year 2000. This was triggered by high concentrations of lead in the environment and health problems resulting from lead exposure [30]. The presence of high concentrations of lead indicates its non-degraded or persistence in the environment. According to a study in Brazil [31] the concentration of lead in the environment remains high despite discontinue of the use of leaded gasoline. This means lead concentration in the environment may come from various sources.

The findings from this study found that there was still lead content detected where lead reading was
lowest at Jalan Ayer Molek location (Figure 5). This caused a significant difference between lead concentration at Jalan Ayer Molek against Jalan TAR and Jalan Raja Abdullah. Previous findings [32] notes that lead is still being released into the environment through the burning of motor oil, fuel and wear of brakes.

According to H. Kamani et al. [33], lead is also associated with road surface conditions, lubricants and paints. There is no doubt that there are several automobile workshops along Jalan TAR and Jalan Raja Abdullah which provide services such as changing of lubricating oil and tires.

Zinc is the most abundant heavy metal in the environment. Based on one-way ANOVA test, there was no significant difference in zinc concentration in all study locations (Figure 6). The absence of significant differences between locations, indicates that pollution comes from the same source despite their traffic densities [24].

Zinc was derived from mechanical corrosion of the car parts as it were involved during the production of brake lining and lubricating oil clumps and cylinder head gasket [34], then when these components were worn out, zinc release occurs.

The same thing happens and was due to the galvanized car parts corrosion [35].

*Different letters indicate significant difference between locations (p<0.05)

**Figure 1.** The mean concentration of cadmium in road dust at each sampling location.

*Different letters indicate significant difference between locations (p<0.05)

**Figure 2.** The mean concentration of chromium in road dust at each sampling location.
*Different letters indicate significant difference between locations (p<0.05)

**Figure 3.** The mean concentration of copper in road dust at each sampling location.

*Different letters indicate significant difference between locations (p<0.05)

**Figure 4.** The mean concentration of nickel in road dust at each sampling location.

*Different letters indicate significant difference between locations (p<0.05)

**Figure 5.** The mean concentration of lead in road dust at each sampling location.
3.2. Health Risk Assessment
The exposure of heavy metals in road dust to the population in four locations was due to three routes of exposure, namely road dust inhalation, skin contact with road dust and road dust ingestion. The model used in this study was based on the method of USEPA (17).

3.3. Non-carcinogenic Heavy Metal
Overall, the trend of HQ readings were same for all study locations (Table 3 & 4). Among the three routes of exposure, the HQ value of the ingestion pathway was the highest for cadmium, nickel, lead and zinc. In contrast whereby chromium has highest HQ through inhalation pathway. The highest HQ at Jalan Tun Razak was recorded on chromium through inhalation pathway. This means the population living in Jalan Tun Razak has the potential for non-cancerous effects of heavy metal chromium because HQ value exceeds 1. The health effects associated with chromium are skin irritation and nasal, bleeding and damage of eardrum [36,37].

Jalan Raja Abdullah, TAR and Jalan Ayer Molek have the highest HQ through the ingestion pathway for lead. Similar findings by previous studied [38] where most heavy metals studied have the highest HQ through ingestion pathway. This indicates that populations in these locations have the risk of getting non-cancerous effects by lead ingestion where HQ value exceeds 1.

Children may be exposed to lead hazards if they are playing nearby dusty places or leaded-paint [4]. Furthermore, according to A. Bradman et al. [39] lead absorption increased when there was a lack of nutrients such as iron and calcium that often occurred in children compared to adults. Integrated HI values (ΣHI) were calculated to evaluate all heavy metals content in road dust because in real situations, the population will be exposed to all heavy metals instead of single metal. Based on the value of ΣHI in all locations, children have higher risk of non-cancer than adults. This finding was similar with study in Beijing [40].

Children are at higher risk because they have high hand-to-mouth activity [41] with nervous system that still growing plus higher rates of heavy metal diffusion [42]. Ingestion of road dust due to this activity will gives a health effect to children.

Furthermore, all readings of ΣHI exceed 1 except for adult group at the location of Jalan Ayer Molek. Previous reports stated that the majority of its study locations in China have ΣHI more than 1 [43]. Meanwhile the road dust study in Pakistan [44] records ΣHI more than 1 for children only. Thus, there was a high probability that populations at all study locations will have non-cancerous effects such as nausea, loss of appetite and headaches.
3.4. Carcinogenic Heavy Metal

Heavy metals of cadmium, chromium, nickel and lead were assumed carcinogens only through inhalation exposure. This health risk assessment was assessed through the products of cancer slope factors (CSF) and road dust exposures [17].

Based on the findings, the adult ΣILTCR in all study locations was higher than that of children (Table 5). ΣILTCR at Jalan Tun Razak and Jalan TAR meant the probability of one to two cases of cancer in 100 000 populations. Whereas ΣILTCR in Jalan Raja Abdullah shows two to three cancer cases in 100 000 populations. ΣILTCR at Jalan Ayer Molek was the lowest recorded with six cases of cancer in 100 000 populations. ΣILTCR at Jalan Raja Abdullah shows two to three cancer cases in 100 000 populations. ΣILTCR at Jalan Ayer Molek was the lowest recorded with six cases of cancer in 100 000 populations. However, no ILTCR value exceeds the threshold value. Any cancer risk value within the range of one case in 1000 000 to one case in 10 000 is considered acceptable.

Overall, ILTCR for nickel was the leading heavy metal for both age groups with ranges of 4.25×10⁻⁶ to 2.16×10⁻⁶. However, all ILTCR of nickel in all study locations were below the threshold, hence the risk of cancer is low.

Similar finding was obtained by previous studied [45]. There were two heavy metals that were not involved in carcinogenic health risk assessment which were copper and zinc because they were not human carcinogen.

However, it should be noted that this health risk assessment was calculated based on conservative assumptions. As a result, the outcome of the risk calculation can be excessive than the actual risk. Despite this, the health risk assessment introduced by USEPA [17] was proven to be a relevant tool for evaluating heavy metal exposure dose and exposure pathways of concern.

| Locations         | Heavy metal | HQ_{inh} | HQ_{der} | HQ_{mag} | HI=ΣHQ | ΣHI  |
|-------------------|-------------|----------|----------|----------|--------|------|
| Jalan Tun Razak   | Cd          | 1.33×10⁻⁴ | 1.83×10⁻⁵ | 2.01×10⁻⁶ | 2.16×10⁻³ | 1.42×10⁻⁶ |
|                   | Cr          | 1.15×10⁻⁰ | 7.51×10⁻⁴ | 9.88×10⁻² | 1.25×10⁻⁰ |      |
|                   | Cu          | 1.50×10⁻³ | 1.37×10⁻³ | 2.44×10⁻² | 2.73×10⁻² |      |
|                   | Ni          | 1.64×10⁻³ | 3.75×10⁻³ | 2.47×10⁻² | 3.01×10⁻² |      |
|                   | Pb          | 7.22×10⁻³ | 6.43×10⁻⁶ | 1.09×10⁻⁶ | 1.16×10⁻⁶ |      |
|                   | Zn          | 9.27×10⁻⁵ | 3.05×10⁻⁹ | 1.40×10⁻² | 1.49×10⁻³ |      |
| Jalan Raja Abdullah | Cd         | 1.80×10⁻⁴ | 2.47×10⁻⁶ | 2.71×10⁻³ | 2.91×10⁻³ | 1.29×10⁻⁶ |
|                   | Cr          | 8.39×10⁻¹ | 5.49×10⁻⁴ | 7.23×10⁻² | 9.12×10⁻² |      |
|                   | Cu          | 1.67×10⁻⁴ | 1.53×10⁻⁴ | 2.72×10⁻² | 3.03×10⁻² |      |
|                   | Ni          | 1.20×10⁻⁴ | 2.75×10⁻³ | 1.81×10⁻² | 2.20×10⁻² |      |
|                   | Pb          | 1.97×10⁻² | 1.76×10⁻⁴ | 2.97×10⁻¹ | 3.17×10⁻¹ |      |
|                   | Zn          | 1.15×10⁻⁴ | 7.91×10⁻⁷ | 1.73×10⁻³ | 1.85×10⁻³ |      |
| Jalan TAR         | Cd          | 2.06×10⁻⁴ | 2.83×10⁻⁵ | 3.11×10⁻³ | 3.34×10⁻³ | 1.63×10⁻⁶ |
|                   | Cr          | 1.10×10⁻⁰ | 7.22×10⁻⁴ | 9.50×10⁻² | 1.20×10⁻⁰ |      |
|                   | Cu          | 2.65×10⁻³ | 2.42×10⁻³ | 4.31×10⁻² | 4.82×10⁻² |      |
|                   | Ni          | 1.58×10⁻³ | 3.61×10⁻³ | 2.38×10⁻² | 2.89×10⁻² |      |
|                   | Pb          | 2.16×10⁻² | 1.93×10⁻⁴ | 3.26×10⁻¹ | 3.48×10⁻¹ |      |
|                   | Zn          | 1.32×10⁻⁴ | 9.06×10⁻⁹ | 1.99×10⁻³ | 2.12×10⁻³ |      |
| Jalan Ayer Molek  | Cd          | 8.24×10⁻⁵ | 1.13×10⁻⁵ | 1.24×10⁻³ | 1.33×10⁻³ | 5.79×10⁻⁶ |
|                   | Cr          | 3.55×10⁻⁴ | 2.32×10⁻⁴ | 3.06×10⁻² | 3.86×10⁻² |      |
|                   | Cu          | 3.34×10⁻⁵ | 2.84×10⁻⁴ | 5.04×10⁻² | 5.33×10⁻² |      |
|                   | Ni          | 5.07×10⁻⁴ | 1.16×10⁻³ | 7.64×10⁻³ | 9.31×10⁻³ |      |
|                   | Pb          | 1.10×10⁻² | 9.82×10⁻⁵ | 1.66×10⁻¹ | 1.77×10⁻¹ |      |
|                   | Zn          | 3.69×10⁻⁵ | 2.53×10⁻⁷ | 5.55×10⁻⁴ | 5.92×10⁻⁴ |      |
Table 4. Hazard Quotient and Hazard Index for non-carcinogenic risk for children groups.

| Locations         | Heavy metal | HQ\textsubscript{inh} | HQ\textsubscript{der} | HQ\textsubscript{mag} | HI=\Sigma HQ | \Sigma HI |
|-------------------|-------------|------------------------|-----------------------|------------------------|--------------|----------|
| Jalan Tun Razak   | Cd          | 2.40×10^{04}           | 1.20×10^{04}          | 1.88×10^{02}           | 1.91×10^{02} | 4.52×10^{00} |
|                   | Cr          | 2.06×10^{00}           | 4.92×10^{03}          | 9.22×10^{01}           | 2.99×10^{00} |          |
|                   | Cu          | 2.70×10^{03}           | 9.00×10^{03}          | 2.28×10^{01}           | 2.40×10^{01} |          |
|                   | Ni          | 2.95×10^{03}           | 2.46×10^{02}          | 2.30×10^{01}           | 2.33×10^{01} |          |
|                   | Pb          | 1.30×10^{02}           | 4.21×10^{04}          | 1.01×10^{00}           | 1.03×10^{00} |          |
|                   | Zn          | 1.67×10^{04}           | 4.17×10^{-06}         | 1.30×10^{-02}          | 1.32×10^{-02} |          |
| Jalan Raja Abdullah| Cd          | 3.24×10^{04}           | 1.62×10^{04}          | 2.53×10^{02}           | 2.58×10^{02} |          |
|                   | Cr          | 1.51×10^{00}           | 3.60×10^{03}          | 6.74×10^{01}           | 2.19×10^{00} |          |
|                   | Cu          | 3.00×10^{03}           | 1.00×10^{02}          | 2.53×10^{01}           | 2.66×10^{01} |          |
|                   | Ni          | 2.16×10^{03}           | 1.80×10^{02}          | 1.69×10^{01}           | 1.89×10^{01} | 5.49×10^{00} |
|                   | Pb          | 3.55×10^{02}           | 1.15×10^{03}          | 2.77×10^{00}           | 2.81×10^{00} |          |
|                   | Zn          | 2.07×10^{04}           | 5.18×10^{-06}         | 1.62×10^{-02}          | 1.64×10^{-02} |          |
| Jalan TAR          | Cd          | 3.71×10^{04}           | 1.85×10^{04}          | 2.90×10^{02}           | 2.95×10^{02} |          |
|                   | Cr          | 1.99×10^{00}           | 4.73×10^{03}          | 8.87×10^{01}           | 2.88×10^{00} |          |
|                   | Cu          | 4.76×10^{03}           | 1.59×10^{02}          | 4.02×10^{01}           | 4.23×10^{01} |          |
|                   | Ni          | 2.84×10^{03}           | 2.37×10^{02}          | 2.22×10^{01}           | 2.48×10^{01} |          |
|                   | Pb          | 3.89×10^{02}           | 1.26×10^{03}          | 3.04×10^{00}           | 3.08×10^{00} |          |
|                   | Zn          | 2.37×10^{04}           | 5.94×10^{-06}         | 1.86×10^{-02}          | 1.88×10^{-02} |          |
| Jalan Ayer Molek  | Cd          | 1.48×10^{04}           | 7.41×10^{05}          | 1.16×10^{02}           | 1.18×10^{02} |          |
|                   | Cr          | 6.38×10^{01}           | 1.52×10^{03}          | 2.85×10^{01}           | 9.25×10^{01} |          |
|                   | Cu          | 5.57×10^{04}           | 1.86×10^{03}          | 4.71×10^{02}           | 4.95×10^{02} | 2.64×10^{00} |
|                   | Ni          | 9.13×10^{04}           | 7.61×10^{03}          | 7.13×10^{02}           | 7.98×10^{02} |          |
|                   | Pb          | 1.98×10^{02}           | 6.43×10^{04}          | 1.55×10^{00}           | 1.57×10^{00} |          |
|                   | Zn          | 6.63×10^{05}           | 1.66×10^{-06}         | 5.18×10^{-03}          | 5.25×10^{-03} |          |

Table 5. Incremental Lifetime Cancer Risk (ILTCR) for inhalation exposure routes.

| Locations         | Heavy metal | ILTCR             | CSF             |
|-------------------|-------------|-------------------|-----------------|
|                   |             | Adult             | Children        |                 |
| Jalan Tun Razak   | Cd          | 3.60×10^{-07}     | 1.30×10^{-07}   | 6.30×10^{-00}   |
|                   | Cr          | 5.76×10^{-06}     | 2.07×10^{-06}   | 4.10×10^{-01}   |
|                   | Cu          | N/A               | N/A             | N/A             |
|                   | Ni          | 1.18×10^{-05}     | 4.25×10^{-06}   | 8.40×10^{-01}   |
|                   | Pb          | 4.55×10^{-07}     | 1.64×10^{-07}   | 4.20×10^{-02}   |
|                   | Zn          | N/A               | N/A             | N/A             |
| \Sigma ILTCR      |             | 1.84×10^{-05}     | 6.61×10^{-06}   |                 |
| Jalan Raja Abdullah| Cd          | 4.86×10^{-07}     | 1.75×10^{-07}   | 6.30×10^{-00}   |
|                   | Cr          | 4.22×10^{-06}     | 1.52×10^{-06}   | 4.10×10^{-01}   |
|                   | Cu          | N/A               | N/A             | N/A             |
|                   | Ni          | 2.16×10^{-05}     | 3.11×10^{-06}   | 8.40×10^{-01}   |
|                   | Pb          | 1.24×10^{-06}     | 4.47×10^{-07}   | 4.20×10^{-02}   |
|                   | Zn          | N/A               | N/A             | N/A             |
| \Sigma ILTCR      |             | 2.75×10^{-05}     | 5.25×10^{-06}   |                 |
| Jalan TAR          | Cd          | 5.57×10^{-07}     | 2.00×10^{-07}   | 6.30×10^{-00}   |
Pollution index (PI) and pollution load index (PLI) are used to assess the contamination level of study locations. The PI values for Cd, Cr, Cu, Ni, Pb, and Zn are obtained for each location. The PLI is calculated by considering all heavy metals loads in road dust. Jalan Tun Razak, Jalan Raja Abdullah, and Jalan TAR have high levels of pollution, with PLI scores exceeding 1, indicating the need for immediate action to address pollution. Jalan Ayer Molek is in good condition, with a PLI score below 1.

3.5. Contamination Level of Study Location

Based on the PI values, the pollution trends of Cd, Cr, Cu, Ni, Pb, and Zn vary according to location. All locations have low Cd contamination. Generally, all locations have very high Ni contamination. The PLI values range from 0.15 to 2.38, indicating the level of pollution in the study locations. Jalan Ayer Molek has the lowest PLI score, indicating a good condition, while Jalan Tun Razak and Jalan Raja Abdullah have high PLI scores, requiring immediate action. Jalan TAR has a moderate PLI score, indicating a need for attention.

* PI: < 1: Low, 1 - 3: Moderate, 3 - 6: High, > 6: Very high.
* PLI: < 1: Area is in good condition, 1: Presence of pollutant at moderate level, > 1: Degradation of area quality.
spread of the wind and cause heavy metal accumulation to occur [46]. This is because Jalan TAR is a busy commercial area with shopping malls and traffic congestions that last until midnight. Furthermore, this location has many tall buildings along the street.

One study of road dust pollution found that developed cities in China, particularly Shanghai, Hangzhou, Guangzhou and Hong Kong have more PLI reading exceeded 1 [47]. In fact, the PLI value was extremely higher than the findings of this study. Based on PLI value in this study, the sequence of pollution in descending order was Jalan TAR (commercial area) > Jalan Raja Abdullah (commercial area) > Jalan Tun Razak (highway area) > Jalan Ayer Molek (residential area). The same finding was reported by J.M Trujillo-González et al. [48].

Referring to this, Calvillo et al. [49] reports that several cities around the world now have a coordinated sweeping system to clean the roads by collecting road dust in containers. In Kuala Lumpur, this system was run by waste management company namely Alam Flora but, the frequency was uncertain. This problem cannot be resolved solely by sweeping services because road dust can be airborne during windy conditions and disruption from vehicles.

4. Conclusion
The sources of heavy metals in road dust were from traffic emissions, economic and construction activities. For carcinogenic health risk assessment, all incremental lifetime cancer risk (ILTCR) values were within the range allowed by USEPA of 1 in 10 000 populations up to 1 in 1000 000 populations. Therefore, the risk of getting cancer from exposure to heavy metals from road dust around the city of Kuala Lumpur is low.

Based on PI, all locations were found to be highly contaminated with nickel. The PLI reading showed that Jalan Tun Razak, Jalan Raja Abdullah and Jalan TAR were at a high level of contamination while Jalan Ayer Molek had a low level of contamination. In conclusion, Jalan TAR (commercial area) is the most polluted location, followed by Jalan Raja Abdullah (commercial area), Jalan Tun Razak (highway area) and Jalan Ayer Molek (residential area).

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