Potential health risk assessment of heavy metal content in Perlis soil

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Abstract. A determination of soil heavy metal (Cu, Mn and Ni) concentrations in Perlis state, Malaysia was performed to define the level of soil pollution. Six soil samples were collected at depth of 0 – 15 cm in industrial, residential and school areas around Perlis. The highest concentration of Mn (57.80 mg/kg) and Ni (2.83 mg/kg) were detected at limestone quarry in Bukit Air, Cu (17.43 mg/kg) in Kampung Wang Ulu. The concentration of Cu, Mn and Ni were well below their soil geochemical background values. The single pollution indices assessment revealed that the soil contamination due to heavy metals in Perlis is insignificant. On the basis of the heavy metal content, the potential health risk assessment for children and adults was calculated for a lifetime of exposure through ingestion, inhalation and dermal contact based on the USEPA model. The exposure assessment found that the exposure pathways of heavy metals to both children and adults are through ingestion. Both Hazard Quotient (HQ) and Hazard Index (HI) values are lower than 1, indicating no health risk. From the result, the HI values indicated that the soil heavy metal contamination could pose more impacts on children as compared to adults.

1. Introduction

1.1. Background of Study

Heavy metal contamination in soil has received much attention in recent years due to its toxicity and persistence in the environment. Heavy metals are known as the metals with a specific gravity of more than 5 g/cm³ if in their standard state [1]. Although heavy metals are naturally present in soil, numerous studies have revealed that the sources of heavy metals causing contamination in soil are mainly derived from anthropogenic activities during the course of the rapid development of industrialization and urbanization particularly in the developing country like Malaysia. Traffic emission, industrial emission, domestic emission, weathering of building and pavement surface, atmospheric deposition, and usage of agrochemicals are the examples of anthropogenic sources of heavy metals [2].

Soil is an earth system component which biologically active, porous that has developed in the uppermost layer of Earth's crust. Soil acts as crucial fundamental of natural resource for human survival, serving as a water and nutrients reservoir, as a medium for the filtration and breakdown of...
injurious wastes, and as a participant in the cycling of carbon and elements through global ecosystem [3]. Heavy metals can be accumulated in topsoil through atmospheric deposition by sedimentation, impaction and interception [4]. High concentration of heavy metals in the soil serves harmful effects to the environment even though some of the trace elements like Co, Cu, Fe, Mn, Mo, Ni, V and Zn play a significant role in the soil [5]. Furthermore, heavy metals are not only toxic but many of them are not degradable either microbiologically or chemically like other soil contaminants, and their total concentration in soils lasts for a long time after their first introduction, thus bioaccumulation can become a threat [6]. However, changes in chemical forms and bioavailability of the heavy metals are possible [7].

Human exposure to the heavy metals in soil can be through three pathways which are direct skin contact with contaminated soil, inhalation of soil particles or ingestion of contaminated food [8]. The consumption of contaminated vegetables is the primary exposure pathway of heavy metal toxicity to humans. At the same time of the plants and vegetative crops acquire the essential nutrients from the soil for the purpose of growth, they also uptake the nonessential metals [5]. The exceeding amount of heavy metals concentration in vegetative crops than its essential physiological demand can cause adverse effect not only in them but also human health through food chain. Different factors including application of agrochemicals, solubility of heavy metals, soil pH, soil types, and plants and crops species have to be taken under consideration when the uptake of heavy metals by the plants and vegetative crops from the soil [9].

The acceleration of industrialization, urbanization, and agricultural activities have led to heavy metal contamination in soil and popped up with the environmental public hazards corresponding to the heavy metal contamination as well. With the occurrence of this phenomenon, people are more crucial in protecting environment and ensuring human health. Therefore, the researches and practices of the soil heavy metal contamination characteristics, mechanism, assessment and management have become prominent issues that all countries must be faced with recently [10].

This research is carried out to study the heavy metal pollution in Perlis soil. Still and all, Malaysia does not have any standard guidelines for heavy metal content in soil. Environmental Quality Standards of Soils GB15618-1995 and the standards or guidelines from the previous studies can be referred to make comparison with the results of the study instead. These guidelines are marked as Maximum Allowable Limit (MAL) and served as a benchmark for the determination of heavy metal content allowed in the Perlis soil. As mentioned before, heavy metal pollution can become a hazard to humans, so the potential health risk assessment is one of the significant parts of the research. Health risk assessment is a complex and multistep process to estimate the potential risks to public health from exposure to agents of concern by combining the available scientific evidence. Health risk assessment is important as it can help people get necessary care before problems build up.

Industrialization, urbanization and agricultural activities have kept increasing over the years in Perlis. These activities apparently contribute to a number of pollutants in soil as more pollutants containing heavy metals are released and seeped into the soil due to the increasing demand for metals during the industrialization and urbanization works [10]. Heavy metals contamination in soil is of concern as they are foremost contaminating agents of our food supply. Plants and vegetative crops have equal ability to acquire essential metals and other nonessential metals from the soil, and these metals will be accumulated and cannot be degraded [5]. Moreover, the contaminated soil can bring far away into the water streams such as drainage system and nearby river, and further contaminate the water sources consequently. Some heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, V and Zn are important in plants and vegetative crops growth, however, high concentration of heavy metals in soil may be harmful to the organisms [5], and even directly or indirectly causing risk to public health. Human can expose to the heavy metals through three primary routes which are either by skin contact, inhalation or ingestion. Excessive human exposure to high concentration of heavy metals will lead to their accumulation in the human body [8] and cause heavy metal poisoning. Thus, it has revealed that heavy metals contamination in soil is a severe environmental problem that cannot be neglected. The establishment of a potential health risk assessment of heavy metal content is very important for the
estimation of risks of public health to the exposure of heavy metal so that the people can get early prevention or treatment before the problems arise. Nevertheless, land area, function and characteristic of soil are known to be great different in different contaminated sites, and there is still no formation of a scientific and efficient soil environmental health risk assessment and management system in Malaysia. The objectives of this study were to (1) determine the concentration of heavy metals in Perlis soil, (2) to assess the pollution level and potential ecological risk of heavy metals in Perlis soil, and (3) to assess the potential health risk assessment from soil heavy metal contamination.

2. Methodology

2.1. Site description and soil sampling

Six sampling sites were selected in three major areas which namely industrial, residential and school in Perlis for this study. The sampling sites were Jejawi industrial site, Bukit Air limestone quarry, Taman Seri Firdaus, Kampung Wang Ulu, Sekolah Menengah Kebangsaan Abi, and Sekolah Kebangsaan Padang Kota as illustrated in Figure 1. Table 1 showed the coordinate of sampling locations assessed using the tool of “Google Earth Pro”. A total of six soil samples were collected from industrial, residential and school areas for this research. The samplings were carried out during hot weather.

![Figure 1. Distance of sampling locations from Kangar centre.](image)

| Area            | Sampling Site                  | Symbol | Coordinate          |
|-----------------|--------------------------------|--------|---------------------|
| Industrial      | Jejawi Industrial Site         | I1     | 6° 26.443’ N        |
|                 |                                |        | 100° 13.569’ E      |
| Bukit Air Limestone Quarry |                       | I2     | 6° 30.840’ N        |
2.2 Soil Analysis

The soil samples were oven dried at 60 °C for 2 days followed by grinding the soil samples into smaller size with mortar and pestle and sieved using a 2 mm sieve. The soil samples were then divided into sub samples to analyse the soil characteristics including the pH, organic matter and heavy metal content. The pH of the soil sample collected was determined using the method of 1:5 of soil to water ratio. For organic matter analysis, the soil sample in the crucible was oven dried at 105 °C for 24 hours. The total weight of soil sample contents and the crucible was measured after cooling in a desiccator. Estimation of the amount of organic matter present in a soil sample was calculated using ‘loss on ignition’ method. The heavy metals metal concentrations were determined by atomic absorption spectrophotometer (AAS).

2.3 Soil Pollution Indices Assessment

The assessment of soil pollution in this research was concentrated on the contamination indices such as single pollution index (PI) and potential ecological risk index (RI).

2.3.1 Single Pollution Index (PI). Single Pollution Index (PI) was used to determine the pollution level of a single heavy metal. Heavy metal that poses highest threat for a soil environment will be known from the calculation of this index [11]. The single pollution index of each heavy metal was attributed using equation (1) below:

\[
\text{PI} = \frac{C_n}{GB}
\]

where \( C_n \) is the content of heavy metal in soil and GB is the value of geochemical background. The geochemical background values for Cu, Mn, and Ni will be used in this study are 38.9, 488, and 29 mg/kg respectively. Table 2 showed the classification of single pollution index.

| Single Pollution Index | Level of Contamination |
|------------------------|------------------------|
| \( \text{PI} \leq 1 \) | Low                    |
| \( 1 < \text{PI} \leq 3 \) | Moderate               |
| \( \text{PI} > 3 \) | High                   |

2.3.2 Potential Ecological Risk Index (RI). Potential Ecological Risk Index (RI) was applied for the assessment of the degree of ecological risk caused by heavy metal content in the soil. This index was introduced by Hakanson [12], and it is calculated using equation (2).

\[
\text{RI} = \sum_{i=1}^{n} E_i^i
\]
where $n$ is the number of heavy metals and $E_r$ is the single index of the ecological risk factor calculated based on equation (3).

$$E^*_i = T^*_i \times P_i$$

(3)

where $T^{*_i}$ is the toxicity response coefficient of an individual metal and $P_i$ is the calculated values for the Single Pollution Index. The assigned toxicity response coefficient of Cu, Mn and Ni are 5, 1, and 5 respectively [12]. Table 3 showed both the classification of potential ecological risk and ecological risk factor respectively.

| Risk Value | Level of Ecological Risk |
|------------|--------------------------|
| $RI < 150$ | Low                      |
| $150 \leq RI < 300$ | Moderate                 |
| $300 \leq RI < 600$ | Considerable             |
| $RI \geq 600$ | Very high                |

**Classification of ecological risk factor.**

| Risk Factor | Level of Ecological Risk Factor |
|-------------|---------------------------------|
| $< 40$      | Low                             |
| $40 \leq < 80$ | Moderate                      |
| $80 \leq < 160$ | Considerable               |
| $160 \leq < 320$ | High                         |
| $\geq 320$  | Very high                      |

2.3.3 Potential Health Risk Assessment

In order to start a health risk assessment, the average daily dose of each desired heavy metals through ingestion, inhalation and dermal contact were calculated. Potential health risk assessment were analysed by calculating the hazard quotient to assess the non-carcinogenic risks for each individual heavy metal via ingestion, inhalation and dermal contact, and the hazard index to assess the overall potential for non-carcinogenic effect from more than one heavy metal.

2.3.4 Exposure Assessment

The exposure of human to heavy metal was calculated based on the models developed by Environmental Protection Agency of United State (US EPA). According to the Exposure Factors Handbook, the average daily dose (ADD) of a pollutant through ingestion, inhalation and dermal contact can be estimated using equations (4), (5), and (6) respectively:

$$ADD_{ing} = \frac{c \times R_{ing} \times CF \times EF \times ED}{BW \times AT}$$

(4)

$$ADD_{inh} = \frac{c \times R_{inh} \times CF \times EF \times ED}{BW \times AT}$$

(5)

$$ADD_{derm} = \frac{c \times S \times CF \times SL \times ABS \times EF \times ED}{BW \times AT}$$

(6)
where $\text{ADD}_{\text{ing}}$ is daily exposure amount of metals through ingestion (mg/kg/day); $\text{ADD}_{\text{inh}}$ is daily exposure amount of metals through inhalation (mg/kg/day); $\text{ADD}_{\text{derm}}$ is daily amount of metals through dermal contact (mg/kg/day). The exposure factors for these models are showed in Table 4.

### Table 4. Exposure factors for dose models.

| Factor | Definition | Unit | Value | Reference |
|--------|------------|------|-------|-----------|
| $c$    | Concentration of the contaminant in soil | mg/kg | | This study |
| $R_{\text{ing}}$ | Ingestion rate of soil | mg/day | 200 | 100 |
| CF | Conversion factor | kg/mg | $1 \times 10^{-6}$ | $1 \times 10^{-6}$ |
| EF | Exposure frequency | days/year | 350 | 350 |
| ED | Exposure duration | years | 6 | 30 |
| BW | Average body weight | kg | 15 | 70 (male) 65 (female) |
| AT | Average time | days | $365 \times \text{ED}$ | $365 \times \text{ED}$ |
| $R_{\text{inh}}$ | Inhalation rate | m$^3$/day | 20 | 20 |
| SA | Exposure skin area | cm$^2$ | 1600 | 5700 |
| SL | Skin adherence factor for soil | mg/cm$^2$ | 0.02 | 0.07 |
| ABS | Dermal absorption factor (chemical specific) | - | 0.001 | 0.01 |

#### 2.3.5 Hazard Quotient (HQ)

Hazard Quotient (HQ) was calculated to assess the non-carcinogenic risks for each individual heavy metal via ingestion, inhalation, and dermal contact. The target hazard quotient was estimated using the equations (7), (8), and (9) below:

$$\text{HQ}_{\text{ing}} = \frac{\text{ADD}_{\text{ing}}}{\text{RfD}}$$

$$\text{HQ}_{\text{inh}} = \frac{\text{ADD}_{\text{inh}}}{\text{RfD}}$$

$$\text{HQ}_{\text{derm}} = \frac{\text{ADD}_{\text{derm}}}{\text{RfD}}$$

where ADD is the daily exposure amount of metals (mg/kg/day) and RfD is the reference dose of heavy metal (mg/kg/day). The respective RfD for Cu, Mn, and Ni are 0.04, 0.14 and 0.02 [13]. The value of HQ ≤ 1 indicates no adverse health effect and HQ > 1 indicates likely adverse health effects.

#### 2.3.6 Hazard Index (HI)

Hazard Index (HI) was calculated to assess the overall potential for non-carcinogenic effect from more than one heavy metal. The equation of hazard index is expressed as equation (10):

$$\text{HI} = \sum \text{THQ}_n$$
where THQ is the sum of HQ for each element and n is the number of elements.

3. Results and Discussion

3.1 Soil pH and Soil Organic Matter Content

It can be seen from the data in Table 5 that all the samples from these sampling sites were slightly alkaline. Soil pH of industrial area ranged from 7.98 – 8.34, for residential area ranged from 7.06 – 8.05 and for school area ranged from 7.63 – 8.24. Highest pH value obtained from I2 might be resulted from the nearby cement and concrete product manufacturing activities. Low soil pH holds an important role in increase available form of metals in soil where metallic elements have much higher mobility in high acidic soils as compared to neutral and alkaline soil. Thus, low level of soil heavy metal contamination can be predicted at these study areas.

The large amount of organic matter found in the soil was probably caused by the residues of leaves, plants and animal material returned to the soil. The soil organic matter content fell in the low level for study areas R2 and S2 while medium level for the rest. This indicated that the metals were less likely to form metal-chelate complexes by bounding to organic matter.

Table 5. Soil pH and organic matter content.

| Characteristic | Parameter | I1   | I2   | R1   | R2   | S1   | S2   |
|---------------|-----------|------|------|------|------|------|------|
| pH            | Mean      | 7.98 | 8.34 | 7.06 | 8.05 | 7.63 | 8.24 |
| OM (%)        | Mean      | 8.16 | 6.33 | 5.07 | 3.12 | 5.45 | 3.50 |

3.2 Heavy Metal Concentration in Soil

The mean concentration of Cu for I1 (15.45 mg/kg), I2 (14.29 mg/kg), R1 (14.35 mg/kg), R2 (17.43 mg/kg), S1 (14.18 mg/kg) and S2 (14.39 mg/kg) are presented in Table 6. The results obtained from the elemental analysis by AAS reported the mean concentration of Cu found from these study areas were lower than the background values (38.9 mg/kg) in soil as mentioned in the research by Kamarudzaman et al. [4]. In spite of that, the availability of Cu in these study areas might because of anthropogenic sources such as industrial, agricultural and transportation activities around them. There is numbers of agricultural lands with paddy crops available at the area of R2. Hence, the high concentration of Cu in R2 is probably affected by the agricultural practices such as application of Cu-based fertilisers and pesticides. Besides, sources of Cu concentration can be caused by atmospheric deposition and road traffic in industrial and school areas respectively where the soil sampling in this study was conducted mainly by the roadside.

Soil pH and organic matter content are dominantly affecting the availability of Cu in soil. In other word, Cu has higher solubility at both low soil pH and organic matter content [14]. Based on the results, Cu content was highly distributed in slightly alkaline (pH 8.05) soil with low soil organic matter content (3.12%) in this study. In overall, Cu concentration of the current research was comparable to the average Cu concentration in Perlis studied by Ripin et al. recorded at 240.59 mg/kg [8] but higher than the results obtained by Kamarudzaman et al. recorded at 9.834 mg/kg [4].

Table 6. Concentration of Cu.

| Element | Parameter | I1   | I2   | R1   | R2   | S1   | S2   |
|---------|-----------|------|------|------|------|------|------|
| Cu      | Mean      | 15.45| 14.29| 14.35| 17.43| 14.18| 14.39|
|         | SD        | 0.06 | 0.03 | 0.05 | 0.30 | 0.06 | 0.03 |
From Table 7, the mean concentration of Mn of all the study areas do not exceed the geochemical background value (488 mg/kg) in soil with the mean value of 31.42 mg/kg for I1, 57.80 mg/kg for I2, 53.41 mg/kg for R1, 38.20 mg/kg for R2, 53.44 mg/kg for S1 and 42.06 mg/kg for S2. The current study found that the mean concentration of Mn detected in all study areas was lower than the results as reported by previous study [4].

| Element | Parameter | I1  | I2  | R1  | R2  | S1  | S2  |
|---------|-----------|-----|-----|-----|-----|-----|-----|
| Mn      | Mean      | 31.42 | 57.80 | 53.41 | 38.20 | 53.44 | 42.06 |
|         | SD        | 0.04 | 0.37 | 0.56 | 0.18 | 0.15 | 0.12 |
|         | Min       | 31.37 | 57.39 | 52.80 | 37.99 | 53.27 | 41.94 |
|         | Max       | 31.45 | 58.10 | 53.91 | 38.31 | 53.55 | 42.16 |

The mean concentration of Ni of I1, I2, R1, R2, S1 and S2 were 0.40 mg/kg, 2.83 mg/kg, 1.43 mg/kg, 2.77 mg/kg, 2.06 mg/kg and 2.55 mg/kg respectively as shown in Table 8. In contrast to earlier findings in Perlis state, mean concentration of Ni in all the study areas was higher than that (2.40 mg/kg) as reported by Ripin et al. except for I1 and R1 [8] while 0.889 mg/kg for Kamarudzaman et al. except I1 [4]. Although Ni is naturally deposited in soil, yet traffic emission from heavy vehicles passed through I2 may also give large contribution in depositing of Ni in soil. However, it is apparent from the table below that the mean concentration of Ni of all the study areas was lower than the geochemical background value of Ni in soil of 29 mg/kg.

| Element | Parameter | I1  | I2  | R1  | R2  | S1  | S2  |
|---------|-----------|-----|-----|-----|-----|-----|-----|
| Ni      | Mean      | 0.40 | 2.83 | 1.43 | 2.77 | 2.06 | 2.55 |
|         | SD        | 0.51 | 0.08 | 0.21 | 0.12 | 0.19 | 0.26 |
|         | Min       | 0.00 | 2.75 | 1.23 | 2.65 | 1.85 | 2.26 |
|         | Max       | 0.81 | 2.92 | 1.65 | 2.90 | 2.23 | 2.71 |

Figure 2 illustrated that the highest concentration of Mn were detected in the studied areas, followed by Cu and Ni. High Mn concentration in this study might be attributed to vegetation activities, direct atmospheric deposition, shedding or excretion of material such as leaves, dead plant and animal material and animal excrement. However, all of these heavy metals concentration do not exceed their natural permissible limit in soil, indicating Perlis state is considered remaining at a safe level.
3.3 Soil Pollution Indices Assessment

3.3.1 Single Pollution Index (PI) Evaluation. The single pollution index was calculated by comparing the current and natural background concentration of the soil for each single heavy metal in this study. The geochemical background values of Cu (38.9 mg/kg), Mn (488 mg/kg) and Ni (29 mg/kg) were applied in this study according to the world soil average level recorded by Kamarudzaman et al. [4].

The mean values of PI of Cu in increasing order were S1 (0.3645) < I2 (0.3674) < R1 (0.3689) < S2 (0.3699) < I1 (0.3972) < R2 (0.4481) as shown in Table 9. The elemental analysis by AAS reported there is Cu content contained in these study areas, yet the assessment showed that the level of contamination in soil is low, which is practically unpolluted by Cu.

Table 9. Assessment of PI values of Cu.

| Study Area | PI   | Level of Contamination |
|------------|------|------------------------|
|            | Min  | Max        | Mean     |                      |
| I1         | 0.3954 | 0.3982   | 0.3972  | Low                  |
| I2         | 0.3668 | 0.3681   | 0.3674  | Low                  |
| R1         | 0.3674 | 0.3697   | 0.3689  | Low                  |
| R2         | 0.4416 | 0.4566   | 0.4481  | Low                  |
| S1         | 0.3627 | 0.3658   | 0.3645  | Low                  |
| S2         | 0.3692 | 0.3707   | 0.3699  | Low                  |

Table 10 suggested that the level of contamination due to Mn concentration in all studied area was found to be low with the mean PI values less than 1. The mean values of PI of Mn in decreasing order were I2 (0.1184) > S1 (0.1095) > R1 (0.1094) > S2 (0.0862) > R2 (0.0783) > I1 (0.0644).

Table 10. Assessment of PI values of Mn.
The results obtained from the analysis of single pollution indices performed the mean values of PI of Ni in decreasing order were I2 (0.0976) > R2 (0.0955) > S2 (0.0879) > S1 (0.0710) > R1 (0.0493) > I1 (0.0138) as recorded in Table 11. From the assessment, low level of soil contamination due to the presence of Ni was found in all the studied area.

Table 11. Assessment of PI values of Ni.

| Study Area | PI | Level of Contamination |
|------------|----|------------------------|
|            | Min | Max  | Mean  |            |
| I1         | 0.0643 | 0.0644 | 0.0644 | Low       |
| I2         | 0.1176 | 0.1191 | 0.1184 | Low       |
| R1         | 0.1082 | 0.1105 | 0.1094 | Low       |
| R2         | 0.0778 | 0.0785 | 0.0783 | Low       |
| S1         | 0.1092 | 0.1097 | 0.1095 | Low       |
| S2         | 0.0859 | 0.0864 | 0.0862 | Low       |

3.3.2. Potential Ecological Risk (RI) Evaluation. Table 12 recorded the mean values of ecological risk index were 2.1192 for I1, 2.4431 for I2, 2.2005 for R1, 2.7962 for R2, 2.2873 for S1 and 2.3755 for S2. The ecological risk indices were observed in the decreasing order of R2 > I2 > S2 > S1 > R1 > I1. The results obtained from this assessment revealing low level of ecological risk caused by concentration of studied heavy metals may pose to the studied areas in this study.

3.3.3 Potential Health Risk Assessment
It was considered that quantitative measures would be useful for potential health risk assessment due to the heavy metal content in soil. Exposure assessment was proceeded to estimate the average daily exposure amount of heavy metals via ingestion, inhalation and dermal contact as well as the analysis of both HQ and HI values for three categories of people including children, adult male and adult female.
Table 12. Assessment of potential ecological risk index.

| Study Area | RI   | Level of Ecological Risk |
|------------|------|--------------------------|
|            | Min  | Max  | Mean  |                  |
| I1         | 2.0411 | 2.1951 | 2.1192 | Low              |
| I2         | 2.4259 | 2.4631 | 2.4431 | Low              |
| R1         | 2.1570 | 2.2433 | 2.2005 | Low              |
| R2         | 2.7430 | 2.8613 | 2.7962 | Low              |
| S1         | 2.2418 | 2.3233 | 2.2873 | Low              |
| S2         | 2.3214 | 2.4071 | 2.3755 | Low              |

3.3.4 Exposure Assessment. Average daily exposure amount of Cu by children via ingestion ranged from $1.81 \times 10^{-4} - 2.23 \times 10^{-4}$ mg/kg/day, for Mn ranged from $4.02 \times 10^{-4} - 7.39 \times 10^{-4}$ mg/kg/day and for Ni ranged from $5.11 \times 10^{-6} - 3.62 \times 10^{-5}$ mg/kg/day. Adult male was estimated to expose $1.94 \times 10^{-5} - 2.39 \times 10^{-5}$ mg/kg/day of Cu, $4.30 \times 10^{-5} - 7.92 \times 10^{-5}$ mg/kg/day of Mn and $5.48 \times 10^{-7} - 3.88 \times 10^{-6}$ mg/kg/day of Ni via ingestion while adult female expose $2.09 \times 10^{-5} - 2.57 \times 10^{-5}$ mg/kg/day of Cu, $4.64 \times 10^{-5} - 8.53 \times 10^{-5}$ mg/kg/day of Mn and $5.90 \times 10^{-7} - 4.17 \times 10^{-6}$ mg/kg/day of Ni through the same exposure pathway. The results in Table 13 described children exposed to higher amount of studied heavy metals through ingestion as compared to both adult male and female, reflecting hand-to-mouth activities and play behaviour of children are probably led to the exposure of the heavy metals. Among the three studied heavy metals, both children and adults exposed to the highest amount of Mn, especially in I2.

Table 13. Average daily exposure amounts of heavy metals via ingestion.

| Study Area | Cu | Mn | Ni |
|------------|----|----|----|
|            | C  | AM | AF | C  | AM | AF | C  | AM | AF |
| I1         | 1.98E-04 | 2.12E-04 | 2.28E-04 | 4.02E-04 | 4.30E-04 | 4.64E-04 | 5.11E-04 | 5.48E-04 | 5.90E-04 |
| I2         | 1.83E-04 | 1.96E-04 | 2.11E-04 | 7.39E-04 | 7.92E-04 | 8.53E-04 | 3.62E-04 | 3.88E-04 | 4.17E-04 |
| R1         | 1.83E-04 | 1.97E-04 | 2.12E-04 | 6.83E-04 | 7.32E-04 | 7.88E-04 | 1.83E-04 | 1.96E-04 | 2.11E-04 |
| R2         | 2.23E-04 | 2.39E-04 | 2.57E-04 | 4.88E-04 | 5.23E-04 | 5.64E-04 | 3.54E-04 | 3.79E-04 | 4.09E-04 |
| S1         | 1.81E-04 | 1.94E-04 | 2.09E-04 | 6.83E-04 | 7.32E-04 | 7.88E-04 | 2.63E-04 | 2.82E-04 | 3.04E-04 |
| S2         | 1.84E-04 | 1.97E-04 | 2.12E-04 | 5.38E-04 | 5.76E-04 | 6.20E-04 | 3.26E-04 | 3.49E-04 | 3.76E-04 |

|            | 04  | 05  | 05  | 04  | 05  | 05  | 05  | 05  | 05  |
|------------|----|----|----|----|----|----|----|----|----|
| I1         | 05  | 05  | 05  | 05  | 05  | 05  | 05  | 05  | 05  |
| I2         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| R1         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| R2         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| S1         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| S2         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |

|            | 04  | 05  | 05  | 05  | 05  | 05  | 05  | 05  | 05  |
|------------|----|----|----|----|----|----|----|----|----|
| I1         | 05  | 05  | 05  | 05  | 05  | 05  | 05  | 05  | 05  |
| I2         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| R1         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| R2         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| S1         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |
| S2         | 04  | 05  | 04  | 05  | 05  | 05  | 05  | 05  | 05  |

a Children  
b Adult Male  
c Adult Female
mg/kg/day of Ni via inhalation while adult female expose $4.18 \times 10^6 - 5.14 \times 10^6$ mg/kg/day of Cu, $9.27 \times 10^6 - 1.71 \times 10^5$ mg/kg/day of Mn and $1.18 \times 10^7 - 8.35 \times 10^5$ mg/kg/day of Ni through the same exposure pathway. The assessment noticed that both children and adults have possibilities to expose highest amount of Cu via inhalation in R2. This is because the soil in R2 might probably contaminated with Cu due to the land application of fertilizers and pesticides.

### Table 14. Average daily exposure amount of heavy metals via inhalation.

| Study | Area | Cu   | Mn   | Ni    |
|-------|------|------|------|-------|
|       | C    | AM   | AF   | C     | AM   | AF   | C     | AM   | AF   |
| I1    | 1.98E-05 | 4.23E-05 | 4.56E-05 | 4.02E-05 | 8.61E-05 | 9.27E-05 | 5.11E-05 | 1.10E-05 | 1.18E-05 |
| I2    | 1.83E-05 | 3.92E-05 | 4.22E-05 | 7.39E-05 | 1.58E-05 | 1.71E-05 | 3.62E-05 | 7.75E-05 | 8.35E-05 |
| R1    | 1.83E-05 | 3.93E-05 | 4.23E-05 | 6.83E-05 | 1.46E-05 | 1.58E-05 | 1.83E-05 | 3.92E-05 | 4.22E-05 |
| R2    | 2.23E-05 | 4.78E-05 | 5.14E-05 | 4.88E-05 | 1.05E-05 | 1.13E-05 | 3.54E-05 | 7.59E-05 | 8.17E-05 |

| Study | Area | Cu   | Mn   | Ni    |
|-------|------|------|------|-------|
|       | C    | AM   | AF   | C     | AM   | AF   | C     | AM   | AF   |
| S1    | 1.81E-05 | 3.88E-05 | 4.18E-05 | 6.83E-05 | 1.46E-05 | 1.58E-05 | 2.63E-05 | 5.64E-05 | 6.08E-05 |
| S2    | 1.84E-05 | 3.94E-05 | 4.25E-05 | 5.38E-05 | 1.15E-05 | 1.24E-05 | 3.26E-05 | 6.99E-05 | 7.52E-05 |

- **Children**
- **Adult Male**
- **Adult Female**

Average daily exposure amount of Cu by children via dermal contact ranged from $2.90 \times 10^8 - 3.57 \times 10^8$ mg/kg/day, for Mn ranged from $6.43 \times 10^8 - 1.18 \times 10^7$ mg/kg/day and for Ni ranged from $8.18 \times 10^9 - 5.79 \times 10^9$ mg/kg/day. Adult male was estimated to expose $7.75 \times 10^7 - 9.53 \times 10^7$ mg/kg/day of Cu, $1.72 \times 10^8 - 3.16 \times 10^6$ mg/kg/day of Mn and $2.19 \times 10^8 - 1.55 \times 10^7$ mg/kg/day of Ni via dermal contact while adult female expose $8.35 \times 10^7 - 1.03 \times 10^6$ mg/kg/day of Cu, $1.85 \times 10^6 - 3.40 \times 10^6$ mg/kg/day of Mn and $2.35 \times 10^8 - 1.67 \times 10^7$ mg/kg/day of Ni through the same exposure pathway. There are many ways to expose heavy metals due to dermal contact from soil such as working, playing and agricultural activities. The exposure assessment data in Table 15 showed the studied heavy metals in negligible amount via dermal contact in this study.

#### 3.3.5 Hazard Quotient (HQ).

Table 16 showed the values of HQ of Cu for children, adult male and adult female via ingestion were ranged from $4.53 \times 10^3 - 5.57 \times 10^3$, $4.86 \times 10^4 - 5.97 \times 10^4$ and $5.23 \times 10^4 - 6.43 \times 10^4$ mg/kg/day respectively. The HQ values of Mn via ingestion were ranged from $2.87 \times 10^3 - 5.28 \times 10^3$ for children, $3.07 \times 10^4 - 5.66 \times 10^4$ mg/kg/day for adult male and $3.31 \times 10^4 - 6.09 \times 10^4$ mg/kg/day for adult female. The HQ values of Ni via ingestion were ranged from $2.56 \times 10^4 - 1.81 \times 10^5$ mg/kg/day for children, $2.74 \times 10^5 - 1.94 \times 10^4$ mg/kg/day for adult male and $2.95 \times 10^3 - 2.09 \times 10^4$ mg/kg/day for adult female. The values of HQ shown in Table 19 were less than 1, reflecting negligible risks were found from the studied metals via ingestion.
### Table 15. Average daily exposure amount of heavy metals via dermal contact

| Study | Cu     | Mn     | Ni     |
|-------|--------|--------|--------|
| Area  | C      | AM     | AF     | C      | AM     | AF     | C      | AM     | AF     |
| I1    | 3.16E- | 8.44E- | 9.09E- | 6.43E- | 1.72E- | 1.85E- | 8.18E- | 2.19E- | 2.35E- |
|       | 08     | 07     | 07     | 08     | 06     | 06     | 10     | 08     | 08     |
| I2    | 2.92E- | 7.81E- | 8.41E- | 1.18E- | 3.16E- | 3.40E- | 5.79E- | 1.55E- | 1.67E- |
|       | 08     | 07     | 07     | 07     | 06     | 06     | 09     | 08     | 07     |
| R1    | 2.94E- | 7.84E- | 8.45E- | 1.09E- | 2.92E- | 3.14E- | 2.93E- | 7.82E- | 8.42E- |
|       | 08     | 07     | 07     | 07     | 06     | 06     | 09     | 08     | 08     |
| R2    | 3.57E- | 9.53E- | 1.03E- | 7.81E- | 2.09E- | 2.25E- | 5.67E- | 1.51E- | 1.63E- |
|       | 08     | 07     | 06     | 08     | 06     | 06     | 09     | 07     | 07     |
| S1    | 2.90E- | 7.75E- | 8.35E- | 1.09E- | 2.92E- | 3.15E- | 4.21E- | 1.13E- | 1.21E- |
|       | 08     | 07     | 07     | 07     | 06     | 06     | 09     | 07     | 07     |
| S2    | 2.94E- | 7.87E- | 8.47E- | 8.60E- | 2.30E- | 2.48E- | 5.22E- | 1.39E- | 1.50E- |
|       | 08     | 07     | 07     | 08     | 06     | 06     | 09     | 07     | 07     |

* Children
* Adult Male
* Adult Female

### Table 16. Hazard quotient of heavy metals via ingestion.

| Study | Cu     | Mn     | Ni     |
|-------|--------|--------|--------|
| Area  | C      | AM     | AF     | C      | AM     | AF     | C      | AM     | AF     |
| I1    | 4.94E- | 5.29E- | 5.70E- | 2.87E- | 3.07E- | 3.31E- | 2.56E- | 2.74E- | 2.95E- |
|       | 03     | 04     | 04     | 03     | 04     | 04     | 04     | 05     | 05     |
| I2    | 4.57E- | 4.89E- | 5.27E- | 5.28E- | 5.66E- | 6.09E- | 1.81E- | 1.94E- | 2.09E- |
|       | 03     | 04     | 04     | 03     | 04     | 04     | 03     | 04     | 04     |
| R1    | 4.59E- | 4.91E- | 5.29E- | 4.88E- | 5.23E- | 5.63E- | 9.14E- | 9.79E- | 1.05E- |
|       | 03     | 04     | 04     | 03     | 04     | 04     | 03     | 04     | 04     |
| R2    | 5.57E- | 5.97E- | 6.43E- | 3.49E- | 3.74E- | 4.03E- | 1.77E- | 1.90E- | 2.04E- |
|       | 03     | 04     | 04     | 03     | 04     | 04     | 03     | 04     | 04     |
| S1    | 4.53E- | 4.86E- | 5.23E- | 4.88E- | 5.23E- | 5.63E- | 1.32E- | 1.41E- | 1.52E- |
|       | 03     | 04     | 04     | 03     | 04     | 04     | 03     | 04     | 04     |
| S2    | 4.60E- | 4.93E- | 5.31E- | 3.84E- | 4.12E- | 4.43E- | 1.63E- | 1.75E- | 1.88E- |
|       | 03     | 04     | 04     | 03     | 04     | 04     | 03     | 04     | 04     |

* Children
* Adult Male
* Adult Female

The values of HQ of Cu for children, adult male and adult female via inhalation were ranged from $4.53 \times 10^{-4}$ – $5.57 \times 10^{-4}$, $9.71 \times 10^{-5}$ – $1.19 \times 10^{-4}$ and $1.05 \times 10^{-4}$ – $1.29 \times 10^{-4}$ mg/kg/day respectively. The HQ values of Mn via inhalation were ranged from $2.87 \times 10^{-4}$ – $5.28 \times 10^{-4}$ for children, $6.15 \times 10^{-5}$ – $1.13 \times 10^{-4}$ mg/kg/day for adult male and $6.62 \times 10^{-5}$ – $1.22 \times 10^{-4}$ mg/kg/day for adult female. The HQ values of Ni via inhalation were ranged from $2.56 \times 10^{-5}$ – $1.81 \times 10^{-4}$ mg/kg/day for children, $5.48 \times 10^{-6}$ – $3.88 \times 10^{-5}$ mg/kg/day for adult male and $5.90 \times 10^{-6}$ – $4.17 \times 10^{-5}$ mg/kg/day for adult female.
values of HQ shown in Table 17 were less than 1, reflecting negligible risks were found from the studied metals via inhalation.

### Table 17. Hazard quotient of heavy metals via inhalation.

| Study | Area | Cu        | Mn        | Ni        |
|-------|------|-----------|-----------|-----------|
|       | C    | AM | AF | C    | AM | AF | C    | AM | AF |
| I1    | 4.94E-04 | 1.06E-04 | 2.87E-04 | 6.15E-05 | 2.56E-05 | 5.48E-05 | 5.90E-05 |
|       | 0.07  | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| I2    | 4.57E-04 | 9.79E-04 | 5.28E-04 | 1.22E-04 | 1.81E-04 | 3.88E-04 | 4.17E-04 |
|       | 0.04  | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| R1    | 4.59E-04 | 9.83E-04 | 4.88E-04 | 1.05E-04 | 1.13E-04 | 9.14E-04 | 1.96E-04 |
|       | 0.04  | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| R2    | 5.57E-04 | 1.19E-04 | 3.49E-04 | 7.48E-04 | 8.05E-04 | 1.77E-04 | 3.79E-04 |
|       | 0.04  | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| S1    | 4.53E-04 | 9.71E-04 | 4.88E-04 | 1.05E-04 | 1.13E-04 | 1.32E-04 | 2.82E-04 |
|       | 0.04  | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| S2    | 4.60E-04 | 9.86E-04 | 3.84E-04 | 8.23E-04 | 8.86E-04 | 1.63E-04 | 3.49E-04 |
|       | 0.04  | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |

a Children  
b Adult Male  
c Adult Female

The values of HQ of Cu for children, adult male and adult female via dermal contact were ranged from 7.25×10^{-7} – 8.91×10^{-7}, 1.94×10^{-5} – 2.38×10^{-5} and 2.09×10^{-5} – 2.56×10^{-5} mg/kg/day respectively. The HQ values of Mn via dermal contact were ranged from 4.59×10^{-7} – 8.45×10^{-7} for children, 1.23×10^{-5} – 2.26×10^{-5} mg/kg/day for adult male and 1.32×10^{-5} – 2.43×10^{-5} mg/kg/day for adult female. The HQ values of Ni via dermal contact were ranged from 4.09×10^{-8} – 2.89×10^{-7} mg/kg/day for children, 1.09×10^{-6} – 7.73×10^{-6} mg/kg/day for adult male and 1.18×10^{-6} – 8.33×10^{-6} mg/kg/day for adult female. The values of HQ shown in Table 18 were definitely less than 1, reflecting negligible risks were found from the studied metals via dermal contact.

### Table 18. Hazard quotient of heavy metals via dermal contact.

| Study | Area | Cu        | Mn        | Ni        |
|-------|------|-----------|-----------|-----------|
|       | C    | AM | AF | C    | AM | AF | C    | AM | AF |
| I1    | 7.90E-07 | 2.11E-07 | 2.27E-07 | 4.59E-07 | 1.23E-07 | 1.32E-07 | 4.09E-07 | 1.09E-07 | 1.18E-07 |
|       | 0.05  | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |
| I2    | 7.31E-07 | 1.95E-07 | 2.10E-07 | 8.45E-07 | 2.26E-07 | 2.43E-07 | 2.89E-07 | 7.73E-07 | 8.33E-07 |
|       | 0.05  | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |
| R1    | 7.34E-07 | 1.96E-07 | 2.11E-07 | 7.80E-07 | 2.09E-07 | 2.25E-07 | 1.46E-07 | 3.91E-07 | 4.21E-07 |
|       | 0.05  | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |
| R2    | 8.91E-07 | 2.38E-07 | 2.56E-07 | 5.58E-07 | 1.49E-07 | 1.61E-07 | 2.83E-07 | 7.57E-07 | 8.15E-07 |
|       | 0.05  | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |
| S1    | 7.25E-07 | 1.94E-07 | 2.09E-07 | 7.81E-07 | 2.09E-07 | 2.25E-07 | 2.11E-07 | 5.63E-07 | 6.06E-07 |
|       | 0.05  | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |
| S2    | 7.36E-07 | 1.97E-07 | 2.12E-07 | 6.15E-07 | 1.64E-07 | 1.77E-07 | 2.61E-07 | 6.97E-07 | 7.50E-07 |
|       | 0.05  | 0.05 | 0.07 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |

a Children  
b Adult Male
c) Adult Female

3.3.6 Hazard Index (HI). Based on the health risk assessment, hazard index for children was ranged from $0.0089 - 0.0128$, for adult male ranged from $0.0011 - 0.0015$ while for adult female ranged from $0.0012 - 0.0017$. Figure 3 illustrated that children have higher chance to pose non-carcinogenic risk as compared to those adults. Earlier study reported the similar result with the present study and justified that children face greater impact due to ingestion of contaminated soil than adults because of their small body weight [13]. From the assessment, it was investigated that the hazard index is depending on the human body weight. The order of HI values in this study was found in decreasing trend: Children > Adult male > Adult female.

![Hazard Index for Children, Adult Male and Adult Female at Study Areas](image)

**Figure 3.** Hazard index for children, adult male and adult female at study areas.

4. Conclusion

Experimental data have been obtained and detailed soil contamination level of study areas in Perlis state have been assessed through soil pollution indices such as single pollution index and potential ecological risks. By measuring the heavy metal concentration in soil, the potential health risk assessment is assessed in the present study.

The soil pH in the study areas falls in the range of $7.06 - 8.34$ while the soil organic matter content is ranged from $3.12\% - 8.16\%$. Among all study areas, it was found that R2 is enriched in Cu with the concentration of $17.43\ mg/kg$. This implied that the application of agrochemical fertilizers and pesticides has contributed the Cu content to the soil. The highest mean concentration of Mn and Ni is $57.80\ mg/kg$ and $2.83\ mg/kg$ respectively in I2. Cement and concrete product manufacturing activities conducting in I2 probably led to the elevated concentration of Mn and Ni by atmospheric deposition as well as traffic emission. Overall, the mean concentration of heavy metals observed in this study is in the following decreasing trend: Mn > Cu > Ni.
From the soil pollution indices assessment, the PI values of Cu, Mn and Ni at all study areas which less than 1 reflected that the metals were found safe. In addition, the potential ecological risk evaluation exhibited low degree of ecological risk caused by the heavy metal in the soil, indicating the studied areas were in safe level and were less influenced by human activities. Humans are possibly exposed to heavy metals via ingestion, inhalation and dermal contact. Among these routes, the exposure assessment in this study showed that ingestion is the main exposure pathway of heavy metals to both children and adults, followed by inhalation and dermal contact. The values of HQ for those pathways of this study showed in the similar order. The values of HI for children are significantly higher as compared to adults, meaning that children face greater harmful health effects than adults if the soil is contaminated, suggesting that exceptional attention should be paid. In conclusion, the heavy metals content in soil pose negligible non-carcinogenic risk to the people living in the study areas since both the HQ values for single metals and the HI values for all studied metals are well below the permissible level for children and adults, indicating no danger from these metals.

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