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Assessing Heavy Metal Accumulation in Urban Plants: Implications for Environmental Health and Traffic-Related Pollution in Al-Diwaniyah City, Iraq

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ABSTRACT

This study aimed to compare the ability of five plant species, including (*Conocarpus erectus, Acacia sensu lato (s.l.), Melaleuca viminalis, Dodonaea viscosa and Lantana camara*) to absorb and accumulate heavy elements in their tissues, which were grown in the central islands in the city of Diwaniyah. This included areas of street in front of the medical college, Umm Al Khail First Street, Umm Al-Khail Street, near Abbas Attiwi Bridge, Al-Adly Street in the Euphrates District, and Clock Field Street, respectively. Results showed that soil samples S_1 and S_3 were contaminated by Pb, and the rest of the sites were contaminated with nickel only. This indicates through the table findings a rise in these heavy metals' concentrations with a rise in traffic momentum. Thus, the Pb concentrations in the growing plants' shoot parts with respect to this research had surpassed the allowed critical limit of 5.00 mg.kg^{-1} dry matter, in which the highest value was recorded at the site with respect to S_3 as well as S_2. Meanwhile, the findings indicate that Cd concentrations in S3 and S1 had increased and exceeded the allowable limit of 0.20 mg.kg-1 dry matter. In the meantime, the nickel concentrations were within the permissible limits of 67.90 mg.kg-1 dry matter. The Zn concentration exceeded the permitted limits of 60.00 mg.kg^{-1} dry matter except for plants (*Acacia s.l. and Lantana camara*) in sites S_5 and S_2. The results confirmed that the values of Heavy Metals Bioaccumulation Coefficient (BAC) for most of the study elements had recorded the highest value in the *Dodonaea* plant for Zn, Cd, and Pb, except for Ni. It was more accumulated in the *Melaleuca viminalis* plant, which indicates the superiority of the *Dodonaea* plant in accumulating Pb, Cd, and Zn over the rest of the study plants, as they took the following order: *Lantana camara* < *Acacia s.l.* < *Conocarpus erectus* < *Melaleuca viminalis* < *Dodonaea viscosa.* The best plants accumulated nickel in the following order: *Acacia s.l.* < *Lantana camara* < *Conocarpus erectus* < *Dodonaea viscosa* < *Melaleuca viminalis.*

INTRODUCTION

The problem of environmental pollution nowadays is receiving great attention not only at the level of third world countries but also at the level of the whole world, as it has become the biggest threat to the world, whether industrial or non-industrial. This is because pollution affects all countries, and there are no limits to prevent it. Hence, it was necessary to address this danger in parallel with technological progress to obtain a safe and clean environment. Furthermore, it was also necessary to encourage stopping the causes of pollution, creating awareness, and motivating the adoption of methods that are more capable of achieving environmental protection (Alkhafajy 2016). The soil is an important component of an ecosystem and the part in which plants grow and are constantly exposed to pollution, which is increasing daily. There are many sources of contamination with heavy metals, including factory chimneys, sewage waste, vehicle exhaust, and chemicals (Monday et al. 2004). Heavy metals, for example, zinc (Zn), cadmium (Cd), and lead (Pb), are considered one of the most dangerous substances that contaminate soil, water, and air. One of the most important sources of this pollution is vehicle exhaust, factory waste, metal smelting, and coal combustion. Some of these heavy metals remain stable for a long time in a place that is polluted without changing chemically. However, due to chemical changes brought on by humidity, heat, microbes, light reactions, and other environmental conditions, some of them were only stable for a brief time (Singh et al. 2011). In a study by Ali (2010) on the pollution status of some soils in the city of Baghdad, the chemical analysis of soil samples showed that some of the studied areas have high concentrations of heavy metals, Cd, Pb, and Cd. This increase was attributed to the recent increase in the number of cars and the use of fuel from multiple sources. In addition to the presence of factories, foundry workshops, electrical power stations, and an oil refinery, burning plastic materials as well as throwing waste were all factors that have led to increased pollution in the capital. Other than that, Alfatlawi & Nibras (2013) showed in their research the determination of the percentages of Pb in gasoline available in the local market and its impact on the environment.

Furthermore, the condition of the current gasoline product in gas stations is poor in terms of performance, which does not amount to high-performance gasoline (Hosseinpour et al. 2010). This leads to the damage of vehicle engines and significant economic damage, in addition to the continuous pollution it causes to the environment. Many plants are characterized by their ability to absorb pollutants from soil, water, and air and accumulate them in their tissues in a way that does not cause any harm to them. Thus, plants play a role in addressing environmental pollution in the sites where they grow. The concentration of these elements in plant tissues varies according to the different sources of pollution, the nature and components of the soil and the extent of the readiness of these elements for absorption.

Furthermore, the difference in its ability to absorb and accumulate pollutants within its tissues depends on the plant's genetic ability to remove pollutants. The difference in this ability is due to the difference in the presence of the active groups present in the cell walls, as well as phosphate, hydroxyl, and ammonia groups, which represent ion exchange and bonding sites. These play a role in linking with these pollutants (Al-Hamdani 2010). Plants resist the toxicity of heavy elements in several different ways, including immobilizing these elements in the plant, excluding them from cells, introducing them into chelating compounds, or displaying stress-resistant types by forming ethylene or stress proteins. Hence, some plant species absorb a limited amount of the element, while in others, the element remains in the root system. Only a small amount of it is transferred to the shoot, and this is the phenomenon of repulsion (exclusion), while in other species, the element is found in all parts of the plant, which are tolerant plants (Szalai et al. 2002).

The current study aims to compare the ability of five plant species (*Conocarpus erectus, Acacia sensu lato, Melaleuca viminalis, Dodonaea viscosa, Lantana camara*) to absorb and accumulate heavy elements in their tissues, which were grown in the central islands in the city of Diwaniyah, by adopting the criterion of bioaccumulation coefficient (BAC)

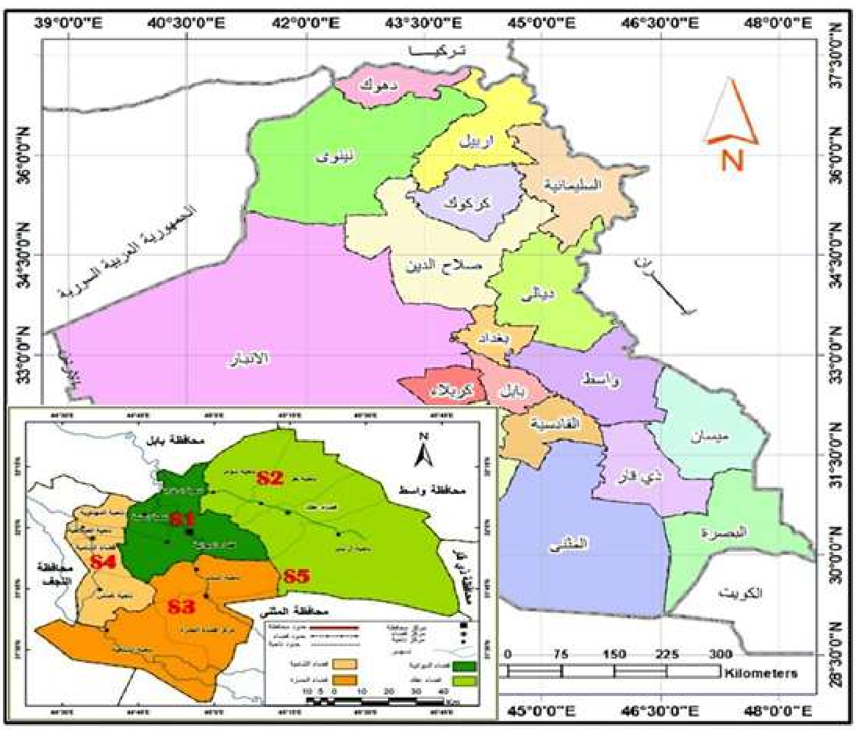

Fig. 1: The distribution of soil and plant sampling areas in the city of Diwaniyah.

in the plant, and the effect of momentum Traffic pollution in the soil and plants growing in it.

MATERIALS AND METHODS

Study Area

Five sites were chosen to collect the study samples, Fig. 1, according to the traffic volume and the open central yards planted with plants five, where the study area includes:

1. Street in front of the Medical College with *Conocarpus erectus* plant (S_1)
2. Umm Al Khail First Street *with Acacia s.l*. plant (S_2)
3. Umm Al-Khail Street, near Abbas Attiwi Bridge with *Melaleuca viminalisp* plant (S_3)
4. Al-Adly Street in the Euphrates District with *Dodonaea viscosa* plant (S_4)
5. The Clock Field Street with *Lantana camara* plant (S_5)

Collection and Analysis

Several leaves were collected from trees and shrubs growing in the study area (*Conocarpus erectus, Acacia sensu lato, Melaleuca viminalis, Dodonaea viscosa, Lantana camara*). The plant leaves were cleaned in distilled water, dried, and placed at a maximum temperature of 70°C and for 48 h in an oven until the weight was stable and crushed according to the wet digestion method with concentrated acids described by Ryan & Matar (1992).

Samples Collection and Analysis

Soil samples were collected from the same plant samples collection sites to a depth of 0-15 cm, dried aerobically, and then crushed and sieved with a sieve of 2 mm. The total heavy metals were estimated by treating 1 gm. of dry soil samples with a mixture of two acids (HNO_3 and $HClO_4$) according to the method of Jones et al. (2001). Subsequently, total heavy metal concentrations were measured using an Atomic Absorption spectrophotometer (AAS). The efficiency of trees in accumulating heavy elements was calculated by adopting the bioaccumulation criterion for the element in the plant Bioaccumulation Coefficient (BAC), which refers to the concentration of the element in the vegetative total to its total concentration in the soil according to the equation (Li et al. 2007, Cui et al. 2007).

BAC = (Metal) Shoot/(Metal) Soil

BAC = Bioaccumulation factor

(Metal) Shoot = The concentration of the element in the vegetative part ($mg.kg^{-1}$ dry matter)

(Metal) Soil = The total concentration of the element in the soil ($mg.kg^{-1}$)

Table 1: The average traffic density for the study sites ($car.h^{-1}$).

Samples sites	Averages daily traffic density for 3 days [$car.h^{-1}$]
Street in front of the Medical College	1120
Umm Al Khail First Street	1000
Umm Al-Khail Street, near Abbas Attiwi Bridge	1400
Al-Adly Street in the Euphrates District	852
The Clock Field Street	800

Traffic Density

The quantification of passing cars in the five designated study sites was conducted with a focus on assessing the prominent source of pollution, the traffic momentum, and emissions emanating from automobile exhaust (refer to Table 1 for detailed statistics). Discrepancies in the number of cars were observed across locations, with continuous traffic prevailing in most areas except for Clock Field Street. Notably, the onset and conclusion of scheduled working hours marked periods of heightened traffic density. To ascertain the impact, the traffic density was systematically calculated by counting the number of automobiles passing through the sampling sites over twelve hours, spanning from 6:00 a.m. to 6:00 p.m., over a three-day duration. This approach aligns with the methodology outlined by (2004).

RESULTS AND DISCUSSION

Total Concentration of Heavy Metals in the Study Soils

When compared to the total concentration in sites S1 and S3, Table 2 revealed the heavy metals total concentration in the study soils. With delimiters from the Food and Agriculture Organization (FAO) as well as the World Health Organization (WHO) (WHO/FAO 2007), we find it contaminated with lead (Pb). As for the rest of the sites, they were contaminated with nickel only. It was also evident from the results of Table 2 that with an increase in traffic momentum, there exists a discernible rise in these heavy metal concentrations, and this may be attributed to their exposure to pollution from car exhaust (Warmate et al. 2011, Fadhel & Abdulhussein 2022). These results are consistent with the findings by Joudah (2013). Soil pollution with heavy metals may come from several different sources, most of which are road traffic and the use of Pb gasoline, especially in vehicles, which increases its concentration in the atmosphere (Karam et al. 2019, Essa & Dunya 2017).

Concentration of Heavy Metals in Study Plant Samples

Table 3 meticulously outlines the concentrations of heavy

Table 2: Total heavy metals concentration in the soils of the middle islands in the road's of city of Al-Diwaniyah (mg.kg^{-1}).

Study sites	Symbol	Heavy metals [mg.kg^{-1}]			
		Pb	Cd	Ni	Zn
Street in front of the Medical College	S_1	106.00	2.53	122.80	125.32
Umm Al Khail First Street	S_2	88.00	2.16	85.72	109.00
Umm Al-Khail Street, near Abbas Attiwi Bridge	S_3	125.32	2.67	131.00	139.70
Al-Adly Street in the Euphrates District	S_4	90.30	2.04	99.52	105.9
The Clock Field Street	S_5	82.91	1.96	69.04	94.78
WHO/FAO (2007)		100.00	3.00	50.00	300.00

metals in the shoot parts in the middle islands of the streets of the city of Al-Diwaniyah under study, which ranged between 7.30-14.90, 0.14-0.24, 2.50-3.00, 51.00-87.00 mg.kg^{-1} dry matter for each of the lead (Pb), cadmium (Cd), nickel (Ni) and zinc (Zn) successively. When comparing the concentrations of Pb for the plants under study, which ranged between 7.30-14.90 mg.kg^{-1} dry matter, the determinants of the World Health and Food and Agriculture Organizations (WHO) (WHO/FAO 2007). Apart from that, we find that it has exceeded the permissible critical limit of 5.00 mg.kg^{-1} dry matter, which indicates the plant's ability to absorb heavy metals via the roots and transfer them to the shoot system, or they may be taken directly from the air through the leaves (Kord et al. 2010). The outcomes also indicated a rise in the Pb concentration in the shoot with an increase in the traffic density, as the highest value was recorded at the site of S_3 and S_2 with values of 14.90 and 12.50 mg.kg^{-1}, successively with a traffic momentum (Table 1). These results were similar to those of Rasheed & Hadeel (2013). The traffic momentum due to the combustion of fuel containing Pb results in an Aerosol suspension containing high concentrations of Pb distributed in the surrounding environment, raising pollution levels for soil, air, and plants.

Table 3: Total heavy metals concentrations in plants shoot for study sites (mg.kg^{-1} dry matter).

Plant species	Heavy metals [mg.kg^{-1} dry matter]			
	Pb	Cd	Ni	Zn
Site one (S1)				
Conocarpus erectus L.	12.50	0.21	4.60	76.00
Site two (S2)				
Acacia s.l.	9.80	0.17	3.00	59.00
Site three (S3)				
Melaleuca viminalis	14.90	0.24	5.20	87.00
Site four (S4)				
Dodonaea viscosa	11.00	0.20	3.80	68.00
Site five (S5)				
Lantana camara	7.30	0.14	2.50	51.00
WHO and FAO (2007)	5.00	0.20	67.90	60.00

The result shown in Table 3, Cd concentrations in the shoot parts of plants grown in the soil under study ranged between 0.14-0.24 mg.kg^{-1} dry matter. Here, the highest value can be observed on sites S_3 and S_1, which reached 0.24 and 0.21 mg.kg^{-1} dry matter sequentially. This was characterized by traffic momentum compared to the rest of the sites (Table 1). When comparing those concentrations with the determinants of the World Health and Food and Agriculture Organizations (WHO) (WHO/FAO 2007), we found that the limit has exceeded 0.20 mg.kg^{-1} dry matter. This demonstrates the traffic density and momentum effect (vehicles staying on the street) on the pollution process of plants growing in the study sites.

The result shown in Table 3, concentrations of nickel in the shoot parts of plants grown in the study soils, which ranged between 2.50-5.20 mg.kg^{-1} dry matter, remained within the allowed limits of 67.90 approved by the World Health and Food and Agriculture Organizations (WHO) (WHO/FAO 2007). This is consistent with what was found by Mohsen & Mohsen (2008). Increasing the concentration of nickel in the soil causes an increase in its concentration in plants growing in it and collects it in its tissues. As for the Zn, the results of Table 3 showed concentrations of Zn for plants grown in the study soils, which ranged between 51.00-87.00 mg.kg^{-1} dry matter. When comparing those concentrations with the determinants of the World Health and Food and Agriculture Organizations (WHO/FAO 2007), we find that they have exceeded the permissible limit of 60.00 mg.kg^{-1} dry matter, except for plants (*Lantana camara* and *Acacia s.l.*) in the S_5 and S_2 sites, which amounted to 51.00 and 59.00 mg.kg^{-1} dry matter. According to the results of Table 3, it was found that the concentrations of heavy metals increased in plants growing in the middle island with heavy traffic (near Abbas Attiwi Bridge, Faculty of Medicine Street) compared with other sites, Table 1. Results are consistent with the findings of Alsaffawi et al. (2014) and Ammar & Nasr (2017) about the high concentrations of lead in the leaves and branches of growing plants in densely populated and high-traffic areas in the city of Mosul. The results of our current study were similar to what was obtained by Ammar & Nasr (2017) in their study on the efficiency of some trees and roadside shrubs in the city of Tikrit in accumulating heavy elements, where the highest concentration of lead was in the leaves of growing trees in the annual road of the city of Tikrit, due to its proximity to the industrial neighborhood that prevails It includes the burning of car tires and some types of fuel available from car waste, which confirms the role of gases emitted from vehicles in polluting the soil with heavy elements and their transfer to growing plants.

Moreover, Ali (2010) found some areas of Baghdad soils have high heavy metal concentrations, including Cd, Pb and Zn. This increase has been associated with the recent increase in vehicles and the use of fuels from different sources. As a result, plants growing in soils polluted with heavy metals absorbed these metals from polluted soil and collected them in their tissues compared to plants grown in unpolluted soils (Chojnacha et al. 2005, Saini et al. 2011).

Bioaccumulation Coefficient (BAC)

The bioaccumulation factor refers to the plant's ability to store and store heavy metals. It reflects the ability of the plant species to accumulate heavy elements through their absorption from the soil and their accumulation in its tissues (Mahmood et al. 2019, Hassan et al. 2020). The higher values of the bioaccumulation coefficient than one indicate that the plant species is highly efficient in absorbing heavy elements (Hamad et al. 2021)**.** We assessed Figs. 2, 3, and 4 that the bioaccumulation coefficient values with respect to heavy metals for the majority of the study metals observed in the *Dodonaea viscosa* plant reached 0.122, 0.098, and 0.642 for Pb, Cd, and Zn, respectively except for nickel. It

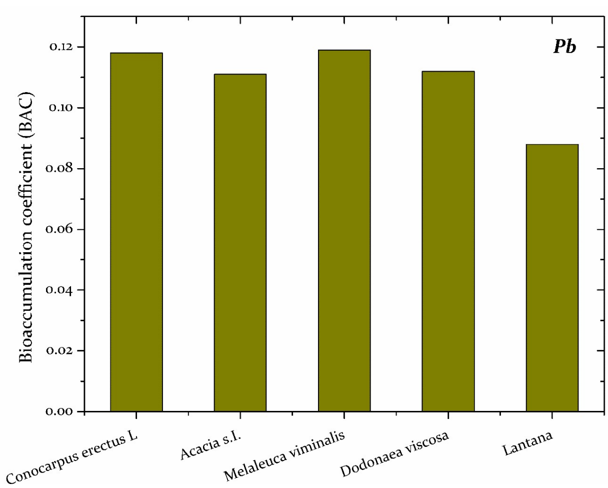

Fig. 2: Bioaccumulation coefficient (BAC) for lead in the study plants.

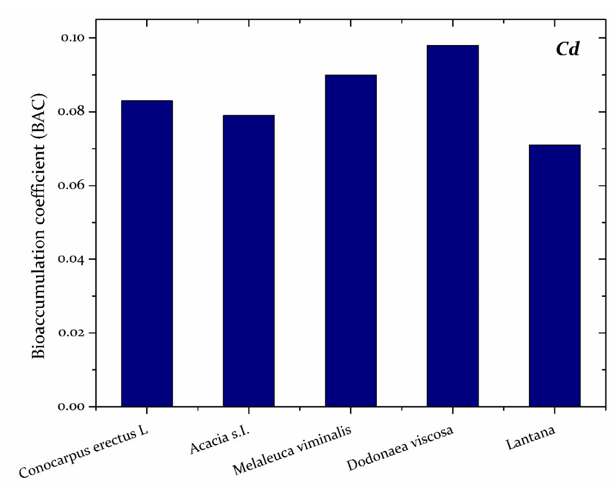

Fig. 3: Bioaccumulation coefficient (BAC) for cadmium in the study plants.

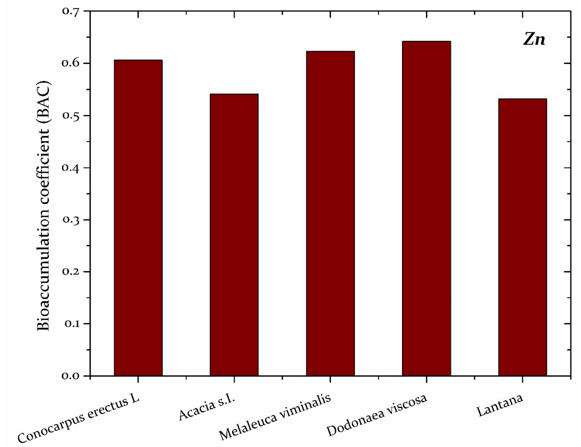

Fig. 4: Bioaccumulation coefficient (BAC) for zinc in the study plants.

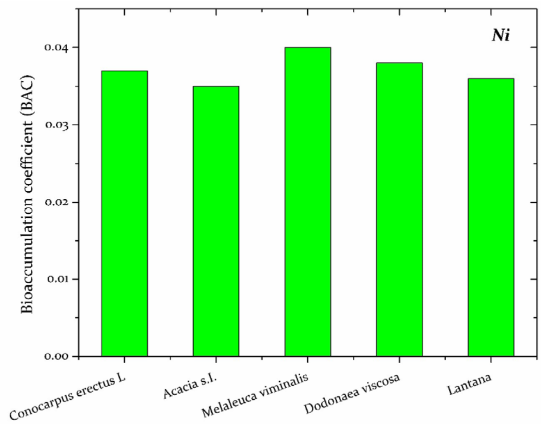

Fig. 5: Bioaccumulation coefficient (BAC) for Nickel in the study plants.

was more accumulated in the *Melaleuca* tree, which had a value of 0.040 (Fig. 5), which indicates the superiority of the *Dodonaea viscosa* plant in accumulating Pb, Cd, and Zn over the rest of the study trees, as they took the following order:

Melaleuca viminalis > *Conocarpus erectus* > Acacia s.l. > *Lantana camara* > *Dodonaea viscosa*

The best tree accumulation for nickel is in the following order:

Melaleuca viminalis > *Dodonaea viscosa* > *Conocarpus erectus* > *Lantana camara* > *Acacia s.l*.

The reason is attributed to the variation in the ability of plants to absorb and accumulate heavy elements based on the physiological nature of plant species (Azita & Seid 2008). These results were proportional to what was found by Ammar & Nasr (2017). The Dodonaea viscosa plant prefers to accumulate Pb and Zn compared to the rest of the roadside trees and shrubs in Tikrit City.

CONCLUSION

The investigation yielded significant findings, pinpointing soil contamination with Pb in S1 and S3, while nickel contamination was evident in the remaining sites. The results showed a discernible rise in the concentrations with respect to the study of heavy metals by increasing the traffic momentum.

The lead (Pb) concentrations in the shoot parts with respect to the growing plants under study exceeded the permissible critical limit, as the highest value was recorded at S_3 and S_2 locations. The results showed an increase in cadmium (Cd) concentrations in S_3 and S_1 sites, and they exceeded the permissible limit. In comparison, the nickel concentrations were within the permissible limits. The zinc (Zn) exceeded the permissible limits except for the plants *(Lantana camara* and *Acacia s.l.*) in the S_5 and S_2 sites. The values of the heavy metals Bioaccumulation Coefficient (BAC) for most of the study metals recorded the highest value in the *Dodonaea viscosa* plant for Pb, Cd, and Zn, except for nickel, which was more accumulated in the *Melaleuca viminalis* tree. This variation is due to the plant's genetic ability to remove pollutants.

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Expansion of the cultivation of *Dodonaea viscosa* and the *Melaleuca viminalis* of the hero in the range of Diwaniyah governorate and similar areas in climatic conditions and its use in the process of air reclamation of soils contaminated with heavy elements due to its ability to absorb and accumulate heavy elements in its tissues.

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