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Assessment of heavy metal pollution of plants grown adjacent to power generators in Ramadi city

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Abstract. Tree leaves are a useful tool for environmental quality monitoring and heavy metal soil pollution assessment. This study aimed to assess the possibility of heavy metals' accumulation in the leaves of urban plants as a biological indicator of soil pollution. The plant leaf and soil samples were collected from 51 sites adjacent to power generators in Ramadi-Iraq. Six common plant species, namely, *Albizia lebbeck*, *Conocarpus lancifolius*, *Dodonaea viscosa*, *Eucalyptus camaldulensis*, *Ficus microcarpa*, and *Ziziphus spina-christi* were selected. The highest heavy metal content was found in **Conocarpus viscosa** leaves followed by **Dodonaea viscosa**. These two plants have a significant difference ($p<0.05$) in the heavy metal content compared to other plants. The total average of plant heavy metal concentration was as follows: Mn (45.23), Cu (12.49), Ni (7.55), Pb (6.49), Cr (6.37), Co (2.04), Cd (0.57) mg per kg. Concentrations of heavy metals in leaves have the trend as Mn> Cu> Ni> Pb> Cr> Co> Cd, whereas, the heavy metal bioaccumulation factor (ACF) in plants follows by the order: Zn> Cu> Cd> Mn> Co> Pb> Ni> Cr. A high concentration of cobalt, cadmium, chromium, nickel, and lead are found in the plant leaves compared to the Food and Agriculture Organization / World Health Organization (FAO/WHO) permissible values. This supports the claim that the leaves of the plant can be used as a good indicator of heavy metal accumulation.
Keywords: heavy metal, plants, leaves, power generators

1. Introduction

Heavy metals are normally present within the soil, geological and human activities have increased the concentration of these metals in harmful quantities for living organisms. Some of these activities include burning fossil fuels, mining, producing batteries, and other industry elements, using pesticides and fertilizers in agriculture, sewage sludge, and disposal of municipal waste [1].

Metabolic fate and the role of each in plants can be described in relation to some basic processes such as absorption, transport within plants, concentration, metabolic processes, deficiency, and toxicity. Some trace elements, especially Cu, Mn, Mo, and Zn, play a major role in plant metabolism processes [2]. Plants are often sensitive to the deficiency of some heavy metal ions as essential micronutrients, while the higher concentrations of cadmium and mercury are highly toxic to metabolism [3].

The main sources of heavy metals in plants are soil, air, and food solutions through which the absorption of heavy metals from the roots or the leaves [4]. In urban areas, higher plants can give a better accumulation of pollutants from the atmosphere. Thus the use of plant leaves primarily as a cumulative biological monitor to determine heavy metal pollution is of great environmental importance [5]. And where the plants have the ability to catch and aggregate heavy metals in an environmentally friendly way. Several studies have been carried out to implement vegetation for environmental protection [6]. Operating a power plant in a region is a major exporter of pollution, as it releases harmful elements, which can lead to serious health and environmental hazards. Several researchers have reported heavy metal concentrations in vegetation around power plants. Accumulation of Fe, Cd, Zn, Ni, Co, Cr, and Pb by plants has been studied. Nine species have

been identified that grow around the power plant, namely *Abutilon indicum*, *Calotropis procana*, *Cassia tora*, *Ipomea carnea*, *Jatropha gossypifolia*, *Nerium indicum*, *Parthenium hysterphorus*, *Prosopis juliflora*, and *Tephrosia purpunea*. The study showed a high accumulation of heavy metals in these plants and can be used for eco-restoration and phytoremediation [7]. Contamination was assessed in areas close to a power plant in India by detecting the amount of (As, Pb, Cr, Cd, and Hg) in soil and leaves of (*Madhuca longifolia* and *Albizia lebbeck*) and vegetables (*Allium cepa* and *Raphanus sativus*). It was found that the accumulation factor of As and Pb in *Madhuca longifolia* leaves was high (1.03 and 0.6 respectively) [8]. Another study indicated that *Ziziphus spina-christi* and *Conocarpus erectus* showed a high ability to accumulate the Pb and Zn in its leaves compared with other plants. The trend of heavy metal was in the order of Cd > Cr > Pb > Cu > Zn [9]. The current study aims to determine the pollution of heavy metals in the leaves of trees in the vicinity of electric generators in the Ramadi city and study the accumulation factor of minerals in the leaves.

2. Methods

2.1. Study area.

Ramadi city is located in Iraq and is about 110 km from seen west of Baghdad. It is located at a point N (33° 25′ 11″) and E (43° 18′ 45″) as shown in the figure (1). Ramadi has a desert climate that is hot and dry in summer, and most of the rain falls in the winter. About 115 mm of precipitation falls annually [10].
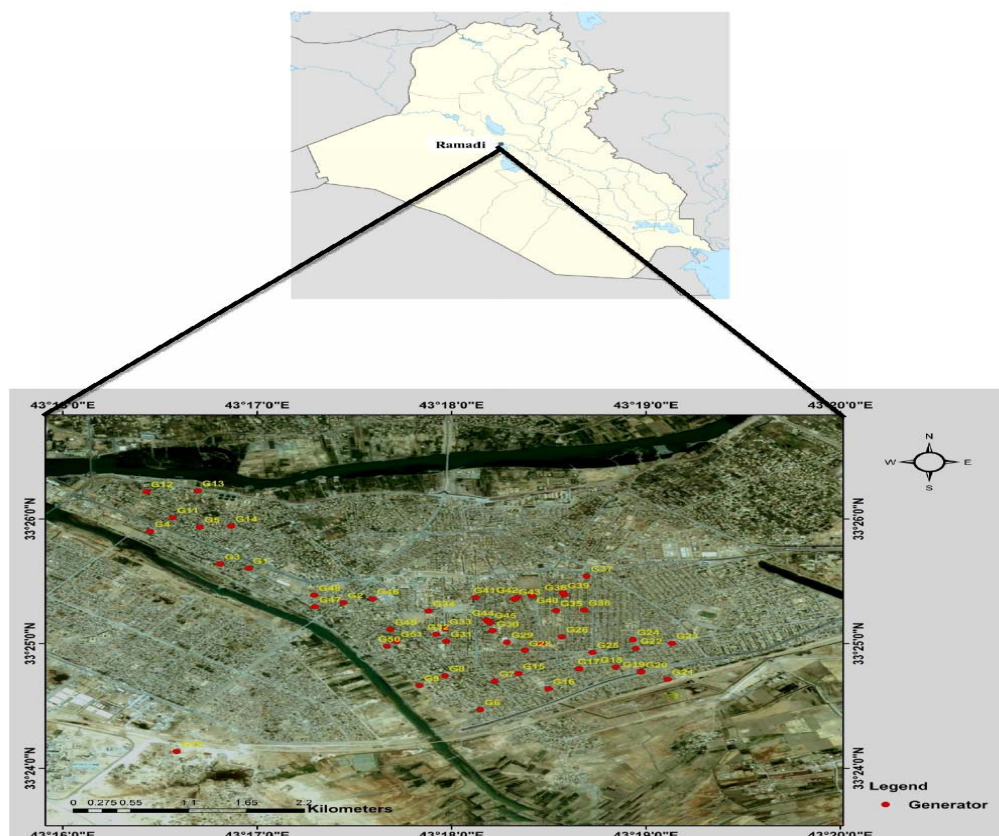

Figure 1: The study area (Ramadi city center) based on GPS

2.2. Sample collection.

 (51) plant samples were collected from tree leaves growing around power generators in Ramadi for the period from September to December 2019. Sampling sites were recorded with the Garmin 72 GPS device at each sampling site. Healthy leaves, exposed to sunlight and without signs of food stress or moisture, and undamaged by insects were selected [11]. Soil samples were taken at a depth of 10-20 cm. all samples were stored in plastic bags and transported to the laboratory. The samples were dried in the oven at 70 °C for 48 hours, then grinned and sieved through a (106 μm) steel sieve to remove large particles and impurities. Samples were preserved in polyethylene.

2.3. Analysis of samples.

(1) gm of the sample was placed in the reference container. 25 mL of the digestion mixture ($HCl:H_2SO_4:HNO_3$, 3:2:2) was added to the reaction flask and introduced into the microwave. The digested solution was cooled and filtered. Then the sample was made up to 50 ml with distilled water and kept in special containers [12]. The concentration of (8) heavy metals in the soil and plant was estimated, which included minerals (cadmium, cobalt, lead, zinc, nickel, chromium, copper, and manganese) using the atomic absorption spectroscopy technique (Phoenix - 986, USA).

2.4. Heavy metals bioaccumulation.

The Accumulation factor (ACF) was estimated for the ability of plants to absorb heavy metals. The Accumulation factor (ACF) is the ratio of the plant metals content to the soil content. The ACF is calculated using the following formula:

$$ACF = C_{plant} / C_{soil}$$

Where C_{plant} is the metal concentration in the plant and C_{soil} is the metal concentration in the soil [13].

2.5. Plants classification.

The Desert Studies Center classified the studied plants - the University of Anbar, which included six plant species: *Albizia lebbeck*, *Conocarpus lancifolius*, *Dodonaea viscosa*, *Eucalyptus camaldulensis*, *Ficus microcarpa*, and *Ziziphus spina-christi*.

2.6. Statistics and data analysis.

 Statistical analysis, including mean, minimum, maximum, standard errors, analysis of variance, and Duncan post hoc test, was performed using IBM Spss Statistics V23 software.

3. Results and discussion

3.1. Heavy metals in the soil

The concentrations of Cadmium, Cobalt, Chromium, Copper, Manganese, Nickel, Lead, and Zinc were estimated in Iraqi soil. Table (1) shows the content of heavy metals in soil. Soil heavy metal concentrations were in the order: Cr > Mn > Ni > Zn > Pb > Cu > Co > Cd. It is shown that all estimated heavy metals in the soil were above the reference values for U.S. Environmental Protection Agency (USEPA). The amount of chromium and nickel identified in the soil was higher than in previous Iraqi studies cited by [14].

Table 1: Heavy metals concentrations in soil samples

HM	Concentration (mg/kg) (Mean ± SE)	Ref. values [15]
Cd	2.55 ± 0.11	1
Co	16.62 ± 0.32	2.9
Cr	360.90 ± 11.87	7.5
Cu	36.54 ± 3.38	13.2
Mn	302.77 ± 15.37	194.8
Ni	283.65 ± 9.34	6.4
Pb	130.75 ± 11.90	11.3
Zn	190.96 ± 17.03	25.7

SE standard error (n=51)

3.2. Heavy metals in plants

Urban plants are able to reduce environmental pollution through the bioaccumulation of pollutants in their tissues. The accumulation of chromium, cobalt, cadmium, copper, lead, nickel, manganese, and zinc was investigated in the leaves of six types of plants in Ramadi city around electric power generators. Plants in contaminated environments are enriched with heavy metals compared to those in virgin environments, and this is commonly due to traffic emissions and generator fuel combustion. The concentration of the heavy metals was estimated in the tree leaves surrounding the power generators figure 1.

Significantly high amounts of heavy metals were detected in leaves of *C. lancifolius* and *D. viscosa* compared to the other studied plants. This may be related to prolonged exposure to heavy metals in their environment. In general, the average of heavy metals concentrations in tree leaves (for this study) follows a descending order: Zn> Mn> Cu> Ni> Pb> Cr> Co> Cd. This trend was found in the following plants: *Z. spina-christi*, *F. microcarpa*, and *E. camaldulensis*, and a similar trend was obtained in *A. lebbeck*, *D. viscosa*, and *C. lancifolius* with a slight difference observed in both Pb and Cr as Zn> Mn> Cu> Ni> Cr> Pb> Co> Cd (see Table 2). Heavy metal concentration in plant leaves depends on many factors like metal concentrations in the soil, soil pH, Solubility, soil type, organic matter content, cation exchange capacity, plant species, and plant age [16].

Table 2: Heavy metals concentration in the leaves of the different plants

Plants	Heavy metals concentration (mg/kg)							
	Zn	Ni	Cd	Cr	Pb	Co	Mn	Cu
Albizia lebbeck	51.08 ±5.44	7.36 ±0.70	0.25 ±0.14	6.92 ±0.54	5.42 ±0.38	1.71 ±0.10	46.17 ±3.75	12.09 ±1.01
Conocarpus lancifolius	62.95 ±2.96	7.71 ±0.18	0.93 ±0.18	7.26 ±0.41	6.99 ±0.44	2.13 ±0.08	49.64 ±3.23	14.03 ±0.84
Dodonaea viscosa	58.75 ±5.39	7.81 ±0.26	1.00 ±0.26	6.86 ±0.68	6.52 ±0.45	1.98 ±0.11	40.99 ±2.57	15.30 ±0.79
Eucalyptus camaldulensis	49.21 ±4.8	7.44 ±0.14	0.24 ±0.14	4.97 ±0.38	6.54 ±0.53	2.12 ±0.14	42.69 ±2.77	10.63 ±0.45
Ficus microcarpa	46.69 ±2.96	7.48 ±0.64	0.10 ±0.01	5.48 ±0.72	6.70 ±0.39	2.24 ±0.09	43.95 ±1.37	8.94 0.87±
Ziziphus spina-christi	45.00 ±7.45	7.04 ±0.13	0.10 ±0.01	4.66 ±0.73	5.98 ±0.46	1.92 ±0.11	41.64 ±3.28	9.58 ±1.37

The results showed statistically significant differences ($p > 0.05$) in the concentrations of heavy metals among the studied plants. Also, the Duncan test confirmed the significant difference for both *C. lancifolius* and *D. viscosa* with the other plants. This significant variation clearly appears among plants in the metals *Zn*, *Cu*, *Cr*, and *Cd*, while there was no significant difference in the heavy metals concentration of *Pb*, *Ni*, *Mn*, and *Co* among plants.
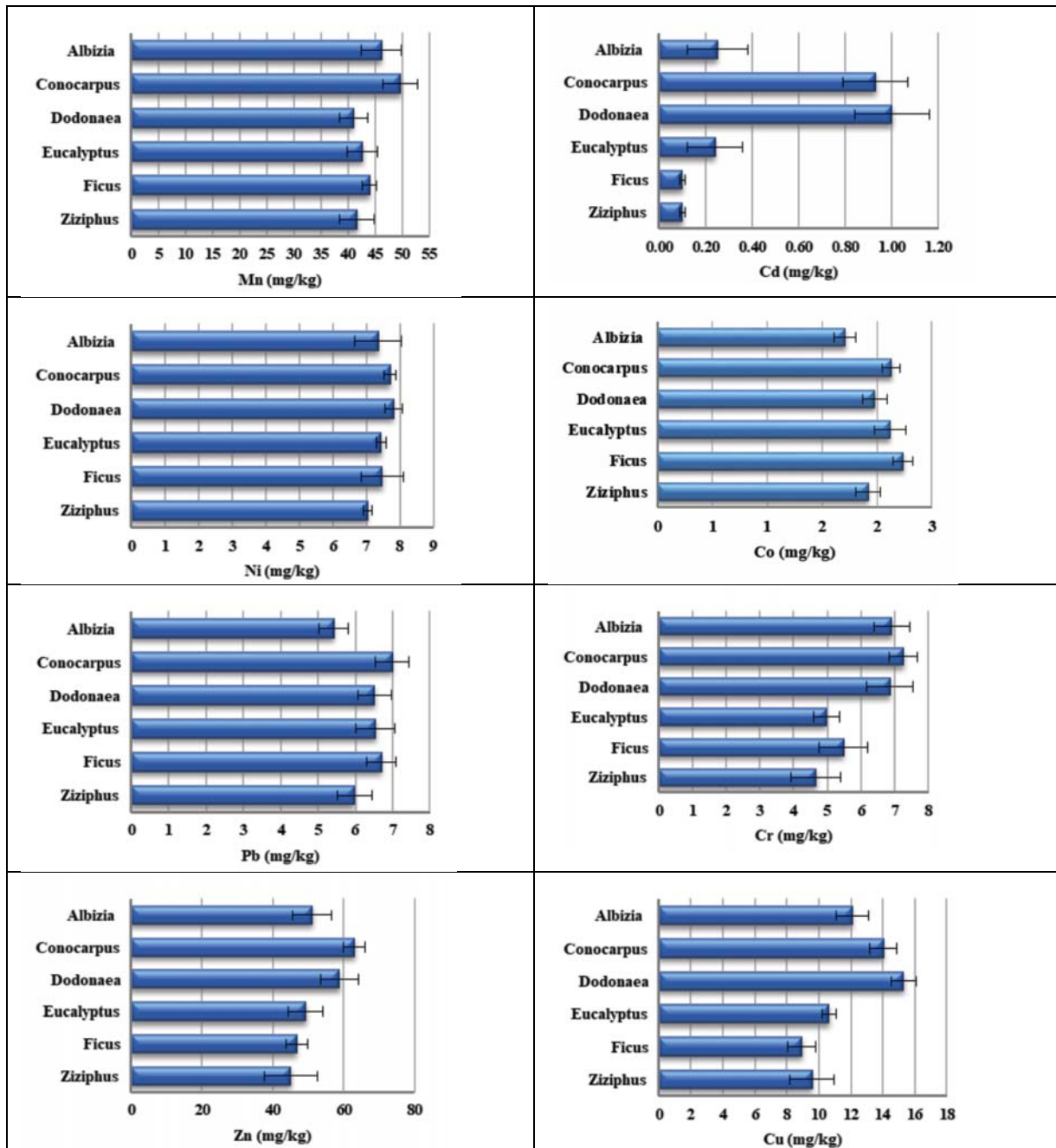

Figure 2: Heavy metal levels in the tree leaves

Table 3 shows the mean, minimum, and maximum concentration of heavy metals in the studied trees, limit values, and their accumulation coefficient (ACF). It was found that copper, zinc, and manganese were below the permissible value recommended by the WHO / FAO. These results agree with which reported in previous studies [17,18]. In this study, most of the heavy metals (Cd, Co, Cr, Pb, and Ni) are found to be in excess of the level permitted by WHO / FAO, which indicates the presence of pollution from electric power generators. However, the high concentrations of cadmium can be caused by the use of fertilizers that contain cadmium. In addition, it has a greater solubility in water and bioavailability in the soil more than others [19]. Moreover, the high level of lead and cobalt in the leaves may be due to the traffic present near the area of study [20]. Also, the concentration of nickel increases in specific areas due to human activities such as burning coal and oil, mining work, emissions from smelters, pesticides, phosphate fertilizers, and sewage [21].

The ACF of heavy metals was shown in the tested plants in the following order: Zn > Cu> Cd> Mn> Co> Pb> Ni> Cr. The higher ACF was detected for Zn followed by Cu; this may be due to the fact that Zn and Cu are more important to plants for growth. A similar pattern of ACF for both zinc and copper has been reported in previous studies [22], which may be related to the co-transport mechanism in plants. The high zinc ACF corresponds to the ACF obtained by [23].

The lowest bioaccumulation factor was for chromium and nickel (0.02 and 0.03, respectively), despite their high concentration in the soil, and this may be due to the strategy adopted by plants by avoidance or detoxification mechanisms [24].

The bioavailability of heavy metals in plants is closely related to the concentration and metal characteristics in the soil solution. The accumulation of heavy metals in plants depends on several factors such as plant species, metal forms, soil parts, and properties such as solubility. Therefore, the plant absorption of heavy metals in the soil varies greatly with the pH and organic content, and the absorption of heavy metals by plants tends to increase with an increase in the soil concentration [25].

Table 3: Plants heavy metals concentrations, Permissible values, and accumulation factor

HM	Mean mg/kg	Min.	Max.	Permissible value [26]	ACF
Cd	0.57±0.09	0.36	1.15	0.10	0.19
Co	2.04±0.05	1.12	2.81	0.05	0.12
Cr	6.37±0.26	2.91	10.18	2.30	0.02
Pb	6.49±0.21	3.35	9.94	0.20	0.08
Ni	7.55±0.19	3.76	10.50	1.50	0.03
Cu	12.49±0.49	6.36	19.19	40.00	0.48
Mn	45.23±1.42	31.65	89.14	67.90	0.16
Zn	55.02±2.03	21.29	98.41	100.00	0.52

4. Conclusions

Heavy metal concentrations were determined in soil and plants adjacent to the Power generators. Average amounts of heavy metals in plants were in the following descending order: Mn> Zn> Cu> Pb> Ni> Co> Cr> Cd. However, most heavy metals were above Permissible limit values set by FAO/WHO, while only Cu, Zn, and Mn were found below this limit values which may be attributed to the role of power generators that release a high amount of Cd, Co, Cr, Ni and Pb to the atmosphere, this may also occur due to the density of traffic within the study area. This study shows that the highest accumulation factor (ACF) was for zinc,

followed by copper. Overall, the average ACF of heavy metals in tree leaves was in the following order: Zn> Cu> Cd> Mn> Co> Pb> Ni> Cr.

Finally, we found that the levels of heavy metals in the soil and plant samples compared to the permissible limits showed significant contamination from the power generators. Therefore, periodic studies of heavy metals in soil and plants growing adjacent to power generators and other human sources should be performed routinely.

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