Environmental Geochemical Mapping on Distribution of Metal Contamination in Topsoils Perlis, Malaysia

Siti Norbaya Mat Ripin
Universiti Teknologi Mara Shah Alam, Malaysia
Email: norbaya24@gmailcom

Sharizal Hasan and MohdLias Kamal
Universiti Teknologi Mara Perlis, Malaysia
Email: sharizal187@perlis.uitm.edu.my, mohdlias@perlis.uitm.edu.my

***Abstract*—An extensive survey was conducted in this study to determine the spatial distribution and possible sources of 7 heavy metals (Pb, Cu, Zn, Cr, Ni, Co, Mn) in the soils in Perlis and producing a heavy metal distribution maps. 18 soil samples around Perlis undergo microwave digestion and analyzed by inductively coupled plasma mass spectrometry ICP-MS. The spatial distribution pattern shows that Cu, Pb, Cr and Zn have similar patterns of spatial distribution. Main sources of these element mainly form anthropogenic sources such as industrial activity and transportation in main roads where high traffic density was identified as contributor to heavy metal contamination in soil. Meanwhile the spatial distribution patterns of Ni, Co and Mn show hot-spot areas were mainly located in the sides of the urban area where the road dust was significantly influenced by natural soils. Besides that geoaccumulation index was calculated and the values showed that all seven element classes as uncontaminated to moderately contaminated and possibly become seriously contaminated if no implementation of remediation effort.**

***Index Terms*—spatial distribution, anthropogenic, geoaccumulation index**

I. Introduction

Soil is an essential compartment for recycling and redistribution of nutritive elements, this medium is usually considered as a sink for all pollutant that deposited into soil [1]. Soil contamination has become severe with increasing pathways of pollutants sources. Through the wet and dry atmospheric deposition heavy metals contaminate the surface of all environmental compartments such as soil, water and vegetation [2]. Soil contamination by heavy metals due to non-decay by time and long biological half-lives has been severely considered [3], [4] Heavy metals reaching the soil remain present in the pedosphere for many years even after removing of the pollution sources [5].

Distribution of heavy metals accumulation in topsoil tend to increase because it may be affected by parents materials and anthropogenic souces [3,] [4], such as vehicular emissions, industrial residues, agricultural activity, the atmospheric deposition of dust and aerosols and other industrial sources [2], [6]. Combinations of spatial and temporal data are important in order to understand and identify anthropogenic influence [7]. The determination of anthropogenic sources needed for deep understanding on spatial distribution of heavy metals in the soil [8]. To describe these spatial structures, mapping based on geographical information systems (GIS) and geostatistical methods are useful approaches.

There has been little research on soils in Malaysia. Perlis is the smallest populated city, located northwest Malaysia near Thailand border and one of developing state in Malaysia. These studies have shown chemical degradation processes affect soils in Perlis. The reasons behind this situation are associated to the achieving development mission in 2015 (Perlis Maju 2015). An understanding of the problem may be inferred by taking into account the following: (1) increasing urbanization that has produced considerable loss urban greenspace, (2) the intense road traffic volume, (3) the existence of many industrial activities such cement production, quarry plant, sugar mill production, and chemical industries in Perlis. Limited information exists concerning the spatial distribution and availability of heavy metals in soil. Furthermore, there is no data regarding temporal changes of metal concentrations in contaminated soils. The objective of this study was to assess spatial changes of metals in surface soils in Perlis. Specifically, (1) the total content of Pb,Cu, Zn, Cr,Ni and As in topsoils of the city of Perlis was measured, (2) produce spatial distribution maps.

II. Materials and Methods

A. The Study Area and Soil Sampling

Perlis smallest state in Malaysia located northern part of the west coast of Penisular Malaysia. The city area occupies with 821 km2, and has approximately 227,025(198,850) inhabitant. The climate is typically

Manuscript received July 30, 2013; revised September 30, 2013.

doi: 10.12720/jomb.3.4.277-281

tropical monsoon with temperature is relatively uniform within the range of 21 ℃ to 32 ℃ throughout the year. The average rainfall per year is 2,032 mm to 2,540 mm and the wettest months are from May to December. A total of 18 surface soil samples were collected using stainless steel hand auger on Mei to July 2012 in sampling point shown in Fig. 1. The coordination of the sampling point was recorded with a global positioning system (GPS) receiver. About one kilograms of each sample was stored in sealed polyethylene bags and transfer into laboratory for further analysis. Collected samples were oven-dried at 60 C during 48 hours, grind, sieved to remove large debris through a 2 mm polyethylene sieve and stored in plastic bottles [9].

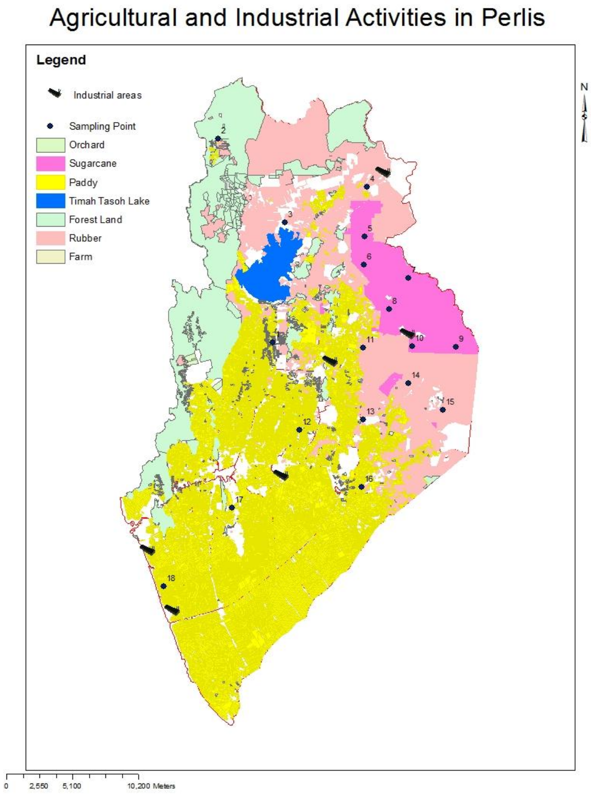


Figure 1. Sampling areas

B. Chemical Analysis

About 0.5grams of sieved soil sample were digested in triplicate in Teflon microwave vessel Milestone ETHOS HPR-1000 using a mixture 9:3 of HCl-HNO_3 and the vessels was place inside the rotor of the microwave digestion system, sealed, tighten using a torque wrench and finally submitted to a microwave dissolution program [10]. To assess contamination, the same treatment (without sample) was applied for the blank analysis. After digestion, the vessels were cooled for 30 min and opened in a fume hood. Then the solutions were filtered through Whatman No.1 filter papers and volumes were adjusted to 50 ml using double deionized water (Mili-Q 18.2 M_/cm resistivity) [2], [11]. Then the digested sample were filtered through 0.45μm syringe before proceed to instrumentation. The heavy metals concentration of Pb, Cu,Zn, Cr, Ni and As were determined using inductively coupled plasma mass spectrometry (ICP-MS Perkin Elmer).

C. Contamination Assesment Methods

The geo-accumulation index (Igeo) introduced by Muller [12], [13] has been used since the late 1960s, and has been widely employed in European trace metal studies. The Igeo was used to assess heavy metal contamination in soils [14], [15] Geoaccumulation index is expressed as follows:

$$Igeo = \log_2 (Cn/1.5Bn)$$

Where Cn is the concentration of element in urban soil, Bn is the background value. Background values of soil chosen from CNEMC 1990 [16]. The geo-accumulation index consists of 7 classes. The seven propose descriptive classes for Igeo values are given in Table I (Muller, 1969). The constant 1.5 allows us to analyze natural fluctuations in the content of a given substance in the environment and to detect very small anthropogenic influences.

TABLE I. SIX CLASSESS OF GEO-ACCUMULATION INDEX [8]

Class	EF	Terminology
0	Igeo≤ 0	Practically uncontaminated
1	0 < Igeo < 1	Uncontaminated to moderately cotaminated
2	1< Igeo <2	Moderately contaminated
3	2<Igeo<3	Moderately to heavily uncontaminated
4	3<Igeo<4	Heavily contaminated
5	4<Igeo<5	Heavily to extremely contaminated
6	5<Igeo	Extremely contaminated

D. Geostatistical Analysis

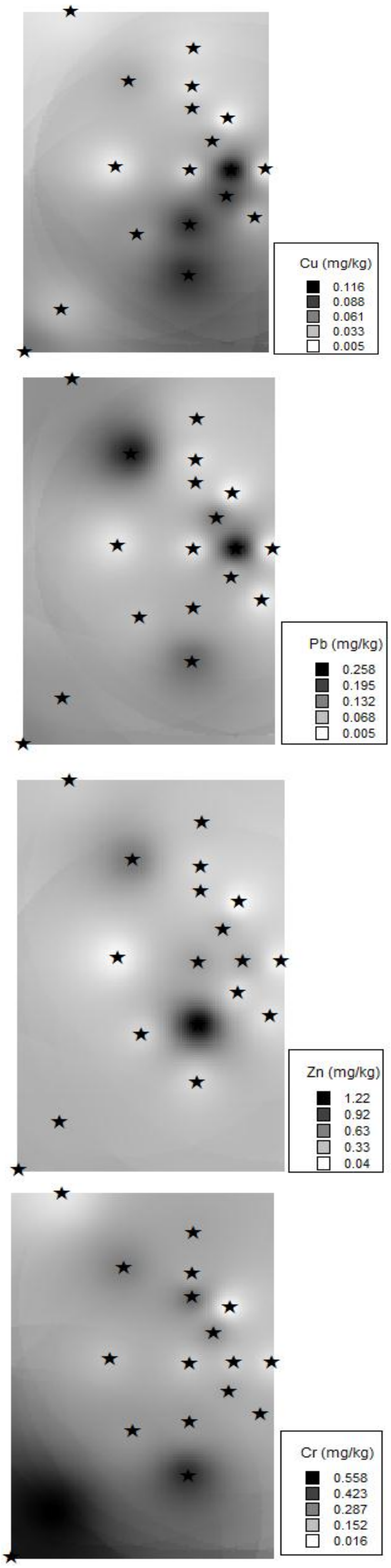
All statistical analyses were performed using Microsoft Excel 2008. Map was generated using ArcGIS 10 and Mapinfo. The main application of geostatistics to soil science has been the estimation and mapping of soil attributes in unsampled areas and to estimate concentration levels of metals in un-sampling sites and determine the pollution patterns influenced by each potential pollution source.

III. RESULT AND DISCUSSION

A. The Spatial Distribution of Soil Heavy Metals

The spatial distribution of heavy metals in soils was analysed using GIS methods. The geochemical maps of Pb, Cu, Zn, Cr, Ni, Co and Mn were presented in Fig. 2. In general, darker colors indicated overlap of higher metal concentrations, lightly colored suggested both low concentrations and little overlap of areas with high metal concentrations. Similar spatial distribution patterns of Cr and Ni were found in the geochemical maps, likewise, for Mn and Pb, and for Cu, Zn and Co. This provided a refinement and reconfirmation of the results in the statistical analysis, in which strong associations were found among these metals. The integrated color map was an indicator of the heavy metal contamination in soils.

In comparison, several darker hotspots and strips of high metal concentrations were identified in the composite geochemical maps (Fig. 2) by comparing with industrial and agricultural maps (Fig. 1). From the spatial distribution maps (Fig. 2) it shows that Pb, Cu, Zn and Mn give darker color in point 10,11,13,14 that closely to industrial areas and point 3 that mainly cover with agricultural activity.



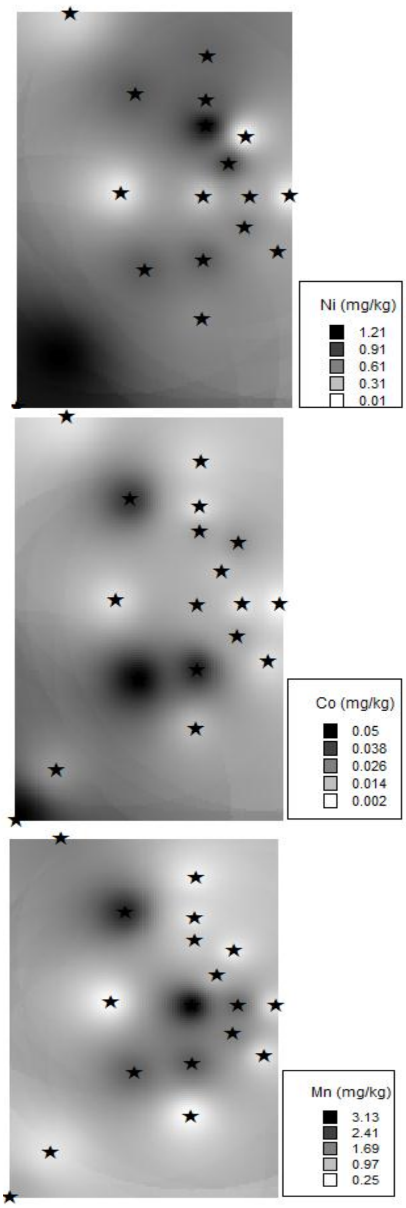


Figure 2. Spatial distribution of heavy metals in soil

Higher concentration of these element majority come from industrial activities such as cement production, sugar mill processing, quarry, chemical and power plant and agricultural activity. Besides that, traffic emission also leads to the elevation of heavy metal in study areas. Emission heavy metal in the form of ash or smog from huge vehicle passed by the main roads in sampling point have deposited into the soil.

Meanwhile, Ni, Co and Cr show dark color in station 17 and 18 and mainly associated with natural sources compared with anthropogenic sources.

According to distribution maps in Xiaoping Li et al 2012 [17], it shows that darker color for Cu, Pb, Zn and Cr which means high concentration of heavy metals in the study area were associated with anthropic activities ((industrial sources, combined with coal combustion as well as traffic factor). In addition, many research found that Cu, Pb, Zn, Cr and Ni mainly originated from industrial activities such as cement production, chemical plant processing, quarry activity and also combustion of coal or fossil fuel in factory or from vehicle [14], [18], [19]. As reported by A.Mandal *et al.*, [18] heavy vehicular give large contribution in depositing Cu, Pb, Cr, Ni through traffic emission. Cr Ni,Co and Mn are mainly originated from natural sources [6], thus the concentration not greatly vary from each station.

Therefore, the concentration spatial distribution map of heavy metals was an indicator of the heavy metal contamination in soils. The contamination can be contributed to the local industrial and anthropogenic activities.

B. Geoaccumulation Index

Geoaccumulation index (Igeo) of heavy metals was calculated for each sample for seven elements. The Igeo of Pb, Cu, Zn, Cr, Ni, Co and Mn was in the range of class 2 (0< Igeo < 1), which means all sampling areas were uncontaminated to moderately contaminated. The max Igeo values were founded in sampling area 3 (Pb), 10 (Pb, Cu), 11 (Mn), 13 (Zn), 17 (Ni, Cr) and 18 (Co). When referring to sampling areas maps, reasons for high Igeo values because anthropogenic sources impact. There are industrial activity such as cement plant, quarry, sugar mill and chemical plant that located near station 10 and 11 and power plant at station 18. In addition vehicular emission also take part in releasing heavy metal through fuel combustion, brake linning in the vehicle that constantly pass through at station 3, 10, 11, 13, 17 and 18 because this site consider as main roads for huge vehicle transportation. All seven elements for other station likely from natural sources. Previous study reported that Cu, Pb, Cr and Zn were associated with anthropic activities (industrial sources, combined with coal combustion as well as traffic factor [1], [19]. Road dust from traffic emission significantly increase heavy metal level in soil besides it becomes long-term accumulate when enter into soil [14]. From this result, Igeo can also be an effective tool to differentiate a natural origin from anthropogenic sources in the study and predict contamination classes for all study area. Even though, all the calculated Igeo values in class 2 but there is high possibility of entering into serious Igeo classes if anthropogenic sources of heavy metals continuously increase.

IV. CONCLUSION

The results of this study show that Pb,Cu,Zn,and Cr mainly derived from industrial sources as well as traffic emission. Meanwhile Ni,Co and Mn originated from natural sources such as parents materials. In the geochemical map, the distribution characteristics of Cu, Pb, Cr and Zn are also similar. The spatial distribution of heavy metals concentration was explained by various anthropogenic activity including industrial activity (Pb, Cu, Zn) and traffic emission (Cr, Cu) This study demonstrates that the combination of environmental mapping and multivariate geostatistical analysis can be an appropriate tool to characterize spatial distribution of heavy metals and to determine their sources. Anthropogenically impacted and background soils on major roadsides were assessed using geoaccumulation index for Pb,Cu,Zn,Cr,Ni,Co and Mn. The geoaccumulation index showed that all sampling areas are uncontaminated to moderately contaminated.

ACKNOWLEDGMENT

The authors sincerely appreciate the Applied Science Department, Universiti Teknologi Mara Shah Alam and Universiti Teknologi Mara Perlis in support and helping in many sites for completing this work. This study was supported in part by a grant Universiti Teknologi Mara Perlis which is Dana Kecemerlangan Universiti Teknologi Mara Perlis.

REFERENCES

[1] S. Maas, R. Scheifler, M. Benslama, N. Crini, *et al*., "Spatial distribution of heavy metal concentrations in urban, suburban and agricultural soils in a Mediterranean city of Algeria,' *Environmental Pollution*, vol. 158, pp. 2294-2301, February 2010.

[2] B. Skrbi ća, S. Milovaca, and M. Matavulj, "Multielement profiles of soil, road dust, tree bark and wood-rotten fungi collected at various distances from high-frequency road in urban area," *Ecological Indicators*, vol. 13, pp. 168–177, May 2011.

[3] A. Hani, "Spatial distribution and risk assessment of As, Hg, Co and Cr in kaveh industrial city, using geostatistic and GIS," *World Academy of Science, Engineering and Technology*, vol. 71, 2010.

[4] A. Hani and M. Kariminejad, "Toxic metal distribution in soils of kaveh industrial city, Iran," *World Applied Sciences Journal*, vol. 8, no. 11, pp. 1333-1342, 2010.

[5] M. Imperato, P. Adamo, D. Naimo, M. Arienzo, *et al*., "Spatial distribution of heavy metals in urban soils of Naples city (Italy)," *Environmental Pollution*, vol. 124, pp. 247–256, December 2002.

[6] A. Lu, J. Wang, X. Qin, K. Wang, *et al.*, "Multivariate and geostatistical analyses of the spatial distribution and origin of heavy metals in the agricultural soils in Shunyi, Beijing, China," *Science of the Total Environment*, vol. 425, pp. 66–74, 2012.

[7] A. Oliveira, C. Plma, and M. Valenc, "Heavy metal distribution in surface sediments from the continental shelf adjacent to Nazare´ canyon," *Deep-Sea Research II*, vol. 58, pp. 2420–2432, April 2011.

[8] G. Yuan, T. Sun, P. Han, and J. Li, "Environmental geochemical mpping and multivariate geostatistical analysis of heavy metals in the topsoils of a closed steel smelter: capital Iron and Steel Fatory, Beijing, China," *Journal of Geochemical Exploration*,vol. 130, pp.15-21, March 2013.

[9] B. A. Adelekan and K. D. Abegunde, "Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria," *International Journal of the Physical Sciences*, vol. 6, no. 5, pp. 1045-1058, 2011.

[10] S. Franky, K. Lias, B. T. Jamil, and D. Norsila, "Biomonitoring of heavy metals using soil near teluk ewa cement plant: Preliminary study," *IEEE*, June 2011.

[11] P. S. Khillare, D. S. Jyethi, and S. Sarkar, "Health risk assessment of polycyclic aromatic hydrocarbons and heavy metals via dietary intake of vegetables grown in the vicinity of thermal power plants," *Food and Chemical Toxicology*, vol. 50, pp. 1642–1652, February 2012.

[12] G. Muller, "Schwermetalle in den sediments des Rheins-Veran-derungen seitt 1971," *Umschan*, vol. 79, pp. 778–783, 1979.

[13] G. Müller, *Die Schwermetallbelastung Der Sedimente Des Neckars Und Seiner Nebenflüsse Eine*, 1981.

[14] B. Wei, F. Jiang, X. Li, and S. Mu, "Spatial distribution and contamination assessment of heavy metals in urban road dusts from Urumqi, NW China," *Microchemical Journal*, vol. 93, pp. 147–152, 2009.

[15] K. B. Mmolawa, A. S. Likuku, and G. K. Gaboutloeloe, "Assessment of heavy metal pollution in soils along major roadside areas in Botswana," *African Journal of Environment Science and Technology*, vol. 5, no. 3, pp. 186-196, 2011.

[16] China National Environmental Monitoring Centre, *The Background Values of Chinese soils*, Environmental Science Press of China, Beijing, 1990.
[17] X. Li and L. Feng, "Multivariate and geostatistical analyzes of metals in urban soil of Weinan industrial areas, Northwest of China," *Atmospheric Environment*, vol. 47, pp. 58-65, 2011.
[18] A. Mandal and M. Voutchkov, "Heavy metals in soils around the cement factory in Rockfort, Kingston, Jamaica," *International Journal of Geosciences*, vol. 2, pp. 48-54, 2011.
[19] X. Li, "Geostatistical analyses and contamination assessment of hazardous metals in urban soil, NW China," *IEEE*, 2010.

Siti Norbaya Mat Ripin was born on 24 october 1988 at Kelantan. She starts her education in Sekolah Kebangasaan Sri Chempaka Kelantan and then enter Sekolah Menengah Sains Pasir Puteh in Kelantan. After that, she continues her study in Perak Matriculation and then proceeds with degree level in Bachelor of Applied Chemistry (Hons) in Universiti Teknologi Mara Perlis, Malaysia. Now she furthers her study in Master in Science in Universiti Teknologi Mara. While studying she works as a part time clerk. I also have present a paper in 25th Regional Symposium Malaysian Analytical Sciences (SKAM-25) 2011 in title (A preliminary study on analysis and pollution assessment of heavy metal in soil from perlis) and also received Silver medal for Invention, Innovation & Design (IID) 2011 in UiTM Perlis in project in title (Wound Cream Formulation from Chromolaena Odorata sp. Essential oil).

Sharizal Hasan was born on 8 January 1970. He has doctor of philosophy in Australia and now works as chemistry lecturer in Universiti Teknologi Mara Perlis. Dr Sharizal has published 2 paper in Journal of Inclusion Phenomena and Macrocyclic Chemistry and Australian Journal of Chemistry. He also had presented 3 more paper at 3th International Workshop on Nanotechnology and Application, International Conference on Nanotechnology-Research and Commercialization and 24th Regional Symposium Malaysian Analytical Sciences (SKAM-24)

Mohd Lias Kamal was born on 17 May 1969. He Studies doctor of philosophy in the United Kingdom and now works as chemistry lecturer in Universiti Teknologi Mara Perlis. He also had published a paper in Regional Symposium on Membrane Science and Technology, UTM, Prince of Songkla, and University of Bandung, Indonesia & UNESCO, Hotel Putri Pan Pasific, Johor Bahru and 7th International Conferences on Membrane Science & Technology (MST 2009). There are a few awards received by him such as PETRONAS, Invertors Award, 1996: Incentive Award and bronze in BioMalaysia 2011.