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The patterns of lead and copper levels in the vicinity of heavy metal sources in Lampung, the southern part of Sumatra, Indonesia

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The patterns of lead and copper levels in the vicinity of heavy metal sources in Lampung, the southern part of Sumatra, Indonesia

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Abstract. Heavy metals may easily move through the air system and may deposit and accumulate in the soil system by water precipitation away from their sources. This research aimed to evaluate the soil concentrations of Pb and Cu in the vicinity of several sources of heavy metals in Lampung, the southern part of Sumatra, Indonesia. Soil samples were collected at distances of 0 (Central Points) to 500 m from the presumed centers of heavy metal sources, including industrial areas, heavily traffic/railroads, and the residential areas of Panjang (Bandar Lampung City), Tanjung Bintang, and Natar (South Lampung Regency). The results show similar patterns of Pb and Cu distributions along with the sampling points. The soil concentrations of Pb and Cu were highest at the central points (0 m) and decreased with distances towards the farthest sampling points of 500 m. The concentrations of Pb and Cu in Panjang were higher than those in Tanjung Bintang and Natar.

1. Introduction

Even though some are essentially needed by the living things, heavy metals are toxic at concentrations higher than their allowable levels [1-3]. However, almost all heavy metals have been silently accumulating in the soil environment in the last decades [4-11]. Reports show that many heavy metal sources have contributed to the accumulated heavy metals in the soil environment. Some are at excessive concentrations that may disturb the growth and health of plants, animals, and humans [3, 5,7,8,12].

While a great deal of researchers may have probably solved the problem of heavy metals in the soil environment *in situ* by physical, chemical, and biological engineering [13-19], their emission into the soil environment must also be understood. Part of heavy metals may move in the soil system by mass flow and diffusion, water percolation and leaching, water runoff and erosion [8, 20, 21, 22, 23]. A significant part may also move through the air system along with fine particle materials exhausted into the atmosphere and may deposit into the soil system by gravitation and water precipitation [5, 7, 8, 24, 25, 26]. Air movement of heavy metals may occur from several potential sources like industrial exhausts, traffic exhausts, and industrial materials like coal [3, 9, 27, 28]. All these processes may cause soil variability in heavy metal concentrations and may give different effects on the living things.

Many research reports on soil heavy metal levels caused by heavy metal movement in the vicinity of heavy metal sources are found in the current literature [1, 3, 5, 8, 21, 23]. However, such kind of data is scarce for tropical soils, in particular for Lampung and Indonesia. This research aimed to evaluate the soil levels of heavy metal concentrations in the vicinity of several presumed heavy metal sources in Lampung Indonesia.

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2. Methods

Soil samples were collected from presumed sources of heavy metals in Lampung, the southern part of Sumatra, Indonesia, i.e. the older industrial center of Bandar Lampung (Panjang) and the more recently established industrial area of Lampung (Tanjung Bintang, South Lampung). From each of these areas three different metal source types were evaluated i.e. industrial area, heavily traffic road area, and residential area (figure 1 and 2) that were located approximately 1.0 to 3.5 km apart from each other. One other presumed metal source in Lampung, i.e. coal transportation railroad in Natar, South Lampung (figure 3), was also evaluated. Soil samples were collected at distances of 0, 50, 100, 250, and 500 m from the presumed centers of heavy metal sources (0 m). Distances were determined using Global Positioning System (GPS). The locations of the soil sampling are listed in table 1.

Table 1. Locations of the soil sampling.

Source Types	Distance (m)	Panjang Bandar Lampung	Tanjung Bintang South Lampung	Natar South Lampung
Industry	0	5° 30’52” S 105° 20’ 52” E	5° 23’ 14” S 105° 22’ 58” E	-
	50	5° 30’52” S 105° 20’ 55” E	5° 23’ 14” S 105° 23’ 01” E	-
	100	5° 30’51” S 105° 20’ 57” E	5° 23’ 14” S 105° 23’ 05” E	-
	250	-	5° 23’ 14” S 105° 23’ 14” E	-
	500	-	5° 23’ 14” S 105° 23’ 28” E	-
Heavily Traffic /Rail Road	0	5° 29’26” S 105° 19’ 32” E	5° 22’ 59” S 105° 23’ 00” E	5° 20’ 24” S 105° 13’ 15” E
	50	5° 29’26” S 105° 19’ 34” E	5° 22’ 59” S 105° 23’ 04” E	5° 20’ 21” S 105° 13’ 15” E
	100	5° 29’26” S 105° 19’ 37” E	5° 22’ 59” S 105° 23’ 07” E	5° 20’ 17” S 105° 13’ 15” E
	250	5° 29’27” S 105° 19’ 42” E	5° 22’ 59” S 105° 23’ 17” E	5° 20’ 06” S 105° 13’ 15” E
	500	-	5° 22’ 59” S 105° 23’ 33” E	5° 19’ 51” S 105° 13’ 15” E
Residential Area	0	5° 29’52” S 105° 19’ 50” E	5° 23’ 57” S 105° 23’ 17” E	-
	50	5° 29’50” S 105° 19’ 53” E	5° 23’ 54” S 105° 23’ 19” E	-
	100	5° 29’49” S 105° 19’ 55” E	5° 23’ 51” S 105° 23’ 23” E	-
	250	5° 29’46” S 105° 20’ 01” E	5° 23’ 54” S 105° 23’ 19” E	-
	500	-	5° 23’ 45” S 105° 23’ 32” E	-

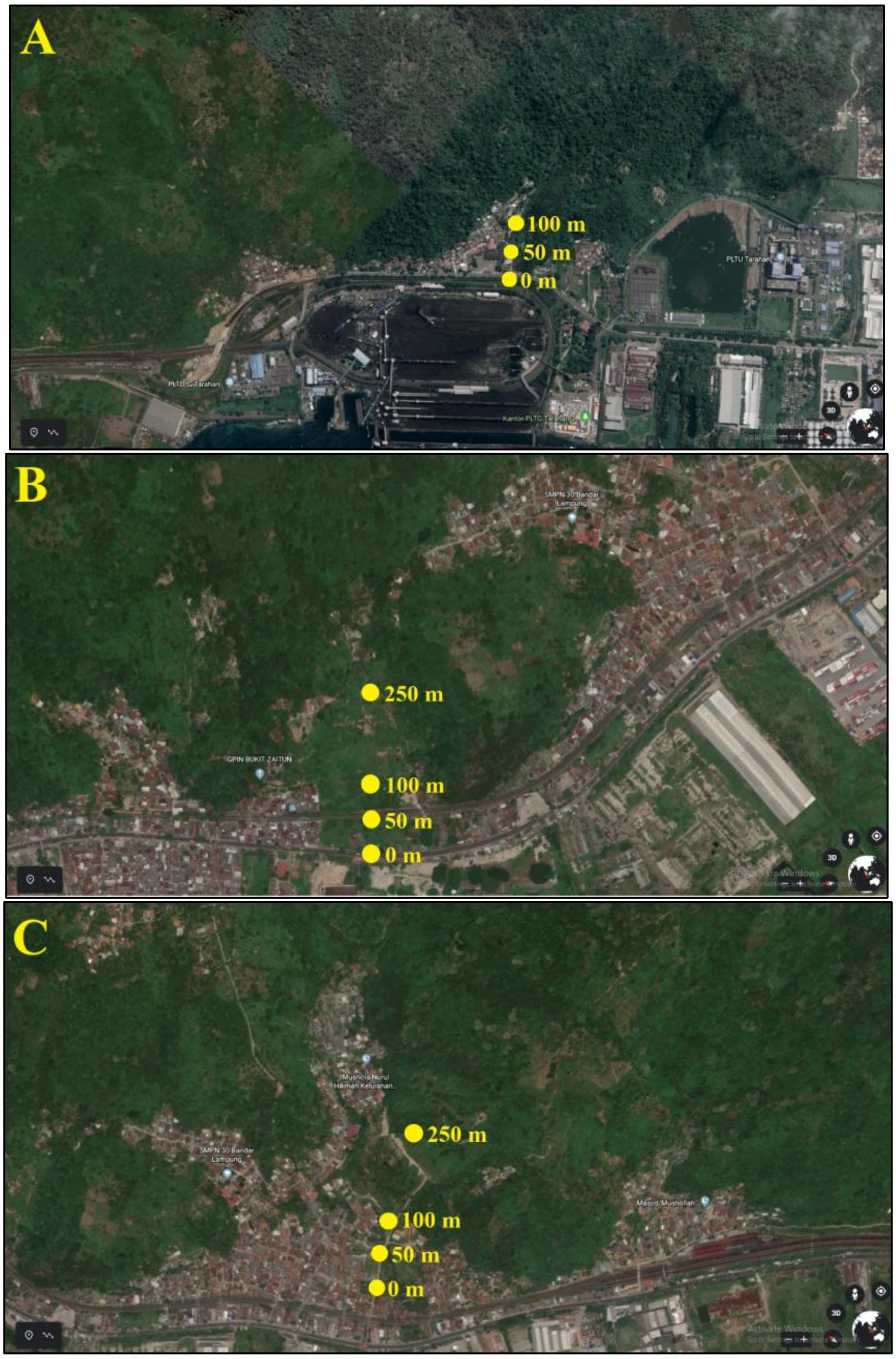

Figure 1. Soil sampling sites in Panjang Bandar Lampung
(A. Industrial Area, B. Heavily Traffic Road, C. Residential Area).

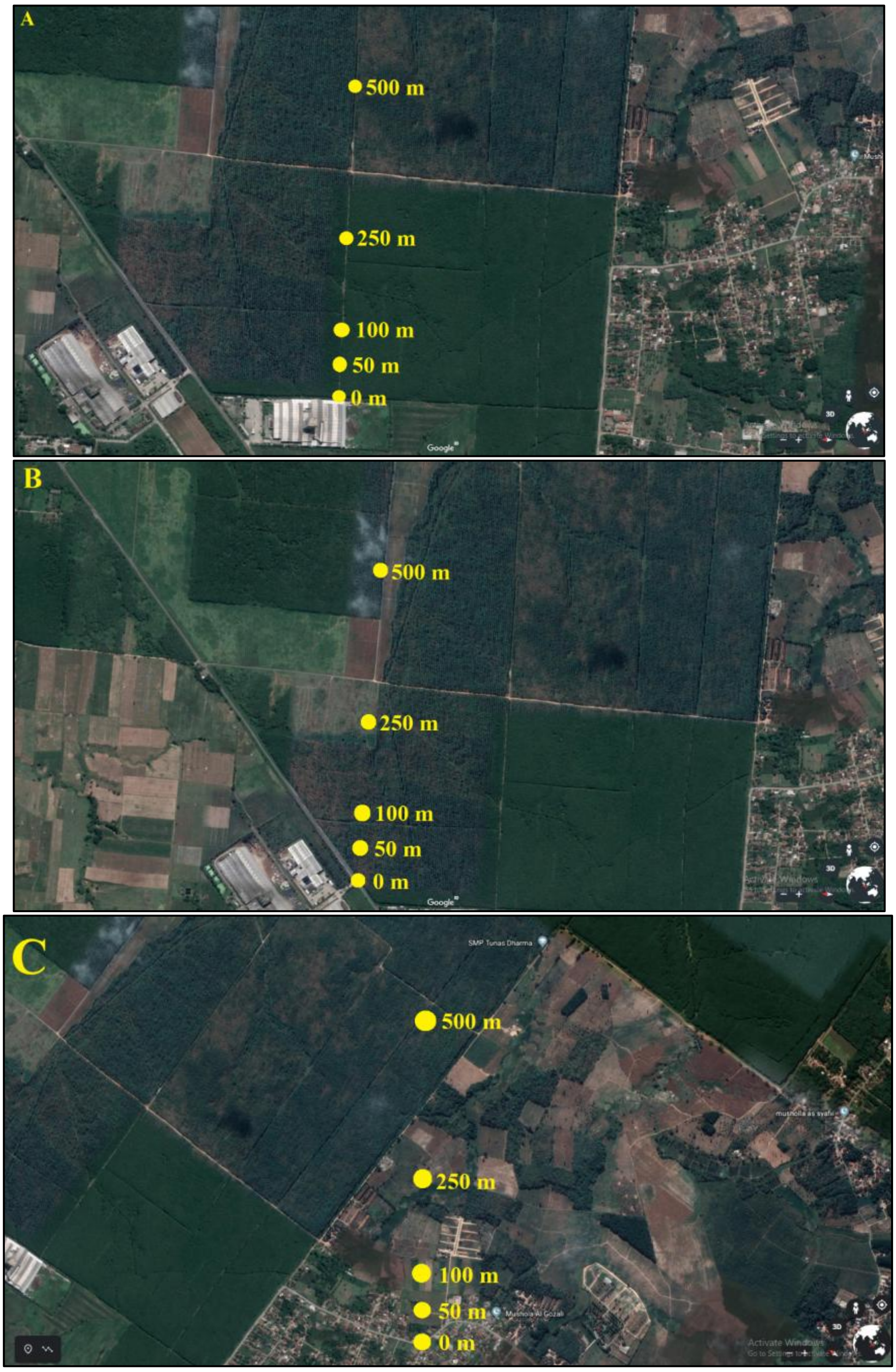

Figure 2. Soil sampling sites in Tanjung Bintang South Lampung (A. Industrial Area, B. Heavily Traffic Road, C. Residential Area).

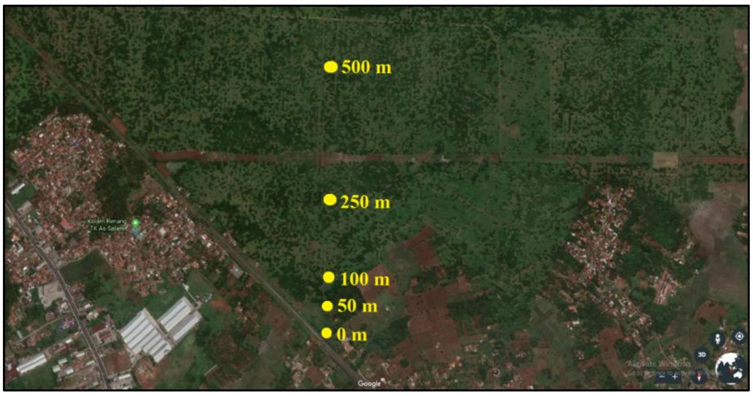

Figure 3. Soil sampling sites in Natar South Lampung (Coal Rail Road).

Soil sample from each location was composite, taken from A_p horizons at 3 sampling points of 10 m apart around each sampling site. Soil samples were air-dried, sieved to 2 mm, and thoroughly mixed before analysis. Heavy metals in soil were extracted by employing 1 *N* HNO_3. The concentrations of Pb and Cu after filtration using whatman papers were measured using the iCE 3000 flame atomic absorption spectrophotometer (Flame AAS).

3. Results and Discussion

The absolute values of the concentrations of Pb and Cu at the center points (0 m) for each area and each heavy metal source type are listed in table 2. The concentrations of Pb and Cu were shown to be much higher in the industrial area, heavily traffic road, and residential area of Panjang than those in Tanjung Bintang except that Cu in the residential area of Tanjung Bintang was much higher than that in Panjang. The center point of the residential area of Tanjung Bintang was fairly close to a temporary disposal site for residential trashes, causing higher Cu. The higher Pb and Cu concentrations in Panjang are easily understood because the industrial area of Panjang was much older than that of the relatively new established industrial area of Tanjung Bintang. The industrial area of Tanjung Bintang was established recently while that of Panjang was established long time ago. The heavily traffic road of Panjang was also much older and was the main road for transportation from Jakarta to Palembang, while that of Tanjung Bintang was relatively new and not the main road with heavy traffics. In addition, it was very clear in the field that the area of Panjang was bordered by relatively stiff hills to the north (figure 1), that may have hindered the movement of metal movement through air system.

Table 2. The soil concentrations of Pb and Cu at the center points (0 m).

	Industry	Heavily Traffic/ Rail Road	Residential Area
	……………..………	mg kg^{-1}	………………..……….
Pb			
Panjang	7.31	4.34	3.59
Tanjung Bintang	1.61	1.87	2.74
Natar	-	2.49	-
Cu			
Panjang	27.0	5.60	3.59
Tanjung Bintang	0.54	1.09	12.1
Natar	-	1.19	-

The significant differences between Panjang, Tanjung Bintang and Natar was also consistently shown by two different types of heavy metals sources, i.e industrial area and heavily traffic roads (table 2). For example, the concentrations of Pb and Cu in the industrial area of Panjang were respectively 4.54 times and 50.0 times greater than those in Tanjung Bintang. The concentrations of Pb and Cu in the heavily traffic roads of Panjang were respectively 2.32 times and 5.14 times greater than those in Tanjung Bintang. These observations suggest that the accumulation of Pb and Cu in Panjang were more intense than that in Tanjung Bintang.

The relative concentrations of Pb (Pb_R) and Cu (Cu_R) as a function of distances from the center points (0 m) for each area and heavy metal sources are depicted in figure 4 and figure 5, respectively. The Pb_R or Cu_R is the ratio of soil Pb or Cu concentration at any sampling distance compared to that at the center points (0 m) as expressed by Equation 1 and Equation 2, where Pb_R or Cu_R is the relative concentration of Pb or Cu, Pb_i or Cu_i is the concentration of Pb or Cu at distances i, and Pb_0 or Cu_0 is the concentration of Pb or Cu at the center point (0 m), and i is distance from the center point, i.e 0, 50, 200, 250, or 500 m.

$$Pb_R = \frac{Pb_i}{Pb_0} \quad (1)$$

$$Cu_R = \frac{Cu_0}{Cu_0} \quad (2)$$

The Pb_R for all areas and all heavy metal sources shows a pretty similar pattern, with the highest was at the center points (0 m), and decreased with sampling distances and being the lowest at the farthest points (figure 4). However, there were differences in the magnitude of Pb movements. The Pb_R at 100 m was only 20% of the center point in Panjang, while that in Tanjung Bintang was 80% of the center point at the same distance, and that at 500 m was about 75%. This observation shows that Pb in Tanjung Bintang moved away freely due to the more level topography (figure 2) while in Panjang the Pb movement was hindered by the bordering stiff hills (figure 1). Therefore, Pb was accumulated more at closer distances from the center point in Panjang. The pattern of Pb distribution in Natar was in general similar to that in Tanjung Bintang due to its similar topography (figure 3).

The movement of Pb from heavily traffic road in Panjang was also similar to that from the industrial area, but Pb moved more freely because hills were located further away from the center point (figure 1). However, the movement of Pb from the heavily traffic road in Tanjung Bintang was similar to that in the industrial area (figure 4). The Pb_R at 250 m of about 0.90 in Tanjung Bintang was higher than that in Panjang of about 0.40 due to the hindering hills. Therefore more Pb was accumulated in Panjang than that in Tanjung Bintang at the same distances. The patterns of Cu_R and Cu movement were in general similar to that of Pb (figure 5). The concentration of Cu was highest at the center point (0 m) and decreased with sampling distances.

The concentrations of Pb and Cu in the residential area of Panjang were comparable to those in heavily traffic roads (table 2). However, Pb and Cu were relatively evenly distributed along the soil sampling sites of 50 – 250 m with Pb_R and Cu_R 80 to 70% and 85 to 70%, respectively (figure 1 and figure 2). Similarly, Pb in the residential area of Tanjung Bintang was comparable to that in the heavily traffic road (table 2), but it was distributed at lower portion from 70 to 50% (figure 1). Part of Pb moved farther than 250 m (figure 1).

The concentration of Cu in the residential area of Tanjung Bintang was relatively high, about 11 and 22 times much higher than those in the heavily traffic road and industry, respectively (table 2). However, much lower concentrations (< 5%) were found at 50 to 500 m. This phenomenon indicates that the contaminating Cu did not move away from its source.

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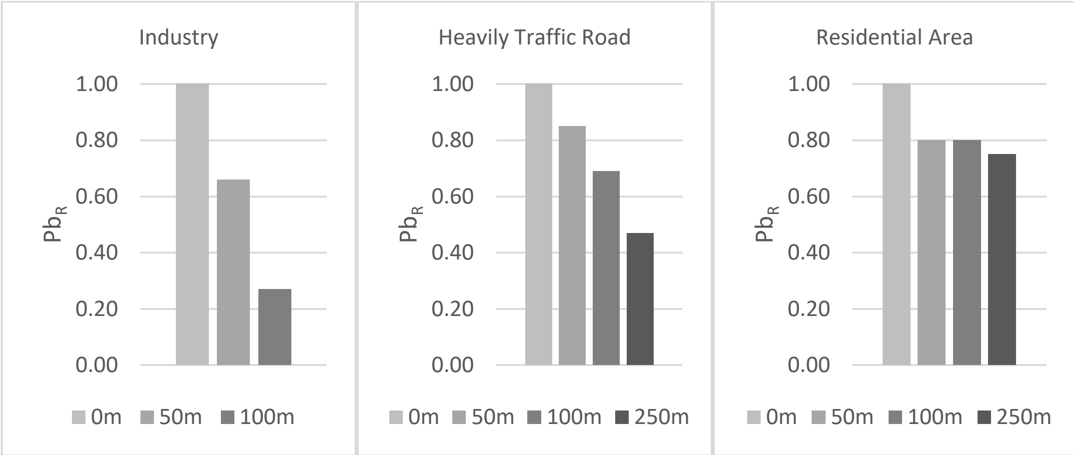
A. Panjang, Bandar Lampung



B. Tanjung Bintang, South Lampung

C. Natar, South Lampung

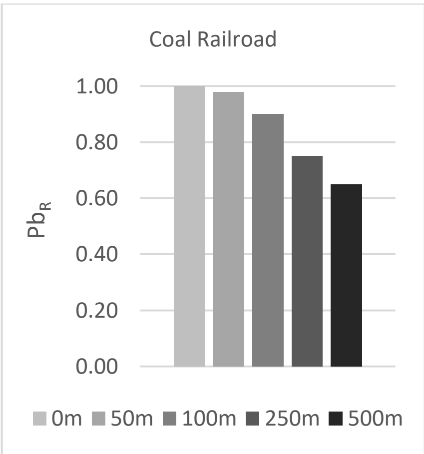
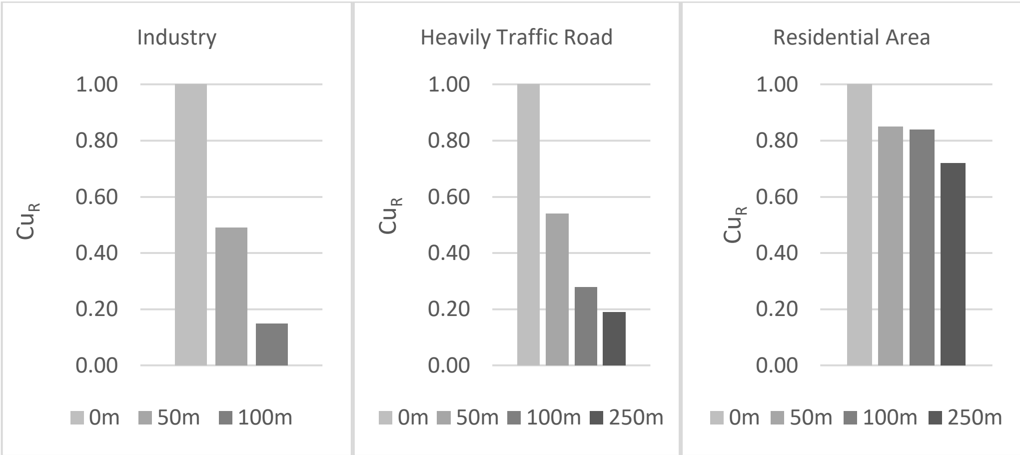
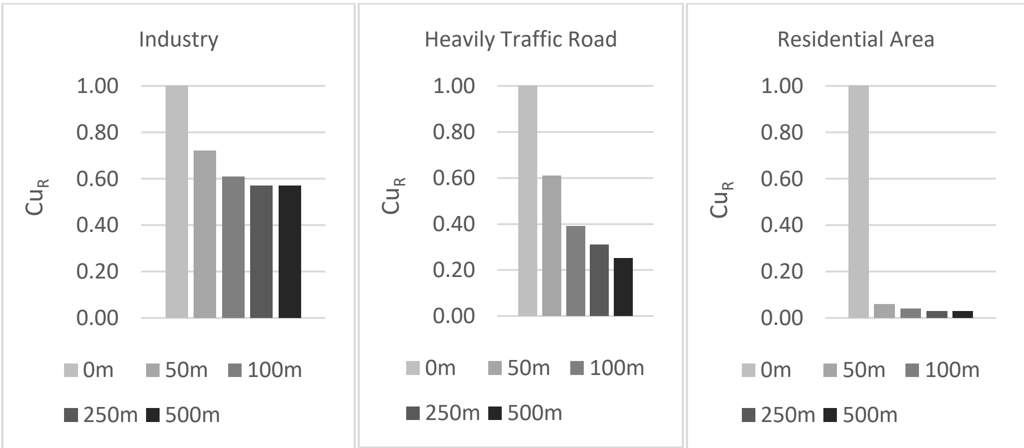


Figure 4. The relative concentrations of Pb along the sampling sites in Lampung.

A. Panjang, Bandar Lampung



B. Tanjung Bintang, South Lampung



C. Natar, South Lampung

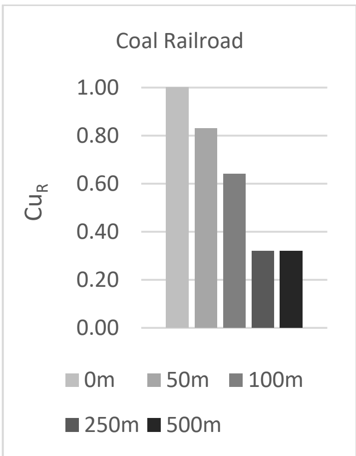


Figure 5. The relative concentrations of Cu along the sampling sites in Lampung.

4. Conclusion
There were similar patterns of Pb and Cu distributions along with the sampling points. The soil concentrations of Pb and Cu were highest at the center points (0 m) and decreased with distances towards the farthest sampling points of 500 m. The concentrations of Pb and Cu in Panjang were higher than those in Tanjung Bintang and Natar, indicating that all heavy metal sources' soil pollution was higher in Panjang.

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