Malaysian Journal of Fundamental and Applied Sciences Vol.9, No.4 (2013) 185-190

ISSN 1823-626X

Malaysian Journal of Fundamental and Applied Sciences

available online at http://mjfas.ibnusina.utm.my

Distribution of Chromium, Copper, Lead and Zinc in Soil From Kimanis, Papar, Sabah

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Received 5 January 2013, Revised 15 March 2013, Accepted 19 April 2013, Available online 21 May 2013

ABSTRACT

This paper discusses the distribution of selected heavy metals namely chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn) in soil from Kimanis, Papar, Sabah. Fourteen soil samples were collected from soil originated from sedimentary rock of Crocker Formation and Quaternary deposit. The Crocker Formation consists of thick sandstone unit and inter-bedded sandstone and shale unit with the age of Late Eocene to Early Miocene. The physico-chemical analysis of soil include the pH value, moisture content, organic content and particle size. Soil of Crocker Formation were classified as sandy loam and sandy clay loam, while Quaternary deposit were classified as sand, sandy loam, sandy clay loam and clay with loam. The result of analysis shows the soils were acidic with pH values range from 3.06-5.65. Organic matter content ranges from 0.98%-7.63% and moisture content were 13.8%-60.51%. All heavy metals were analyzed using ICP-OES. The result of analysis indicated that Zn shows the highest value then followed by Cu, Pb and Cr. Soil sample from Crocker Formation show significantly high Zn and Cu content, where SC6 and SC7 have Zn value of 274.36 µg/g and 127.82 µg/g respectively, whereas 127.98 µg/g of Cu. The distribution of heavy metals in soil samples are controlled by the mobility and leaching process during chemical weathering and also adsorption by clay particles and organic matter as well as the human activities within the area.

| Heavy metals | Physical properties | sandstone | quaternary deposit |

http://dx.doi.org/10.11113/mjfas.v9n4.107

1. INTRODUCTION

Heavy metals, or trace metals, is a term applied to a large group of trace elements [1]. Pollution of the natural environment by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded [2]. Exposure of heavy metals to human was through contaminated soil as well as consumption of contaminated food and drinking water. Heavy metals could cause serious health problem and in some cases could lead to death. Their total load in sediments depends on the myriad of factors including the local geology, human activities and the ecological health of the system [3]. This study focuses on the distribution of selected heavy metals chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn) in soil taken from Kimanis, Papar, Sabah (Figure 1).

The rock unit in the study area comprise of Crocker Formation aged Late Eocene to early Miocene and Quaternary deposit. The Crocker Formation was made of clastic sedimentary rocks showing turbidite deposit sequence that suggests the depositional environment was deep marine. It consists of thick sandstone unit and inter-bedded sandstone and shale unit, whereas Quaternary Deposits were made of sand, gravel, silt, mud and organic material (Figure 2) [4].

2. EXPERIMENTAL

2.1 Materials, method and instruments

A total of 14 soil samples from Crocker Formation (SC1-SC7) and Quaternary deposits (SQ1-SQ7) in Kimanis, Papar, Sabah (Figure 3) were gathered and analysed for their heavy metals using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Selected heavy metals were analysed namely chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn). Additional test on soil samples were done to study their pH, moisture content, organic content and particle size distribution.

2.2 Heavy Metals Analysis

About 14 ml of Aqua Regia was added to 1.0 g soil sample and being left overnight. Then, solution was heated on sand bath until the solution decreases to 10 ml and cooled before adding another 4 ml of Aqua Regia. The solution was heated again on sand bath for 30 minutes. After it cooled, stir the solution then filtered into 50 ml bottle and analysed using ICP-OES Perkin Elmer Optima 5300 DV). The heavy metals concentration obtained were calculated using the following formula:

$$\text{Heavy metals concentration (ppm)} = \frac{A \times V \times dF}{m} \times 100$$

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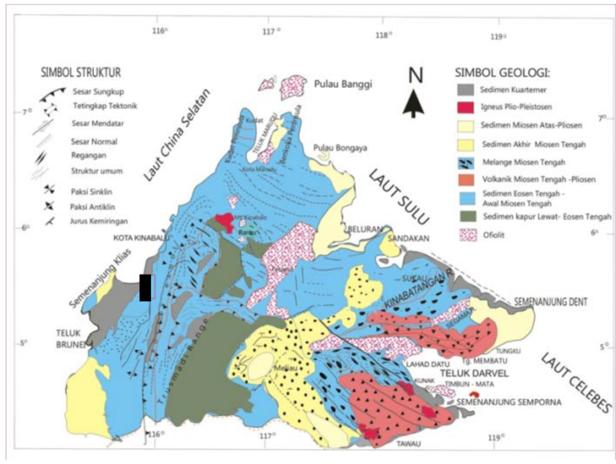

Fig. 1 Geological map of Sabah showing the location of study area.

MY	Epoch		Rock Unit	Characteristics
0	Quaternary		Quaternary Deposits	Sand, gravel, silt, mud and organic material
5	Pliocene			
10	MIOCENE	Late		
15		Middle		
20				
25		Early		
30	OLIGOCENE	Late	Crocker Formation	Thick sandstone unit and Interbedded sandstone and shale unit
35		Early		
40	EOCENE			
45		Late		
50		Middle		
55		Early		

Fig. 2 Stratigraphic column showing the rock units in study area.

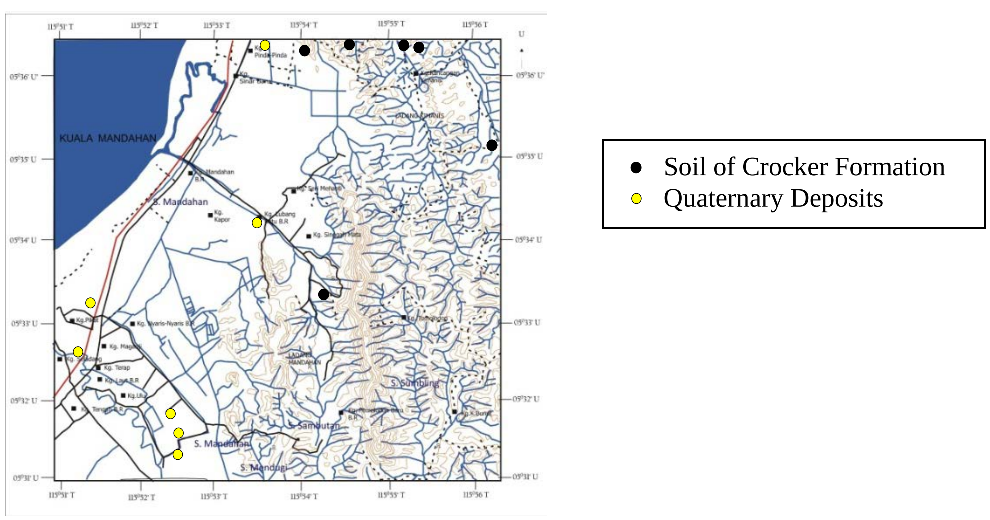

Fig. 3 Location study area and sampling stations.

A = concentration obtained from ICP-OES
V = volume of solution in bottle
dF = dilution factor
m = weight of soil sample (10 g)

2.3 Physico-chemical Test

Physico-chemical analyses on soil samples were done by pH test, moisture content, organic content and particle size distribution. pH values were determined using digital electrometer where 10 g soil added to 25 ml distilled water and stirred, after 30 minutes pH reading was taken.

Moisture content test was done by preparing 20 g of soil sample in a beaker placed overnight in oven with the temperature between 105°C-110°C. Then the sample weight was taken and the moisture content was determined using the formula:

$$\text{Moisture content} = \frac{m_2 - m_3}{m_3 - m_1} \times 100$$

m_1 = weight of beaker
m_2 = weight of beaker + wet sample
m_3 = weight of beaker + dry sample

Dry soil sample was placed in furnace with temperature of 400°C for 24 hours and then weight to get its organic matter content using the formula:

$$\text{Organic matter content} = \frac{m_2 - m_3}{m_3 - m_1} \times 100$$

m_1 = weight of beaker
m_2 = weight of beaker + dry sample
m_3 = weight of beaker + dry sample from furnace

3. RESULTS & DISCUSSION

3.1 Physico-chemical Properties

Table 1 shows the results of soil physical-chemical properties. Both soil samples were acidic with pH values range from 3.06 – 5.65 where soils from Crocker Formation were more acidic with the average value of 4.21 than 5.09 in Quaternary deposits. Acidic soil in the study area may be resulted by the leaching process of clay minerals and degradation of plants and organisms [5].

Organic matter content was low in both soil samples. Crocker Formation ranges from 0.98% to 5.60% and in Quaternary deposits 2.03% to 7.63%. The average value of moisture content in Crocker Formation was 25.11% and moderately high in Quaternary deposit with the percentage of 37.92%.

Soil classification was determined by the percentage of sand, silt and clay particles. Soil samples from Crocker Formation were classified as sandy clay loam (SC3, SC4) and the rest were sandy loam. While, soil samples of Quaternary deposits classified into sand, sandy loam, sand with loam, clay with loam and sandy clay loam.

3.2 Heavy Metals Distribution

Table 3 and Table 4 show the result of Cr, Cu, Pb and Zn concentrations in soil samples of Crocker Formation and Quaternary deposits respectively. Zn shows the highest concentrations in all soil samples followed by Cu and Pb while the lowest was Cr element. The average value of Zn concentration in Crocker Formation was 80.24 µg/g, and 47.00 µg/g in Quaternary deposits. Cu was recorded 36.60 µg/g in samples from Crocker Formation and lower in Quaternary Deposits with the average of 7.57 µg/g, meanwhile Pb concentration was 14.73 µg/g in Crocker Formation and 7.87 µg/g in soil of Quaternary deposits. The lowest element concentration was Cr with the average of 13.17 µg/g in soil sample collected from the Crocker Formation and 5.64 µg/g in Quaternary deposits. Most of the concentrations were recorded high in soil samples of Crocker Formation.

Significant value of Zn and Cu elements detected in soil samples of Crocker Formation where Zn has the highest concentration of 274.36 µg/g in sample SC6 and 127.82 µg/g in SC7. Highest Cu was recorded in sample SC1 with the concentration of 127.98 µg/g. Table 5 shows the normal range and critical values of metals in soils [1]. Critical values refer to the presence of toxic effects above those concentrations [6]. Soil samples of SC6 and SC7 which show high Zn falls under the critical concentration in soil. The other elements were under normal range in soils.

High concentration of these heavy metals in the study area was controlled by their mobility and leaching process during chemical weathering and also adsorption by clay minerals and organic matter [5]. Other factor controlling the high concentration of heavy metals in Crocker Formation especially Pb was believe to be generated by human activities as the sampling stations were located at oil palm field and near to residences. It is because soils act as a sink for anthropogenic lead, and the main sources of this metal are well characterized, the most important being mining and metallurgical works, manure and wastewater sludge used in agriculture and also car exhaust [7].

3.3 Correlation between Heavy Metals to Moisture, Organic Matter and pH

Figure 4 shows the correlation between moisture content and heavy metals on all soil samples. Cr and Zn concentrations increased as the moisture content gets higher. While, Cu and Pb concentrations decreases when the soils moisture increased. When organic matter and pH were correlated with the heavy metals concentrations as shown in Figure 5 and Figure 6, Cr and Zn elements were observed to have positive correlation. The other elements, Cu and Pb show decreasing concentrations as organic matter and pH values gets higher in soils, which means that both this elements tends to accumulate more in acidic soil. Soil pH plays an important role: as pH diminishes lead solubility increases, especially in soils with good ventilation, where oxides predominate [7].

Table 1 Physical properties of soil samples from Crocker Formation

Sample	Moisture Content, Wo (%)	Organic Matter, OM (%)	pH	Particle Size (%)			Soil Classification
				Sand	Silt	Clay	
SC1	21.97	3.03	4.00	69.33	19.29	11.38	Sandy lom
SC2	29.59	1.80	4.80	70.27	21.62	8.11	Sandy lom
SC3	33.06	3.63	5.60	56.30	22.41	21.28	Sandy clay lom
SC4	29.45	5.60	3.06	47.22	43.80	8.97	Sandy clay lom
SC5	26.45	3.62	4.40	58.23	26.41	15.37	Sandy lom
SC6	13.81	1.56	4.12	53.54	26.55	19.91	Sandy lom
SC7	21.44	0.98	3.46	56.75	23.29	19.96	Sandy lom
Range	13.81-33.06	0.98-5.60	3.06-5.60				
Average	25.11	2.89	4.21				

Table 2 Physical properties of soil samples from Quaternary deposit

Sample	Moisture Content, Wo (%)	Organic Matter, OM (%)	pH	Particle Size (%)			Soil Classification
				Sand	Silt	Clay	
SQ1	38.06	3.82	4.90	95.01	1.84	3.15	Sand
SQ2	19.24	2.14	4.54	63.63	24.87	11.50	Sandy loam
SQ3	53.56	2.03	5.32	72.82	10.11	17.07	Sandy loam
SQ4	25.34	6.96	5.65	84.26	5.90	9.84	Sand with loam
SQ5	60.51	7.63	4.62	35.56	31.03	33.41	Clay with loam
SQ6	26.86	2.32	5.61	54.10	42.69	3.22	Sandy loam
SQ7	41.88	7.28	4.96	50.17	25.53	24.29	Sandy clay loam
Range	19.24-60.51	2.03-7.63	4.54-5.65				
Average	37.92	4.60	5.09				

Table 3 Distribution of heavy metals in soil samples from Crocker Formation

Element Sample	Cr μg/g	Cu μg/g	Pb μg/g	Zn μg/g
SC1	4.23	127.98	8.54	2.59
SC2	11.03	16.94	17.31	48.15
SC3	16.36	3.10	1.47	47.29
SC4	6.56	2.44	29.50	21.90
SC5	20.11	4.13	3.13	39.59
SC6	16.79	42.76	26.92	274.36
SC7	17.08	58.82	16.26	127.82
Range	4.23-20.11	2.44-127.98	1.47-29.50	2.59-274.36
Average	13.17	36.60	14.73	80.24

Table 4 Distribution of heavy metals in soil samples from Quaternary deposit

Element Sample	Cr µg/g	Cu µg/g	Pb µg/g	Zn µg/g
SQ1	0.64	1.49	1.74	58.57
SQ2	8.50	12.40	11.01	62.39
SQ3	3.62	6.46	9.34	55.65
SQ4	1.06	2.33	1.95	22.95
SQ5	11.01	13.85	14.18	50.52
SQ6	8.26	9.66	7.64	32.83
SQ7	6.40	6.81	9.22	46.10
Range	0.64-11.01	1.49-13.85	1.74-14.18	22.95-62.39
Average	5.64	7.57	7.87	47.00

Table 5 Normal range and critical concentrations of metal in soils [1]

Metal	Normal range in soils (mg kg−1)	Critical concentration in soils (mg kg−1)
Cu	2.00 - 250	60 - 125
Pb	2.00 - 300	100 - 400
Zn	1.00 - 900	70 - 400

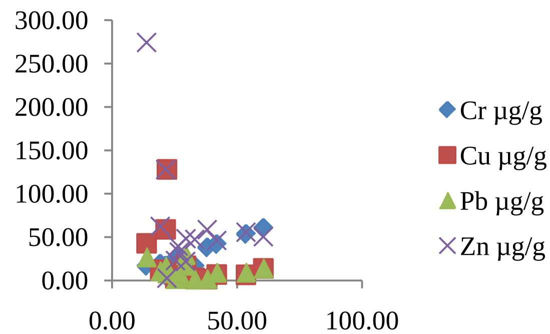

Fig.4 Correlation of moisture content and Cu, Cr, Pb and Zn in soil samples.

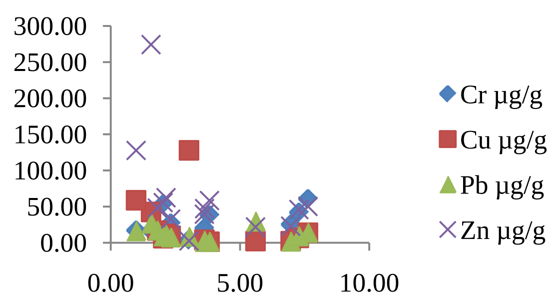

Fig.5 Correlation of organic matter content and Cu, Cr, Pb and Zn in soil samples.

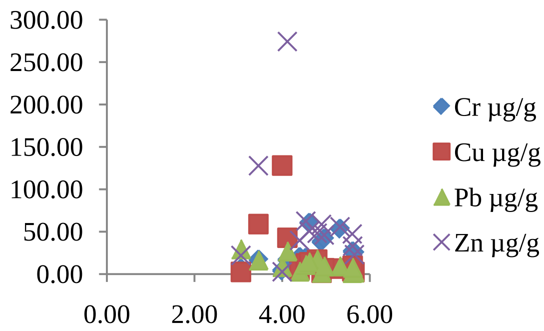

Fig.6 Correlation of pH and Cu, Cr, Pb and Zn in soil samples.

4. CONCLUSION

In the study area the highest distribution of heavy metals was Zn followed by Cu, Pb and Cr in all soil samples where, soils from Crocker Formation have higher value than soils of Quaternary deposits. The significantly high value of Zn and Cu recorded in soil samples of Crocker Formation was due to their mobility and leaching process and also by adsorption by clay and organic matter. Human activities also contributed to the high concentration of Cu, Pb and Zn. The physical properties of the soils (organic content, moisture, pH and clay particles) also controlled the presence of heavy metals.

ACKNOWLEDGEMENT

Author would like to thank Universiti Malaysia Sabah for funding the study.

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