DETERMINATION OF SELECTED HEAVY METALS CONCENTRATION IN PALM OIL SOIL

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ABSTRACT

Heavy metal occurs naturally in soil but anthropogenic influenced such as agricultural, mining and industrial activities could enhance the concentration in soil. The application of chemical fertilizer in agricultural land can increase the level of heavy metal. This study was carried out in a palm oil plantation to determine the availability of selected heavy metal in soil and to estimate the heavy metal pollution level. The soil samples were collected in triplicates using a hand auger, samples then were digested and heavy metal were analyzed using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). Geo-accumulation index (Igeo) was used to assess the degree of heavy metal contamination. Heavy metal concentration range were as follow; 0.76 – 2.00 mg/kg for Cu, 0.29 – 1.58 mg/kg for Zn, 0.07 – 0.22 mg/kg for Pb and 0.01 – 0.05 mg/kg for Ni. Cu concentration was found to be higher than other metal concentrations. The accumulation of Cu and Zn in soil perhaps related to the application of chemical fertilizers. All samples showed Igeo value less than 2 indicating the soil were uncontaminated. This suggests the application of chemical fertilizer is still under controlled. Nevertheless, it should be noted that a comprehensive study is required for more metal analysis such as As and Cd as well as the distribution pattern of metal in agricultural soil to evaluate the toxicity level.

Keywords: Agricultural land, chemical fertilizer, geo-accumulation index, heavy metal.

INTRODUCTION

Soil pollution is occurring since the last few decades which become environmental concern especially in developed countries [1]. Soil contains organic matter, mineral particles, water, air and living organisms. Soil that contaminated by heavy metal becomes the main types of soil pollution especially involving agricultural soil. In the agricultural soils such as palm oil plantation, generally a great amount of chemical product is consumed whether as fertilizers or pesticides. This application contributes to the abundance of heavy metals such as cadmium (Cd), lead (Pb) and arsenic (As) [2]. In fact, application of fertilizers does not only serve for plant nutrients, however it can alter the bioavailability of heavy metals in soil [3]. The nitrogen fertilizers application at palm oil plantation contributes the release of nitrous oxide (N_2O) [4]. Soil that polluted by heavy metals creates adverse impact to human and other living organisms through high carcinogenic and noncarcinogenic [5].

The excessive use of chemical fertilizers in agricultural activities contributed to the environmental problem especially in soil. The abundance of chemical fertilizers can alter the soil properties such as pH and surface charge or directly react with heavy metal ions in soil. Other than that, excess amount of fertilizer contributes negative impacts such as leaching, pollution of water resources as well as destruction of micro-organisms in soil fertility [6].

It is important to note that increased heavy metal contents can directly affect the public health through food intake, direct ingestion, and dermal contact, especially for children [7]. This is necessary to determine the concentration of the metals uptake in agricultural soil. Thus, this study is carried out in a palm oil plantation area in Jengka 8, Pahang as a pilot study to determine the selected heavy metal concentrations.

METHODOLOGY

Study Site

Soil samples were collected around palm oil plantation which area of 33.64 ha at Felda Jengka 8, Pahang (Figure 1). FELDA Jengka or generally known as Jengka Triangle was first formed in 1967. The area is located in the east coast state of Pahang, Malaysia. Most of the people reside in the area are fully involved in the agricultural activities especially related to rubber trees and palm oil. Agricultural activities in this area have been applying the modern farming approach where various types of pesticides and chemical fertilizers have been widely used.

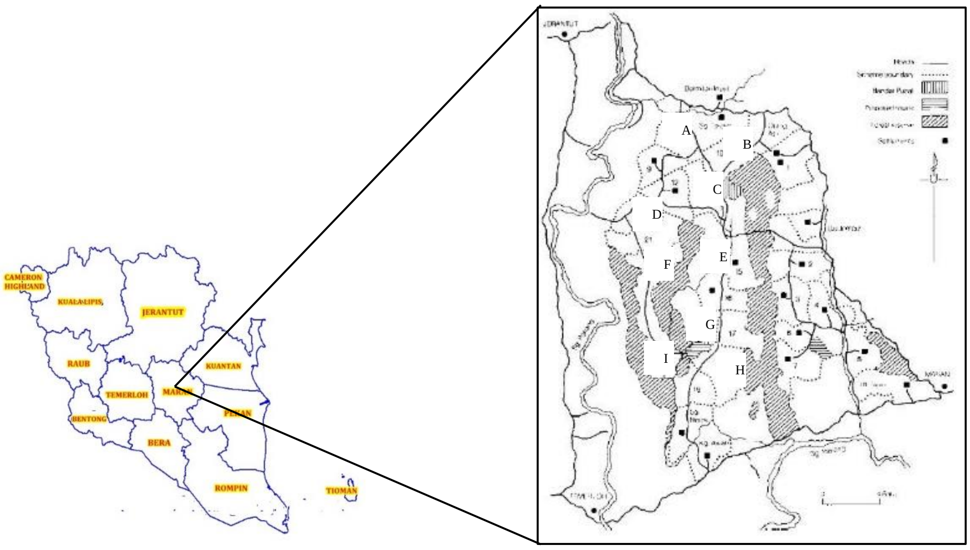

Figure 1. Sampling location in Felda Jengka 8, Pahang.

Sample Collection and Preparation

Soil samples were collected from nine different points which were indicated with A, B, C, D, E, F, G, H and I as shown in Figure 1. The soil samples were collected as triplicates to a depth of range 0 – 45 cm using the hand auger within a 9 m radius between two palm oil trees. The soils collected were followed the schematic triangular method proposed by [4] as seen in Figure 2. All soil samples were collected during sunny day and after application of fertilizers. Then, it was stored in polyethylene bags. Control soil sample was collected from undisturbed area and not involved in any agricultural and fertilizer activities as a background value of the metal for this study.

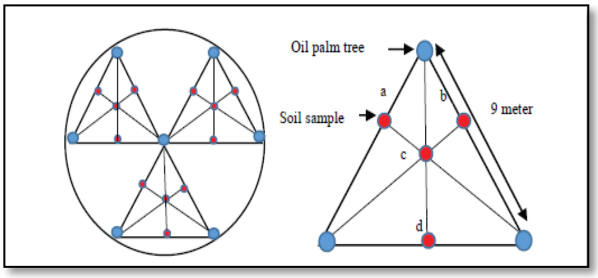

Figure 2. Schematic triangular sampling of soil modified from Mat Akhir et al. (2015).

The soil samples were sieved with 2 mm sieve to remove leaves, roots and stones. The collected soil samples were dried in room temperature for 3 days. The samples were ground into fine particles using mechanical grinder. Then, the samples were digested by wet digestion method. About 1.0 g of sample was weighed. The soil samples were digested with a mix of 6 ml of nitric acid, HNO_3 (65%) and 2 ml of hydrogen peroxide, H_2O_2 (30%). The mixture was heated on hot plate at 130^0C for 2 hours until complete solubilisation. After that, the mixture was filtered through Whatman 42 filter paper. The filtered samples were diluted with deionized water until calibration mark by using 50 ml volumetric flask. The soil samples were acidified with nitric acid to pH less than 2 and stored to 4°C in refrigerator for preservation to avoid or to minimise biological, chemical or physical changes that can occur between time of collection and analysis [8].

Metal Analysis

The heavy metal concentration of the solutions was determined by Inductively Coupled Plasma- Optical Emission Spectrometer (Agilent Technologies 5100 ICP-OES). The standard solution that used for calibration was prepared by diluting a stock solution of 100 mg/L (Cu, Zn, Pb and Ni). The standard solution with 0.5, 1.5, 2.5, 3.5 and 4.5 ppm were prepared. The soil samples were run simultaneously. The same procedure also used for control soil. Quality assurance and quality control (QA/QC) is required to produce consistent and representative data [9, 10]. Three replications were conducted for each sample. QA/QC for metals in agricultural soils were estimated by determining metal contents in the standard reference material as recommended by the World Health Organization (WHO).

RESULTS AND DISCUSSION

Heavy Metal Concentration in Analyzed Soil Samples

Four heavy metals concentrations (Cu, Zn, Pb, and Ni) were determined. Table 1 shows the concentration of heavy metal in soil samples in mg/kg. The concentration of Cu had the highest value for each point of soil samples as expected. The heavy metal concentration range for the studied metals were observed as follows, 0.76 – 2.00 mg/kg for Cu, 0.29 – 1.58 mg/kg for Zn, 0.07 – 0.22 mg/kg for Pb and 0.01 – 0.05 mg/kg for Ni. The highest average Cu content in soil for point B was 2.00 mg/kg. The lowest Cu concentration was determined in control soil (0.76 mg/kg). The highest concentration of Zn was found in point B soil (1.58 mg/kg) as seen in Table 1. While, the average concentration of Pb in soil was higher at point B was 0.22 mg/kg compared with other points. For Ni, all soil samples had very low concentration for this metal. The soil that contained highest amount of Ni at point B was 0.05 mg/kg. It can indicate that point B soil supposedly more contaminated by heavy metal compare to other points.

Table 1. Concentration of heavy metal in soil samples in mg/kg (mean±SD).

Soil samples	Cu	Zn	Pb	Ni
Point A	0.91±0.13	0.46±0.19	0.12±0.03	0.02±0.007
Point B	2.00±0.19	1.58±0.73	0.22±0.04	0.05±BDL
Point C	1.18±0.22	0.55±0.32	0.09±0.02	0.02±0.007
Point D	1.53±0.66	0.90±0.37	0.12±0.06	0.03±0.02
Point E	1.87±0.23	0.85±0.49	0.13±0.01	0.03±0.007
Point F	1.37±0.55	0.53±0.21	0.09±0.04	0.04±0.02
Point G	1.26±0.24	0.51±0.03	0.09±0.02	0.03±0.02
Point H	1.30±0.46	0.76±0.25	0.08±0.03	0.05±0.007
Point I	1.29±0.23	0.73±0.08	0.12±0.02	0.04±0.007
Control	0.76±0.34	0.29±0.05	0.07±0.04	0.01±BDL

*BDL = Below detectable limit

*Data represented the mean of three replicates.

The highest concentration at point B was related with anthropogenic sources. It is because besides the application of chemical fertilizers at point B, the location itself influenced the concentration of heavy metals. Point B was situated near the paved road. The combustion process from vehicles, the layer of road degradation and the particles in road contributed to release pollutant to the surrounding [11]. Agricultural activities such as application of chemical fertilizers will increase the metal concentrations in soil [9]. The main composition for chemical fertilizers contained macronutrients and micronutrients. The macronutrients like nitrogen, phosphorus and potassium. However, micronutrients refer to sulphates or oxides of zinc, copper and manganese [12]. The uses of copper sulphate ($CuSO_4$) and cupric oxide (CuO) to increase the growth process probably enhance the Cu concentration [1]. The other micronutrients like zinc oxides (ZnO), and zinc sulfate ($ZnSO_4$) that contain 70 – 80% zinc and 22 – 36% sulphate [13].

Geo-Accumulation Index (Igeo)

Geo accumulation index (Igeo) was used in this study to determine the degree of heavy metals contamination in the soils at oil palm plantation area. The control soil was used as background value for Igeo calculation. The Igeo of metal in soil can be calculated using Eq. 1 [14];

$$I_{geo} = \log_2 (C_n / 1.5B_n) \quad (1)$$

where;

C_n : the measured concentration of heavy metal in the soil.

B_n : the geochemical background value in average shale of element.

Table 2 represented the classification for Igeo value. There are six classes for Igeo that consist from uncontaminated to very highly contaminated.

Table 2. Classification for Igeo value.

Igeo value	Class	Terminology
≤ 0	0	Uncontaminated
0 - 1	1	Uncontaminated to fairly contaminated
1 – 2	2	Fairly contaminated
2 – 3	3	Fairly to high contaminated
3 – 4	4	Highly contaminated
4 – 5	5	Highly to very highly contaminated
>6	6	Very highly contaminated

Table 3 shows that all sampling points have low Igeo values for Cu, Zn, Pb and Ni in palm oil plantation soil. This indicates palm oil plantation soil was uncontaminated to moderately contaminated by the four metals. Point B shows the highest Igeo values for heavy metals. The Igeo values for Zn and Ni at point B were 1.09 and 1.00. The excessive application of fertilizers around point B contributed to the accumulation of heavy metal in soil. However, the Igeo values for Cu and Pb at point B were 0.53 and 0.63. Respectively, this indicates that the soil was uncontaminated to moderately contaminated by Cu and Pb. The soil samples at point A, C, D, E, F, G, H and I had low Igeo values for both metals.

Table 3 Geo accumulation index (Igeo) for selected metals in soil samples.

Soil samples	Cu	Zn	Pb	Ni
Point A	0.24	0.32	0.34	0.40
Point B	0.53	1.09	0.63	1.00
Point C	0.31	0.37	0.27	0.40
Point D	0.40	0.62	0.34	0.60
Point E	0.49	0.59	0.37	0.60
Point F	0.36	0.37	0.26	0.80
Point G	0.33	0.35	0.25	0.60
Point H	0.34	0.53	0.23	0.94
Point I	0.34	0.51	0.34	0.74

CONCLUSION

From this study, the palm oil plantation soil does not indicate serious pollution problem. The concentration of heavy metal in soil was mainly from natural sources such as windblown dust, derivative of rock and soil or from sewage sludge. However, the application of chemical fertilizer in this palm oil soil will increase the level of heavy metal in soil unless under the control. The copper as dominance of heavy metal in soil samples was related by application of chemical fertilizer. The amount of chemical fertilizers that applied to the palm oil should be control to avoid the toxicity of soil. Further study should focus on the evaluation of more metals for example Arsenic (As) and Cadmium (Cd) in order to determine the possible contamination and toxicity level in agricultural soil.

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