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**Research Article**

# Health risks and environmental assessments of heavy metals in road dust of Ramadi, Iraq

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## Abstract

Air dust is a host medium for potentially harmful substances in atmospheric emissions. Contaminated air with metals causes serious threats to human health. This research aimed to examine the features of road dust pollution and evaluate related heavy metals' health risks. All samples were collected from outdoor environments by including fifty different places in Ramadi using a soft plastic brush. Five heavy metals were evaluated in this study, including nickel (Ni), cadmium (Cd), chromium (Cr), copper (Cu), and lead (Pb). Roadside dust pollution in urban Ramadi streets was assessed using the ecological risk index (RI). Hazard quotient (HQ) and hazard index (HI) calculations were performed for all three exposure pathways (dermal contact, ingestion, and inhalation). The results showed that copper (mean = 49.520 mg/kg) and chromium (mean = 34.742 mg/kg) had the highest heavy metal concentrations, followed by nickel, lead, and cadmium. Even though cadmium was the lowest, however; its ecological risk index was higher than other heavy metals, as cadmium was determined to be higher for dermal adsorption of dust than for inhalation or ingestion in adult people.

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## Introduction

Dust is accounted as the primary source of pollution by heavy metals (HMs), which leads to the accumulation of HMs on soil surfaces due to air deposition (Alloway, 2013). Dust deposition introduces heavy metals from different natural and daily anthropogenic sources, including factory emissions, agricultural activities like soil preparations, road aerosols, car emissions, waste incineration, construction processes, and oil combustion (Kumar, 2013; Wati et al., 2015; Husnizar et al., 2018; Yulianto et al., 2019; Li et al., 2020). Dust aerosols significantly impact ecosystems and human health, and heavy metal-contaminated road dust is a primary environmental concern (Huang et al., 2016). The human body can be exposed to toxic metals linked to dust particles by inhalation, digestion, and dermal (skin) absorption (Li et al., 2017). Children are often exposed to heavy metals by inhaling dust while playing or mouthing non-food objects (Goudarzi et al., 2017). Hazard quotient (HQ) and hazard index (HI) are used to evaluate and assess whether or not something is carcinogenic, which are used more significantly than measuring the quantity of heavy metals in any environment (Ma et al., 2016). Heavy metals and other pollutants caused by road dust can continually enter receptors via nasal inhalation, accidental dust ingestion, and skin contact with dust, which pose a health risk (Chen et al., 2021).

People are highly exposed to road dust through the largest leisure, sporting, commercial activity centers, recreational areas, and city squares in urban areas. People are becoming more aware of their health and entertainment as living conditions and lifestyles improve, and there is a rise in human activity in these locations (Faisal et al., 2022). Due to the release of dangerous gases, industrial regions are considered significantly more polluted than other areas

(Ackah, 2019). Thus, the environment's low quality impacts the health of nearby residents. Through inhalation, resuspension, ingestion, and skin contact, heavy metal-containing dust enters the human body and causes major health problems. Because of this, it is critical to evaluate and reduce pollution levels and their negative impacts on human health (Faisal et al., 2021). The mutagenic, teratogenic, and carcinogenic effects of several trace metals have been demonstrated in numerous investigations (Yang et al., 2019). Therefore, looking into and evaluating the toxicity and health risks associated with metals is essential. Heavy metal deposition in the dry and wet atmosphere is the source of urban water contamination. Metals are released into the atmosphere to become part of the surface and road aerosols via industrial fuel gases, fossil fuels burning, wear of car tires, mining, dust adsorption, and as a result of the weather. Rainfall is another element that affects runoff pollution on the flows via the public pipeline, water contamination with heavy metals, and causing damage to the entire water system (Mohmand et al., 2015).

## Materials and Methods

### *Study area*

Ramadi is a city in central Iraq, the capital of Anbar province, located at (33°24'59.99"N 43°17'60.00" E), as shown in Figure 1. The town extends along the Euphrates, and it is the largest in Anbar province. It is bordered on the north and west by the Euphrates River and on the southeast by Lake Habbaniyah. The city prospered after it became the starting point for a trade route across the desert to Jordan and Syria (AL-Heety et al., 2021a).

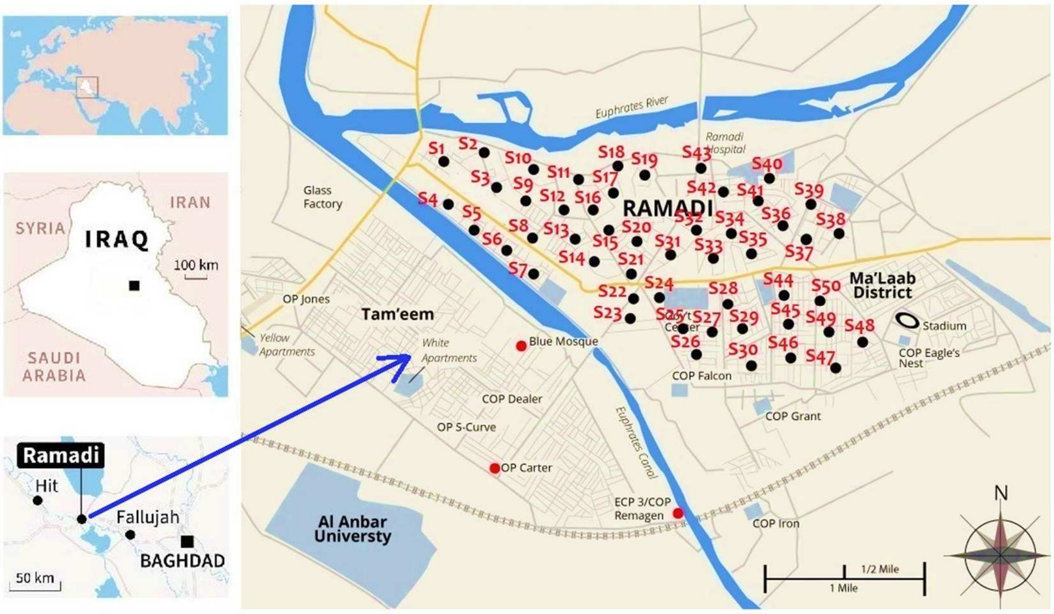


Figure 1. Map represents the study area through Ramadi city, S1- S50.

### *Collection of samples*

Fifty sites were determined and selected in Ramadi city (Figure 1), comprising the main roads and places in the city, where the largest number of the city's population resides and those are directly exposed to aerosols and road dust. The study sampling included 150 samples collected from the determined study sites. Three samples of road dust were collected from each area: the first sample was taken from the front of the buildings along the roads, the second sample was taken from the side of the road, and the third sample was taken from the middle of the road.

### *Sample processing and measurement*

To eliminate coarse debris, each sample was sieved separately using a 200-mesh sieve (Laboratory test sieve, Endecott's LTD, London, England) before being collected into a new bag. The samples were digested using procedure 3050B of the Environmental Protection Agency. Briefly, the samples were digested with a weight of 0.1 g per sample, 15 mL of concentrated nitric acid ($HNO_3$, 70%) was added to a 100 mL glass beaker, then placed on a hotplate for 30 minutes at 300 °C inside a fume hood for digestion. The digestate ceased emitting brown fumes, indicating complete digestion. Samples were left to cool at room temperature and then diluted to 100 mL with deionized water and filtered using filter paper at room temperature. Atomic absorption spectrometry was used to determine the amounts of heavy metals in the dust.

### *Ecological risk assessment*

The ecological risk index (RI), developed by Hakanson (1980), was used to determine the possible ecological hazard levels of certain metals (Cd, Cr, Cu, Ni, and Pb) in road dust particles. The following formula was used to determine RI:

$$RI = \sum_{i=1}^{n}(E_i) \quad \text{(Equation 1)}$$

$$E_i = T_i\, f_i \quad \text{(Equation 2)}$$

$$f = \frac{C_i}{B_i} \quad \text{(Equation 3)}$$

where: (i) represents the metal, ($E_i$) represents the ecological risk factor, and ($T_i$) represents the metal toxic factor. ($f_i$) represents the metal pollution factor, ($C_i$) represents the concentration of metals in dust samples, and (Bi) represents the metal reference value (Lu et al., 2014).

***Health risk assessment***

The risk presented by the five metals was evaluated using the Hazard Quotient (HQ) formula. The ADD for each of the three exposure routes was multiplied by the reference dose (RfD) (mg/kg/day) for certain metals to calculate the HQ. The RfD threshold establishes the likelihood that a given pollutant will have health impacts throughout a lifetime. If the HQ value is less or equal to 1.0, there is no chance that the specific pollutant will have any negative health effects. If the HQ is more than 1.0, the exposure pathway will almost certainly negatively influence human health (Chen et al., 2021). The HI is the total of HQs (Eq. 5) used to evaluate the overall danger posed by a single metal. If HI is equal to 1.0, it is believed that there is no discernible danger from impacts, similar to how HQ is interpreted. If HI > 1, the potential for non-carcinogenic consequences exists, with the likelihood likely to rise as HI does ( USEPA, 2001; Du et al., 2013; Kabir et al., 2022).

$$HQ = \frac{ADD}{RfD} \quad \text{(Equation 4)}$$

$$HI = \sum_{i=1}^{3}(HQ_i) \quad \text{(Equation 5)}$$

***Statistical analysis***

All calculations were performed using Microsoft Excel Professional Plus 2016, which was also used to describe the data (mean, standard errors) and plot the graphs.

## Results and Discussion

***Heavy metal levels in outdoor aerosols***

Results of this study indicated that Cr, Cu, Ni, and Pb had the largest levels of heavy metals in the road dust, whereas Cd had the lowest amounts, according to each sample's calculation values. The general order in which the mean amounts of all tested heavy metals in the dust sample was Cu > Cr > Ni > Pb > Cd. Other research revealed that Cu, Cr, or Ni concentrations are usually much higher in road dust and that their variations across sample sites are also significantly greater (Tang et al., 2013; Padoan et al., 2017). The mean concentration values for each heavy metal are shown in Table 1.

Table 1. Mean values of heavy metal concentrations.

| | **Concentration (mg/Kg)** | | | | |
|---|---|---|---|---|---|
| | **Cd** | **Cr** | **Cu** | **Ni** | **Pb** |
| **Mean** | 2.206 | 34.742 | 49.520 | 29.275 | 21.032 |
| **Std. Error** | 0.048 | 1.043 | 0.959 | 0.966 | 0.862 |

The Cu mean value of 49.520 mg/L in the current study's data was found to be the highest and much higher than that in earlier reference studies conducted in Iraq (Kadhum, 2020; Khwedim et al., 2022)). The Cr, Ni, and Pb levels were greater than those found in the cited research. This reveals that street cleaning and rainfall management do not affect heavy metal dispersion.

***Ecological risk assessment***

Figure 2 shows the potential ecological risk (ER) calculations of heavy metals collected from road dust. The results indicated that the RI value of all samples was (295.658), and the samples are of moderate ecological risk (150 < RI < 300). The most prevalent contaminant was determined to be cadmium (Cd), with an ER value of 220.579, followed by nickel (Ni) and copper (Cu), with ER values of 36.594 and 34.873, respectively. Therefore, all three heavy metals, Cd, Ni, and Cu, are believed to be harmful. It may be noted that the road dust in Ramadi City contains these three metals somewhat regularly, and they urgently need to be addressed to safeguard both the environment and public health from these dangerous metals. Cr and Pb in Ramadi dust samples were considered relatively safe by the ecological risk assessment approach, which conceded that they were not very harmful to the environment or people's health. Cd was higher on the ER scale than Ni, Cu, Pb, and Cr. Pb (1.933) and Cr (1.678), two elements with the lowest ranks in a single sample, showed minimal contamination at the sampling location.

***Health risk assessment***

When exposed to road dust laden with hazardous metals, vulnerable populations with compromised immune systems risk developing major health issues (USEPA, 1996). The health risks of children and adults exposed to heavy metals were determined by inhaling outdoor dust samples in Ramadi. Dust laden with toxic metals polluting highways seriously threatens children and immunocompromised adults (Faisal et al., 2022).

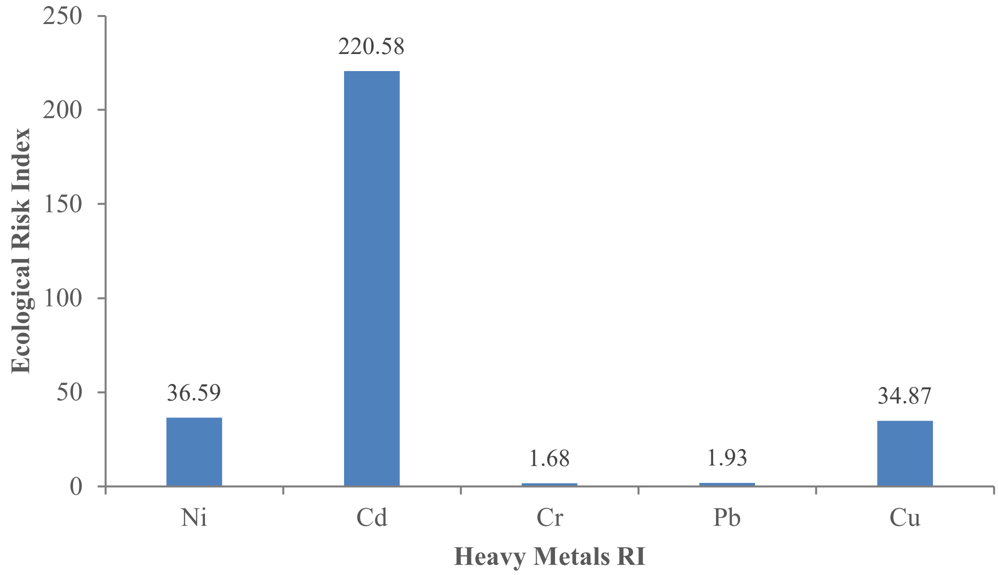


Figure 2. Ecological risk index of heavy metals.

The Environmental Protection Agency of the United States indicates that non-carcinogenic risk should be disregarded if the Hazard quotient values are less than $1x10^{-6}$. But corrective action should be performed if the numbers are large enough and exceed $1x10^{-4}$ (Kurt-Karakus, 2021). Five heavy metals with different exposure pathways were studied by calculating their HQ values. The levels of non-carcinogenic risks for each heavy metal were significantly higher for children when compared to those for adults. Results of this study showed that people exposed to the five studied metals had a non-carcinogenic risk index of < 0.1. Lead is harmful to human health as it accumulates over time in the body, and its danger lies in the fact that it interferes with tissues, organs, and neurodevelopment (Ackah, 2019). Furthermore, high blood concentrations of lead can affect the kidneys and neural synapses of humans and could affect the brain tissues and create bone deformities, especially in young people (Yang et al., 2019).

Table 2. Hazard Quotient (HQ) and Hazard Index (HI) values for heavy metals in road dust samples.

| **Element** | **Cu** | **Pb** | **Cr** | **Cd** | **Ni** |
|---|---|---|---|---|---|
| **Adult** | | | | | |
| HQing | 8.722E-04 | 4.233E-03 | 8.159E-03 | 1.554E-03 | 1.031E-03 |
| HQinh | 1.276E-07 | 6.190E-07 | 1.259E-04 | 2.285E-07 | 1.472E-07 |
| HQdermal | 1.160E-05 | 1.126E-04 | 1.628E-03 | 6.200E-04 | 1.524E-05 |
| HI | 8.839E-04 | 4.347E-03 | 9.912E-03 | 2.174E-03 | 1.047E-03 |
| **Children** | | | | | |
| HQing | 8.140E-03 | 3.951E-02 | 7.615E-02 | 1.450E-02 | 9.625E-03 |
| HQinh | 2.978E-07 | 1.444E-06 | 2.937E-04 | 5.332E-07 | 3.435E-07 |
| HQdermal | 7.598E-05 | 7.376E-04 | 1.066E-02 | 4.061E-03 | 9.981E-05 |
| HI | 8.217E-03 | 4.025E-02 | 8.710E-02 | 1.857E-02 | 9.725E-03 |

A hazard quotient (HQ) value was calculated by dividing each metal dose and exposure route by the appropriate reference dose (mg/kg/day) (Table 2). In numerous areas in Ramadi, Iraq, dust exposure of adults and children to heavy metals was measured. The results indicated that Cu, Cr, Pb, and Ni ingestion risks are substantially greater than inhalation and dermal adsorption. Still, Cd dermal adsorption risks are higher than ingestion and inhalation in adults. The results are consistent with other findings (Ma and Singhirunnusorn, 2012; Rahman et al., 2019; Zingaretti and Baciocchi, 2021). Ma and Singhirunnusorn (2012) found that ingesting dust particles for all examined metals was much more significant than inhalation and cutaneous contact. The greatest dangers can be posed through inhalation and ingestion of dust particles carried those metals under study by both children and adults. Regarding ingestion risk for an adult, Cu had the highest HQing value (8.722E-04), while Ni had the lowest (1.031E-03). Ni had the greatest HQing value for children by ingestion (9.625E-03), while Cd had the lowest (1.450E-02). The risk (hazard quotients, HQs) values of the three exposure routes (i) ingestion, (ii) inhalation, and (iii) dermal adsorption were used to determine the hazard index (HI) for each studied metal (Dong et al., 2020; Mihankhah et al., 2020; Al-Heety et al., 2021b).

## Conclusion

Significant metal pollution seriously threatens the public's health, particularly in densely populated urban regions with numerous industrial facilities, a lot of traffic, and various human-caused activities. Copper (Cu) and chromium (Cr) showed the highest levels of heavy metal concentration, whereas nickel (Ni), lead (Pb), and cadmium (Cd) were determined to have the lowest levels. Ecological risk assessment (RI) results showed that Cd and Ni were the most prevalent pollutants. The United States Environmental Protection Agency (USEPA) created a technique for evaluating the health risks of three-road input for adults and children. Cu, Cr, Pb, and Ni are at very high risk (HQs) of ingesting dust particles are significantly higher for dermal adsorption of dust than for ingestion and inhalation, and Cd is higher for dermal adsorption of dust than for ingestion and inhalation in adults. Metal in the dust necessitates immediate and thorough pollution prevention and control measures throughout the metropolis.

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