Heavy Metal in Soil Surrounding Dong Thanh Landfill Site, Ho Chi Minh City, Vietnam

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Abstract – The environmental issues around landfill sites are currently major concern to many environmental protection organizations as well as researchers. In which heavy metal contaminated in soil is one of the most serious problems because of its negative impact to quality of surrounding environment and human health. Dong Thanh landfill located in the north of Ho Chi Minh City has been operating for a long time and there have been environmental incidents (leaking leachate, broken sewage reservoir) during its operation. The purpose of this study is to determine the status of heavy metals in the soil, hotspots, and factors that affect the accumulation of heavy metals in the area around Dong Thanh landfill. The entire study area was conducted to take 68 soil samples for three main heavy metals: Cu, Pb, Zn that randomly taken and analyzed by Flame Atomic Absorption Spectrophotometry method (TCVN 8246: 2009; EPA Method 7000B). Geo statistical method and GIS technique are used to produce the spatial distribution of heavy metals. The results showed that the Cu concentration was from 2.16 - 96.5 mg/kg, Pb from 0.17 - 26.7 mg/kg and Zn from 0-285.5 mg/kg. Compared to the allowed standard determined by national technical regulation, zinc concentration is close pollution and 2 elements Pb, Cu is below the allowed threshold. The areas that tend to accumulate high concentration of heavy metal in soil is identified to be located in the Northwest-Southeast. This direction also reflects the elevation changes, run-off characteristics, and the land use/land cover. This study shows that during the operation of the landfill is the main cause that leads to the accumulation of heavy metal in the soil in the areas surrounding Dong Thanh landfill. According to National Technical Regulation on the allowable limits of heavy metals in soils QCVN 03-MT: 2015/ BTNMT, the results showed that Cu, Pb concentrations are still below the allowed threshold of pollution, however, Zn concentration has nearly reached the highest allowed threshold of pollution. Factors affecting to accumulate high concentrations are elevation, land use/ land cover and run-off characteristics. This result is also a reference for managers and decision-makers to have better environmental protection policies of the landfill area.

Keywords – Spatial Distribution, Heavy Metals, GIS Technique, Kriging Interpolation.

I. INTRODUCTION

Vietnam is a developing country with rapid industrialization and urbanization in recent decades. This process is particularly fast in two major cities: Ha Noi and Ho Chi Minh where the population is densely populated and increasing of various human and industrial activities. Ho Chi Minh city is the largest city in Vietnam with an area of 2,095 km2 and about a population over 10 million in 2020. Approximately up to 5000 tons/day of unclassified waste generated daily and be then concentrated in the city's major landfills. With the large amount of municipal waste every day, it is causing an overload in the waste treatment system and bring more problems into the urban environment.

Landfill is still the main disposal route in Vietnam and other developing countries as well. Moreover, they do

not have waste separation system and this is the reason why a lot of hazardous substances are sending to landfills. It is no doubt that there is a high threat of such substances migration into the environment with the poor condition at landfills [1]. Therefore, observing the contamination of heavy metals in soil is an important task and need to be paid more and more attention in order to protect urban environment in surrounding areas of landfills.

There are many previous studies has been carried out to identified the soil pollution caused by contaminated heavy metals. According to the study of Vergara and Tchobanoglous (2012), heavy metals have been considered as the main soil polluter near landfill sites [2]. In many countries, they strictly control heavy metal mobile by different parameters, for example in Ukraine, they control the distance of 50, 100, 200 and 500 m from a landfill [1]. The changes of contamination level of heavy metal in soil are also analyzed and defined for different distance buffered from a landfill [3]. Besides, the spatial distribution of heavy metal in soil within landfill body have been mapped by Xie et al. (2009) [4]. The heavy metal concentration within and outside the landfill is also compared by Bahaa-Eldin et al. (2008) [5]. The contamination and extent of heavy metals: Cd, Cu, Pb Cr, Ni, Cr, As and Zn which strongly impact on natural ecosystem and are threat to human health through food chain, have identified successfully by various studies [6, 7, 8, 9].

It is known that, heavy metals are naturally present in the soil, but the process of accumulating heavy metals in the soil is increasing and becoming more and more complicated, exceeding the permitted level and causing significant impacts on the soil, water and living environment of humans and organisms. In order to deal with problem of heavy metal contamination, GIS-based approached is used since it has ability to display, simulate, analyse and measure problem related to environmental components (i.e. Soil, water…) [10]. Geo-statistics, multivariate methods and Geographic Information System (GIS) have been widely used in numerous studies that allow for faster and more accurate information. They are power tools for determination of spatial distribution in soil pollution study [7, 11, 12, 13].

GIS is considered as the most successful technique that can help investigator gain more insight into current environmental issues as giving information about spatial distribution in a map with different colours that makes easy to distinguish between polluted and unpolluted areas. From there, hotspots of heavy metal contamination in soil also can be identified easily and more accurately. This information can help to provide a better understanding about the pathway of exposure and the source of the pollutants [14].

Although, there are many studies have been conducted to determine heavy metal contamination in soil, however, the long-term impact of landfills including the potential heavy metals released from landfill body is still need more and more investigation to make clearly understanding about heavy metal impacts to the human health since it obviously might cause toxic effects to biological organism.

In this study, Kriging - an GIS interpolation method is used to map the spatial distribution of heavy metal contamination in Soil around Dong Thanh landfill, Ho Chi Minh City, Vietnam. Kriging is one of the most commonly used methods for spatially interpolation in environmental studies [13, 15]. It has been applied successfully to describe the spatial variability of certain soil parameters and predict value for unknown points/ areas [12, 16, 17].

II. STUDY AREA

Ho Chi Minh (HCM) is the largest and the most developed city. It is located in the Southern part of Vietnam. There are 4 main landfill sites in HCMC: Dong Thanh, Go Cat, Tam Tan (or Phuoc Hiep), and Da Phuoc. Dong Thanh landfill located in Dong Thanh commune, HCMC (Figure 1). It was originated from illegal dumping around 1989 and became an official site with an area of 43 ha and a capacity of 4000 tons/day in 1992. It stopped to receive municipal waste from 2002, however, because of unsanitary design and operation without a proper disposal process that caused serious pollution both inside and outside landfill body. Leachate from open dump flows into surrounding areas, goes into soil caused soil, water, underground water pollution in and around landfill site. The concern is that this problem is still going on and polluted areas are still extended.
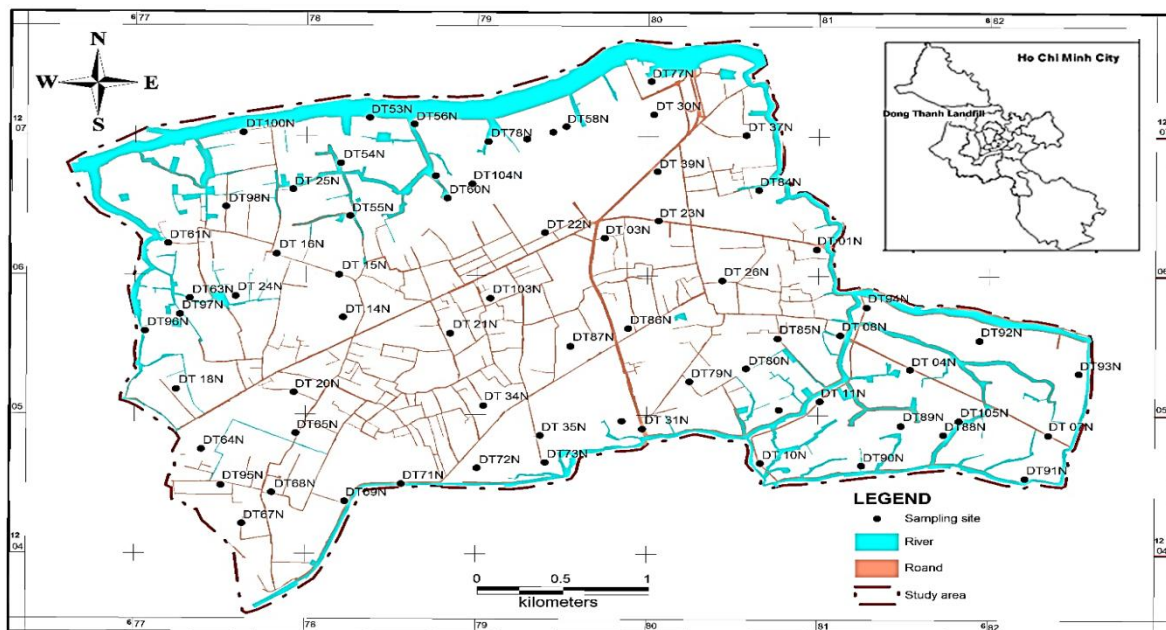

Fig. 1. Soil sampling points denoted in the map of the study area - Dong Thanh commune, HCMC.

(Source: Based map collected from Vietnam Academy of Science and Technology)

III. DATA

3.1. *Soil Sampling*

The soil sampled area was focused on Dong Thanh commune (Figure 1). Soil sampling points were taken randomly around Dong Thanh landfill body. There are 68 soil samples were collected from the outer surface to 20-30 cm depth with a total 2-3 kg of soil/ sample following the Guidance on Sampling Technique of Vietnam (TCVN 7538-2: 2005 (ISO 10381 - 2: 2002). All soil samples were 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). Soil sample material was analyzed Cu, Pb and Zn.

3.2. *Land Use/ Landcover and Topography Maps*

Land Use/ Land Cover map in 2014-2015 and Topography map with scale: 1/10,000 were used in this study as ground reference data for result assesment and explanation. This ground data help to provide overview about status of landuse/ landcover and topograpgy of the study area insiting for getting a fully understanding about current environmental problems over this area.

IV. METHODOLOGY

4.1. *Chemical Analysis to Determine Heavy Metal Contamination in Soil*

Chemical properties of soil samples were obtained following the standard procedures. The soil samples were air-dried at room temperature and milled to a particle size of < 2 mm 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.

In order to determine the concentration of heavy metals, the soil samples were digested in a combination of acids including hydrochloric acid and nitric acid. In the following step, the concentration of metals was determined by ICP: OES in accordance with EPA method.

4.2. *Spatial Analysis using GIS Techniques*

The heavy metal contamination will be used as input data for mapping spatial distribution of contaminated heavy metal in soil in the study area. In GIS applications, spatial interpolation is typically applied to estimate values for unknown points from a set of control points. At basis assumption is spatial interpolation is that the value to be estimated at a point is more influenced by nearby known points that those father away.

In this study, Kriging method is used for estimating spatial distribution of heavy metals. This is one of the most frequently used method of Geo statistical interpolation [18, 19]. 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:

$$Z_0 = \sum_{i=1}^{n} Z_x W_x \tag{1}$$

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. The weight can be derived from solving a set of simulation equations. For example, the following equations are needed for a point (0) to be estimated from three known point (1, 2, 3).

$$W_1 \gamma(h_{11}) + W_2 \gamma(h_{12}) + W_3 \gamma(h_{13}) + \lambda = \gamma(h_{10}), W_1 \gamma(h_{21}) + W_2 \gamma(h_{22}) + W_3 \gamma(h_{23}) + \lambda = \gamma(h_{20}), W_1 \gamma(h_{31}) + W_2 \gamma(h_{32}) + W_3 \gamma(h_{33}) + \lambda = \gamma(h_{30}), W_1 + W_2 + W_3 + 0 = 1.0$$

Where $\gamma(h_{ij})$ is the semivariance between known points i and j, $\gamma(h_{i0})$ is the semi variance between the ith known point and the point to be estimated, and λ is a Lagrange multiplier, which is added to ensure the minimum possible estimation error.

Once the weights are solved, Eq. (1) can be estimated z_0, $z_0 = z_1 W_1 + z_2 W_2 + z_3 W_3$

V. RESULTS AND DISCUSSION

5.1. *Heavy Metal Concentration in Soil*

The concentrations of 3 main heavy metals extracted from soil samples in the study area were summarized in

the Table 1. The results showed that the metal in ascending of mean concentrations were Pb, Cu and Zn. The largest mean value was found for Zn (29.86 mg/kg).

The contamination value of Cu was observed from soil samples in range of 2.16 - 96.5 mg/kg. The maximum of Cu is 96.5 mg/kg that very close to the limit value (100 mg/kg). Similarly, for Zn, contaminated value from 0 to 285.4 mg/kg. The maximum value of Zn exceeds the limit value (200 mg/kg). For Pb, the observed values are from 0 to 26.6 mg/kg that are still lower than allowed threshold.

Table 1. Statistical summary of heavy metal concentration extracted from soil samples (mg/kg).

Heavy metals	Min	Max	Mean	Standard Deviation	Close to allowed threshold (70% of allowed threshold)	Allowed threshold
Pb	0	26.7	2.34	3.92	49	70
Cu	2.16	96.5	27.03	19.85	70	100
Zn	0	285.4	29.86	58.61	140	200

5.2. *Spatial Distribution of Heavy Metals*

The spatial differences in the concentration of the selected heavy metals: Pb, Cu and Zn over the study area were investigated using Ordinary Kriging method. The interpolated maps of above mentioned risk elements are illustrated in Figure 2, 3 and 4.

For Cu, concentration and spatial distribution of this element over study area are shown in Table 1 and Figure 2 respectively. It can be seen that Cu values observed from soil samples were under the limit, especially samples located in the center of the study area. The higher contamination of Cu was found for samples located in the Northwest and Southeast part of the study area (Figure 2, dark brown color). The reason for this distribution is due to higher terrain in the center part of the study area and lower toward in both Northwest and Southeast directions, run-off characteristics, and the land use, land cover status.
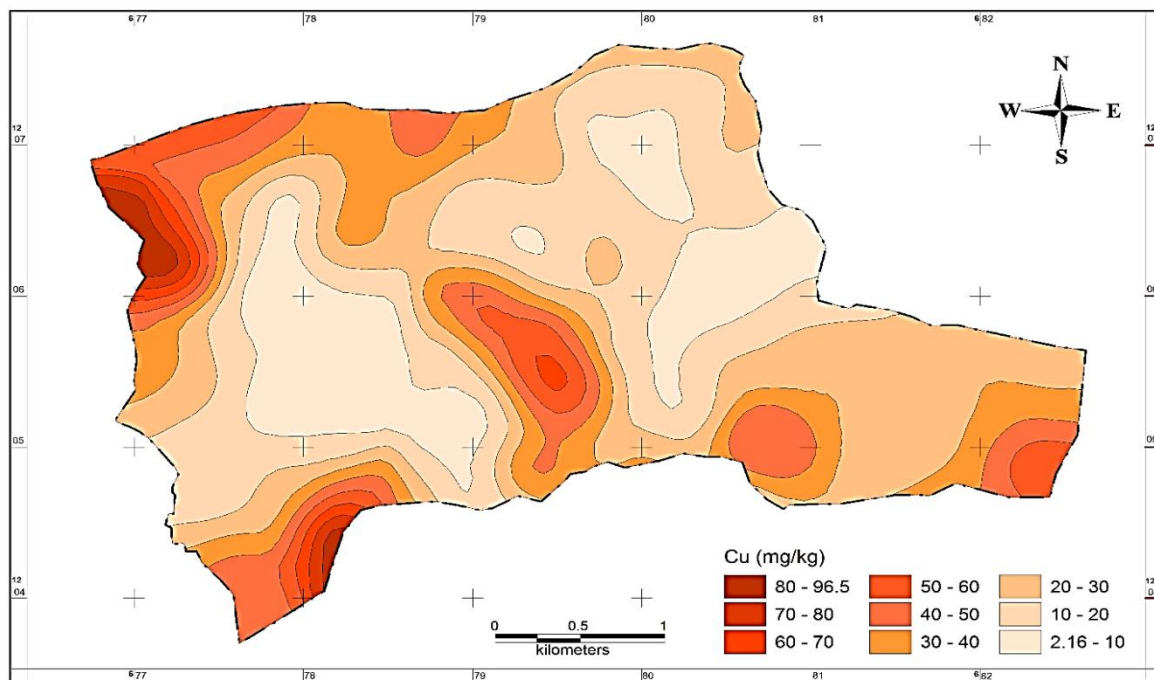

Fig. 2. The spatial distribution map of Cu concentration estimated by using Kriging method.

For Zn, the concentration monitored from soil samples ranged from 0 to 285.4 mg/kg (Table 1) and its spatial distribution is shown in Figure 3. It can be observed from the interpolated map that the higher levels of Zn were also recorded on the Northwest and Southeast sides of the study area.
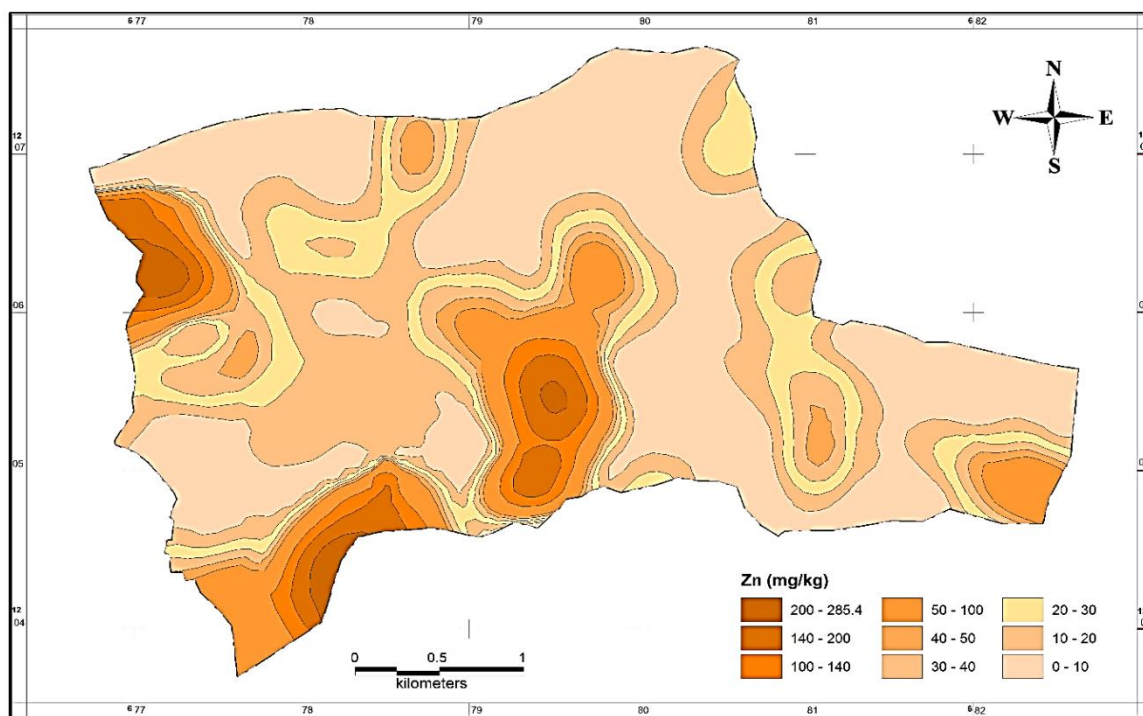

Fig. 3. The spatial distribution map of Zn concentration estimated by using Kriging method.

For Pb, the lead concentrations for the analyzed soil sample ranged from 0 - 26.7 mg/kg (Table 1). Its spatial distribution across the study area show in Figure 4. It can be observed from Figure 4 that the higher level of Pb were monitored approximately on the Southeast part of the study area.
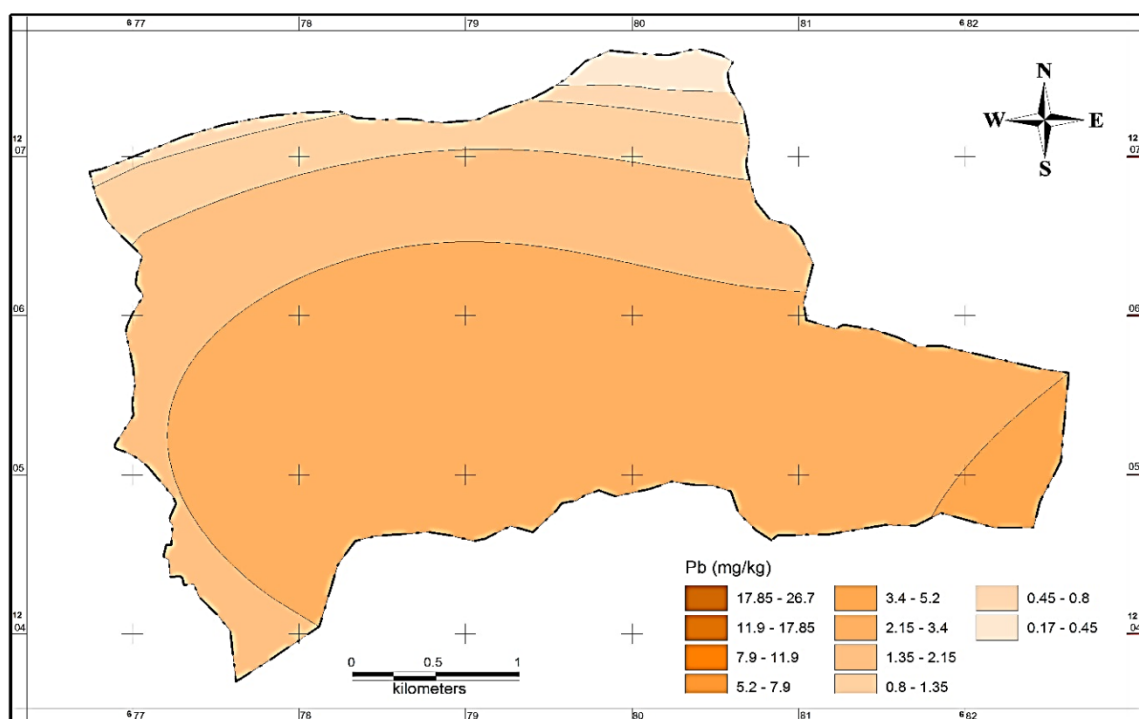

Fig. 4. The spatial distribution map of Pb concentration estimated by using Kriging method.

VI. CONCLUSIONS

This study proposed a method for determining heavy metal contamination in soil and mapping their spatial distribution in surrounding landfill areas. The results indicated that lower concentrations were found for Pb and observed Pb values are still under the limit. Most of samples with high Pb contents located in Southeast part of the study area. Meanwhile, high concentration values of Zn and Cu mainly distributed in Northwest and Southeast of the study area due to effect of lower terrain in these both sides. Cu concentrations ranged from 2.16 to 96.5 mg/kg. This element has highest values of 96.5 mg/kg that is very close to the limit (100 mg/kg) and it needs to be paid more attention in monitoring and controlling Cu concentration in the study area. Besides that, Zn concentration ranged from 0 to 285.4 mg/kg and it can be seen clearly that the samples with highest values of 285 mg/kg already exceeded the limit (200 mg/kg). This result indicated that surrounding areas of Dong Thanh landfill were contaminated by exceeding Zn accumulation in soils at some surveyed sites.

This study examined the heavy metal concentration and spatial distribution of heavy metals in a near landfill area where has been considered as a high risk of soil pollution by contaminated heavy metals. From the finding of heavy metals maps, it could be concluded that the geo statistics and GIS techniques were efficient in estimating spatial distribution and mapping the results in a proper way. The results provide useful information about current state and potential pollution risks as well as locations of high of heavy metals in soil over the study area. This can be used as a reference data source for better strategies in managing landfill sites and environment quality in urban area.

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