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# المخاطر البيئية المرتبطة بالتراكم الحيوي للمعادن الثقيلة في النباتات على جوانب الطرق في مدينة الرمادي،العراق

**رفرف عبد العزيز عبد القادر،**
**سفيان محمد شرتوح**
**قسم علوم الحياة ، كلية العلوم ، جامعة الانبار، العراق**

**الملخص**
تهدف هذه الدراسة إلى التحقيق في التراكم النباتي لعناصر الزنك (Zn)، والنحاس (Cu)، والكروم (Cr)، والرصاص (Pb)، والكادميوم (Cd) في الأنسجة النباتية التي جُمعت من جوانب الطرق. شملت الدراسة تصنيفات مختلفة للطرق في مدين ة الرمادي، غرب العراق، وهي: الطرق السريعة، والمناطق الصناعية، والطرق متعددة الاستخدامات، والطرق السكنية.تم تقييم الحمل التلوثي في تربة هذه المواقع باستخدام مؤشر حمل التلوث (PLI)، والذي قدم صورة متكاملة عن العبء الإجمالي للمعادن الثقيلة في كل موقع. أكدت قيم مؤشر التلوث (PLI) بشكل قاطع وجود حمولات بشرية المصدر كبيرة على طول الطرق الصناعية (حيث وصل المؤشر إلى 3.09) والطرق متعددة الاستخدامات (بمؤشر وصل إلى 1.52)، مما يشير إلى حالة من التدهور الواسع للتربة التي تعد الخزان الرئيسي لامتصاص المعادن من قبل النبات.رسمت النتائج التحليلية تسلسلاً هرمياً واضحاً للعناصر داخل الأنسجة الورقية، حيث تجاوزت تركيزات الزنك (Zn) بشكل ملحوظ تركيزات الكروم والنحاس والرصاص، بالإضافة إلى الكادميوم (Cd) شديد السمية. وحدد التحليل المكاني أن الطرق متعددة الاستخدامات وقطاعات الطرق السريعة هي المناطق الرئيسية لإغناء المعادن، حيث وصلت القيم الذروية إلى 24.8 جزء في المليون (ppm) للزنك، وقيمة مرتفعة حرجة بلغت 0.69 جزء في المليون للكادميوم، وهو تركيز يتجاوز بشكل كبير حدود السلامة المقررة للأنسجة النباتية.كشفت حسابات عامل التركيز الحيوي (BCF) عن وجود تباين ملحوظ بين قيم مؤشر تلوث التربة (PLI) وبين الامتصاص البيولوجي الفعلي؛ فبينما سجلت المناطق الصناعية أعلى قيم لمؤشر حمل التلوث، أظهرت النباتات فيها آليات استبعاد دفاعية وقد سجلت في تلك المناطق قيمًا منخفضة لـعامل التركيز الحيوي (BCF). وعلى النقيض من ذلك، أظهرت المواقع ذات قيم مؤشر تلوث التربة (PLI) المتوسطة، مثل المناطق السكنية والمواقع متعددة الاستخدامات، كسراً متاحاً نباتياً أكبر وكفاءة نقل أعلى؛ مما يشير إلى أن حجم تلوث التربة وحده لا يعد مؤشراً كافياً للتنبؤ بالمخاطر البيئية.إن التراكم الواضح لعنصري الكادميوم والكروم في الأنسجة النباتية عند نقاط محددة، والذي يتجاوز بشكل ملحوظ الحدود المرجعية، يؤكد وجود خطر بيئي ملموس. وتؤكد هذه النتائج أن النشاط المروري غير المنظم، مقترناً بالظروف المناخية القاحلة التي تساعد على إعادة تعليق الملوثات ، يحول الغطاء النباتي على جوانب الطرق من مجرد مؤشرات حيوية سلبية إلى قنوات محتملة لـ التضخم الحيوي للمعادن الثقيلة؛ مما يشكل خطراً جوهرياً على الماشية التي ترعى في تلك المناطق وعلى سلامة االسلسلة الغذائية المحلية. وهذا يستلزم الدمج العاجل لتقييمات مخاطر الاستخلاص النباتي ضمن أطر الإدارة البيئية الحضرية.

# Environmental risks associated with heavy metal bioaccumulation in roadside plants in Ramadi City, Iraq

**Rafraf Abdulaziz Abdulqader,Sufyan Mohammed Shartooh**
**Department of Biology ,College of Science,University of Anbar,Iraq**

**Abstract**
This aim of this study is to investigate the phytoaccumulation of zinc (Zn), copper (Cu), chromium (Cr), lead (Pb), and cadmium (Cd) in plant tissues collected roadside to highway, industrial, mixed, and residential road typologies in Al-Ramadi city, western Iraq. The pollution load of the supporting soil matrix was evaluated using the Pollution Load Index (PLI), which provided an integrated snapshot of the total heavy metal burden at each site. The PLI values unequivocally confirmed significant anthropogenic loading along industrial roads (PLI up to 3.09) and mixed-use roads (PLI up to 1.52), denoting a state of pervasive soil degradation that constitutes the primary reservoir for plant metal uptake. The analytical results delineated a distinct elemental hierarchy within foliar tissues, with Zn concentrations

significantly exceeding those of Cr, Cu, Pb, and the profoundly toxic Cd. Spatial analysis identified mixed-use roads and highway segments as the principal zones of metal enrichment, where peak values reached 24.8 ppm for Zn and a critically elevated 0.69 ppm for Cd a concentration that substantially surpasses established safety thresholds for plant matrices. The computation of the Bioconcentration Factor (BCF) revealed a striking disconnect between the soil PLI and the actual biological uptake: while industrial zones exhibited the highest PLI values, the plants therein displayed defensive exclusion mechanisms, yielding lower BCF values. In contrast, locations with moderate PLI values, such as residential and mixed-use sites, demonstrated a greater phytoavailable fraction and higher translocation efficiency, indicating that the magnitude of soil pollution alone is an incomplete predictor of ecological risk. The pronounced accumulation of cadmium and chromium in plant tissues at specific nodes, markedly exceeding reference limits, underscores a tangible ecological hazard. These findings confirm that unregulated vehicular activity, coupled with arid climatic conditions favoring contaminant resuspension, transforms roadside flora from mere passive bio-indicators into potential conduits of heavy metal biomagnification, posing a substantive risk to grazing livestock and the integrity of the local food chain. This necessitates the urgent integration of phytoextraction risk assessments into urban environmental management frameworks.

**Keywords**:Heavy metal, phytoaccumulation, plants, Roadside, Pollution Load Index (PLI), Bioconcentration Factor (BCF), food chain, Iraq

## 1. Introduction

Heavy metals (HMs) constitute a prominent class of environmental contaminants characterized by their high atomic density, environmental persistence, and inherent toxicity even at trace concentrations. Elements are ubiquitously released into the pedosphere and atmosphere through a spectrum of anthropogenic activities, including vehicular emissions, industrial processes, and the abrasion of mechanical components. Unlike organic pollutants, HMs resist microbial and chemical degradation, enabling their long-term retention within environmental matrices and their progressive transfer across ecological compartments [1].The environmental significance of these metals is compounded by their dual nature; while certain elements like Zn and Cu function as essential micronutrients at low concentrations, they transition into potent toxicants when their environmental loads exceed physiological thresholds, disrupting enzymatic functions and inducing oxidative stress within biological systems [2]. The escalation of global urbanization and the exponential growth of vehicular traffic have transformed road networks into linear sources of heavy metal emissions. Mechanical abrasion of brake pads liberates substantial quantities of Cu, tire wear releases Zn in particulate form, and fuel combustion historically contributed to Pb deposition, while Cd persists as a contaminant in lubricants and low-grade automotive components [3]. Vegetation established along transportation corridors occupies a unique and vulnerable position at the soil-atmosphere interface, functioning simultaneously as a passive sink for atmospheric deposition and as an active accumulator of soil-borne contaminants. Plants growing in roadside environments are exposed to heavy metals through a dual mechanism: root uptake from contaminated soil substrates and direct foliar absorption of metal-rich particulate matter deposited on leaf surfaces [4].The accumulation of HMs in roadside vegetation represents a significant environmental concern that extends beyond phytotoxicity to encompass broader implications for food chain contamination and public health. When plant tissues accumulate metals such as Cd and Cr at concentrations exceeding established safety thresholds, they constitute a direct threat to grazing livestock and, through biomagnification processes, to human consumers of animal-derived products [5].The chronic ingestion of Cd-contaminated forage by farm animals can result in the accumulation of this nephrotoxic metal in renal and hepatic tissues, manifesting as metabolic bone disease and impaired reproductive function, while excessive Pb burdens are linked to neurological impairment and hematological abnormalities [6].Furthermore, the leaf-level sequestration of toxic metals, although a protective mechanism for the photosynthetic apparatus, renders the aboveground biomass a concentrated source of contaminants that can re-enter the environmental cycle through litter decomposition or biomass burning [7].The toxicological profile of individual metals varies considerably; Cd is classified as a Group 1 carcinogen by the International Agency for Research on Cancer, exhibiting high mobility in the soil-plant system and a pronounced tendency to substitute for essential divalent cations such as calcium and zinc in biological processes [8].while Pb, despite its lower phytoavailability, exerts potent neurotoxic effects that are particularly devastating in developing organisms [9].Conocarpus erectus L., commonly known as buttonwood or button mangrove, is a perennial evergreen tree belonging to the family Combretaceae, widely cultivated in arid and semi-arid urban landscapes for its exceptional tolerance to drought, salinity, and compacted soils. Native to coastal regions of the Americas and West Africa, this species has been extensively adopted as an ornamental and shade tree along roadways, in public parks, and within urban greenbelts throughout the Middle East, including Iraq [10]. Its morphological characteristics including a dense, multi-branched canopy, thick coriaceous leaves with a well-developed cuticle, and a deep, extensive root system confer a remarkable capacity to intercept atmospheric particulates and to access soil-bound contaminants across a broad rhizospheric zone[11]. The present study, conducted along the major transportation routes of Al-Ramadi city, a representative arid urban center in western Iraq, aims to address this knowledge gap by quantifying the concentrations of Zn, Cu, Cr, Pb, and Cd in C. erectus leaves relative to the underlying soil metal loads, employing the Bioconcentration Factor as a diagnostic metric. Through the integration of geochemical indices and biological accumulation parameters, this investigation endeavors to elucidate the environmental risks linked to heavy metal bioaccumulation in roadside vegetation and to provide an empirical basis for informed urban environmental management strategies in rapidly developing arid-region cities.

## 2. Materials and Methods

### 2.1 Study Location

The study was conducted in Ramadi city, one of the cities of Anbar Governorate Located in west-central Iraq, Anbar is a region of immense geographical importance, covering approximately one-third of Iraq's total land area. Ramadi city, serves as a vital strategic hub, stretching along the banks of the Euphrates River. Its significance is further amplified by its location on major international transit routes connecting Iraq with neighboring countries. The region is characterized by a desert climate (Arid climate), featuring high temperatures and minimal precipitation throughout the year. These climatic conditions, particularly the scarcity of rainfall and frequent dust events, play a crucial role in the accumulation and distribution of heavy metals within roadside plants [12].

**2.2 Sample collection and analysis**

Roadside vegetation samples were collected Ramadi city, representing different levels of anthropogenic and vehicular activities. These categories include ,Highway Road Characterized by high-speed transit and heavy-duty vehicle traffic .Industrial Road Located near workshops and industrial activities .Mixed-use Road Areas combining commercial activities and moderate traffic .Residential Roads within residential neighborhoods with lower traffic density .To establish a baseline for comparison, a Control Site (CS) was selected in area far from the influence of traffic emissions and industrial plumes. Samples were dried at 105 0C for 24 hours and separate according to its volume by using sieves 106 µm . Volumes fewer than 106 µm were taken for analysis .Samples were analyzed according to a protocol [13]. One gram of each oven-dried and ground plants and soil was digested at 80 °C in a 15 ml tri-acid mixture containing HNO3, H2SO4, and HClO4 in a 4.5:1:1 ratio to obtain a clear solution. The solution was then filtered, and the resulting filtrate was adjusted to a volume of 50 ml by adding distilled water [14]. The clear solution then underwent additional filtering, and distilled water was added to the filtrate to bring its volume to 50 ml [15].AAS (Atomic Absorption Spectrometry) instrument was used to detect and measure heavy metal content in the samples.

**2.3 pollution assessment methods**

There are several indices employed to assess the pollution levels in soil and plants samples. In our study, the pollution load index (PLI) and Bioconcentration Factor (BCF) were used to assess the heavy metals pollution level in roadside plants samples of Ramadi City.

**2.3.1 Pollution Load Index**

The Pollution Load Index (PLI) is a potent geochemical tool used to determine the collective level of heavy metal contamination in a specific environment (soil, sediment and dust, ). Unlike individual contamination factors, the PLI provides a comprehensive "snapshot" of the total pollution burden at a site [16]. The CF and PLI were calculated using the below-mentioned equations [17] [18]:

$$CF = C_m / B_m$$

$$PLI = (CF_1 \times CF_2 \times CF_3 \times CF_4 \times CF_5 \times \ldots\ldots\ldots\ldots \times CF_n)^{1/n}$$

Cm represents the metal constration in soil, while , Bm is the background value of the metal ,n represents number of elements [19]. PLI is calculated as the nth root of the product of the CF of each element for the examined . the PLI value of less than 1 indicates no pollution, whereas a value greater than 1 indicates pollution [20].

### 2.3.2 Bioconcentration factor

The Bioconcentration Factor (BCF) is used to measure the ability of plant to absorb and accumulate heavy metals from soil, providing a direct indication of an element's bioavailability [21]. to quantify the enrichment of HMs in plant ,the following equation was used [22] :

Where Cleave represents the metal concentration in the leave, Csoil represents the metal concentration in the soil [23] . The BCF refers to the ratio of the heavy metal concentration in a plant to that in soil . Values greater than 1, BCF (Bioconcentration Factor) indicate higher BCR (Bioconcentration Ratio) that the plant is a potential heavy metal and vice versa [24].

## 3. Results and Discussion

### 3.1 Heavy metal concentration in plant tissue

Mean values ± standard deviation of Zn, Cu, Cr, Pb and Cd in various plant samples collected from high way, industrial, mixed and residential roads within AlRamadi city in addition to control sample located far away from any motor road were presented in Table 3.1

**Table 3.1: Mean heavy metals (ppm) ± Standard deviation in plant samples collected from 5 locations adjacent to different roads within Al-Ramadi city**

| Road Type | Locations | Heavy Metal Concentration in ppm (Mean ± SD) | | | | |
|---|---|---|---|---|---|---|
| | | Zn | Cu | Cr | Pb | Cd |
| High way Road | L 1 | 18.5 | 3.5 | 2.86 | 2.0 | 0.38 |
| | L 2 | 18.4 | 5.5 | 4.5 | 2.0 | 0.54 |
| | L 3 | 16.9 | 5.1 | 5.72 | 3.0 | 0.33 |
| | L 4 | 17.0 | 4.9 | 3.8 | 2.5 | 0.44 |
| | L 5 | 15.8 | 4.5 | 2.9 | 1.99 | 0.39 |
| Indus. Road | L 1 | 14.0 | 2.9 | 3.76 | 2.5 | 0.38 |
| | L 2 | 22.9 | 2.5 | 2.15 | 2.5 | 0.39 |
| | L 3 | 20.0 | 2.7 | 2.73 | 1.95 | 0.32 |
| | L 4 | 14.0 | 3.0 | 3.14 | 2.0 | 0.33 |
| | L 5 | 21.5 | 3.2 | 2.69 | 2.2 | 0.32 |
| Mixed Road | L 1 | 24.8 | 2.8 | 2.86 | 2.2 | 0.69 |
| | L 2 | 23.8 | 3.0 | 3.86 | 1.91 | 0.54 |
| | L 3 | 12.0 | 2.5 | 2.85 | 1.88 | 0.31 |
| | L 4 | 12.0 | 3.6 | 2.71 | 1.82 | 0.23 |

$$BCF = C_{leave}/C_{soil}$$

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| | | | | | | |
|---|---|---|---|---|---|---|
| | L 5 | 18.9 | 2.9 | 3.95 | 1.99 | 0.6 |
| Reside. Road | L 1 | 17.2 | 2.5 | 3.43 | 1.78 | 0.15 |
| | L 2 | 10.5 | 2.42 | 2.86 | 1.79 | 0.15 |
| | L 3 | 19.0 | 2.5 | 3.15 | 1.8 | 0.3 |
| | L 4 | 14.8 | 2.5 | 2.14 | 1.52 | 0.22 |
| | L 5 | 9.9 | 1.82 | 2.72 | 1.78 | 0.35 |
| Control | C | 9.1 | 3.3 | 3.0 | 0.95 | 0.12 |

The statistical analysis for tin Ramadi he concentrations of heavy metals (Zn, Cu, Cr, Pb, and Cd) in roadside vegetation adjacent to transport ways in Ramadi City,and the analysis results were shown in figure 3.1 act as a critical bio-indicator of atmospheric deposition and soil-to-plant transfer. The results indicate a hierarchical abundance of metals in the order, Zn > Cr > Cu > Pb > Cd. This hierarchy suggests that mechanical wear (Zinc) and industrial/high-speed traffic emissions (Chromium) are the primary contributors to the botanical metal burden in the region [27]. The results confirms a severe environmental risk for specific elements where Cadmium (Cd) peak value of 0.69 ppm is nearly 35 times higher than the WHO/FAO limit of 0.02 ppm. Chromium (Cr) The peak of 5.72 ppm significantly exceeds the safety limit of 1.30 ppm .urban plants in developing regions often act as sinks for Cd and Cr, reaching levels that pose a direct threat if they enter the local food chain through grazing. This excessive accumulation indicates that the plants have surpassed their natural detoxification capacity, posing a severe hazard to any livestock grazing in these areas [28] .when Cd and Cr in plants exceed safe margins, it can lead to metabolic disturbances and oxidative stress within the botanical structure[29]. Highest Pollution Site of Mixed Road Location 1 and Highway Location 3 emerged as the primary hotspots for metal accumulation. These sites are likely 67characterized by "stop-and-go" traffic, higher vehicle density, or proximity to maintenance workshops Lowest Pollution Site Excluding the control, Residential Road Location 5 generally showed the lowest metal uptake, reflecting lower traffic volumes and a lack of industrial activity [30]. The plants along Al-Ramadi city major roads are bio-accumulating toxic metals (Cr, Pb, and Cd) at levels exceeding WHO/FAO safety standards. underscore that proximity to traffic is the dominant factor determining plant toxicity [31]. plants have a higher natural tolerance for Zn and Cu as they are essential micronutrients, unlike Cd and Pb [29].

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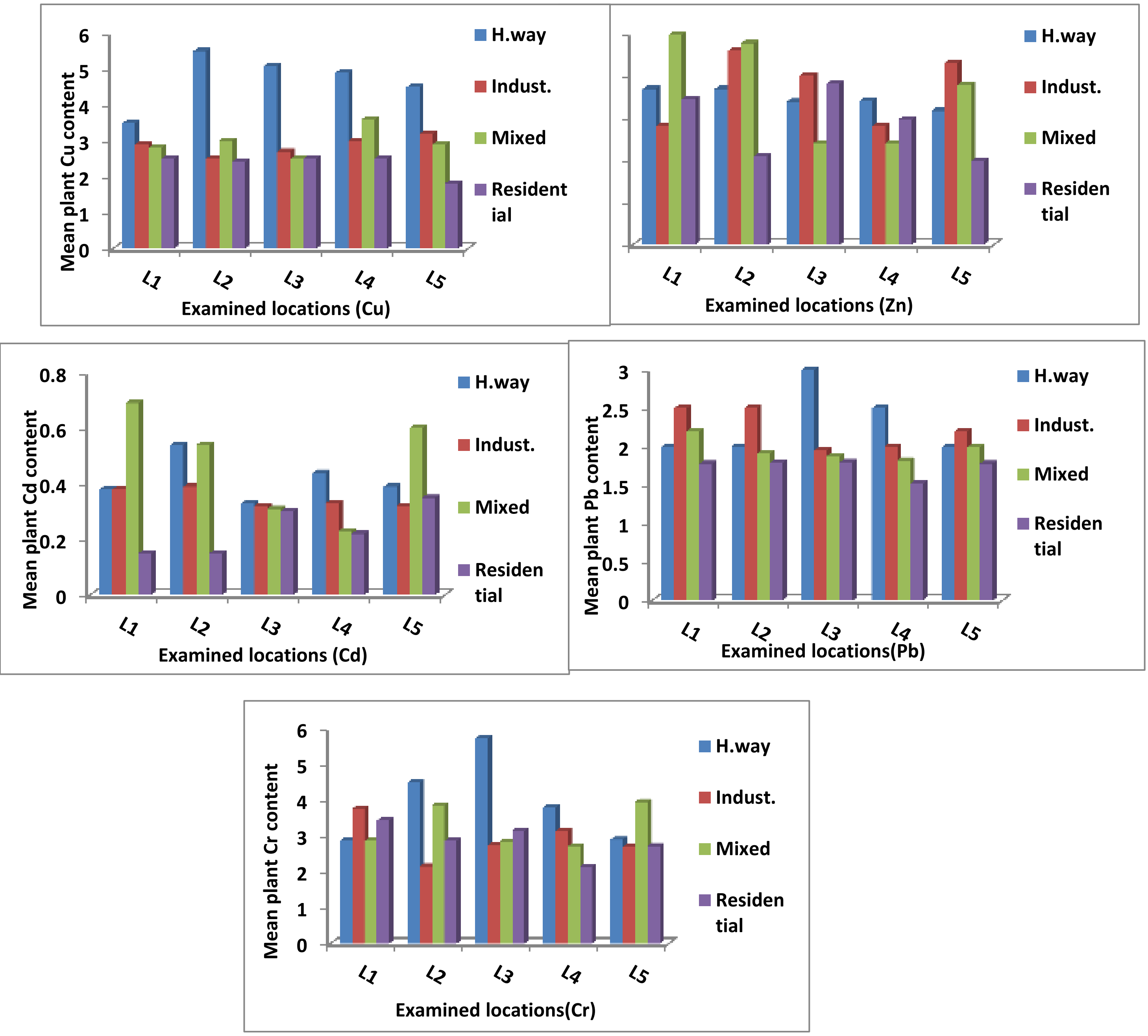


**Figure 3.1 :Mean plant heavy metal concentration(ppm) in all road type location**

## 3.2 Soil Criteria

soil criteria are indispensable for evidence-based environmental management, risk assessment, and the design of remediation strategies in urban and peri-urban ecosystems [32] . Values of pollution load index (PLI) in soil samples collected from 5 locations from high way, industrial, mixed and residential roads are presented in Table 3.2.

**Table 3.2: Values of PLI in soil collected from 5 locations from high way, industrial, mixed and residential roads**

| Site | Location | PLI |
|---|---|---|
| **High way** | L1 | 1.110203 |

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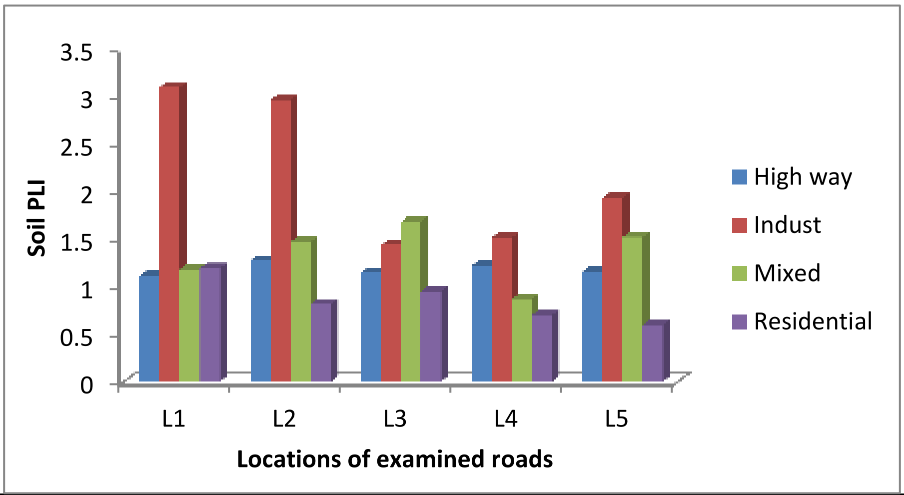
| | | |
|---|---|---|
| | L2 | 1.274405 |
| | L3 | 1.148443 |
| | L4 | 1.217194 |
| | L5 | 1.157219 |
| **Industrial** | L1 | 3.093019 |
| | L2 | 2.962055 |
| | L3 | 1.43745 |
| | L4 | 1.512459 |
| | L5 | 1.929621 |
| **Mixed** | L1 | 1.182001 |
| | L2 | 1.469539 |
| | L3 | 1.682148 |
| | L4 | 0.868527 |
| | L5 | 1.519601 |
| **Residential** | L1 | 1.192869 |
| | L2 | 0.811507 |
| | L3 | 0.951151 |
| | L4 | 0.697093 |
| | L5 | 0.594178 |




**3.3 Pollution load index (PLI)**

Regarding PLI, highest values were found in industrial locations ranged from 1.43745 in location 3 to 3.093019 in location 1) followed by those of mixed road locations (0.868527-1.519601 for locations 4 and 5), then high way locations (1.110203 for location 1 to 1.274405 for location 2), while lowest values of (0.594178 in location 5 - 1.192869 in location 1) were recorded in residential road locations (Fig. 3.2).

**Figure 3.2: Soil heavy metal pollution load index (PLI) in 5 locations of examined roads**

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However, according the PLI values the roads of high way, industrial and mixed were polluted because the PLI levels exceeds (1), while the residential road was almost not polluted where PLI levels are less than (1) except for location 1. The results indicate that Industrial and Mixed road locations are the most heavily impacted by anthropogenic activities .industrial sites recorded the highest PLI values Specifically, L1 and L2. These values indicate severe pollution [33]. PLI values exceeding 3.0

Yet, The Residential sector generally recorded the lowest PLI values, .Since these values are below 1, these specific sites are classified as "unpolluted" relative to the established baseline, , indicating a localized pollution source or proximity to a higher-traffic area [34]. residential zones located downwind from industrial clusters often show elevated PLI values due to the atmospheric transport of fine particulate matter [35].

### 3.4 Plant bioaccumulation factor (BCF)

Table 3.3 consists of calculated values of bioaccumulation factor (BCF) in plants sampled from 5 locations of high way, industrial, mixed and residential roads. Obviously, highest values were recorded in plant Zn from all roads locations while the lowest values were detected in plant Pb again from all examined locations.

**Table 3.3: Calculated values of bioaccumulation factor (BCF) in plants in 5 locations collected from high way, industrial, mixed and residential roads**

| Site | Location | Zn | Cu | Cr | Pb | Cd |
|---|---|---|---|---|---|---|
| **High way** | L1 | 0.311337 | 0.170732 | 0.190667 | 0.097561 | 0.141264 |
| | L2 | 0.367265 | 0.257009 | 0.25 | 0.048309 | 0.216 |
| | L3 | 0.393939 | 0.159875 | 0.353086 | 0.108696 | 0.170103 |
| | L4 | 0.377778 | 0.201646 | 0.223529 | 0.081967 | 0.157143 |
| | L5 | 0.287273 | 0.15 | 0.2 | 0.076834 | 0.19598 |
| **Industrial** | L1 | 0.199147 | 0.020451 | 0.163478 | 0.010734 | 0.120635 |
| | L2 | 0.343328 | 0.011876 | 0.081132 | 0.021626 | 0.12381 |
| | L3 | 0.355872 | 0.080597 | 0.145213 | 0.050914 | 0.118959 |
| | L4 | 0.257827 | 0.092879 | 0.160204 | 0.041667 | 0.115789 |
| | L5 | 0.357143 | 0.079012 | 0.106324 | 0.025611 | 0.106667 |
| **Mixed** | L1 | 0.443649 | 0.189189 | 0.161582 | 0.072848 | 0.222581 |
| | L2 | 0.407534 | 0.142857 | 0.176256 | 0.035902 | 0.189474 |
| | L3 | 0.17991 | 0.074184 | 0.135714 | 0.038367 | 0.089595 |
| | L4 | 0.324324 | 0.313043 | 0.180667 | 0.085047 | 0.106977 |
| | L5 | 0.303371 | 0.113725 | 0.205729 | 0.044124 | 0.171429 |
| **Residential** | L1 | 0.323308 | 0.181159 | 0.211728 | 0.035108 | 0.063025 |
| | L2 | 0.272727 | 0.284706 | 0.194558 | 0.086473 | 0.071429 |
| | L3 | 0.584615 | 0.245098 | 0.172131 | 0.059016 | 0.12 |
| | L4 | 0.416901 | 0.304878 | 0.2675 | 0.076 | 0.104762 |
| | L5 | 0.380769 | 0.288889 | 0.312644 | 0.11125 | 0.181347 |

Regarding plant Zn, the highest values were found to vary from 0.199147 µg/g (location 1, industrial road) to 0.584615 µg/g (location 3, residential road), whereas plant Cu gave values varying from 0.011876 µg/g (industrial location 2) to 0.313043 µg/g (location 4, mixed road). In case of plant Cr, these values were found to vary from 0.081132 µg/g (location 2, industrial) to 0.353086 µg/g (location 3, highway), whilst for plant Pb, it was found the values of BCF have varied from 0.010734 µg/g (location 1, industrial road) to 0.11125 µg/g (location 5, residential road). Finally, plant Cd values were recorded to range from 0.063025 µg/g (location 1, residential) to 0.19598 µg/g in location 5 of high way (Fig. 3.3).

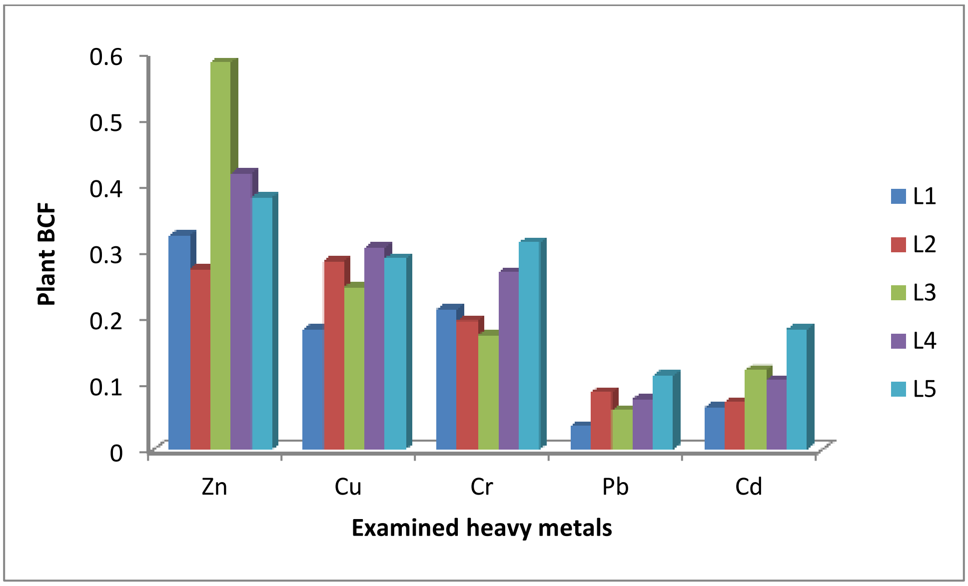


**Figure 3.3: Plant bioaccumulation factor (BCF) in 5 locations of residential roads**

Nevertheless, the total values of BCF reveals that the heavy metals contamination levels in soil are higher compared with what absorbed by the plants, since the BCF values of all locations are less than (1). The Industrial sites represent the most "polluted" soil environments. Highly polluted soil. yet they paradoxically show the lowest BCF values for several metals. Zinc (Zn) Recorded the highest BCF values among all examined metals. Zn often exhibits higher BCF values because it is an essential micronutrient for plant enzymatic functions, facilitating its active transport compared to non-essential elements like Pb [36] .Also, Lead (Pb) Consistently showed the lowest BCF values across all sites, Pb has low bioavailability and tends to be sequestered in the soil-root interface, which explains the minimal BCF values observed plant samples [37]. Never the less, Cr values varied from 0.081132 (Industrial L2) to 0.353086 (High way L3). Cu showed a similar moderate accumulation pattern, peaking at 0.313043 in mixed road L4. Cadmium (Cd) Showed BCF values ranging from 0.063025 in residential L1 to 0.19598 in high way L5. Although Cd is highly toxic, its BCF remains low, indicating limited phytoavailability in these specific soil conditions [38]. Interestingly, the residential road locations showed a "similar sequence" of heavy metal uptake compared to high-traffic areas, but with slightly higher BCFs for Zn in specific spots like L3. This suggests that while soil concentrations are higher in industrial zones [33].efficiency of plant uptake (BCF) does not necessarily increase linearly with soil pollution, often due to soil pH or organic matter binding [39].

**Conclution**

The study conclusively demonstrates that roadside plants in Ramadi city are actively bioaccumulating toxic heavy metals from vehicular and industrial emissions. The accumulation hierarchy zinc dominating, followed by chromium, then copper, with lead and cadmium being lowest confirms that tire wear and brake abrasion are the primary pollution sources, not natural background geology.Mixed-use roads and highways emerged as the most critical contamination hotspots, where frequent stop-and-go traffic and unregulated workshops create synergistic accumulation zones. Most alarmingly, cadmium and chromium concentrations in plant tissues far exceeded international safety thresholds, indicating that local flora have surpassed their natural detoxification capacity, posing a direct threat to grazing livestock and the food chain.Plants accumulate metals through two pathways: root uptake from soil and, more significantly in this arid climate, foliar absorption of re-suspended dust. Despite severe soil pollution, bioconcentration factors remained below unity, revealing that native plants employ root-level exclusion strategies to limit metal translocation a survival mechanism that is not absolute, as evidenced by measurable contamination in above-ground tissues.Zinc showed the highest uptake due to its role as an essential micronutrient that facilitates active transport, while industrial sites paradoxically exhibited the lowest bioconcentration factors, indicating adaptive exclusion in chronically polluted environments.roadside vegetation serves as a sensitive bioindicator of transport-related pollution, but the current levels of cadmium and chromium accumulation demand immediate intervention. Without green buffers, low-accumulator species, and phytoremediation strategies, this hidden pathway will continue to threaten ecosystem integrity and public health in Ramadi.

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