Journal of Advanced Scientific Research

Available online through https://sciensage.info

ISSN
0976-9595
Research Article

Heavy Metal Deposition in Freefall Atmospheric Dust Under Meteorological Observation in Industrial City, Kota, India, Having a Coal-fired Thermal Power Plant

Manju Meena[1], Bhairu Lal Kahtik Naraniya[1], Adhiraj Singh Shekhawat[2], Uttra Chandrawat[1], Bharat Singh Meena[1]*
[1]Department of Chemistry, Government College, Kota, Rajasthan, India.
[2]Department of Computer Science and Engineering, Manipal University Jaipur, Jaipur, Rajasthan, India.
*Corresponding author: meenabharat81@gmail.com

Received: 02-05-2026; Accepted: 22-05-2026; Published: 30-05-2026

https://doi.org/10.55218/JASR.2026170502

ABSTRACT

This study was conducted to examine the concentrations of eight heavy metals (Zn, Cu, Pb, Cd, Cr, Ni, Fe, and Ca) in freefall atmospheric dust under the influence of meteorological conditions. Dust samples were collected during the winter season, from November 2024 to February 2025, in and around Kota, Rajasthan. The mean concentrations (mg/L) of Zn, Cu, Pb, Cd, Cr, Ni, Fe, and Ca were recorded as 4.3248, 0.7770, 1.5683, 0.1130, 1.0517, 0.8899, 77.4911, and 1666.42, respectively. The results indicate that the concentration levels of these metals are significantly affected by prevailing meteorological conditions during the study period, although some variations were observed, likely due to fluctuations in wind speed. Wind rose analysis revealed that sampling locations predominantly facing North-East and East wind blow (67.66%) from the Kota Thermal Power Plant exhibited the highest metal concentrations, as these sites are situated closest to the emission source. Furthermore, Pearson's correlation and principal component analysis (PCA) suggest that Zn, Cu, Pb, Cd, Cr and Ni primarily originate from coal combustion processes at the Kota Thermal Power Plant, along with contributions from other industrial activities in the region.

Keywords: Heavy metals, freefall atmospheric dust, Pearson's correlation, Principal component analysis.

INTRODUCTION

In recent years, growing global concerns regarding air quality have led to increased research on the characterization of atmospheric particulate matter [1–2]. Atmospheric falling dust represents a broad category of particulate matter, consisting of particles that settle onto the ground under the influence of gravity. These particles typically range in size from greater than 10 μm to less than 100 μm in diameter. From an aerodynamic perspective, pollutants associated with falling dust can contribute to localized contamination, as such particles tend to deposit readily near their emission sources. Consequently, dust deposition serves as an important indicator for assessing environmental quality [3–4].

Atmospheric falling dust in urban environments exhibits a complex mineralogical and chemical composition, as it originates from a combination of natural (geogenic) and human-induced (anthropogenic) sources [5–10]. Geogenic contributions to road-deposited particles primarily arise from the erosion of nearby soils and local geological formations, along with the atmospheric transport and subsequent deposition of naturally derived particulates [11–12]. In contrast, anthropogenic inputs to atmospheric dust are largely associated with industrial activities—such as emissions from power plants, coal combustion processes, metallurgical operations, automobile repair facilities, and chemical industries—as well as traffic-related sources. These include vehicular exhaust emissions, tire and brake wear, road surface degradation, construction materials, application of road salts and paints, and debris generated by pedestrian activities [13–14].

Atmospheric dust plays a significant role in the transport and distribution of contaminants, acting as a reservoir for a wide range of pollutants [15–16]. Unlike other environmental media, it possesses a high potential for resuspension [17], which facilitates the re-entry of associated metals into both the atmosphere and surrounding soils. This characteristic results in multiple human exposure pathways, including inhalation, ingestion, and dermal contact, thereby increasing potential health risks [18–20]. The problem is particularly severe in mining regions, where substantial amounts of metal-enriched dust are generated from activities such as ore extraction, smelting operations, tailings storage, and exposed waste rock. These fine particles are readily dispersed by wind and can be easily resuspended under dry conditions, contributing to continuous environmental contamination and enabling long-range atmospheric transport [21–23]. Thus, heavy metals such as cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb) and zinc (Zn), having toxicity at low concentration are significantly contributed by resuspension of this atmospheric dust into the atmosphere, becoming hazardous to all living organisms [24-25].

Chronic exposure to cadmium, even at relatively low concentrations (around 1 mg/L), has been associated with adverse health effects such as prostate abnormalities, pulmonary cell damage, bone fragility, and renal dysfunction. Although iron is an essential micronutrient for human health, its excessive accumulation can promote harmful algal blooms and reduce dissolved oxygen levels in aquatic systems. Extended exposure to nickel has been linked to an elevated risk of carcinogenic effects, while high concentrations of lead may cause multiple health disorders, including anemia and impairment of the central nervous system. In aquatic organisms, excessive zinc levels can negatively affect reproductive performance and developmental processes [26–30].

In the industrial city of Kota, along with numerous Kota stone manufacturers, among other small and large-scale enterprises, production of large amounts of fly ash, which is a homogenous blend of different metallic oxides, from Kota Thermal Power Plant, further escalate concentration of heavy metals [31]

Additionally, meteorological conditions play a very important role in controlling the concentration, transport, and deposition of heavy metals. These metals are mostly attached to particulate matter (PM), so weather directly affects their behavior [32].

The complexities of heavy metal pollution—encompassing its diverse sources, toxic characteristics, persistence, non-biodegradable nature, and tendency for bioaccumulation—pose significant risks to environmental systems [24, 32].

Therefore, accurately evaluating heavy metal contamination status in freefall atmospheric dust and identifying their sources is crucial for developing effective treatment and control strategies [22,33-34].

The main objectives of this study include: (i) To determine the concentration of Zn, Cu, Pb, Cd, Cr, Ni, Fe and Ca metals in freefall atmospheric dust samples collectedat selected 50 sampling sites covering entire Kota city area; (ii) to identify possible sources of heavy metals associated with atmospheric dust using Pearson correlation coefficient and Principal Component Analysis; (iii) to study the effect of climate on the concentration levels of heavy metals as a function of meteorological parameters such as temperature, relative humidity, wind speed and wind direction.

The study will help in indicating the influence of coal-based thermal power plants and the industrialization of the rapidly growing city on the concentration levels of heavy metals in atmospheric dust.

MATERIAL AND METHODS

Study area

Located on the Chambal River bank at eastern side, at 25°11 N and 75°51 E, Kota is a major industrial city of south Rajasthan and is the nation's power production center owing to the Kota Thermal Power Plant. Its semi-arid climate lies between 6.6 and 36.11°C (in winter). This area produces a significant volume of slurry, mostly composed of oxides of Ca, Mg and Si, as a result of the excavation, cutting, and polishing of a well-known Kota stone from more than 200 stone units[23].

Freefall atmospheric dust collection and analysis

Through the Global Positioning System, 50 sampling sites were chosen as per some certified standards[35]. Figure 1 shows the location of all the sampling sites of Kota City chosen for the present study. All freefall atmospheric dust samples (n = 50 samples x 04 months = 200 samples) were collected in the months of the winter season, which are November, December, January and February during 2024-2025. In plastic trays of 1m^2 area situated at a height of 6 meters above the roof surface, the samples were collected at the end of the month. It should be noted that these samples represent only dry freefall atmospheric dust collected during 30 days dry period (excluding any rain event). Following sampling, freefall atmospheric dust was scraped off the trays according to the washing method used earlier[36]. The dried samples were subjected to a digestion process for metal analysis after passing through the sieves with 300BSS (< 53 μm). Each dust sample was collected and immediately placed into a brand-new, labeled airtight polyethylene package for secure storage and transit[37].

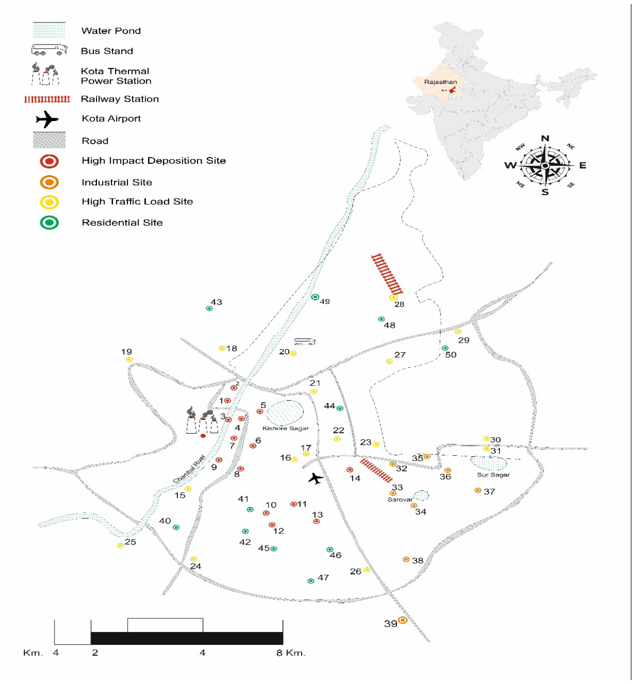

Fig. 1: Location of sampling sites of Kota city at the study area.

Total heavy metal digestion

After the samples were run through 300 BSS (< 53 μm) sieves, they were digested for further process. Since the concentration of the metals in these samples determines their mode of occurrence, a digestion procedure was used to extract only the nitric acid-soluble fraction[38]. Total metal extraction was carried out through Nitric acid (HNO3) digestion [39]. After digestion, the concentrations of chosen metals (Zn, Cu, Pb, Cd, Cr, Ni and Fe) were measured using the Direct Air – Acetylene Flame method (AAS-Shimadzu-6300), with the Ca metal being measured using the Flame Photometer (Systronics -128) method. With the use of quality control blanks, certified reference material, and internal standards, the precision and accuracy of the analysis were kept under observation.

Table 1: Meteorological conditions of Kota City during the winter season.

Meteorological conditions	*Measurements*
Temperature (°C)	19.23 ± 07.00
Relative humidity (RH) (%)	64.15 ± 11.60
Wind speed (km/h)	0.88 ± 0.52
Rainfall (mm)	1.30

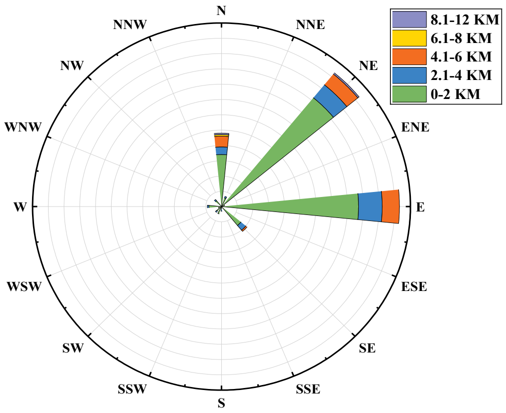

Fig. 2: Wind rose in Kota city during the sampling period

Monitoring of meteorological parameters

During the measurement period (November, 2024 to February, 2025), the Automated Weather Station (model number: DCPAWS02) installed at the Kota Aerodrome, India, provided the meteorological data as given in Table 1 and Figure 2. The data were recorded hourly and averaged across the 24-hour operation time of the samplers.

Statistical analysis

Statistics were performed from the data using SPSS 22.0 and MS-Excel 2021.

RESULTS AND DISCUSSION

Metal analysis

Table 2 presents the descriptive statistics of Zn, Cu, Pb, Cd, Cr, Ni, Fe and Ca concentrations, which followed the order Ca>Fe>Zn>Pb>Cr>Ni>Cu>Cd and were found to be 1666.42 (1134.28–2492.11) mg/L, 77.4911 (63.6581–91.7363) mg/L, 4.3248(1.1639–6.7216) mg/L, 1.5683 (0.112–4.7737) mg/L, 1.0517 (0.0793–2.0793) mg/L, and 0.8899 (.1321–1.9809) mg/L,0.7770 (0.0417–1.9638) mg/L, 0.1130 (0.0152–0.4661) mg/L, respectively. Average concentrations of Zn, Pb, Cd, Cr and Ni are found to exceed WHO standard limits, which might be due to coal combustion activity at the point source Kota Thermal Power Plant, besides other anthropogenic activities. We observe variations in the elemental concentration as a function of sampling sites and wind velocity (speed and direction). The skewness values for Cu, Pb, Cd, Cr, and Ni were predominantly positive, indicating that the mean concentrations were greater than the median values. This suggests the occurrence of episodic high pollution events and highlights the temporal nature of the highest concentrations across different sampling locations.

As the present research aims at determining the pollution load of copper, lead, cadmium, zinc, calcium, and iron under meteorological observation, it is worth mentioning here that the higher concentration of Zn, Cu, Pb, Cd, Cr and Niare found at the sites which are at closest distance to the point source Kota Thermal Power Plant and lower concentration of Zn, Cu, Pb, Cd, Cr and Ni metals are found at the sites which are farthest from Kota Thermal Power Plant.

Table 1 displays themeteorological conditions of Kota City during the sample collection with average values of temperature (19.23°C), relative humidity (64.15%) and wind speed (0.88 m/h) (Table 1) at the studied sampling sites. Ca and Fe, mostly found in the local soil, are mobilized or resuspended before being assimilated in the study area. Higher concentrations of Ca metal are due to its abundance in the earth's crust and soil, while Fe is found as oxide, such as limonite, siderite, etc. [40-41] In addition to emissions from Kota Thermal Power Plant, lubricants, rubber tire remnants, and corrosion of vehicle components could be the source of Zinc particles found in the ambient air. [42 - 44]. As lead has a longer half-life in the atmosphere than other elements, besides being present in fly ash emissions from Kota Thermal Power Plant, its persistent presence in atmospheric dust is more likely the result of past vehicle emissions (prior to the ban of Pb-containing fuel) [38].

Pearson's Correlation Analysis

Table 3 displays the correlation coefficient of heavy metals in atmospheric dust which indicated positive correlation between Cu-Zn (0.565), Pb-Zn (0.610), Cd-Zn (0.640), Cr-Zn (0.686), Ni-Zn (0.637), Pb-Cu (0.605), Cd-Cu (0.619), Cr-Cu (0.699), Ni-Cu (0.697), Cd-Pb (0.631) Cr-Pb (0.703), Ni-Pb (0.795), Cr-Cd (0.791), Ni-Cd (0.764), Ni-Cr (0.877) suggesting their common origin i.e. point source Kota Thermal Power Plant mainly beside other common industrial activities. Similarly, a positive correlation observed between Ca-Fe (0.762) indicates that these metals have a common source, possibly natural soil.

Principal component analysis

Principal component analysis (PCA) accounts for statistical variance by deriving the least number of major factors. It is useful in

Table 2: The descriptive statistics of Zn, Cu, Pb, Cd, Cr, Ni, Fe, and Ca (mg/L) in atmospheric dust samples during the winter season.

Element	*Min*	*Max*	*Mean*	*SD*	*Skewness*	*Kurtosis*
Zn	1.1639	6.7216	4.3248	1.0960	-0.220	-0.219
Cu	0.0417	1.9639	0.7770	0.3778	0.382	0.203
Pb	0.0112	4.7737	1.5683	1.1254	0.454	-0.587
Cd	0.0152	0.4661	0.1130	0.0579	1.107	5.480
Cr	0.0793	2.0793	1.0517	0.5124	0.045	-1.112
Ni	0.1321	1.9809	0.8899	0.4568	0.174	-0.822
Fe	63.6381	91.7363	77.4911	6.6845	0.078	-0.835
Ca	1143.28	2492.11	1666.42	325.91	0.616	-0.347

Table 3: Correlation coefficients between the concentration values of metals analyzed during the winter season (* significant at 5% level)

Metal	*Zn*	*Cu*	*Pb*	*Cd*	*Cr*	*Ni*	*Fe*	*Ca*
Zn	1.000							
Cu	0.565	1.000						
Pb	0.610	0.605	1.000					
Cd	0.640	0.619	0.631	1.000				
Cr	0.686	0.699	0.703	0.791	1.000			
Ni	0.637	0.697	0.795	0.764	0.877	1.000		
Fe	-0.438	-0.479	-0.511	-0.433	-0.555	-0.564	1.000	
Ca	-0.442	-0.421	-0.576	-0.392	-0.511	-0.565	0.762	1.000

Table 4: PCA displaying loading of 8 variables with two varimax factors (VF) in freefall atmospheric dust samples during winter season

Variable	*Component*	
	VF 1	*VF 2*
Cd	0.871	-0.155
Cr	0.870	-0.320
Ni	0.845	-0.382
Cu	0.765	-0.259
Zn	0.763	-0.240
Pb	0.728	-0.424
Fe	-0.267	0.904
Ca	-0.299	0.876
% of variance	51.09 %	27.03 %
Cumulative (%)	51.09 %	78.13 %

reducing the dimensionality of the large data sets and in clarifying the relationship between the variables [45-46]. To further identify pollution sources of freefall atmospheric dust in the present study, PCA was carried out with varimax rotation. The results of principal component analysis (PCA) showed that only two eigenvalues were >1, which explains over 78.13% of the variance. The results in the rotated component matrix (Table 4) showed that all eight metal species are explained by two factors (varimax factors 1 and 2). The first factor (VF 1), which explained over 51.09 % of variance, showed high loading of the heavy metals such as Zn, Cu, Pb, Cd, Cr and Ni, indicating the influence of anthropogenic activities, mainly coal combustion at Kota Thermal Power Plant. VF 2, which accounted for 27.03% of the layout variance, showed high loading of Ca and Fe, indicating the influence of crustal aerosols [46].

CONCLUSION

In this study, we illustrated heavy metal contamination in road dust samples collected from 50 sampling sites in Kota City, Rajasthan, during the winter months, viz. November 2024 to February 2025 and threw a light on their possible source. The pollution load of copper, lead, cadmium and zinc was assessed under varying meteorological conditions. The results indicate that concentrations of Zn, Cu, Pb, Cd, Cr, and Ni were highest at sampling sites located nearest to the point source, the Kota Thermal Power Plant, whereas lower concentrations of these metals were observed at sites situated farther away from the plant.

The positive correlations and Principal Component Analysis (PCA) indicate that heavy metals such as Zn, Cu, Pb, Cd, Cr, and Ni originate from common sources within the city. These sources are mainly associated with the activities at the coal-based Kota Thermal Power Plant, along with other industrial activities and vehicular emissions. Therefore, it is essential to evaluate air quality in Kota City with respect to heavy metal contamination to minimize potential health risks. Additionally, these pollution sources must be carefully considered by authorities during urban planning and management.

ACKNOWLEDGMENTS

The authors are thankful to UGC for providing financial support for research work and DST FIST Laboratory Department of Chemistry, Government College, Kota for providing necessary facilities during the Research work.

REFERENCES

1. Boevski I, Daskalova N, Havezov I. Determination of barium, chromium, cadmium, manganese, lead and zinc in atmospheric particulate matter by inductively coupled plasma atomic emission spectrometry (ICP-AES). Spectrochimica Acta Part B: Atomic Spectroscopy. 2000 Nov 1;55(11):1643-1657. doi:10.1016/S0584-8547(00)00265-2
2. Donahue NM, Robinson AL, Pandis SN. Atmospheric organic particulate matter: From smoke to secondary organic aerosol. Atmospheric Environment. 2009 Jan 1;43(1):94-106. doi:10.1016/j.atmosenv.2008.09.055
3. Del Vento S, Dachs J. Atmospheric occurrence and deposition of polycyclic aromatic hydrocarbons in the northeast tropical and subtropical Atlantic Ocean. Environmental science & technology. 2007 Aug 15;41(16):5608-5613.
4. Wang ZH. The research on the aerolion dust deposition monitoring. J Arid Land Resour Environ. 2003;17(1):54-59.
5. Abed AM, Al Kuisi M, Khair HA. Characterization of the Khamaseen (spring) dust in Jordan. Atmospheric Environment. 2009 Jun 1;43(18):2868-2876.
6. Chen TH, Xu HF. TEM investigation of atmospheric particle settlings and its significance in environmental mineralogy. Acta Petrologica et Mineralogica. 2003;22(4):425-428.
7. Fergusson JE, Kim ND. Trace elements in street and house dusts: sources and speciation. Science of the total Environment. 1991 Mar 1;100:125-150.
8. Amato F, Pandolfi M, Escrig A, Querol X, Alastuey A, Pey J, Pérez N, Hopke PK. Quantifying road dust resuspension in urban environment

by multilinear engine: a comparison with PMF2. Atmospheric Environment. 2009 Jun 1;43(17):2770-2780.

9. Kreider ML, Panko JM, McAtee BL, Sweet LI, Finley BL. Physical and chemical characterization of tire-related particles: Comparison of particles generated using different methodologies. Science of the Total Environment. 2010 Jan 1;408(3):652-659.
10. Amato F, Pandolfi M, Moreno T, Furger M, Pey J, Alastuey A, Bukowiecki N, Prevot AS, Baltensperger U, Querol X. Sources and variability of inhalable road dust particles in three European cities. Atmospheric Environment. 2011 Dec 1;45(37):6777-6787.
11. Beckwith PR, Ellis JB, Revitt DM, Oldfield F. Heavy metal and magnetic relationships for urban source sediments. Physics of the Earth and Planetary Interiors. 1986;42(1):67-75.
12. Haynes HM, Taylor L, Rothwell J, Byrne P. Characterisation of road-dust sediment in urban systems: a review of a global challenge. Journal of Soils and Sediments. 2020 Dec;20(12):4194-4217.
13. Rogge WF, Hildemann LM, Mazurek MA, Cass GR, Simoneit BR. Sources of fine organic aerosol. 3. Road dust, tire debris, and organometallic brake lining dust: roads as sources and sinks. Environmental Science & Technology. 1993 Sep 1;27(9):1892-904.
14. Navarro-Ciurana D, Corbella M, Farré-de-Pablo J, Corral I, Buixadera E, Morera-Valverde R, Proenza JA. Rare Earth Elements' particles in road dust: A mineralogical perspective for source identification. Atmospheric Environment. 2023 Sep 15;309:119927.
15. Chang X, Yu Y, Li YX. Response of antimony distribution in street dust to urban road traffic conditions. Journal of Environmental Management. 2021 Oct 15;296:113219.
16. Gope M, Masto RE, George J, Hoque RR, Balachandran S. Bioavailability and health risk of some potentially toxic elements (Cd, Cu, Pb and Zn) in street dust of Asansol, India. Ecotoxicology and Environmental Safety. 2017 Apr 1;138:231-241.
17. Hou S, Zheng N, Tang L, Ji X, Li Y, Hua X. Pollution characteristics, sources, and health risk assessment of human exposure to Cu, Zn, Cd and Pb pollution in urban street dust across China between 2009 and 2018. Environment international. 2019 Jul 1;128:430-437.
18. Feng W, Guo Z, Xiao X, Peng C, Shi L, Ran H, Xu W. Atmospheric deposition as a source of cadmium and lead to soil-rice system and associated risk assessment. Ecotoxicology and Environmental Safety. 2019 Sep 30;180:160-167.
19. Zhu X, Yu W, Li F, Liu C, Ma J, Yan J, Wang Y, Tian R. Spatio-temporal distribution and source identification of heavy metals in particle size fractions of road dust from a typical industrial district. Science of the total environment. 2021 Aug 1;780:146357.
20. Men C, Liu R, Wang Q, Guo L, Miao Y, Shen Z. Uncertainty analysis in source apportionment of heavy metals in road dust based on positive matrix factorization model and geographic information system. Science of the Total Environment. 2019 Feb 20;652:27-39.
21. Xie F, Yu M, Yuan Q, Meng Y, Qie Y, Shang Z, Luan F, Zhang D. Spatial distribution, pollution assessment, and source identification of heavy metals in the Yellow River. Journal of Hazardous Materials. 2022 Aug 15;436:129309.
22. Zheng J, Wang P, Shi H, Zhuang C, Deng Y, Yang X, Huang F, Xiao R. Quantitative source apportionment and driver identification of soil heavy metals using advanced machine learning techniques. Science of the Total Environment. 2023 May 15;873:162371.
23. Bucşe A, Pârvulescu OC, Vasiliu D, Rădulescu F, Lupaşcu N, Ispas BA. Spatial distribution of trace elements and potential contamination sources for surface sediments of the North-Western Black Sea, Romania. Frontiers in Marine Science. 2024 Jan 12;10:1310164.
24. Sultana S, Hossain MB, Choudhury TR, Yu J, Rana MS, Noman MA, Hosen MM, Paray BA, Arai T. Ecological and human health risk assessment of heavy metals in cultured shrimp and aquaculture sludge. Toxics. 2022 Apr 2;10(4):175.
25. Bandara KR, Manage PM, Heavy metal contamination in the coastal environment and trace level identification. In Marine pollution-recent developments. Intech Open. 2022 Nov 11; DOI: 10.5772/intechopen.106653
26. Bhuyan MS, Kunda M, Bakar MA, Senapathi V, Husain SA, Chowdhury E, Ali MM, Pandit D. Heavy metal and mineral analysis of cultivated seaweeds from Cox's Bazar Coast, Bay of Bengal, Bangladesh: a human health risk implication. Discover Oceans. 2024 Jun 24;1(1):11.
27. Chaturvedi R, Varun M, Paul MS. Phytoremediation: Uptake and role of metal transporters in some members of Brassicaceae. In Phytoremediation: Management of Environmental Contaminants. Cham: Springer International Publishing.2016 Sep 24; 3: 453-468.
28. Corral-Bobadilla M, Lostado-Lorza R, Somovilla-Gómez F, Escribano-García R. Biosorption of Cu (II) ions as a method for the effective use of activated carbon from grape stalk waste: RMS optimization and kinetic studies. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 2022 Jun 15;44(2):4706-4726.
29. Rahman MS, Hossain MB, Babu SO, Rahman M, Ahmed AS, Jolly YN, Choudhury TR, Begum BA, Kabir J, Akter S. Source of metal contamination in sediment, their ecological risk, and phytoremediation ability of the studied mangrove plants in ship breaking area, Bangladesh. Marine pollution bulletin. 2019 Apr 1;141:137-46.
30. Tanjin F, Rahman MM, Jolly YN, Riya KK, Akter S, Albeshr MF, Arai T, Yu J, Hossain MB. Accumulation and phytoremediation potentiality of trace and heavy metals in some selected aquatic plants from a highly urbanized subtropical estuary. Journal of Marine Science and Engineering. 2024 Jul 5;12(7):1131.
31. Meena BS, Meena C, Hada PS, Chandrawat U, Meena M. Determination of Heavy Metals in Indoor Dust in the Vicinity of Kota Thermal Power Plant under Meteorological Influence at an Industrial City. Current World Environment. 2024;19(1):283.
32. He Z, Li F, Dominech S, Wen X, Yang S. Heavy metals of surface sediments in the Changjiang (Yangtze River) Estuary: Distribution, speciation and environmental risks. Journal of Geochemical Exploration. 2019 Mar 1;198:18-28
33. Xia F, Zhao Z, Niu X, Wang Z. Integrated pollution analysis, pollution area identification and source apportionment of heavy metal contamination in agricultural soil. Journal of Hazardous Materials. 2024 Mar 5;465:133215.
34. Meena M, Meena BS, Chandrawat U, Rani A. Seasonal variations and sources of heavy metals in free fall dust in an industrial city of Western India. Iranica Journal of Energy & Environment. 2014 Apr 1;5(2):e64521.
35. Rajput JS, Trivedi MK. Determination and assessment of elemental concentration in the atmospheric particulate matter: a comprehensive review. Environmental monitoring and assessment. 2022 Apr;194(4):243.
36. Yadav S, Rajamani V. Air quality and trace metal chemistry of different size fractions of aerosols in N–NW India—implications for source diversity. Atmospheric Environment. 2006 Feb 1;40(4):698-712.
37. Meena M, Meena BS, Chandrawat U, Rani A. Dry deposition of heavy metals associated with free fall atmospheric dust and its characterization in an industrial city Kota (India) under meteorological influence. Research Journal of Recent. 2019Jul;8(3):1-11.
38. Rashed MN. Total and extractable heavy metals in indoor, outdoor and street dust from Aswan City, Egypt. Clean–soil, air, water. 2008 Nov;36(10-11):850-857.

39. Bakshi P, Pappu A, Gupta MK. A review on calcium-rich industrial wastes: a sustainable source of raw materials in India for civil infrastructure—opportunities and challenges to bond circular economy. Journal of Material Cycles and Waste Management. 2022 Jan;24(1):49-62.doi: 10.1007/S10163-021-01295-4.
40. Banerjee D. Study of precipitation chemistry over an industrial city. International Journal of Environmental Science & Technology. 2008 Jun;5(3):331-8. doi: https://doi.org/10.1007/bf03326028.
41. Wang X, Sato T, Xing B, Tamamura S, Tao S. Source identification, size distribution and indicator screening of airborne trace metals in Kanazawa, Japan. Journal of Aerosol Science.2005 Feb 1;36(2):197-210. doi:https://doi.org/10.1016/j.jaerosci.2004.08.005.
42. Fang GC, Wu YS, Huang SH, Rau JY. Review of atmospheric metallic elements in Asia during 2000–2004. Atmospheric Environment. 2005 Jun 1;39(17):3003-3013. doi: https://doi.org/10.1016/j.atmosenv.2005.01.042.
43. Banerjee AD. Heavy metal levels and solid phase speciation in street dusts of Delhi, India. Environmental pollution. 2003 May 1;123(1):95-105. doi: https://doi.org/10.1016/s0269-7491(02)00337 8.
44. Di Blasio L, Droetto S, Norman J, Bussolino F, Primo L. Protein Kinase D1 Regulates VEGF-A-Induced αvβ3 Integrin Trafficking and Endothelial Cell Migration. Traffic. 2010 Aug;11(8):1107-1118. doi: https://doi.org/10.1111/j.1600 0889.2010.00454.x.
45. Zhang P, Dudley N, Ure AM, Littlejohn D. Application of principal component analysis to the interpretation of rainwater compositional data. Analytica chimica acta. 1992 Mar 8;258(1):1-10. doi: https://doi.org/10.1016/0003 2670(92)85192-9.
46. Araja A, Bertins M, Celma G, Busa L, Viksna A. Distribution of minor and major metallic elements in residential indoor dust: A case study in Latvia. International journal of environmental research and public health. 2023 Jun 22;20(13):6207. doi: https://doi.org/10.3390/ijerph20136207.

HOW TO CITE THIS ARTICLE: Meena M, Naraniya BLK, Shekhawat AS, Chandrawat U, Meena BS . Heavy Metal Deposition in Freefall Atmospheric Dust Under Meteorological Observation in Industrial City, Kota, India, Having a Coal-fired Thermal Power Plant. *J Adv Sci Res*. 2026;17(5): 5-10 **DOI:** 10.55218/JASR.2026170502