International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 7, Issue 8 Ver. I (Aug 2018), PP. 25-29

GIS-based Techniques for Estimating Spatial Distribution of Heavy Metals in Urban Soil: A Case Study in Hoc Mon District, Ho Chi Minh City, Vietnam

Tuan Tran Quang[1,3*], Tien Yin Chou[2], Hoang Thanh Van[2], Mei Hsin Chen[2], Danh Mon[3], Luu Hai Tung[3]

[1] *Ph.D Program of Civil and Hydraulic Engineering, Feng Chia University, Taiwan*
[2]*GIS Research Center, Feng Chia University, Taiwan*
[3] *Department of Land Resources, HoChiMinh City Institute of Resources Geography, Vietnam*
[*]*Corresponding Author:Tuan Tran Quang*

Abstract: *Heavy metal concentration in urban soil is one of big problems that contribute directly or indirectly to the general life quality in city areas. Heavy metals can affect to the human health and might cause toxic effects to biological organism. Ho Chi Minh city (HCMC), Vietnam is the home to many industrial activities and is the populous area resulting in many environmental problems. However, there has been no investigation of urban soil pollution in order to monitor, control and manage soil quality in HCMC. This study mainly focuses on determining concentration of metals in soil and applying Geostatistic and GIS techniques to estimate spatial distribution of heavy metal for better understanding their contamination characteristic. The results showed that the spatial pattern of heavy metals is successfully interpolated based on in situ data by using Ordinary Kriging technique. The higher contamination is found for Cu and Zn in the study area. The impacts of polluted soil were assessed by comparing observed concentration of heavy metals to the national standard for the allowable limits of heavy metal in soil.*

Keywords*: Heavy metal concentration, GIS technique, Spatial interpolation, heavy metal mapping, Ordinary Kriging.*

Date of Submission:01-12-2018 Date of acceptance: 17-12-2018

I. INTRODUCTION

Heavy metals are naturally present in the soil, however, their concentration has been changed and increased caused by geologic and anthropogenic activities. Especially in the urban soil, the metal contamination is being to be a serious environmental problem that is harmful to human being and plants. Plants growing on heavy metal polluted soils show a reduction in growth due to changes in their physiological and biochemical activities and it is especially true when the heavy metal involved does not play any beneficial role towards the growth and development of plants [3]. Soil polluted with high concentration of heavy metals is one problem that directly or indirectly give a bad influence to general quality of life in the city. The contamination and extent of heavy metals such as Cd, Cu, Pb Cr, Ni, Cr, As and Zn have identified by previous studies [2, 13]. These toxic heavy metals in soil strongly impact on natural ecosystem and are threat to human health through food chain [5, 12]. Estimating and analyzing the spatial distribution of heavy metals are particular interest for the purpose of controlling and managing soil quality.

Generally, the accumulation of heavy metals in soil influenced by different variables in nature (parent rocks, soil types, soil properties, etc.) as well as human activities (industry, traffic, agriculture, etc.). Changes in heavy metal concentration may modify soil properties, especially soil biological properties [11], therefore, monitoring these changes is truly necessary that allow to identify their source and assess potential risks associated with heavy metal contamination. There are diverse criteria and methods used to access environmental soil quality based on the heavy metal content in soil. People used different indices for soil pollution monitoring such as pollution load index, potential of ecological risk index, geo-accumulation index and so on. Geo-statistics, multivariate methods and Geographic Information System (GIS) that allow for faster and more accurate information, have been widely used in numerous studies. And they are power tool for determination of spatial distribution in soil pollution study [3, 4, 9, 13]. Kriging is a geo-statistical and one of the most commonly used methods for spatially interpolation in environmental studies [10, 13]. It has been applied successfully to describe the spatial variability of certain soil parameters and predict value for unknown points/areas [6, 7, 9].

Currently, there has been no detail investigation about urban soil quality in the study area (Hooc Mon district, HCMC), this study first aims to determine the concentration of heavy metals in urban soil; produce a

geochemical maps of heavy metals and then identify possible hot spots of elevated concentration using GIS technology.

II. MATERIALS AND METHODS

2.1Study Area

Ho Chi Minh (HCM) is the largest and the most developed city in Vietnam, with an area of 2,095 km2 and population estimated to be about 10 million in 2020. It is located in the Southern part of Vietnam. A small area was chosen as a test site in Hoc Mon district since there is a currently existing environmental problem caused by Dong Thanh landfill (DT) (Figure 1). DT landfill is one of three main landfills in HCM city. It is the official dumping site form 1992 with an area of 43 ha and its capacity of 4000 tons/day. There have been many problems on odour's and leachate in landfills for a long time that cause adverse impacts on the soil environment and public health. Moreover, most of land in Hoc Mon district is used for growing vegetables and these products are then delivered for selling in HCM city and surrounding areas. The main soil types in the study site are Acrisols, Ferralsols and Fluvisols and the average elevation of 1.5 m above sea level.

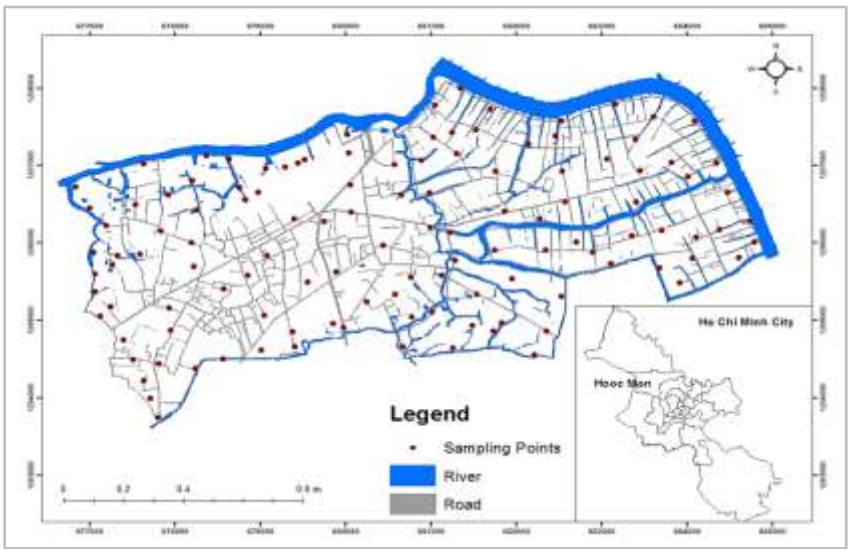

Figure 1. Sampling points denoted in the map of the study area

2.2 Soil Sampling

The total number of soil sampled was 120. And they are randomly taken over the entire the study area (Figure 1). Soil samples were collected from the outer surface to 20 - 30 cm depth with a total 2-3 kg of soil per sample following the Guidance on sampling techniques of Vietnam (TCVN 7538-2:2005 (ISO 10381-2:2002). They are stored in polyethylene bag for transport and then analyzed in the laboratory in accordance with the standard of Vietnam (TCVN 6647:2007; ISO 11464:2006).

2.3 Chemical analysis

Chemical properties were obtained following the standard procedures. The soil samples were air-dried at room temperature and milled to a particle size of < 2mm after dried. They will be then classified as representative samples for later analysis.

The total concentrations of heavy metal were determined using Flame Atomic Absorption Spectrophotometry method (TCVN 8246:2009; EPA Method 7000B). This method is simple, rapid and applicable to a large number of environmental samples. For determining the concentration of heavy metals, the soil samples were digested in a combination of acids including hydrochloric acid and nitric acid. Because metals are not equally stable in the digestate, especially if it only contains nitric acid and not a combination of acids including hydrochloric acid (HCl). So the addition of HCl can helps to stabilize Sn, Sb, Mo, Ba, and Ag in the digestate. In the following step, the concentration of metals was determined by ICP:OES in accordance with EPA method.

2.4 Geo-statistical Analysis based on GIS

Geo-statistic method as employed in this study for estimating spatial distribution of heavy metals. Ordinary Kriging is a linear spatial interpolation that estimates spatial data at unknown location using a weight function of adjacent data points [13]. The general equation for estimating the z value as a point is:

$$Z_0 = \sum_{i=1}^{n} Z_x W_x \qquad (1)$$

Where Z_0 is the estimated value, Z_x is the known value at point x, W_x is the weight associated with point x. And n is the number of sample points used in estimation.

III. RESULTS AND DISCUSSION

3.1 Heavy metal concentration

The concentration of heavy metals and statistical analysis results of the soil in the study site can be seen as Table 1. There are 3 heavy metals that can be identified from soil samples in the study site including Cu, Pb and Zn. Among these 3 metals, Cu and Zn have higher value of concentration compared to Pb. The maximum value of Cu concentration up to 96.5 mg/kg that almost reach the maximum permissible concentrations as defined by government regulations (100 mg/kg for agricultural and residential lands; 200mg/kg for industrial land). The maximum concentration value of Zn is 285.4 mg/kg which also higher than permissible threshold (200 mg/kg for agricultural and residential lands; 300mg/kg for industrial land)

The variation coefficient of Cu, Pb and Zn in the soil were 0.66, 1.18 and 1.37, respectively. This implying that Pb and Zn metals had the larger variability throughout the study area compared to Cu in the study site.

Table 1: Statistical summary of metal concentration in soil (mg/kg)

	Cu	**Pb**	**Zn**
Min	2.16	0.22	0.61
Max	96.5	27.13	285.4
Standard deviation	17.3	5.28	67.05
Coefficient of variation	0.66	1.18	1.37

2.1. Spatial distribution of heavy metals content in soil

Kriging interpolation method and GIS mapping technique were applied to produce the spatial distribution maps of total metal concentration for Cu, Pb and Zn in the study area. These distribution maps were illustrated in Figure 2, 3, 4 for Cu, Pb and Zn, respectively.

It can be seen that the Cu content in studied soil samples ranged from 2.16 to 96.5 mg/kg. This results demonstrated that the maximum value of Cu concentration is very close to the limits of the Vietnamese standard with the allowable threshold of 100 mg/kg in some places over Dong Thanh ward and this is also the most heavily contaminated areas by Cu metal (Figure 2).

The lead (Pb) concentrations for the analyzed soil sample ranged from 0.22 – 27.13 mg/kg. Its spatial distribution of Pb across the study area show in Figure 3. It is observed that the highest level of Pb were recorded in central of Dong Thanh and Nhi Binh wards, and another one in the southern part of Nhi Binh ward. Pb concentration analyzed from soil samples are below the allowable threshold according to Vietnamese standard (70 mg/kg).

The concentrations of Zn were found to be in the range of 0.61 to 285.4 mg/kg. There are 4 hotspots in Dong Thanh ward and 3 hotspots in Nhi Binh ward where are heavily contaminated by Zn element. The Zn concentration in the study area is still under control and below than the allowable threshold.

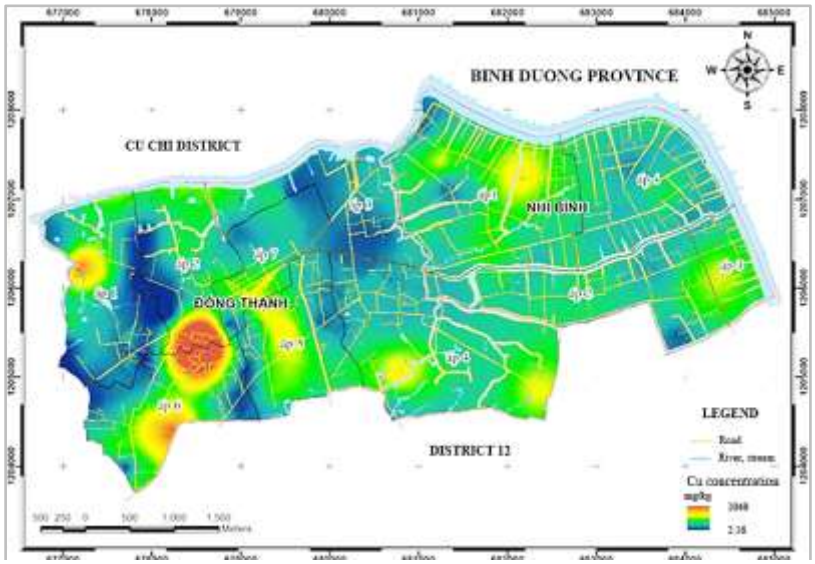

Figure 2. The spatial distribution map of estimated Cu concentration

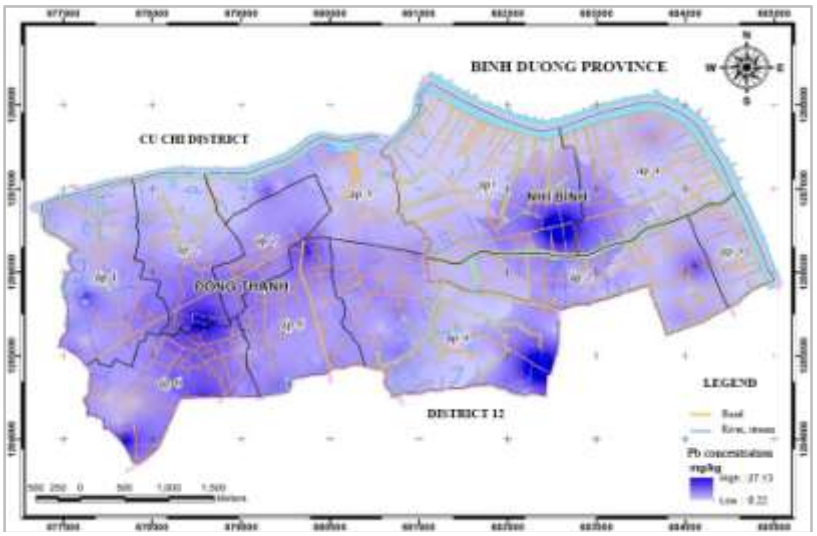

Figure 3. The spatial distribution map of estimated Pb concentration

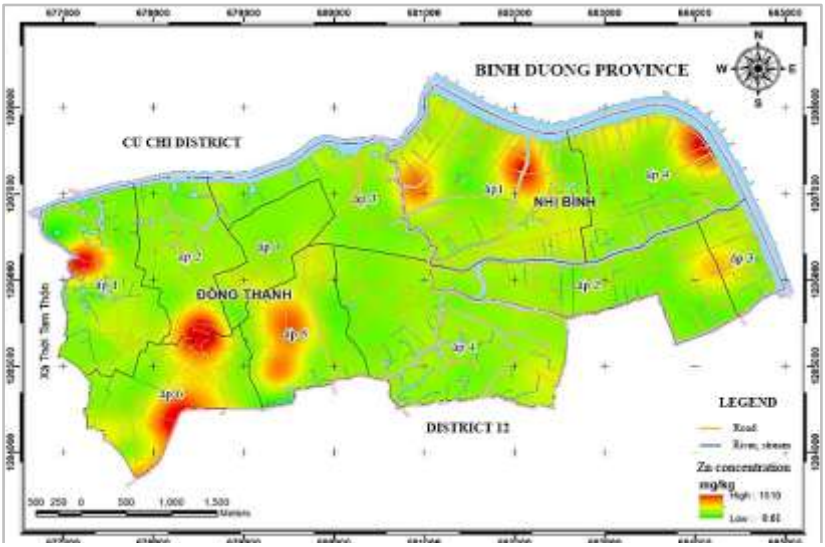

Figure 4. The spatial distribution map of estimated Pb concentration

IV. CONCLUSIONS

This study is the first attempt studying about concentration of heavy metals in the study area, Hooc Mon district, Ho Chi Minh City, Vietnam. Geostatistic and GIS-based mapping technique have applied in this study to predict spatial distribution of metals across study site.

The results showed that the concentration of Cu and Zn in some locations was very close to the allowable threshold. And it can be seen from GIS-based spatial maps that a few hotspots, area of elevated concentrations, were indicated over the study area. These points were suggested an anthropogenic source for such high concentration, especially there is a big landfill located in the study area.

As a result, these metals can pose a risk to soil quality, human health and environment. This study may provide useful information on soil quality monitoring, heavy metal content in soil for better strategies protection environment and life quality in urban areas.

REFERENCES

[1]. Cressie, N., 1990. Statistics for Spatial Data. 1st ed. Wiley, New York.

[2]. F. Santos-Francés, A. Martínez-Grana, C. Asvila Zarza, A. García Sánchez, P. Alonso Rojo. 2017. Spatial Distribution of Heavy Metals and The Environmental Quality of Soil in The Northern Plateau of Spain by Geostatistical Methods. Int. J. Environmental Research and Public Health, 14, 568. doi:10.3390/ijerph14060568.

[3]. G.U. Chibuike and S. C. Obiora. 2014. Heavy Metal Polluted Soils: Effect on Plants and Bioremediation Methods. Applied and Environmental Soil Science, Vol. 2014.

[4]. Gong, M., Wu, L., Bi, X.Y., Ren, L.M., Wang, L., Ma, Z.D. 2010. Assessing heavy-metal contamination and sources by GIS-based approach and multivariate analysis of urban–rural topsoils in Wuhan, central China. Environ. Geochem. Health 32 (1), 59–72.

[5]. Hiller, E.; Lachk*á*, L.; Jurkovi˘c, L.; Durža, O.; Faj˘c ˇ *í*kov*á*, K.; Vozá*r*, J. 2016. Occurrence and distribution of selected potentially toxic elements in soil of playing sites: A case study from Bratislava, the capital of Slovakia. Environ. Earth Sci. 75, 1390.

[6]. Imperato, M.; Adamo, P.; Naimo, D.; Arienzo, M.; Stanzione, D.; Violante, P. 2003. Spatial distribution of heavy metals in urban soil of Naples city (Italy). Environ. Pollut. 124, 247–256.

[7]. Kishné, A.S.; Bringmark, E.; Bringmark, L.; Alriksson, A. 2003. Comparison of ordinary and lognormal kriging on skewed data of total cadmium in forest soil of Sweden. Environ. Monit. Assess. 84, 243–263.

[8]. Lee, C.S., Li, X., Shi, W., Cheung, S.C., Thornton, I. 2006. Metal contamination in urban, suburban, and country park soils of Hong Kong: a study based on GIS and multivariate statistics. Sci. Total Environ. 356, 45–61.

[9]. Lee, C.S.L.; Li, X.; Shi, W.; Cheung, S.C.N.; Thornton, I. 2006. Metal contamination in urban, suburban, and country park soil of Hong Kong: A study based on GIS and multivariate statistics. Sci. Total Environ. *356*, 45–61.

[10]. Lin, Y., Cheng, B., Chu, H., Chang, T., Yu, H. 2011. Assessing how heavy metal pollution and human activity are related by using logistic regression and kriging methods. Geoderma 163, 275–282.

[11]. M. Friedlova. 2010. The influence of heavy metals on soil biological and chemical properties. Soil and Water Research, vol. 5, no. 1, pp. 21–27.

[12]. Zahra, A.; Hashmi, M.Z.; Malik, R.N.; Ahmed, Z. 2014. Enrichment and geo-accumulation of heavy metals and risk assessment of sediments of the Kurang Nallah - Feeding tributary of the Rawal Lake reservoir, Pakistan. Sci. Total Environ. 470–471, 925–933.

[13]. Mihailovíc, Lj. Budinski-Petkovíc, S Popov, J. Ninkov, J. Vasin, N.M. Ralevíc, M. Vuciníc Vasíc. 2015. Spatial Distribution of Metals in Urban Soil of Novi Sad, Serbia: GIS-based Approach. Journal of Geochemical Exploration 150, 104-114.

Tuan Tran Quang" GIS-based Techniques for Estimating Spatial Distribution of Heavy Metals in Urban Soil: A Case Study in Hoc Mon District, Ho Chi Minh City, Vietnam" International Refereed Journal of Engineering and Science (IRJES), vol. 07, no. 08, 2018, pp. 25-29