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To cite this article: M I Sujaul *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **244** 012016

IOP Conf. Series: Earth and Environmental Science **244** (2019) 012016 doi:10.1088/1755-1315/244/1/012016

Evaluate the ecological risk indexes soil heavy metals pollution in industrial estate

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Abstract. This study was carried out to evaluate the soil heavy metals pollution in Gebeng industrial area using reliable ecological risk indexes. The inductively coupled plasma-mass spectrometry was used to identify the concentration of selected heavy metals (As, Ba, Cd, Co, Cr, Cu, Ni, Mn, Pb, and Zn). Based on the results, the decreasing of heavy metals concentrations in the soil samples were in order as follows: Mn > Cu > Pb > As > Zn > Ba > Ni > Co > Cr > Cd. Ecological risk indexes (Geo-accumulation, Contamination Factor and Pollution Load Index) indicated that the industrial zone (IZ) was moderately to highly polluted by As, Cu, Pb, Co, Cd and Ni, whereas there was no toxic metals in the residential zone (RZ) and swampy area (SA).

1. Introduction

In the recent years, the accumulation of heavy metals in soil by the rapid industrial development has caused the intensification in metals concentration and intensive environmental pollution [1]. The heavy metals often release from industrial activities into the environment that in most cases are possibly detrimental to human health and ecosystem [2]. Therefore, the heavy metals accumulation in soil has gained further attention due to their potential risks to human and ecosystem [3]. The ecological risk of heavy metals has become a major concern in developing countries like Malaysia. Gebeng, which is considered as one of the largest industrial city in Malaysia that covered 8600 hectares having wide industries such as chemical and petrochemical, metal, manufacturing and mining, polypropylene, food and beverage, gas and power [4,5]. These types of industries discharge their pollutants into the soil. The soil contamination by heavy metals in Gebeng has become a great problem in soil ecosystem, and human health in and around the Gebeng city [6]. Therefore, this research aims to assess the soil pollution level due to heavy metal element in Gebeng industrial area. Geo-accumulation index (I_{geo}), contamination factor (CF), and pollution load index (PLI) were used to evaluate the heavy metals contamination in the study soil samples.

2. Materials and Methods

2.1 Study area

Gebeng is considered a big city in Malaysia with the speedy extension of industrialization over the last few decades. The located of Gebeng is on the east coast of peninsular Malaysia that lies between latitudes 03°54′00″ N to 04°00′00″ N and longitudes 103°21′00″ E to 103°25′30″ E (Figure 1). The main industries such as polymer, chemicals, petrochemicals, palm oil mills, metal works factories, pipe coating, oil and gas industries, steel industries, energy, cool mining, detergent and air product, chicken food, concrete ducting and concrete ducting release their contaminants in the soil which led to polluted the study area [4].

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2.2 Sample collection

Ten samples stations were established along the Gebeng industrial area. Samples were collected throughout a year during the dry and wet season from three major zone namely residential zone (RZ, n=3), industrial zone (IZ, n=4), and swampy area (SA, n=3) (Figure 1). The soil samples were collected from the top soil (0-20 cm depth) using Dutch auger and reserved into Ziploc polyethene bags for storage. At the room temperature, the soil samples were dried by air and sieved into <2 mm mesh and kept in sealed polyethene bags until instrumental analysis.

Figure 1: Map of the study area and location of sampling stations

2.3 Analysis methods

The inductively coupled plasma-mass spectrometry (ICP-MS) was used to determine a total of 10 heavy metals (As, Ba, Cd, Co, Cr, Cu, Ni, Mn, Pb, and Zn) in the soil samples from the Gebeng industrial area, Malaysia. The soil samples digested before analyzing the heavy metals by using concentrated nitric acid (5 ml) mixed with 0.5 g dried soil in a 50 ml Folin digestion tube. The combination heated at 130°C for 15 h and then treated with hydrogen peroxide. The sample was diluted to 50 ml with 2% nitric acid after digestion directly and then the solution was additional diluted 1:9 (solution: nitric acid) for analysis by ICP-MS (EPA 2007a). Soil pH and electrical conductivity (EC) was measured using soil survey standard method [7], whereas soil organic matter (OM) was analyzed by weight loss ignition method [8].

2.4 Geo-accumulation index (I_{geo})

Since the late of the 1960s, the geo-accumulation index (I_{geo}) was used to assess the pollution states of the samples [9]; [10]. The calculation formula for I_{geo} is as follows in Eq. (1).

$$I_{geo} = \log2\ (Cn/1.5Bn) \quad (1)$$

Where: *Cn* is the concentration of heavy metals in measuring soil, while *Bn* is the metals geochemical background concentration. The factor 1.5 used to regulate the variations in the baseline data [11]. All the stations were categorized based on contamination level with I_{geo} 0, uncontaminated to moderately contaminated with 0 < I_{geo} 1, moderately contaminated with 1 < I_{geo} 2, moderately to heavily contaminated with 2 < I_{geo} 3, heavily contaminated with 3 < I_{geo} 4, heavily to extremely contaminated with 4 < I_{geo} 5, and extremely contaminated with I_{geo} > 5 [3] and [12].

2.5 **Contamination Factor (CF)**

The CF was used to determine the level of metal contamination in soil. It was calculated by using the following (Eq. 2):

$$CF = C_{metal} / C_{background} \quad (2)$$

Where: C_{metal} is the concentration of soil heavy metals whereas $C_{background}$ is the background concentration of heavy metals. CF was categorized into four classes, CF < 1, low contamination factor; 1< CF >3, moderate contamination factor; 3 < CF < 6, considerable contamination factor; CF > 6, very high contamination factor [13] and [14].

2.6 **Pollution Load Index (PLI)**

Pollution Load Index (PLI) was done to evaluate a particular sampling site for soil metal pollution levels. The PLI was calculated using the following equation (Eq. 3).

$$PLI = (CF1x\ CF2x\ CF3x \ldots\ldots CFn)^{1/n} \quad (3)$$

Where: n is the number of metals while CF is the contamination factor. The PLI value higher than 1 indicates that the samples are polluted whereas the value less than one indicates no pollution occurred [15].

3. Results and Discussion

The pH values were found to be low at all the sampling sites and ranged from 3.10 to 6.03 with the mean value of 4.75±0.94. However, the concentration of EC was significantly higher at all the sites. The range of EC was recorded from 264.78 μS/cm to 1729.67 μS/cm. Soil organic matter content at RZ and SA sampling sites was relatively higher compared to the IZ sites. The result shows that the mean contents of As, Cr, Mn, Co, Ni, Cu, Zn, Cd, Ba and Pb were about 18.73±23.21 ppm, 2.71±1.12 ppm, 97.67±89.21 ppm, 4.63±6.83 ppm, 10.80±11.55 ppm, 27.11±28.76 ppm, 17.02±16.10 ppm, 0.15±0.14 ppm, 14.85±13.05 ppm and 20.96±18.99 ppm respectively. The mean concentration of heavy metals in the study area were in the order Mn > Cu > Pb > As > Zn > Ba > Ni > Co > Cr > Cd. The results also indicates that Mn, Cu, Pb, As, Zn and Ba were found to be the dominant metals in the studied soils. The concentration of Ni, Co and Cr were found to be lower compared to Mn and Cu, whereas the lowest mean concentration of Cd was recorded in the study area. It has been demonstrated that the distribution of the highest heavy metals concentrations were obtained in the industrial zone (IZ), whereas the lowest concentrations were recorded in residential zone (RZ) and swampy area (SA).

Krishna and Mohan [16] reported that the industrial activities direct or indirectly caused the heavy metals input into the soils releasing from wastewater, solid waste and air pollutants.

3.1 Geo-accumulation index (I_{geo})

Based on I_{geo} values, the main contamination elements in industrial (IZ) area were As, Cu, Pb, Cd, Co, Ni and Zn; and the mean values were 3.44±0.27, 3.14±0.30, 2.08±0.80, 1.42±0.68 and 1.37±1.34, 0.52±0.55 and 0.08±0.29, respectively. The mean contamination factors for these metals indicated that the pollution level in soils of IZ site was falling under higher than moderate pollution class, due to release of industrial effluents on to the surface soils in industrial zone (IZ) [6], whereas the I_{geo} mean values of the following metals in the RZ and SA sites was obtained low (< 1) except Pb value (RZ), which indicated that no pollution has occurred in surface soils of the two areas [16].

3.2 Contamination Factor (CF)

The concentrations value of As, Cu, Pb, Co, Cd and Ni were higher than the corresponding background values (>1) at all the station in IZ sites; which specifies that the study area is polluted by these metals due to receive of a huge quantity of metals discharge related by industrial plant [17]. The CF contamination index values are shown in (Table 1). On the order hand, the low value of CF for the following metals was found at the sites RZ and SA. Overall, the soil in the study area was not contaminated by Cr, Mn, Zn and Ba metals.

3.3 Pollution Load Index (PLI)

The load index of pollution (PLI) values varied from 0.03 to 1.27 (Table 1). According to the PLI values, the industrial area was polluted by heavy metals. The order of PLI for all the sampling sites is SA2 > SA1 > RZ2 > RZ1 > RZ3 > SA3 > IZ1 > IZ3 > IZ2 > IZ4. The results of the present study show that the residence and swampy areas are not polluted by PLI. Similar results were recorded by Samir et al. [15] in Tunisia. The calculated value of PLI ranged from 0.03 to 0.20 in residence and swampy areas. The mean concentration in and around the industrial zone, residence zone and swampy area was recorded 1.03±0.20, 0.14±0.03 and 0.10±0.09, respectively.

Table1: The contamination factor (CF) and pollution load index (PLI) in soils of the study area

	CF										PLI
Sample	As	Cr	Mn	Co	Ni	Cu	Zn	Cd	Ba	Pb	
Residential zone											
RZ1	0.02	0.06	0.20	0.19	0.11	0.53	0.09	0.33	0.03	0.48	0.13
RZ2	0.06	0.06	0.02	0.17	0.15	0.44	0.26	0.27	0.03	0.42	0.12
RZ3	0.11	0.05	0.14	0.07	0.17	1.28	0.08	0.40	0.04	1.85	0.18
Mean	0.06	0.06	0.12	0.14	0.14	0.75	0.14	0.33	0.03	0.92	0.14
SD	0.05	0.01	0.09	0.06	0.03	0.46	0.10	0.07	0.01	0.81	0.03
Industrial zone											
IZ1	8.39	0.13	0.18	0.47	1.15	5.14	0.56	0.93	0.06	5.07	0.78
IZ2	5.46	0.07	0.51	3.61	0.92	4.68	0.82	2.67	0.14	2.40	1.08
IZ3	7.41	0.09	0.42	1.70	0.57	7.27	0.62	1.67	0.19	2.05	0.98
IZ4	7.71	0.08	0.58	3.03	1.37	6.67	0.85	2.4	0.14	3.86	1.27
Mean	7.25	0.09	0.42	2.20	1.00	5.94	0.71	1.92	0.13	3.35	1.03
SD	1.26	0.03	0.17	1.40	0.34	1.23	0.14	0.78	0.05	1.39	0.20

Swampy area											
SA1	0.08	0.03	0.03	0.01	0.02	0.34	0.03	0.6	0.02	1.06	0.07
SA2	0.05	0.04	0.01	0.01	0.004	0.58	0.06	0.07	0.03	0.42	0.03
SA3	0.77	0.05	0.18	0.00	0.23	0.17	0.09	0.47	0.03	0.31	0.20
Mean	0.30	0.04	0.07	0.01	0.08	0.36	0.06	0.38	0.03	0.59	0.10
SD	0.41	0.01	0.09	0.01	0.13	0.21	0.03	0.28	0.01	0.41	0.09

4. Conclusion

This study results revealed that the soils of IZ site has been contaminated by the selected toxic metals, which were higher than their background values in Gebeng industrial city. The industrial area shows a potential great pollution risk due to anthropogenic contamination. The concentration of heavy metal in the studied soil samples followed the order of sites SA > RZ > IZ. The I_{geo} and CF values indicate that the concentration of As, Cu, Pb, Co, Cd and Ni were higher loading pollutants in the IZ site and lower loading in unpolluted zone (RZ and SA). The value of PLI indicates that the heavy metal contamination in industrial soils have a serious threat on the ecosystem. For the sustainability of the study area, it is recommended to utilize various remediation techniques to minimize the rate of contamination in order to safes the public health and environment.

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Acknowledgement

The authors are very thankful to Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang (UMP) for financial support through the project RDU 170342. We also heartily thank the Libyan Government for supporting the student scholarship.