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Original Article

Health Risk Assessment on Bioavailability of Heavy Metals in Klang District Urban Surface Soil

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Abstract

Background: The aim of this study was to determine bioavailability heavy metal concentrations of Cu, Cd, Cr, Co and Zn and health risk assessment in different types of Klang district, Selangor (Malaysia) urban surface soil using in Physiologically Based Extraction Test in vitro human digestion model.

Methods: A total of 76 urban surface soil was sampled based on seven different types of land use, namely, industrial, residential, agriculture, town area, port, school and mangrove. For bioavailability of heavy metal concentration, the soil solution was analysed using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES).

Results: Heavy metal concentrations for this study were in the following order: Zn, Cu, Co, Cd and Cr. Results of bioavailability heavy metal concentration from ICP-OES was used to establish Hazard Quotient in order to determine non-cancer risk. The results of Hazard Quotient are < 1 for all surface soil samples.

Conclusion: All the soil samples in Klang district are safe from the non-cancer risk to human.

Keywords: Heavy metal, Bioavailability, Health risk assessment

Introduction

Urban soils, which sometime called as a "developed land", are the soils that are found within a city, town or metropolitan area (1). As stated by some studies, sources of heavy metal in environment are mainly generated from anthropogenic sources (2-4). In urban soil, traffic emission, industrial emission, domestic emission, building weathering, atmospheric deposition, waste disposal, urban effluent, vehicle exhausts, sewage sludge and application of pesticides and fertilizers are the anthropogenic sources of heavy metal (2-7).

Urban soil serve as a sink for heavy metal contamination (1) and heavy metal can accumulate in soil from elevated emissions and their deposition over time may lead to abnormal enrichment that can cause heavy metal contamination of the soil (8). Human population may get toxic effect if exposed to these elements at trace level. Generally, exposure of children to heavy metal was accepted as highest risk group in the urban population because children have a higher adsorption rate of heavy metal due to their accidental ingestion of soil particles from hand-to-mouth activities (8, 9).

For heavy metal determination in soil, total heavy metal concentration is commonly measured (10, 11). Total heavy metal determination will overestimate pollution level (12). Total heavy metal concentration is insufficient for exposure and health risks assessment as well as inadequate for toxic effect determination meanwhile by using bioavailability of heavy metal concentration via Physiologically Based Extraction Test in vitro digestion model will provides exposure that is more realistic and health risk assessment (13).

This study aimed to determine bioavailability of heavy metal concentration (Cu, Cd, Cr, Co and Zn) in urban surface soil of Klang. In addition, this study also aimed to assess non-cancer risk of the heavy metal to human using the health risk assessment through ingestion pathway.

Materials and Methods

Seventy six urban surface soil samples were collected in Klang District, Selangor, Malaysia based on their different soil activities which industrial, residential, agriculture, town area, port, school and mangrove (Fig. 1). Sampling sites were chosen randomly based on description of sampling site and its activity. At each sampling site, urban surface soil, from the top of 5 cm layer was randomly collected using a stainless steel scoops and then placed in a polyethylene bag for transportation to the laboratory. Then, the urban surface soil samples were air-dried for one week and homogenize using pestle and mortar. After the homogenization process, the urban surface soil samples were then passed through 2 mm mesh screen and stored in polyethylene bags.

In order to prevent uncertain contaminations and to ensure the apparatus were clean to use before analysis, all laboratory equipment's used were left in 10% HNO_3 for 24 hours and were then rinsed three times with deionized water and left to dry at room temperature (14). In addition, all of the chemical especially enzyme were stored in its storage temperature before and after used in order to prevent from denatured.

In order to determine heavy metal bioavailability for human exposure, Physiologically Based Extraction Test in vitro digestion model described by (15) was adapted in this study. Simulation of the condition of stomach and intestine in human are the most important part in this study. Gastric solution for this model was prepared by adding 3 ml of NaCl, 0.5g of malate, 0.430 mL of lactic acid, 0.5 mL of acetic acid and 1.25 g of pepsin (Sigma Chemical Co.) into 1 L of deionized water and with pH of 1.5 using 12 M HCl. One g of soil was added into 50 mL plastic centrifuge tube and 30 mL of prepared gastric solution was added and shaken with shaker using 55 rpm for 1 hour at 37°C. Simulation of gastric condition was changed to intestinal condition by adjusting pH to 7.0 using 1 M NaOH and 0.06g of porcine bile extract and 0.018g of porcine pancreatin (Sigma Chemical Co.) was added. During the intestinal condition simulation, the urban surface soil samples were shaken with same shaker used previously at 3300 rpm for 10 minutes at 37°C. Then, the supernatant was filtered through a 0.45μm Millipore filter in order to reduce any effects from microbial activity (15).

Health risk assessment is a model developed to estimate the risk posed to human that cause by contaminants. Health risk assessment contains of four main components, which are hazard identification, exposure assessment, dose-response assessment and risk characterization. In order to evaluate health risk assessment through ingestion exposure pathways adults, the average daily dose (ADD) (mg/kg/day) of a contaminant was applied and equations 1 was used in the estimation of ADD via ingestion exposure pathways.

Equation 1:

$$ADD_{ingest} = \frac{C_{soil} \text{ X IngR X EF X ED}}{\text{BW X AT}} \text{ X CF}$$

The Exposure Factors Handbook were used as a main guide in order to obtain the IngR, EF, ED and AT values in ADD calculation for soil. Then, potential health risk (non-cancer risk) was deter-

mined by using equations 2 and the oral RfD values from Integrated Risk Information System (IRIS) was used. After that, the hazard quotient (HQ) value was compared with the following values of risk acceptability for non-carcinogenic health effects. In cases where the non-cancer risk does not exceed unity (HI < 1), it is assumed that no chronic risks are likely to occur at the site.
Equation 2:
Hazard Quotient (Non cancer risk) = ADD/RfD

Results

Table 1 show the mean and SD values of heavy metal concentrations (Cu, Cd, Cr, Co and Zn) in Klang. Heavy metal concentrations for this study were in the following order Zn, Cu, Co, Cd and Cr. The highest heavy metal concentration in Klang urban surface soil are Zn while the lowest heavy metal concentration in Klang urban surface soil are Cr. For the health risk assessment in this study, result of HQ showed that heavy metal contamination in Klang and Kapar, Klang District may not pose a non-cancer health risk to human via soil ingestion because the HQ value in this study were below than 1.

Table 1: Mean and SD values of heavy metal concentrations (Cu, Cd, Cr, Co and Zn) in urban surface soil of Klang district (mg/kg)

Elements	Mean±SD
Cu	3.0±6.9
Cd	0.14±0.10
Cr	0.10±0.072
Co	0.22±0.14
Zn	5.6±6.1

Table 2: Mean and SD values for HQ (non-cancer risk) in each studied heavy metal using Klang district urban surface soil samples

Elements	Mean±SD
Cu	0.00012±0.00028
Cd	0.00021±0.00015
Cr	5.1E-05±3.7E-05
Co	1.7E-05±1.1E-05
Zn	2.9E-05±3.1E-05

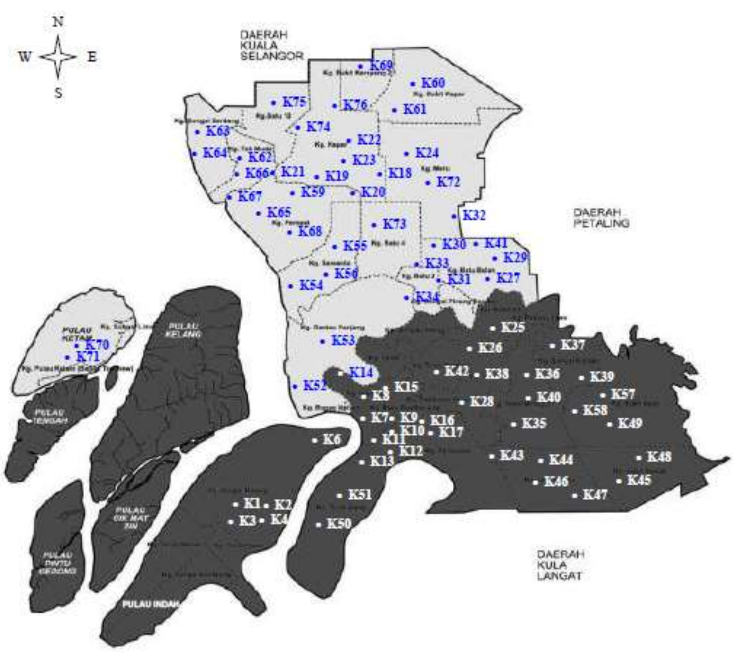

Fig. 1: Location of Klang District

Discussion

Concentration of Cu is because of the use of copper-based Fungicides and Cu that is strongly bound to organic material, might have been added as a contaminant with organic soil adjustments (16). For Cd, the concentrations of Cd are related to anthropogenic sources, which are atmospheric deposition which depends on the distance from emitting sources (10). Furthermore, the main sources of heavy metal contamination in Klang were industrial wastewater and port activities (17). In addition, major sources of Cd atmospheric emissions can be related to non-ferrous metal production as well as iron and steel production (5). Meanwhile for Zn, the concentration of Zn in urban area is due to the traffic emission in urban area (18). For Cr, the concentration of Cr is highest in the mangrove because of their location which are at the boundary between land and sea and mangroves obtain large amounts of sewage emanating from rivers through estuaries (19). In addition, mangroves which located under demographic pressure that are combined with industrial development, has cause to the release of heavy metal into the environment. For Co concentration, the contribution of Co in environment is due to the industrial waste emission (20).

Heavy metal concentrations in soil are insufficient to describe health risk arises from the exposure (21). Thus, a health risk assessment needs to be conducted in order to measure the risk of heavy metal pollution in human. In this study, HQ has been calculated in order to measure the health effect of heavy metal to human and result in this study showed that not all soil samples in Klang District may pose any non-cancer effect to human and it is safe to the human.

Conclusion

Heavy metal concentrations for this study were in the following order Zn, Cu, Co, Cd and Cr. For the health risk assessment in this study, result of HQ showed that heavy metal contamination in, Klang District might not pose a non-cancer health risk to human via soil ingestion.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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