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Research Article

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Detection of Air Pollution with Lead, Cadmium, and Zinc in Selected Industrial Areas of Baghdad

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Abstract: The objectives of this study are to investigate the concentrations of heavy metals in two selected industrial areas. Airborne heavy metal pollution represents a persistent environmental and public health problem in rapidly urbanizing cities. This research assesses the seasonal distribution of lead (Pb), cadmium (Cd), and zinc (Zn) associated with airborne particulate matter in two selected industrial areas including Al Bayaa on the Karkh side and Al Shurta Tunnel on the Rusafa side of Baghdad and a rural control site. Samples of air were collected during four seasons autumn, winter, spring, and summer and then analyzed using atomic absorption spectrometry AAS. The results revealed pronounced seasonal differences, Lead concentrations varied across the four seasons, with the highest concentration recorded in the summer at the Al Shurta Tunnel, reaching 5.8 μg/m³, while the lowest concentration was recorded in the same area during the winter at 0.0185 μg/m³. Cadmium concentrations were recorded at their lowest value of 0.0294 μg/m³ in winter in the police tunnel and at their highest concentration of 4 μg/m³ in the Al Bayyaa area in spring. As for zinc, its concentrations ranged between 2.257 μg/m³ and 43.8 μg/m³ in the winter and spring, respectively, in the police tunnel area. In general Cd levels remained low but exhibited episodic increases, particularly in Al Bayaa. Although most measured concentrations were below commonly cited health-based guideline values, the consistent detection of heavy metals highlights their persistence in Baghdad industrial atmosphere. These findings provide baseline data for Baghdad and emphasize the necessity for continuous monitoring and strengthened air quality management strategies.

Keywords: Heavy metals; Seasonal variation; Industrial atmosphere; Public health; Air quality.

1. Introduction

Air pollution in urban and industrial environments is a major global concern due to its well-documented impacts on human health and ecosystems [1, 2]. Among atmospheric pollutants, heavy metals are of particular importance because of their toxicity, persistence, and ability to accumulate in biological tissues [3, 4]. Unlike many organic pollutants, heavy metals are non-biodegradable and may remain in the environment for extended periods, posing long-term risks to exposed populations [5]. Lead (Pb) is a potent neurotoxin associated with impaired cognitive development and cardiovascular disorders [1]. Cadmium (Cd) is recognized for its carcinogenic and nephrotoxic properties, while excessive exposure to zinc (Zn), although an essential trace element, can cause respiratory irritation and inflammatory responses when presenting at elevated concentrations [3]. Numerous studies have demonstrated that these metals are commonly associated with airborne particulate matter, facilitating inhalation exposure and long-range atmospheric transport [6, 4].

Seasonal variability in airborne heavy metal concentrations has been reported worldwide and is influenced by emission intensity, industrial activity, traffic density, meteorological conditions, and resuspension of contaminated dust [7, 8]. In arid and semi-arid regions, such as central Iraq, dust storms and high temperatures may further enhance the redistribution of metal-laden particles [9]. Despite rapid urbanization and industrial growth, systematic monitoring of airborne heavy metals in Iraq remains limited [10]. In particular, data from industrial areas of Baghdad are scarce [11]. This study aims to address this gap by quantifying the seasonal concentrations of Pb, Cd, and Zn in selected industrial zones of Baghdad and comparing them with a rural background site. The results provide valuable baseline information to support environmental management and public health decision-making.

2. Materials and Methods

2.1 Study Areas

Two monitoring locations were selected:

1. **Al Bayaa:** A densely industrialized district characterized by manufacturing activities and heavy industrial operations.
2. **Al Shurta Tunnel:** An area strongly influenced by industrial activities and intense vehicular traffic Figure 1.

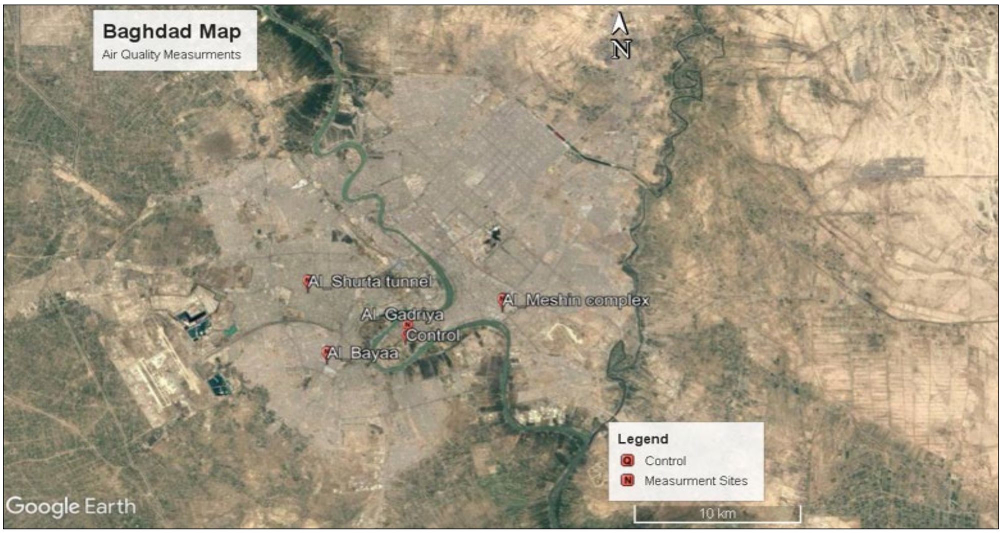

Figure 1. Map of the studied area.

2.2 Sampling and Analysis

Airborne particulate samples were collected seasonally during autumn, winter, spring, and summer at fixed sampling points within each study area by use sniffer device (Sniffer, Rade Co., USA) as shown in Figure 2. The air samples were collected during four seasons from Autumn 2020 to Summer 2021. During this period, four samples each month from selected site were collected. Sampling was conducted at different times of the day to account for diurnal variability. Sample of air was collected on filter served in plastic petri dish and tightly sealed, then all samples transported to the nano laboratory of the minerals research office at the Iraqi Ministry of Science and Technology and central laboratory in college of science- University of Baghdad for analysis. Filters before sampling, were dried at 40 °C for 30 minutes and then weighted to record initial weight (Wi) by using sensitive balance, then collected samples were subjected to acid digestion, and concentrations of Pb, Cd, and Zn were quantified using atomic absorption spectrometry, a widely accepted and reliable method for trace metal analysis in environmental samples. Quality control procedures included instrument calibration with certified standards and repeated measurements to ensure analytical accuracy.

Figure 2. Sniffer low volume sampler.

3. Results

The measured seasonal concentrations of Pb, Cd, and Zn exhibited clear spatial and temporal variations across the study sites as shown in Table 1.

Table 1. The concentration of heavy metals in the air at the various locations and across seasons is as follows (all values are in µg/m³)

Verablies	Al Bayaa				Al Shurta tunnel			
	Autumn 2020	Winter 2021	Spring 2021	Summer 2021	Autumn 2020	Winter 2021	Spring 2021	Summer 2021
Pb µg/m³	0.0237	0.0289	6.5	10	0.0194	**0.0185**	4.2	**5.8**
Cd µg/m³	0.0667	0.0801	**4**	0.45	0.0318	**0.0294**	0.35	0.43
Zn µg/m³	2.915	3.844	37.7	42.8	3.108	**2.257**	**43.8**	33.4

3.1 Lead (Pb)

Pb concentrations showed clear seasonal variability across all sites. The lowest values were recorded during autumn and winter, while pronounced increases were observed in spring and summer, particularly in the industrial areas. Al Bayaa exhibited the highest Pb concentrations during summer, indicating strong influence from industrial and traffic-related emissions under warmer conditions. Figure 3 illustrates a sharp increase in Pb levels during spring and summer in Al Bayaa and Al Shurta Tunnel, while the control site shows comparatively moderate and stable concentrations.

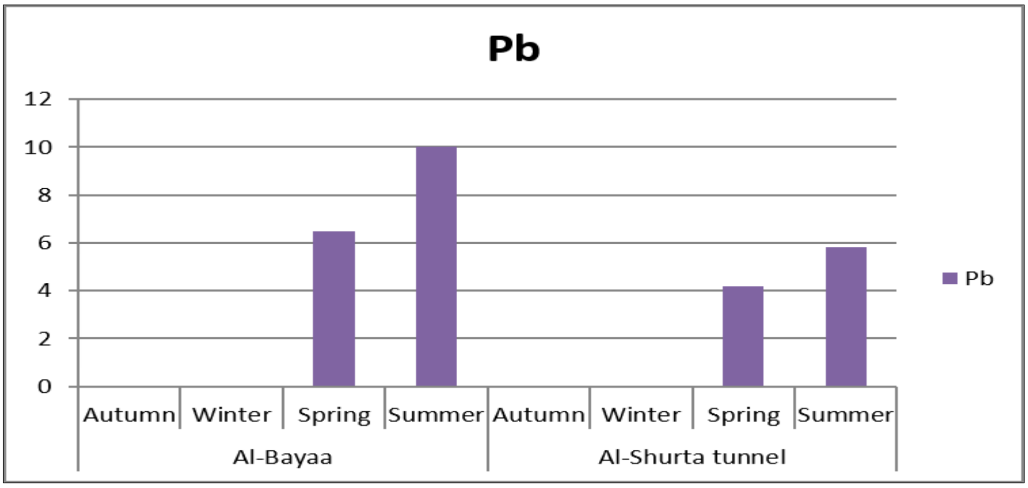

Figure 3. Seasonal variation of lead (Pb) concentrations across the study sites.

3.2 Cadmium (Cd)

Cadmium concentrations remained generally low throughout the study period. However, a notable increase was detected in Al Bayaa during spring, suggesting episodic industrial or combustion-related emissions. Other sites displayed relatively stable and low Cd levels across all seasons. Figure 4 illustrates a distinct springtime peak in Cd at Al Bayaa, whereas Al Shurta Tunnel and the control site maintain low and nearly constant concentrations.

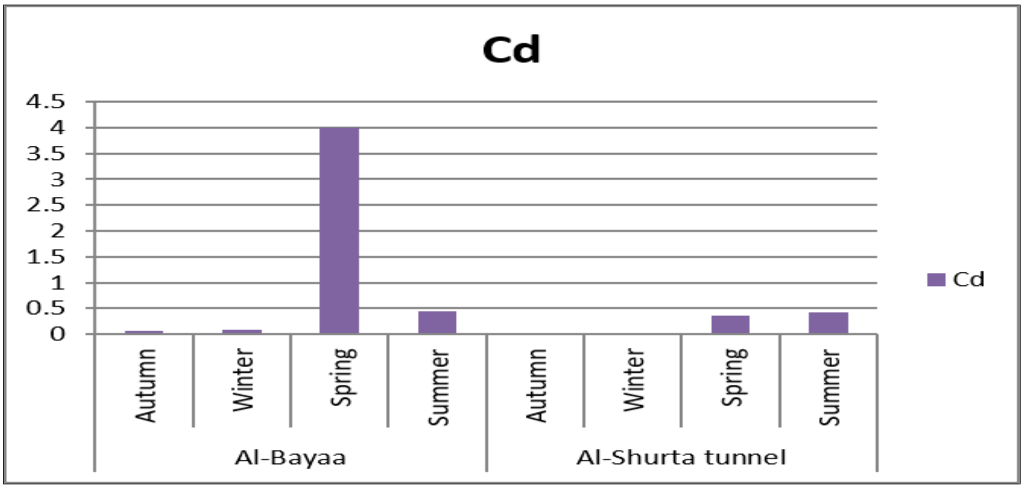

Figure 4. Seasonal variation of cadmium (Cd) concentrations across the study sites.

3.3 Zinc (Zn)

Zinc exhibited the greatest seasonal variability among the investigated metals. Concentrations increased markedly during spring and summer in both industrial locations. In contrast, the control site showed relatively higher Zn levels during autumn and winter, likely reflecting contributions from natural dust and soil resuspension. Figure 5 demonstrates strong seasonal fluctuations in Zn, with pronounced peaks in industrial areas during warmer months and comparatively elevated background levels at the control site during cooler seasons.

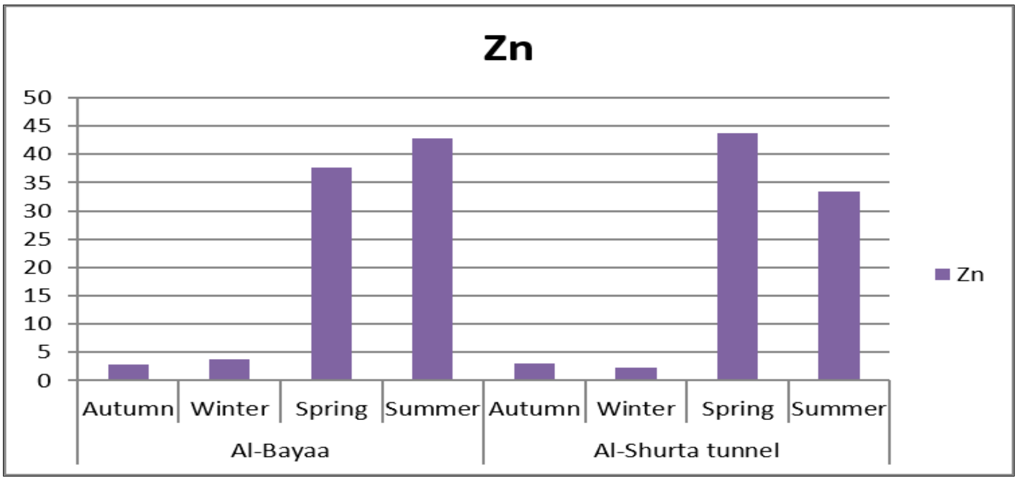

Figure 5. Seasonal variation of zinc (Zn) concentrations across the study sites.

3.4 Comparative Seasonal Trends of Heavy Metals

Figure 6 compares the seasonal behavior of the three metals, showing that Pb and Cd peaks are concentrated in Al Bayaa, while Zn displays high variability in both industrial areas.

The observed seasonal trends are consistent with international studies reporting higher airborne heavy metal concentrations during warmer periods in industrial and arid regions [12]. Elevated Pb and Zn levels in spring and summer may be attributed to increased industrial activity, enhanced traffic emissions, and atmospheric conditions that favor particle accumulation [13].

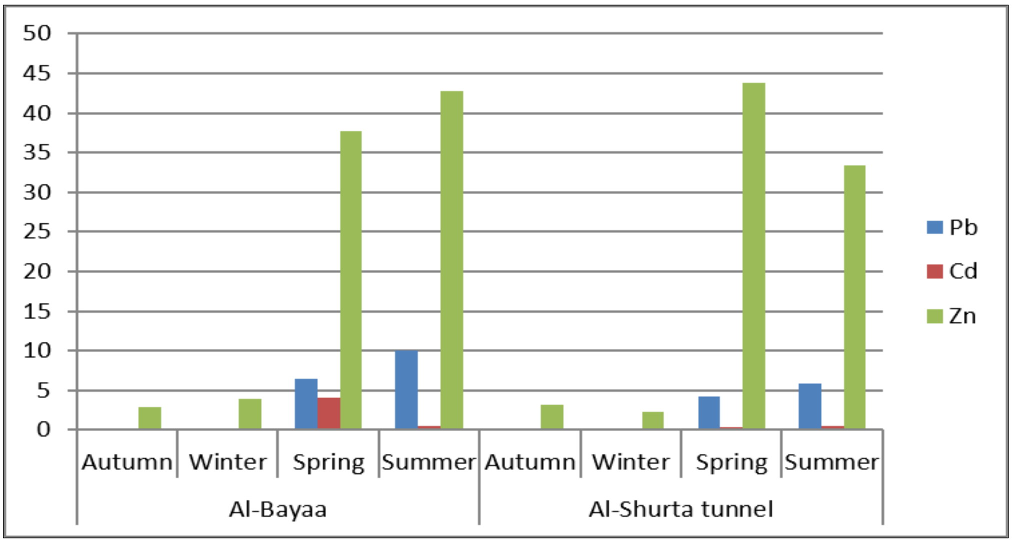

Figure 6. Comparative seasonal trends of Pb, Cd, and Zn across all monitoring sites.

The relatively low Cd concentrations align with findings from other urban environments [14]. However, the springtime peak in Al Bayaa indicates the influence of episodic emission sources [15*]*. Comparison with global data suggests that although absolute concentrations are generally lower than those reported in heavily industrialized cities, the persistence of these metals in Baghdad's atmosphere remains environmentally significant [16]. Limited regulatory standards for ambient heavy metals complicate direct risk assessment. Nevertheless, chronic exposure to low-level metal concentrations may still pose long-term health risks, emphasizing the importance of precautionary monitoring [17].

3.5 Influence of Weather Factors on Heavy Metals Concentrations in the Air

Air temperature plays a significant role in the creation and removal of pollutants in the air, during winter and due to decrese in temperture obsorbed increses in pollutant concentrationand vice versa is true [18]. About wind speed, generally, rise in speed of wind accompanied with a reduction in the levels of pollutants such as heavy metals and when wind speed decreses concentrations of pollutants will increse [19]. The wind speed has an important role in the spread of pollutants where the wind transported contaminants from emitted sources toward the prevailing wind. Therefor, when built factories must become within prevailing wind through the year to spread among large area and then dilute these pollutants [20]. The elevation of moisture causes the negative influnces of damaging air pollutants because it aids to collect and compressthem in the air and this negatively affects population health [21].

4. Discussion

Significant seasonal variation in airborne Pb, Cd, and Zn concentrations was observed, with peak levels occurring during spring and summer in industrial areas. Al Bayaa consistently exhibited the highest metal concentrations, indicating strong industrial influence. Although most concentrations were below commonly cited guideline values, the continuous presence of heavy metals highlights the need for sustained air quality surveillance in Baghdad.

5. Conclusions

Establish continuous monitoring networks for airborne heavy metals in industrial zones of Baghdad. The development of national ambient air quality is essential for guidelines to trace metals based on international standards. The implement emission control strategies are important to targeting industrial activities and vehicular sources. The study results showed a clear increase in the concentrations of the heavy metals under investigation in the studied industrial areas. The presence of residential areas near industrial areas poses a real risk to the public health of the residents of these areas.

Supplementary Materials: Not applicable.

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Conflicts of Interest: The author declares no conflicts of interest.

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