

Original Research Article

EVALUATION OF HEAVY METAL SOIL CONTAMINATION IN ROAD SIDE SOILS ALONGSIDE OBIOMA – NSUDE – NGWO - ABOR ROAD IN AWKA - ENUGU ROAD, SOUTHEASTERN NIGERIA

ABSTRACT

Top soil sample collected from edge of roads to about 150 meter off the road were analyzed. Total concentrations of cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), cobalt (Co), and chromium (Cr) were determined using a Buck 210 VGP atomic absorption spectrophotometer (AAS). Soil contamination was evaluated with Pollution Index (Pi) and index of Enrichment Factor (EF). The enrichment index of Cu is generally low. This implies that Cu toxicity in the area is not significant. The Enrichment and Pollution indices of Cd and Pb are high. The study area is highly contaminated by cadmium and lead but moderately polluted with respect to nickel, zinc and chromium. The enrichment and pollution trends of the metals is are in descending order: Cd > Pb > Ni > Zn > Cu > Cr > Co. The pollution trend follows the order: Cd > Pb > Ni > Zn > Cu > Cr > Co. Total heavy metal content of soils studied was slightly higher than the levels reported in literature for similar soils, suggesting some degree of pollution by heavy metals.

Key Words: Pollution index, Enrichment factor, Heavy metals, Contamination, Health Risk Level.

INTRODUCTION

Roads play a major role in stimulating social and economic progress. Mechanics, auto electricians and others settle along roads sides. Major activities of the settlers include sales of vehicle parts, repairs and scavenging of useful motor parts from scrapes. Wastes emanating from such activities could lead to contamination of land. Contamination by heavy metals in any environment is a major concern because of their toxicity, threat to life and the ecosystem. Automobile mechanic work wastes has been implicated for elevated concentrations of Cd, Cr, Cu, Pb, Ni, and Zn in soil profiles in the vicinity of Automobile waste dumps in Nigeria [1]. Remarkable metal contamination especially lead pollution has been caused by automobile emissions in the roadside ecosystems [2]. Most researchers have reported the influence of the traffic load on heavy metal contents in topsoil and their variability with distance [3] and [4]. Viard *et al* [5], reported that the deposition and the levels of metals in surface soils decreased with increasing distance from highways. He also found that the impact of the highway was clear up to 320 m, at least (lead), but the most important contamination was observed near the road. Nabuloa *et al* [6], reported that leaves of roadside crops can accumulate trace metals at high concentrations causing serious health risk to consumers. Hence, accurate evaluations of the heavy metal contents in polluted soils are required to assess the potential ecological risk of these areas. The objectives of this study are to assess the heavy metal contamination in roadside top soil along the old road passing through Obioma- Nsude – Ngwo and Abor communities and to compare the observed level of pollution in the area with established standards of unpolluted soils. It is envisaged that the study would provide background data for subsequent investigation of the environment, biological dose response and effect on human health.

OVERVIEW OF GEOLOGY OF THE STUDY AREA:

The study area lies within longitudes $7^{\circ}20' - 7^{\circ}22'E$ and latitudes $6^{\circ}21' - 6^{\circ}30'N$ (Fig 1). The Night Mile Corner Ngwo-Uno, has been centre of industrial activities in recent times, particularly those industries that require large amount of water as major raw material. This is in realization that large amount of water exists underground. The area situates completely on Ajalli Formation which encloses large confined aquifer. This water bearing Ajalli Formation (where samples for this study were collected) is made of well sorted, massive, coarse – grained, white sandstone broken by occasional thin beds of white shale. Rivers Ekulu, Iva, Oroho and Nyaba take off from the base of the Ajalli Formation on the Enugu escarpment descending through underlying Mamu Formation into Enugu Town (Fig 1). The Mamu Formation trends N-E of the study area (Fig 1) and comprises alternations of sandstones, dark-blue or grey shales, sandy shales and mudstones with local coal seams at various horizons [7].

MAP OF PART OF SHEET 301 UDI NE (STUDY AREA)

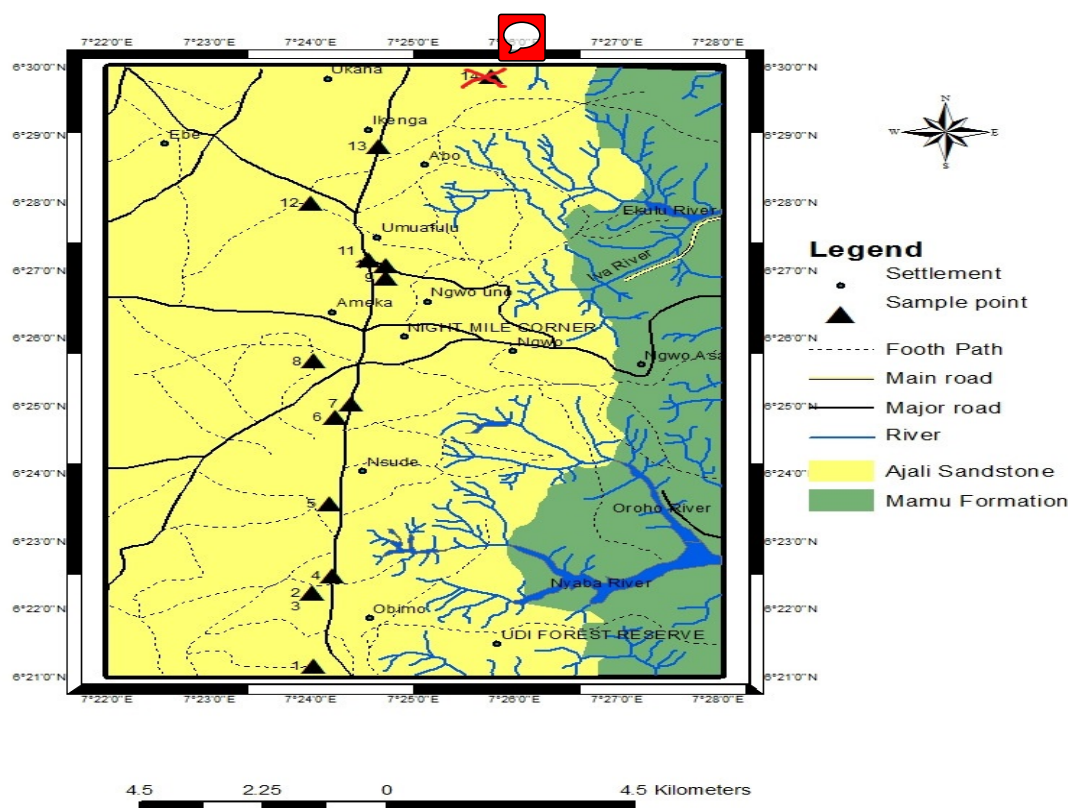


Figure 1: Location and geology of the study area

MATERIALS AND METHOD

Fourteen (14) topsoil samples were systematically collected along old road (Awka to Enugu) passing through Obioma- Nsude - Ngwo - Abor communities which stretches about 17 kilometers (Fig 1). Collection of samples was from the edge of road to 15 meter off the road within depths of 0-15/20cm from the surface using a pick axe. Site localities were recorded using a standard Garmin eTrex global positioning system (GPS) instrument. The samples' coordinates, names and descriptions are presented in Table 1. Soils collected varied in texture from clay to sand. The grain size ranges from fine to coarse. Some samples were grayish, reddish and brown in colour. A good vegetation cover is seen with *Imperata cylindrica* (tall grasses) dominating. Soil pH which is a measure of the acidity or basicity considered master variable was taken measured by the use of an electronic pH-meter, in which a rod is inserted into moistened soil and measures the concentration of hydrogen ions (Table 2).

The soil samples were sun air-dried, disaggregated and mechanically sieved through 100-mesh screen. Sample is considered acceptable if 100% passes through 100-mesh screen [8] and also to ensure homogeneity [9] prior to digestion. Digestion of soil samples were according to standard procedure described by [10] and [11]. The procedure used by [10] applies acid mixture of nitric acid – perchloric acid – and hydrofluoric acid in the ratio of 5:3:2, where 0.2 grams of each sample was weighed with digital balance and kept in dried crucibles. The samples were digested in acid mixture of 5 ml L nitric acid, 3 ml L perchloric acid and 2 ml L hydrofluoric acid [10]. They were placed on hot plates for ten minutes and later transferred to a fume chamber where they were allowed to cool. The cooled solutions were made up to 250 ml L in volumetric flasks with de-ionized water. The soil sample obtained solutions were used for the measurement of ion concentrations of heavy metals: Lead (Pb), Copper (Cu), Chromium (Cr), Nickel (Ni), Cadmium (Cd), Zinc (Zn) and Cobalt (Co) by use of Buck 210 VGP atomic absorption spectrophotometer.

RESULTS

Data acquired from field sampling and laboratory analyses were used for this evaluation. Concentrations of heavy metals are expressed in milligram per kilogram (mg/kg) of dry weight of the soil samples. Analytical data of soil samples in mg/kg is shown in Table 2. The Enrichment Factor (EF) and Pollution Index (Pi) are presented in Tables 3 and 4 respectively. Table 5 shows the range and average values of heavy metal contents (mg/kg) of soil samples and related established background values from [12], [13], [14], [15] and [16] for non-polluted soils.

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Table 1: Location of soil samples

Sample Location	Latitude N(degrees)	Longitude E (degrees)	Remarks
Obioma -1	06°29'748''	07° 24' 186''	Fine grained, well sorted friable, loose sand. Flat terrain dotted with shrubs.
Obioma -2	06°21'803''	07° 24' 034''	Gray coloured clayey soil, thick tall grasses
Obioma -3	06°22'299''	07° 24' 016''	Dark, well sorted fine sand.
Nsude-4	06°22'748''	07° 24' 189''	Fine grained friable sand and ironstone rubbles with concretions.
Nsude-5	06°23'334''	07° 24' 109''	Brown ironstones, quartz pebbles, medium grained sand.
Nsude-6	06°24'497''	07° 24' 133''	Light brown, fine grained and well sorted sand.
Ngwo-7	06°25'406''	07° 24' 181''	Thick vegetation cover with tall grasses, medium grained well sorted sand.
Ngwo-8	06°25'019''	07° 24' 267''	Iron stone rubbles, dark grey coloured, poorly sorted lateritic sand.
Ngwo-9	06°26'536''	07° 24' 439''	Loose friable, gray coloured well sorted sand.
Ngwo-10	06°27'023''	07° 24' 422''	Brown ironstones, quartz pebbles, medium grained sand.
Abor-11	06°27'496''	07° 24' 350''	Angular grained, white sand, flat terrain with scanty vegetation cover.
Abor-12	06°28'474''	07° 24' 414''	Medium grained, dark coloured well sorted sand.
Abor-13	06°21'803''	07° 24' 034''	Ironstone boulders, red coloured soil, quartz pebbles.

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Table 2: Concentrations (mg/kg) of Metals in Soil Samples

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Sample Location	Concentration of Metals in mg/kg							
	Cd	Cr	Cu	Ni	Pb	Co	Zn	pH
Obioma-1	6.12	1.37	2.87	6.36	4.12	0.62	7.00	6.0
Obioma-2	5.25	1.50	2.50	1.50	0.87	0.00	7.00	6.0
Obioma-3	4.75	0.00	0.12	10.3	3.50	0.00	2.87	5.0
Nsude-4	4.62	4.00	0.12	6.75	1.75	0.00	3.62	6.0
Nsude-5	2.50	3.00	1.00	2.62	2.25	1.12	4.37	6.0
Nsude-6	1.12	0.00	0.75	10.1	1.87	0.62	1.87	6.0
Ngwo-7	1.12	0.00	0.12	4.00	4.75	0.37	4.00	6.0
Ngwo-8	0.72	1.12	1.87	0.87	3.25	0.00	6.00	5.0
Ngwo-9	0.25	3.75	2.25	11.1	0.50	0.37	5.00	6.0
Ngwo-10	0.00	3.62	0.87	11.0	2.25	0.87	0.00	5.0
Abor-11	1.50	0.00	3.75	6.62	1.37	0.25	3.50	6.0
Abor-12	1.62	2.12	0.62	11.8	2.62	0.37	2.62	6.0
Abor-13	1.12	5.12	1.12	1.62	3.50	0.87	7.25	6.0

Abor-14	0.37	2.37	2.00	0.75	3.75	0.25	6.25	6.0
Total	30.59	27.97	20.21	85.5	36.35	6.08	61.85	81
Average	2.18	1.99	1.44	6.11	2.59	0.43	4.41	5.7

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Table 3: Enrichment Factors (EF) of Soil Samples.

Sample Location	Enrichment Factors (EF) of Metals						
	Cd	Cr	Cu	Ni	Pb	Co	Zn
Obioma-1	84.04	0.41	4.37	4.44	15.43	1.27	4.00
Obioma-2	120.22	0.76	6.36	1.74	5.43	1.27	6.67
Obioma-3	113.20	0.00	0.97	12.56	22.75	0.00	2.85
Nsude-4	175.86	3.38	0.50	13.06	18.16	0.00	5.74
Nsude-5	38.50	1.02	1.71	2.05	9.45	2.58	2.80
Nsude-6	19.04	0.00	1.41	8.74	8.67	1.58	1.32
Ngwo-7	21.01	0.00	0.25	3.81	24.31	1.04	3.12
Ngwo-8	24.81	0.85	7.16	1.52	30.35	0.00	8.61
Ngwo-9	5.17	1.72	5.17	11.70	2.82	1.14	4.31
Ngwo-10	0.00	1.53	1.83	10.64	11.67	2.48	0.00
Abor-11	28.45	0.00	7.90	6.38	7.08	0.71	2.76
Abor-12	32.13	0.93	1.36	11.97	14.17	1.10	2.16
Abor-13	22.47	2.28	2.49	1.65	19.15	2.61	6.06
Abor-14	9.95	1.41	5.97	1.02	27.51	1.00	7.00
Total	694.85	14.29	47.45	91.28	217.15	16.78	54.41
Average	49.63	1.02	3.38	6.52	15.51	1.19	3.88

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Table 4: Pollution Index (Pi) of Metals in soil samples

Sample Location	Pollution Index (Pi) of Metals						
	Cd	Cr	Cu	Ni	Pb	Co	Zn
Obioma-1	76.50	0.01	0.10	0.10	0.37	0.03	0.09
Obioma-2	65.62	0.01	0.09	0.02	0.07	0.01	0.03
Obioma-3	59.37	0.00	0.01	0.17	0.31	0.00	0.03
Nsude-4	57.75	0.02	0.00	0.11	0.15	0.00	0.05
Nsude-5	31.25	0.02	0.03	0.04	0.20	0.05	0.06
Nsude-6	14.00	0.00	0.02	0.17	0.17	0.03	0.02
Ngwo-7	14.00	0.00	0.00	0.06	0.43	0.01	0.05
Ngwo-8	9.00	0.00	0.06	0.01	0.29	0.00	0.08
Ngwo-9	3.12	0.02	0.08	0.18	0.04	0.01	0.06
Ngwo-10	0.00	0.02	0.03	0.18	0.20	0.04	0.00
Abor-11	11.75	0.00	0.13	0.11	0.12	0.01	0.04
Abor-12	20.00	0.01	0.02	0.20	0.23	0.01	0.03
Abor-13	14.00	0.03	0.04	0.02	0.31	0.04	0.10
Abor-14	4.62	0.01	0.07	0.01	0.34	0.01	0.08
Total	138.23	0.15	0.79	1.38	3.23	0.25	0.72
Average	27.73	0.01	0.03	0.09	0.14	0.01	0.05

Table 5: Average and range values of heavy metal content (mg/kg) of all sampled sites and related to background values from different sources.

Metal	Values of sites (this study)	Background values from different sources				
		Bowen (1979)	Shacklette/Boerngen (1984)	Kabata-Pendias (1995)	Krauskopf (1979)	Rudnick/Gao (2003)
Cd	Min. 0.00	0.01	—	—	—	—
	Max. 6.12	2.00	—	0.05	0.15	0.08
	Ave. 2.18	0.35	—	—	—	—
Cr	Min. 0.00	42.0	—	—	—	—
	Max. 5.12	329.2	54.00	—	100.00	135.00
	Ave. 1.99	124.5	—	—	—	—
Cu	Min. 0.12	14.2	—	—	—	—
	Max. 3.75	68.9	25.00	100.00	50.00	27.00
	Ave. 1.44	40.0	—	—	—	—
Ni	Min. 0.87	54.6	—	—	—	—
	Max. 11.87	378.0	19.00	30.00	75.00	59.00
	Ave. 6.11	157.8	—	—	—	—
Pb	Min. 0.50	33.4	—	—	—	—
	Max. 4.75	163.3	19.00	20.00	12.50	11.00
	Ave. 2.59	80.9	—	—	—	—
Co	Min. 0.00	-	—	—	—	—
	Max. 1.12	-	—	50.00	22.00	20.00
	Ave. 0.43	-	—	—	—	—
Zn	Min. 0.00	187.9	—	—	—	—
	Max. 7.25	1087.0	—	300.00	70.00	72.00
	Ave. 4.41	476.7	—	—	—	—

DISCUSSION

Pollution is any process whether natural or man-made which leads to harmful or objectionable increase in the amount of any factor in the environment [17]. Pollution Index (Pi) and Enrichment Factor (EF) indices were employed to assess the pollution of individual metal in the top soils. The tolerable limits set by various established standards of non-polluted soils from [12], [16], [15], [14] and [13], (Table 5) were used as assessment criteria.

Table 2 shows the concentrations (mg/kg) of metals determined from the soil samples and Table 5 shows the range of values used for comparison. Cadmium in an unpolluted soil is in the concentration range of 0.01 – 0.35 mg/kg according to tolerable standards by [12]. Cadmium in Table 2 ranged from <0.37 to 6.12 mg/kg with an average value of 2.18 mg/kg. The average value exceeded the tolerable limits of 2.00 mg/kg by [12]; 0.05 mg/kg by [14]; 0.15 mg/kg of [15] and 0.08 mg/kg of [16]. It implies then that Cd has impacted negatively on the agricultural soil and the environment at large. Cadmium in the studied medium may be derived from both natural and anthropogenic sources. Chromium ranged from < 1.12 to 5.12 mg/kg with an average value of 1.99 mg/kg. At sampling sites 3, 6, 7 and 11, chromium was not detectable. Chromium values and the mean value are much lower than the referenced

standard levels. Copper varied from 0.12 to 3.75 mg/kg, with mean value of 1.44 mg/kg. Again Copper is lower than the established tolerable limits. It implies, Cr and Cu have no significant effect on the environment. Nickel ranged from 0.87 – 11.87mg/kg and averaged 6.11 mg/kg. Cobalt ranged from 0.25 to 1.22 mg/kg with 0.43 mg/kg as the average value. Cobalt was not detected in some locations (Table 2). Average concentrations of Cr (1.99 mg/kg) and Co (0.43 mg/kg) were very low when compared with established limits of [16], [13] and [12] in Table 5. They therefore pose no risk to health and the environment. Concentration of lead is slightly below toxic level. Lead ranged from 0.50 to 4.75 mg/kg) with highest concentrations at sites 7 and 14. At these two locations auto mobile mechanic workshops are near and active. Zinc ranged from <1.87 to 7.25 mg/kg with an average value of 4.41 mg/kg. Concentration sequence of the examined metals in descending order is: Ni > Zn > Pb > Cd > Cr > Cu > Co (Table 2). The average value of Ni (6.11 mg/kg) is considered high but below the 50 mg/kg tolerable limit set by [12]. The toxicity of excess Ni present in the soil could account for the poor growth of weeds at some of the locations. Nickel is carcinogenic and affects the reproductive health of organisms [18]. The high level in the study area may be due to aerial deposition, manure and phosphate fertilizer application.

The concentration of an element in the soil solution is believed to depend on the equilibrium between soil solution and the solid phase, with pH playing a decisive role [19]. While discussing the relatively high mobility of heavy metals with regard to pH, [20] considered that in acid soils (pH 4.2 – 6.6) the elements: Cd, Ni, and Zn are highly mobile, Cr is moderately mobile, and Cu and Pb practically immobile. Soil pH in this study ranged from 5.0 - 6.0 with an average value of 5.7. (Table 2). This is quite acidic, indicating a high potential of acidic leachates generation and confirming the lack of inherent alkalinity producing minerals. Unpalatable situations would in turn affect the larger predators and compel them to move to other places once they lose their food supply. Crops cannot naturally grow well and flourish in a polluted soil. The acidic level may have adverse effect on agricultural soil.

Table 3 shows the Enrichment Factors (EF) in the sampled soils. Enrichment factor can fully reflect the impact which was brought to the environment by human activities [21]. It is also a convenient measure of geo-chemical trend for making comparisons between an area and overtime [22]. Based on (EF), the health risk level (HRL) is inferred. When the (EF) is less than 1, it indicates that there is no contamination, HRL is zero. When it is equal to one or two, it indicates that the pollution is minimal and HRL is 1. When (EF) lies in between 2 and 5, it indicates a low level and HRL is 2. When (EF) ranges from 5 - 20, HRL is 3. This shows an intermediate level of pollution. When (EF) is 20 – 40, HRL is 4 and it indicates a high level of pollution but when (EF) is greater than 40, HRL is 5, it means that pollution is intense. Average values (Table 3) indicate that the enrichment trend of the metals is in this order: Cd > Pb > Ni > Zn > Cu > Cr > Co. Cobalt and Chromium, each has HRL of 2 and this indicates a low level pollution condition. Nickel, Zinc and Copper are at intermediate levels of pollution with a HRL of 3. Cadmium and Lead show respective HRL of 5 and 3. Their pollution levels are considered high.

The pollution index (Pi) was introduced as part of assessing pollution levels by considering the joint effects of all polluting metals in soils [23]. Pollution index was extensively used for soil pollution studies in China [24]; [25] and [26] and proved to be simple and effective because it related to a certain quality criterion. The Pollution Index data (Table 4) highlights the pollution status of the soils in the area. Pollution index (Pi) was also adopted here to assess the contamination of individual metals. The pollution index was calculated based on concentration of seven metals namely: Cd, Cr, Cu, Ni, Pb, Co and Zn which are considered significant in the pollution assessment of the area. The pollution index (Pi) was calculated by

averaging the ratios of the concentration of the heavy metals to the hazard criteria (tolerable level) using the formula as shown $P_i = C_i/S_i$, [27], where P_i = Pollution index; C_i = Average concentration of heavy metal in the medium and S_i = relevant standard (tolerable level) for this metal [16]. Based on Pollution Index (P_i), soil contamination levels can be classified into unpolluted ($P_i < 1$); slightly polluted ($1 \leq P_i < 2$); moderately ($2 \leq P_i < 3$) and heavily polluted ($P_i \geq 3$). The pollution index of Cadmium in an unpolluted soil from literature should be less than one. Table 4 shows Cadmium pollution index ranged from 0.00 - 76.50 with an average value of 27.73 mg/kg. This implies a high pollution level according to the criteria of [16]. Lead varied from 0.07 mg/kg to 0.37 mg/kg without local enrichment at any of the localities. The average Lead value 0.14 mg/kg is below the toxic limit. All the remaining five metals analyzed were either below detection levels or are very low in pollution index criteria. They ranged from (0.00 – 0.43) mg/kg with averages Cr (0.01) mg/kg, Cu (0.03) mg/kg, Ni (0.09) mg/kg, Co (0.01) mg/kg and Zn (0.05) mg/kg. The pollution trend is in the order: $Cd > Pb > Ni > Zn > Cu > Cr > Co$. None of the average values exceeded one (Table 4). This, according to the classification of [16], implies no pollution by these metals. Their health risk level is zero and thus does not pose any health risk to humans though may have some implications to soil and associated plants.

CONCLUSION

Cadmium concentration was generally high in the examined area compared to the typical range found in unpolluted agricultural soils. The study area has been highly contaminated by cadmium and lead but moderately polluted with respect to nickel, chromium and zinc. Copper and cobalt are deficient and pose no risk to the environment. Enrichment Factor (EF) for the elements in the different sites shows significant variability. It is suggested that the (EF) variability is due to anthropogenic activities in these areas. Anthropogenic sources include agricultural (fertilizers, animal manures, pesticides), carbides used for welding works as well as micro-electronics, sewage sludge and scrap disposals [28]. Traffic pollution may be a likely source for heavy metal contamination. Another source is bush burning which according to [29] releases the heavy metals contained in leaves and tissues in plants into soils.

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