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# GEOCHEMICAL CHARACTERIZATION OF SEDIMENTS AROUND NUKAKATAN VALLEY, TAMBUNAN, SABAH

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ABSTRACT

The objective of this paper is to assess the concentration and toxicity level of selected heavy metals in sediments from Nukakatan Valley, Tambunan, Sabah. In this study 13 soil samples were collected from different sampling station of river sediments and soil profiles. The determination of concentration of heavy metals in soil samples were carried out using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) analysis. The result of analysis shows that highest concentration was copper with the average of 21.77 ppm, and followed by nickel with concentration level was 15.94 ppm. The concentration of chromium was 15.15 ppm, arsenic was 11.91 ppm and lead was 10.39 ppm. The soils samples are identified as non-polluted due to the low concentration of chromium, copper, nickel and lead but heavily polluted with arsenic when measured using Sediment Quality Guidelines of US EPA. It is concluded that the combined source of heavy metals in the study area would be the parent materials of the soils and other anthropogenic effluent.

## 1. INTRODUCTION

Mason (1958) defined geochemistry as a study to determine the abundances of elements in earth. It also relates to the principles which control the elements distribution and mobility to the various parts of earth. Heavy metal is defined as trace elements that possess a density more than 5 g/cm3. Heavy metals are one of the serious pollutants in our natural environment because of its toxicity (Pekey, 2006). Metal elements existence has importance in the industrial arena and also in our daily life; a trace amount of common metals are found in the environment and in our daily consumption does give benefits to humans. However, severe concentration of a certain metals can harmed plants, animals and even human. Examples of heavy metals are Arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), selenium (Se) dan zinc (Zn). The abundance of heavy metal are influenced by a few factors such as parent rock, clay existence, pH value and organic matter content in soil. Metal concentration levels vary from one place with one another, depending on natural geological factors of the area (Sabri et al., 1993). Therefore, the objective of this paper is to study the concentration of heavy metals in the study area using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) and toxicity level of As, Cr, Cu, Ni and Zn based on Sediments Quality Guidelines (SQG) of US EPA.

DESCRIPTION OF STUDY AREA

The study area is located in Nukakatan Valley; which lies in Tambunan district, northeastern of Sabah region. The study area is bounded between latitudes 5°56′N and 5°51′N and longitudes 116°24′E and 116°31′E, covering an area of 117 km2 (Figure 1). This basin is located afar from Ranau town, and is 700 meters above the sea level. Most of the areas are hilly and formed ridges known as Crocker Range with the highest altitude is 1400 meter. The main river is Nukakatan River, flow from northwest to southeast of Ranau valley.

The study area is covered with Crocker Formation aged from Late Eocene to Early Miocene (Figure 2) and Quaternary aged alluvium (Figure 3). The Crocker Formation consists of flysch deposit of sand stone, siltstone, mudstone, shale and mainly exposed in the area. The Crocker Formation exposed in the surface or covered by recent alluvium and can be found at river or slope cut along road. The alluvium varies from a few centimeters up to three meters thickness of alluvial deposits and mostly covered flat area along the Nukakatan River. The materials of the alluvium are eroded from Crocker Formation or from older alluvium. It contains of sandstone, siltstone and shale in various size of pebbles, gravel, and blocks.

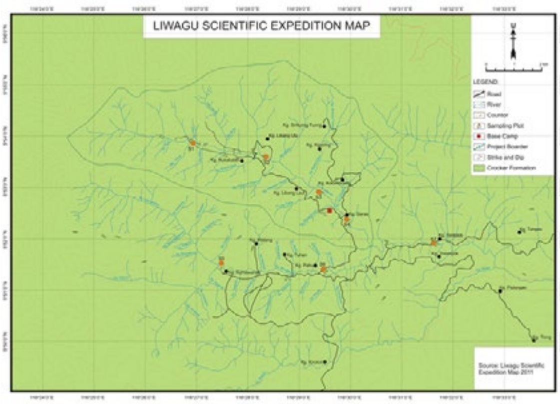


**Figure 1.** Base map of the study area

**Figure 2.** Sandstone interbedded with thin shale located at Nukakatan river (near Kg. Tontolob), 5°51'57.9"N and 116°31'28.4"E. Strike and dip: 114/82.

**Figure 3.** Alluvium deposit at Kg. Nukakatan, 5°53'55.6"N and 116°26'52.2"E.

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## MATERIALS AND METHODOLOGY

Thirteen (13) samples, about 500 gram to 1 kilogram each, of river sediments (S1 – S6) and soil near the river (S7 – S13) were collected at certain sampling station (Table 1). Each sample was collected 15 cm from the surface for the geochemical analysis. Sample is carefully secured in a clean polyethylene bag to avoid any contamination and taken to the lab for further analysis. Sample then undergoes test for the determination of organic matter content, where sample is dried in a furnace with temperature 400°C overnight. The remaining samples are air dried for the next analysis. Particle size distribution is executed to identify the percentage of silt, clay and sand fraction, dry sieving and pipette method are employed to analyse the soil sample (BS1377-1990). For determination of heavy metal concentration, samples are analysed using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) after digested with aqua regia solution (1 HCl: 3 HNO3). The concentration of elements are obtained in ppm (part per million) unit .

**Table 1.** The physico-chemical properties of soil samples in the study area

| Samples | | Moisture Content (%) | Organic Content (%) | pH Value | Sand (%) | Silt (%) | Clay (%) | Soil Classification |
|---|---|---|---|---|---|---|---|---|
| 1 | S1 (river sediment) | 5.91 | 0.25 | 6.25 | 73.60 | 7.92 | 22.67 | Sandy clay loam |
| 2 | S2 (river sediment) | 6.21 | 0.15 | 6.26 | 78.72 | 5.32 | 18.99 | Loamy sand |
| 3 | S3 (river sediment) | 6.48 | 0.14 | 5.99 | 72.28 | 17.64 | 11.21 | Sandy loam |
| 4 | S4 (river sediment) | 3.29 | 0.18 | 6.19 | 78.61 | 7.13 | 16.63 | Sandy loam |
| 5 | S6 (river sediment) | 6.13 | 0.14 | 6.25 | 78.94 | 5.26 | 18.76 | Sandy loam |
| 6 | S7 (river sediment) | 8.49 | 0.23 | 5.75 | 67.29 | 10.90 | 27.89 | Sandy clay loam |
| 7 | S1A (Zon A soil) | 6.98 | 0.30 | 5.9 | 60.02 | 20.48 | 24.23 | Sandy clay loam |
| 8 | S3A (Zon A soil) | 5.64 | 0.19 | 4.85 | 64.14 | 27.59 | 9.02 | Sandy loam |
| 9 | S3O (Zon O soil) | 3.81 | 0.37 | 4.85 | 71.25 | 23.52 | 5.52 | Sandy loam |
| 10 | S4A (Zon A soil) | 5.02 | 0.30 | 5.79 | 58.88 | 19.68 | 27.29 | Sandy clay loam |
| 11 | S4O (Zon O soil) | 4.64 | 0.51 | 5.38 | 49.24 | 37.22 | 15.66 | Loam |
| 12 | S5O (Zon O soil) | 6.20 | 0.56 | 5.24 | 48.39 | 39.57 | 13.69 | Loam |
| 13 | S5A (Zon A soil) | 6.12 | 0.23 | 4.75 | 57.95 | 26.02 | 19.09 | Sandy loam |

Based on Table 1, all samples are classified as sandy clay loam, loamy sand, sandy loam and loam based on different percentage of sand, silt and clay. Sample S1, S6, S7 and S10 were names as sandy clay loam soil, which has a medium texture and suitable for agricultural purposes. Table 1 also shows that all samples have low moisture content (lower than 10%) which indicate the poor water holding capacity of soil samples. The moisture content of sediments are greatly influenced by the distributions of particle size where smaller grain size samples have higher water holding capacity due to permeability properties. All samples show low to moderate organic matter due to low microorganism activity and less affected by any surface residue. For pH value, all river sediment samples (S1 to S6) indicate moderate acidic condition while samples from soil profile (S7 – S13) show higher acidic value due to parent rock of the study area which consist of interbedded of sand and shale of Crocker Formation, and there is no trace of active minerals in the area.

## RESULTS AND DISCUSSIONS

Table 2 shows the concentration of trace elements in soil samples. The concentrations of these elements are controlled by their mobility during weathering process. Fe shows the highest concentration ranges from 28637.06 ppm to 12341.26 ppm due to the formation of ferum oxide during chemical weathering. The increment of Mg, Ca, Na and K may indicate the increase of alkalinity of the sample. The distribution of the element may also responsible by the activity along the river, such as anthropogenic activity and natural causes, exampled by the decay of organism and also input from another tributaries.

**Table 2.** The concentrations of trace elements of soil samples

| Sample | | Value (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pb | Ca | Cd | Mg | Fe | Al | K | Na | Sr |
| 1 | S1 (river sediment) | 8.92 | 3814.61 | 0.60 | 3435.05 | 18463.17 | 11050.71 | 1005.78 | 571.82 | 152.88 |
| 2 | S2 (river sediment) | 3.62 | 4302.58 | 2.23 | 3510.00 | 17439.79 | 8720.51 | 937.70 | 642.38 | 97.39 |
| 3 | S3 (river sediment) | 6.54 | 4545.65 | 0.63 | 3802.18 | 19771.74 | 8956.04 | 746.32 | 750.36 | 164.87 |
| 4 | S4 (river sediment) | 8.84 | 17880.23 | 1.15 | 4697.23 | 23134.90 | 10695.68 | 1072.53 | 1131.69 | 188.52 |
| 5 | S6 (river sediment) | 6.26 | 8371.84 | 1.12 | 5030.16 | 28535.61 | 13504.19 | 1675.05 | 1667.39 | 186.82 |
| 6 | S7 (river sediment) | 2.73 | 3833.76 | 1.35 | 2412.57 | 15263.62 | 7919.88 | 571.44 | 620.01 | 125.88 |
| 7 | S1A (Zon A soil) | 1.10 | 4172.60 | 1.12 | 3037.45 | 15598.17 | 9639.99 | 822.93 | 673.83 | 104.26 |
| 8 | S3A (Zon A soil) | 11.82 | 5355.72 | 1.05 | 2299.09 | 16495.67 | 6549.51 | 628.81 | 691.81 | 100.75 |
| 9 | S3O (Zon O soil) | 0.82 | 3787.24 | 0.31 | 2934.03 | 20199.82 | 7522.21 | 678.07 | 515.23 | 113.87 |
| 10 | S4A (Zon A soil) | 6.22 | 7274.41 | 0.57 | 3730.39 | 21173.29 | 9709.69 | 814.98 | 1017.38 | 158.94 |
| 11 | S4O (Zon O soil) | 12.93 | 8077.18 | 0.53 | 5244.64 | 28637.06 | 15579.83 | 1173.59 | 1069.20 | 178.50 |
| 12 | S5O (Zon O soil) | 16.18 | 5121.80 | 1.30 | 2360.25 | 12341.26 | 6557.35 | 666.37 | 966.31 | 188.27 |
| 13 | S5A (Zon A soil) | 49.14 | 5877.13 | 0.77 | 4422.10 | 24338.08 | 14432.08 | 1559.91 | 2010.55 | 225.93 |

Five (5) elements are chosen in terms of concentration in thirteen (13) sediments, namely: arsenic (As), chromium (Cr), copper (Cu), nickel (Ni) and lead (Pb). A summary of heavy metal concentration of each sampling area and its average against Sediment Quality Guidelines (SQG) of US EPA (Pekey, 2006 after Perin et al., 1997) are shown in Table 3.

**Table 3.** Selected heavy metal concentrations of each sampling area against Sediment Quality Guidelines (SQG) of US EPA

| Elements (ppm) | | As | Cr | Cu | Ni | Pb |
|---|---|---|---|---|---|---|
| SQG of US EPA (ppm) | Non-Polluted | <3 | <25 | <25 | <20 | <40 |
| | Moderately Polluted | 3~8 | 25~75 | 25~50 | 20~50 | 40~60 |
| | Heavily Polluted | >8 | >75 | >50 | >50 | >60 |
| 1 | S1 (river sediment) | 15.96 | 15.52 | 17.48 | 16.44 | 8.92 |
| 2 | S2 (river sediment) | 10.57 | 16.61 | 16.46 | 13.25 | 3.62 |
| 3 | S3 (river sediment) | 23.19 | 16.63 | 19.36 | 16.08 | 6.54 |
| 4 | S4 (river sediment) | 24.25 | 13.32 | 22.92 | 19.08 | 8.84 |
| 5 | S6 (river sediment) | 7.59 | 11.14 | 25.87 | 23.91 | 6.26 |
| 6 | S7 (river sediment) | 1.83 | 17.81 | 14.40 | 9.63 | 2.73 |
| 7 | S1A (Zon A soil) | 14.40 | 16.75 | 16.02 | 11.42 | 1.10 |
| 8 | S3A (Zon A soil) | 11.31 | 18.67 | 22.20 | 12.33 | 11.82 |
| 9 | S3O (Zon O soil) | 6.63 | 15.31 | 21.02 | 14.03 | 0.82 |
| 10 | S4A (Zon A soil) | 8.88 | 14.92 | 21.45 | 15.88 | 6.22 |
| 11 | S4O (Zon O soil) | 10.81 | 11.17 | 27.51 | 21.59 | 12.93 |
| 12 | S5O (Zon O soil) | 10.17 | 18.17 | 20.70 | 9.60 | 16.18 |
| 13 | S5A (Zon A soil) | 9.21 | 10.98 | 37.67 | 23.97 | 49.14 |
| | **Average** | **11.91** | **15.15** | **21.77** | **15.94** | **10.39** |

**Table 4.** Comparison of heavy metal concentration of soil originating from different parent materials. (modified after Shan *et al.*, 2010)

| Parent Material | As | Co | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|
| **Igneous rock** | 6.9 | 13.0 | 58.9 | 22.0 | 25.8 | 22.8 | 80.0 |
| **Sedimentary rock** | 8.3 | 12.5 | 64.4 | 22.5 | 24.8 | 24.4 | 76.9 |
| **Alluvial deposit** | 7.8 | 11.0 | 59.7 | 21.3 | 24.1 | 24.2 | 70.0 |
| **Loess** | 8.6 | 11.7 | 58.9 | 24.2 | 23.8 | 21.6 | 69.7 |

From Table 3, copper (Cr) shows the highest concentrations average of 21.77 ppm, followed by nickel (Ni) with 15.94 ppm, chromium (Cr) with 15.15 ppm, arsenic (As) with 11.91 ppm and lead (Pb) with 10.39 ppm. Sediments can be classified as: non-polluted, moderately polluted and heavily polluted based on the Sediment Quality Guidelines of US EPA (Perin et al., 1997). Based on this guideline, the average concentration of Cr, Cu, Ni and Pb are regarded as non-polluted while As indicated that the area is heavily polluted. The high concentrations of As in river sediments might be occur as a result of pollution from industrial or sewage effluents, while some high concentrations of As in sediment samples most likely to be licked to strong redox gradients that occur below the sediment-water interface of the over depth scales of centimeters. Based on a report by Shan et al. (2010), concentration of heavy metals in soils originating from different parent materials were close to each other for there were no differences among different parent materials except Mn, which may relate to the development history of soils. The reports also mentioned that on the early stages, pedogenesis is mainly controlled by parent material, but in subsequent long term evolution of soil, the effect of other factors on soil forming processes may exceed that of parent material. Parent materials of the study area are sedimentary rocks for S7 to S13 and alluvial deposits for S1 to S6. When the heavy metals concentration from the study area (Table 3) compared to the heavy metals concentration by Shan et al. (2010), there is a slight difference in terms of value but still classified as the same category in SQG by US EPA.

## CONCLUSIONS

The heavy metal concentrations in soils taken from different sampling location in Nukakatan Valley were determined using the ICP-OES technique. The soils samples are identified as non-polluted due to the low concentration of chromium, copper, nickel and lead but heavily polluted with arsenic when measured using Sediment Quality Guidelines of US EPA. It is concluded that the combined source of heavy metals in the study area would be the parent materials of the soils and other anthropogenic effluent.

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