



## Detection of air pollution with copper and chromium in some crowded areas in Baghdad

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### ABSTRACT

Air pollution by heavy metals poses significant environmental and public health concerns in rapidly urbanizing cities due to their persistence, toxicity, and bioaccumulation potential. This study examined the seasonal variation of airborne copper (Cu) and chromium (Cr) in two high-traffic areas of Baghdad (Al-Bayaa and Al-Shurta Tunnel) and a lower-traffic control site. Particulate matter was collected seasonally using a low-volume air sampler equipped with glass microfiber filters, digested with nitric and hydrofluoric acids, and analyzed via flame atomic absorption spectrometry (FAAS). Statistical analyses assessed spatial and seasonal differences.

Results revealed pronounced seasonal variability, with significantly higher Cu and Cr concentrations during spring and summer ( $p < 0.05$ ), particularly at traffic-dominated sites. Maximum Cu concentrations reached  $35 \mu\text{g}/\text{m}^3$  in Al-Bayaa and  $31 \mu\text{g}/\text{m}^3$  in Al-Shurta Tunnel, while Cr peaked at  $3.0$  and  $2.8 \mu\text{g}/\text{m}^3$ , respectively. In several instances, measured levels exceeded World Health Organization (WHO) guideline values, indicating potential health risks. Elevated concentrations were primarily attributed to intense traffic activity, vehicle wear processes such as brake and tire abrasion, and meteorological factors including higher temperatures and lower wind speeds.

A preliminary non-carcinogenic human health risk assessment, based on hazard quotients and hazard indices, suggested potential exposure concerns. Despite limitations related to spatial coverage and lack of metal speciation, the study provides valuable baseline data. The findings underscore the need for continuous air quality monitoring, effective emission control strategies, and urban planning policies to mitigate heavy metal pollution in densely populated areas of Baghdad and similar urban environments.

## 1. Introduction

Heavy metal air pollution represents one of the most critical environmental challenges facing urban areas worldwide [1]. Rapid industrialization, population growth, and increased vehicular traffic have significantly contributed to the release of toxic metals into the atmosphere [2]. Unlike many organic

pollutants, heavy metals are non-biodegradable and can persist in the environment for long periods, posing serious risks to human health and ecosystems [3,4,5].

Copper (Cu) and chromium (Cr) are among the most commonly detected heavy metals in urban air. Copper is mainly emitted from vehicle brake wear, tire abrasion, fuel combustion, and

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certain industrial activities [6,7], while chromium originates from fuel combustion, metallurgical processes, and vehicle component wear [4,5,8]. Chronic exposure to airborne Cu and Cr has been associated with respiratory diseases, oxidative stress, and increased cancer risk [9], particularly in densely populated areas.

Baghdad, the capital of Iraq, has experienced rapid urban expansion accompanied by a sharp increase in vehicle numbers and traffic congestion [10]. Despite this, studies focusing on seasonal variations of airborne heavy metals in Baghdad remain limited [10]. Therefore, this study aims to assess the concentrations of Cu and Cr in high-traffic urban locations across different seasons and to compare the measured levels with international air quality guidelines [1].

## 2. Materials and Methods

### 2.1 Study Areas

Air samples were collected from two high-traffic locations in Baghdad: Al-Bayaa district and Al-Shurta Tunnel. A third site with relatively low traffic density was selected as a control area. Site selection considered traffic intensity, population density, and prevailing wind direction [10].

### 2.2 Air Sampling

Airborne particulate matter was collected using a low-volume air sampler (Sniffer, Rade Co., USA) operating at a constant flow rate [2,3]. Glass microfiber filters (Whatman, Grade D) with a diameter of 4.7 cm were used for sampling. Prior to sampling, filters were dried at 80°C for 15 minutes and weighed to obtain initial mass.

Sampling was conducted seasonally (autumn, winter, spring, and summer). Each sampling event lasted 60 minutes, and eight samples were collected from each site per season. After sampling, filters were sealed, transported to the laboratory, and reweighed to determine particulate mass [2,3].

### 2.3 Sample Digestion and Analysis

Collected filters were cut into small pieces and placed in polyethylene beakers. A mixture of concentrated nitric acid (HNO<sub>3</sub>) and a few drops of hydrofluoric acid (HF) was added for digestion. Samples were heated in a water bath at 60°C for 24 hours. The digested solutions were filtered and diluted to 50 mL using deionized water [2,3].

Copper and chromium concentrations were determined using flame atomic absorption spectrometry (FAAS) following standard analytical protocols. Calibration was performed using certified standard solutions. Blank samples were analyzed to ensure quality control.

### 2.4 Calculation of Metal Concentrations

Metal concentrations in air were calculated using the following equation [2]:

$$\text{Concentration } (\mu\text{g}/\text{m}^3) = (C \times V_i) / V_t$$

Where C is the metal concentration in solution (ppm), V<sub>i</sub> is the final volume of the digested sample (50 mL), and V<sub>t</sub> is the total volume of sampled air (m<sup>3</sup>).

### 2.5 Statistical Analysis

Descriptive statistics (mean ± standard deviation) were calculated for all measured metal concentrations. One-way analysis of variance (ANOVA) was used to evaluate seasonal differences in Cu and Cr concentrations at each sampling site. Independent sample t-tests were applied to assess spatial differences between traffic and control sites. Statistical significance was set at p < 0.05. All analyses were performed using standard statistical procedures commonly applied in environmental studies.

### 2.6 Quality Assurance and Quality Control (QA/QC)

Quality assurance and quality control procedures were implemented throughout sampling and analysis. Field blanks and laboratory blanks were analyzed to assess

potential contamination. Instrument calibration was performed using certified standard solutions prior to analysis. The limits of detection (LOD) and limits of quantification (LOQ) for Cu and Cr were determined based on three and ten times the standard deviation of blank measurements, respectively. Average recovery values ranged between 90–105%, indicating acceptable analytical accuracy. Analytical uncertainty was maintained within  $\pm 10\%$ .

### 3. Human Health Risk Assessment

A preliminary non-carcinogenic health risk assessment was conducted to evaluate potential inhalation exposure to Cu and Cr. The hazard quotient (HQ) for each metal was calculated as the ratio of the estimated exposure concentration to the corresponding reference concentration recommended by the United States Environmental Protection Agency (USEPA). The hazard index (HI) was obtained by summing HQ values for both metals at each site. HQ or HI values greater than unity indicate potential health concern. This assessment provides an initial estimation of health risk and is intended to support, rather than replace, comprehensive epidemiological evaluations.

## 4. Results and Discussion

### 4.1 Spatial and Seasonal Distribution of Copper (Cu)

Copper concentrations showed pronounced seasonal variation across all sites. In Al-Bayaa, Cu levels increased from  $0.0074 \mu\text{g}/\text{m}^3$  in autumn to  $35 \mu\text{g}/\text{m}^3$  in summer. A similar pattern was observed in Al-Shurta Tunnel, with summer concentrations reaching  $31 \mu\text{g}/\text{m}^3$ . These elevated levels during warmer months can be attributed to increased traffic density, higher vehicle brake wear, and reduced atmospheric dispersion [6,7,11]. Figure 1.

The control site exhibited moderate Cu concentrations throughout the year ( $10\text{--}14.5 \mu\text{g}/\text{m}^3$ ), indicating the influence of regional pollution sources and long-range transport of airborne particles [20,22].

The descriptive statistics of airborne Cu concentrations revealed clear spatial and seasonal variability across the investigated sites. Mean Cu concentrations at the two traffic-dominated locations (Al-Bayaa and Al-Shurta Tunnel) were consistently higher than those measured at the control site, indicating the strong influence of vehicular emissions. One-way ANOVA demonstrated that seasonal differences in Cu concentrations were statistically significant at all sites ( $p < 0.05$ ). The highest mean concentrations were recorded during spring and summer, whereas the lowest values occurred in winter.

The elevated Cu levels during warmer seasons can be attributed to increased traffic activity, intensified brake and tire wear, and enhanced resuspension of road dust under dry conditions. Additionally, reduced atmospheric dispersion during periods of lower wind speed likely contributed to the accumulation of Cu-rich particulates. Independent t-test analysis confirmed that Cu concentrations at traffic sites were significantly higher than those at the control site ( $p < 0.05$ ), underscoring the dominant role of traffic-related sources.

### 4.2 Spatial and Seasonal Distribution of Chromium (Cr)

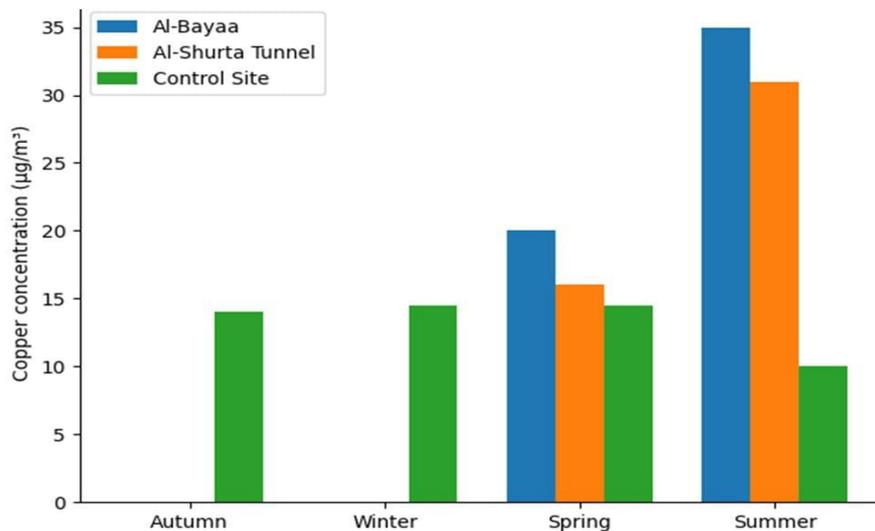
Chromium concentrations were generally lower than Cu but followed a similar seasonal trend. Peak values were recorded in summer at Al-Bayaa ( $3.0 \mu\text{g}/\text{m}^3$ ) and Al-Shurta Tunnel ( $2.8 \mu\text{g}/\text{m}^3$ ). The observed increase during spring and summer may be related to intensified fuel combustion and higher resuspension of road dust under dry conditions figure 2.

Chromium concentrations exhibited patterns similar to those of Cu, although at lower absolute levels. Statistical analysis indicated significant seasonal variation in Cr concentrations (ANOVA,  $p < 0.05$ ), with maximum values observed during spring and summer. Spatial comparison showed that Cr levels at traffic sites were significantly higher than those at the control site (t-test,  $p < 0.05$ ), reflecting the contribution of fuel combustion,

vehicular component wear, and road dust resuspension.

Although the present study quantified total chromium only, the observed concentration levels remain environmentally relevant. Previous studies have shown that traffic-related Cr emissions may include both Cr(III) and the more toxic Cr(VI), suggesting potential health implications even at moderate total Cr concentrations. The absence of chromium speciation is therefore acknowledged as a

limitation, and the results should be interpreted with caution [4,5,8].



**Figure 1.** Seasonal variation of airborne Copper (Cu) concentration

#### **4.3 Comparison with Guidelines and Previous Studies**

Several measured concentrations exceeded WHO guideline values for ambient air, particularly during summer [1]. Comparable studies in other Middle Eastern cities have reported similar seasonal trends [12,13], emphasizing the strong influence of traffic emissions and climatic conditions on airborne heavy metal levels [18,19,21].

#### **4.4 Influence of Meteorological Conditions**

Seasonal trends in Cu and Cr concentrations suggest a strong influence of meteorological conditions. Higher ambient temperatures and reduced precipitation during spring and summer favor particle resuspension and limit wet deposition, leading to elevated metal concentrations in the air. Conversely, lower temperatures, increased rainfall, and stronger winds during winter enhance atmospheric

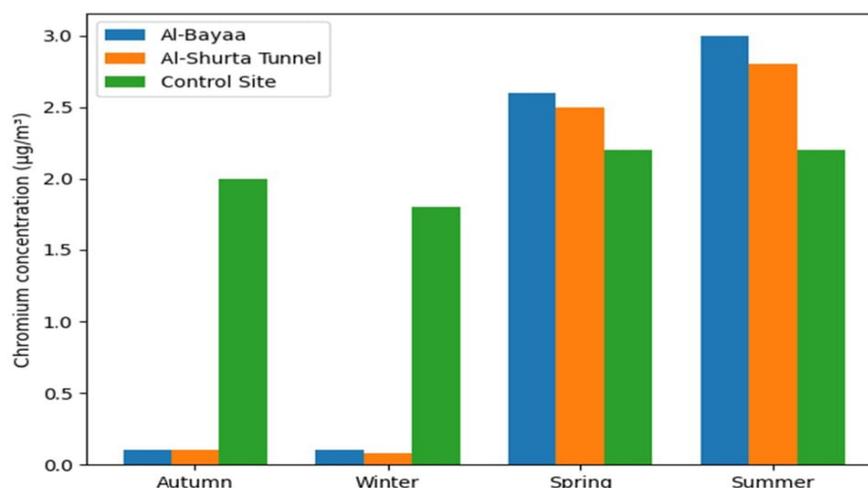
dispersion and removal processes, resulting in lower concentrations. These findings are consistent with previous studies conducted in arid and semi-arid urban environments.

#### **4.5 Comparison with Guidelines and Health Risk Implications**

Measured concentrations of Cu and Cr at traffic sites occasionally exceeded international guideline values for ambient air, particularly during summer. The preliminary health risk assessment indicated that hazard quotient (HQ) values for individual metals were generally below unity; however, cumulative hazard index (HI) values approached or exceeded the threshold at some traffic locations during peak seasons. This suggests a potential non-carcinogenic health concern for populations exposed to prolonged traffic-related air pollution.

It should be emphasized that the health risk assessment presented here is conservative and based on standard exposure assumptions. Nevertheless, the results highlight the importance of continuous air quality

monitoring and the implementation of mitigation strategies to reduce heavy metal emissions in densely populated urban areas.



**Figure 2.** Seasonal variation of airborne Chromium (Cr) concentrations

#### 4.6 Discussion

The statistically significant seasonal differences observed in this study highlight the strong influence of traffic intensity and meteorological conditions on airborne metal concentrations. Higher temperatures and lower wind speeds during spring and summer likely enhance particle resuspension and reduce atmospheric dispersion, leading to elevated Cu and Cr levels. Although this study focused on total chromium, it is acknowledged that the absence of chemical speciation represents a limitation, as Cr(VI) is considerably more toxic than Cr(III). Future investigations should incorporate metal speciation and higher temporal resolution to better quantify health risks.

The limited number of sampling sites may not fully capture the spatial complexity of urban air pollution in Baghdad. Additionally, short-term temporal variability and chromium speciation were not addressed. These limitations are acknowledged and provide direction for future research involving expanded monitoring networks and advanced analytical techniques.

#### 5. Conclusion

This study demonstrated clear seasonal and spatial variations in airborne copper and chromium concentrations across different urban areas of Baghdad. Elevated concentrations were consistently observed during spring and summer, particularly in high-traffic locations such as Al-Bayaa and Al-Shurta Tunnel. These findings indicate that vehicular emissions, brake and tire wear [6], and unfavorable meteorological conditions play a major role in increasing heavy metal concentrations in ambient air [11].

The measured levels of Cu and Cr occasionally exceeded international guideline values, highlighting potential public health concerns in densely populated areas. Continuous monitoring programs, improved traffic management, and stricter emission control policies are strongly recommended to mitigate heavy metal air pollution in Baghdad [14,16,22].

Despite providing valuable insights into airborne heavy metal pollution, this study has

certain limitations. Sampling was conducted at a limited number of sites, which may not fully represent all urban environments in Baghdad [10]. Additionally, the study focused on total metal concentrations without differentiating between chemical species of chromium, which may vary in toxicity [4,26]. Future studies should include a larger number of sampling locations, longer monitoring periods, and metal speciation analysis to better assess health risks [5,27].

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