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Source Apportionment of Heavy Metals and Ionic Species in Road Dust in the Vicinity of University of Lagos, Lagos State, Nigeria

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ABSTRACT

The increasing levels of heavy metals and ionic species in road dust around the University of Lagos and its surrounding environments, which are believed to exceed recommended environmental standards, emphasizes the need for the present study. This study investigates the concentrations of selected heavy metals ((Zn, Pb,Cu,, Ni, Cd) and ionic species(SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-},$C_2O_4^{2-}$) in road dust samples collected around the University of Lagos, Akoka, Lagos State, Nigeria. 44, road dust samples were collected between January and June 2025 across eleven sampling locations, with sampling conducted four times monthly. Dust samples were swept using a hand brush into plastic containers and transferred into sterile vials. The samples were sieved through a 75-µm stainless steel mesh, weighed, and digested using nitric acid (HNO_3) and sulphuric acid (H_2SO_4). Heavy metal concentrations were analyzed using inductively coupled plasma - optical emission spectrometry (ICP - OES), while ionic species were determined using standard analytical procedures. Zinc (Zn) - (1710.86 mg/kg) recorded the highest heavy metal concentration while Cadmium (Cd)-(48.73 mg/kg) had the lowest concentration. Sulphate (SO_4^{2-}) - (1266.62 mg/kg), was the most abundant ionic species while oxalate ($C_2O_4^{2-}$) -(116.05 mg/kg) recorded the lowest value. Principal Component Analysis (PCA) identified three principal components (PC1, PC2, PC3) accounting for 90.78% of total variance, indicating anthropogenic sources such as vehicular emissions, lubricating oil, diesel fuel combustion, waste burning, tire and brake wear, chemical/ solvent usage, construction materials, microplastics, and organic activities. Heavy metal concentrations exceeded WHO/FAO, USEPA and NESREA permissible limits, posing environmental and public health concerns.

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INTRODUCTION

The levels of heavy metals(Zn, Pb, Cu, Ni, and Cd) and ionic species (SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-}, and $C_2O_4^{2})^-$ in road dust around the University of Lagos and nearby environments are believed to be rising above recommended environmental standards .This growing concern emphasizes the need for the present study. Dust comprises tiny solid particles derived from soil and numerous anthropogenic and natural sources that become airborne through several physical processes. These particles readily accumulate in both indoor and outdoor environments, particularly on paved roads and hard surfaces (Lu *et al.,* 2014; Rahman *et al.,* 2019). Dust functions as both a reservoir and a carrier of toxic heavy metals and ionic contaminants, influencing the quality of air and soil (Men *et al.,* 2020).

There are various techniques employed to collecting dust samples which include using a plastic dustpan and brush (Wei *et al.,* 2009; Aguilera *et al.,* 2019; Praveena, 2019), a plastic hand broom and dustpan (Zhang *et al.,* 2012; Soltani *et al.,* 2015), brushing a defined 1 m² asphalt surface (Reyes *et al.,* 2013), portable aspirators (Sahakyan *et al.,* 2014; Saghatelyan *et al.,* 2014), brushes with plastic shovels (Trujillo-Gonzalez *et al.,* 2016), vacuum cleaners (Yu *et al.,* 2014; Tanner *et al.,* 2008), and high-pressure washer devices equipped with piston-fitted rubber domes (Budai *et al.,* 2018).

Heavy metals are metallic elements characterized by high densities and specific gravities greater than 5. Even at relatively low concentrations, these metals can be toxic and are easily dispersed into the environment through anthropogenic activities such as industrial operations, mining, transportation, and agricultural practices (Wise *et al.,* 2017; Kara, 2020; Shaapera *et al.,* 2023). Common examples include zinc (Zn), nickel (Ni), copper (Cu), cadmium (Cd), chromium (Cr), and lead (Pb). Unlike many pollutants, heavy metals are non-biodegradable and can persist in environmental media for extended periods, thereby posing serious ecological and public health concerns. Excessive Zinc exposure may result in anemia, muscular pain, and pancreatic dysfunction (Hegazy *et al.,* 2019). Lead contamination in road dust is commonly linked to vehicular emissions, industrial discharges, and agrochemical applications. Copper pollution is frequently associated with non-exhaust vehicular sources such as brake and tire wear (Valotto *et al.,* 2015), while prolonged exposure may adversely affect the liver, kidneys, and immune system. Cadmium exposure has been connected to kidney disease, infertility, gastrointestinal disorders, and cancer, with major sources including fuels, lubricants, batteries, plastics, tires, and brake materials (Foti *et al.,* 2017; Men et al., 2020). Nickel exposure is also known to increase the likelihood of respiratory, cardiovascular, and carcinogenic effects.

Ionic species are electrically charged atoms or molecules that exist as cations, such as Zn^{2+} and Pb^{2+}, or anions including SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-}, and $C_2O_4^{2-}$. Sulphates mainly originate from fossil fuel combustion and contribute significantly to acid rain formation (Wang *et al.,* 2022).

Nitrates are produced through atmospheric reactions involving nitrogen oxides and can negatively impact respiratory health (Wang *et al.*, 2021). Chlorides commonly arise from sea spray and industrial emissions, contributing to soil salinization (Zhao et al., 2025). Carbonates are often linked to construction activities (Lu *et al.*, 2019), whereas oxalates are indicators of biomass burning and photochemical reactions (Jiao *et al.,* 2020). Several analytical techniques are used to detect and quantify heavy metals and ionic species in dust. Common methods include Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Jreije *et al.,* 2022), X - Ray Fluorescence (XRF) Spectroscopy (Nguyen *et al.,* 2023), Atomic Absorption Spectroscopy (AAS) (Mohamed *et al.,* 2023), Ion Chromatography - Mass Spectrometry (IC-MS) (Pettucci *et al.,* 2016) and Laser Ablation ICP - MS (Rodriguez *et al.,* 2019).

The University of Lagos (UNILAG), one of Nigeria's pioneering first-generation federal universities, was established under the University of Lagos Act of 1962 and officially inaugurated on 22 October 1962. Its establishment was influenced by the recommendations of the Ashby Commission of 1959, which emphasized the urgent need for more universities in Nigeria, especially in Lagos, to address the growing demand for skilled manpower in disciplines such as engineering, administration, business, and the sciences. UNILAG's principal campus is located at Akoka on the mainland of Lagos State, overlooking the Lagos Lagoon. Spanning over 800 acres of land, the campus extends toward Yaba and Idi-Araba, where the College of Medicine is situated. Its strategic urban location places it close to major residential, educational, and commercial areas, including the Yaba technology hub and Yaba College of Technology. The university is also easily accessible through major roads and public transportation systems. Since its inception, UNILAG has experienced remarkable physical and academic expansion, with the development of lecture theatres, laboratories, student hostels, service centres, staff quarters, and other infrastructural facilities.

Although, many studies have investigated heavy metals and ionic species in road dust across Lagos and other regions of the world (Wang *et al.*, 2021; Ogunyinka and Adedeji, 2017), none focused on road dust of the first - generation university campus and its surroundings. The UNILAG Akoka area was selected due to its high traffic density, mixed land use and Population. This study aims to: (1) assess levels of heavy metals and ionic species in road dust (2) identify potential sources of contamination.

MATERIALS AND METHODS

Study Area / Sampling Location

This study was conducted on road dust of University of Lagos, main Campus, Akoka and Environs (N6°3053, 3°2234, - N6°3138, E3°2232) Lagos - State, Southwestern - Nigeria. namely; Unilag junction, Abudu street, Akoka Street, Unilag Front Gate, Unilag sport Centre, Unilage petrol station, FSS printing, Unilag park, Mariere Hall and Faculty of art and Epe - Odogbonle Noforija was used as the control site. (Figure 1).

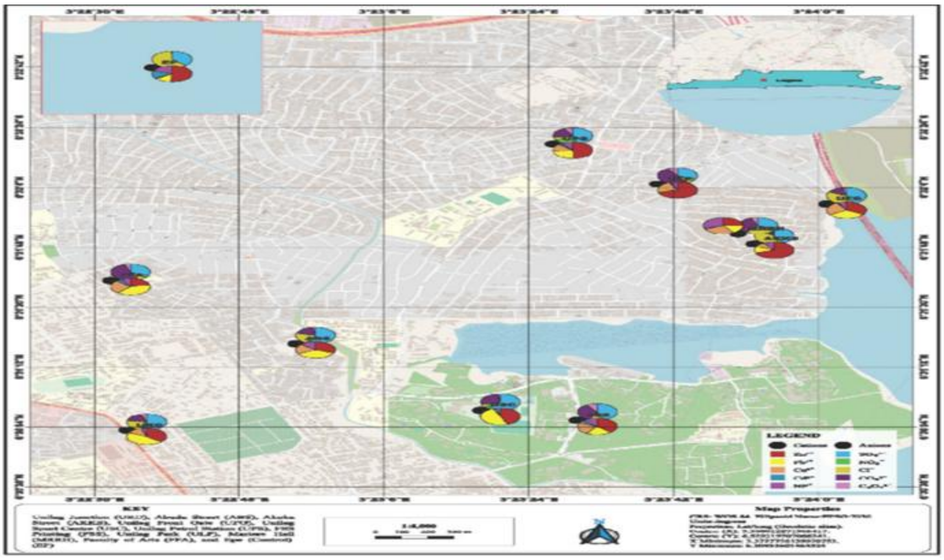

Figure 1: GIS Map Showing the Concentrations of Heavy Metals and Ionic Species in the Study Area

Selection of Sampling Sites/Locations

Eleven (11) sampling sites were carefully chosen based on the impact of anthropogenic activities on the road dust of University of Lagos, main Campus, Akoka and Environs, Lagos - State, Southwestern Nigeria. Global Positioning System (GPS) device was used to record the coordinates for each sampling site (GPS 76S Garmin)) (Table 1).

Table 1: Sampling Sites, Characteristics and Coordinates of the Study Area

S/No.	Location/Sites	Codes	Latitude	Longitude	Site description
1	Unilag junction	URD	N6°3053	E3°2234	It's a busy area with many vehicles moving around on daily bases.
2	Abudu street	ABS	N6°3119	E3°2255	It's a residential area with lots of Commercial vehicles and tricycles.
3	Akoka Street	AKKS	N6°3149	E3°2352	It's a major express road with high commercial and vehicular activities.
4	Unilag Front Gate	UFG	N6°3143	E3°2361	It's a busy area with human and vehicular activities.

S/No.	Location/Sites	Codes	Latitude	Longitude	Site description
5	Unilag sport Centre	USC	N6°3059	E3°2318	A state of art sport facility, it is an area with a 5,000-seat capacity hall.
6	Unilag petrol station	UPS	N6°3179	E3°2327	It's a petrol station alone the commercial road with auto mechanics workshop.
7	Fss Printing	FSS	N6°3056	E3°2330	It's a printing press located opposite faculty of social science shopping complex.
8	Unilag park	ULP	N6°3167	E3°2340	It is a designated area within the university campus where commercial buses and vehicles pick up and drop off passengers.
9	Mariere Hall	MRRH	N6°3152	E3°2350	Mariere hall is male hostel and fuguwa female hostel.Commercial buses and vehicles pick and drop off passengers.
10	Faculty of art	FFA	N6°3138	E3°2232	Is located on the main campus, specifically, along University Road. The faculty is one of the faculties that make up the university.
11	Epe (control)	EP	N6^0 3052	E3^0 64452	It is an area with low anthropogenic activities

Sampling and Sample Collection

Dust samples were collected from eleven locations within the study area, with each site spaced at least 100 m apart. Sampling was conducted four times monthly from January to June, 2025. To ensure consistency, samples were taken in the morning after dust had settled overnight and before heavy traffic could disturb surface particles. At each site, dust was randomly gathered from both sides of the road by sweeping it into plastic waste packers with a plastic brush, then transferring it into pre-labeled polythene bags (Aguilera *et al.*, 2019; Praveena, 2019; Rahman *et al.*, 2019). Materials such as cigarette ends, paper, and plastics were removed by handpicking. The collected dust was then sieved using a 75 μm stainless-steel sieve to obtain fine particulate matter suitable for analysis. All processed samples were subsequently transported to the laboratory for further preparation and detailed examination.

Digestion of Dust Samples for Heavy Metals

0.5 g of the fine, dried dust sample was weighed and digested with 6 mL of an acid mixture (HNO_3 - H_2SO_4, 3:1) using a Milestone ETHOS PLUS microwave digester equipped with an HPR-1000/105 high-pressure rotor. After digestion, each sample was diluted to 50 mL with distilled water in a volumetric flask. The resulting solutions were analyzed for Pb, Ni, Cu, Cr and Zn using Inductively Coupled Plasma - Optical Emission Spectroscopy (ICP -OES). A blank solution, prepared following the same procedure but without a sample, served as a control. Comparing the blank with the sample solutions allowed accurate identification of heavy metal concentrations in the dust (Wahab *et al.*, 2012; Hazem *et al.*, 2025; Awang *et al.*, 2025).

Quality Control and Quality Assurance

To ensure the reliability of the analytical results, blank solutions were prepared, processed, and analyzed alongside the samples using ICP - OES. All glasswares used in digestion and filtration was carefully cleaned: first washed with soap and tap water, then rinsed with distilled water, and finally soaked overnight in 1 % HNO_3 to eliminate any potential heavy-metal contamination. Afterwards, the glasswares were thoroughly rinsed with distilled and deionized water. Samples were stored in a desiccator to remove moisture before analysis. During collection, separate brushes and dustpans were used at each site, and samples were sealed in plastic bags to maintain quality and prevent contamination.

Laboratory Analysis

All chemicals and reagents used in the laboratory analyses - including Sulfaver 4 powder pillows, potassium chromate indicator, standard silver nitrate (0.014 M), standard sodium chloride (0.014 M), aluminum hydroxide suspension, phenolphthalein indicator, hydrogen peroxide (30 %), Nitraver 6 and Nitraver 3 reagents, saturated $NaHCO_3$, NaOH, distilled and de - ionized water, hydrochloric, sulfuric, acetic, phosphoric, and nitric acids, calcium nitrate, ammonium acetate, potassium chloride, bamboo powder, and concentrated NH_4OH - were of analytical grade and purchased from Lazco Scientific, Lagos, Nigeria. All laboratory procedures were carried out at the Analytical Chemistry Laboratory of the Central Research Laboratory, Yaba College of Technology, Lagos.

Extraction of Sulphate ion ($SO_4{}^{2-}$) (Ammonium Acetate - Acetic Acid Extraction Method)

Extraction Reagents

0.5 M ammonium acetate, 0.25 M acetic acid. Thirty- nine grams (39 g) ammonium acetate was weighed into 1000 ml volumetric flask and brought to volume with 0.25 M acetic acid (Prepared by diluting 14.13 ml glacial acetic acid in 1000 ml water).

Procedure for Extraction

Ten grams (10 g) of air-dried sieved dust was weighed into an extraction vessel, 25 ml of extraction reagent was pipetted into the vessel and shaked for 30 minutes with shaker. About 0.15 g or ¼ teaspoon of powdered charcoal was added and shaked for an additional 3 minutes. Ten milliliters (10 ml) of the aliquot was filtered and transferred into another flask. After, which the analysis of Sulphate ion was carried out.

Procedure for Determination of Sulphate ion (Spectrophotometric - Turbidimetric Method)

The Spectrophotometer was turned on and allowed to run a full system check. The hack programs were touched and selected at 680 nm (for Sulphate- $SO_4{}^{2-}$). A clean sample cell was filled with 10 ml of sample. The content of one sulfaVer 4 reagent powder pillow was added to the sample cell (The prepared sample), the solution was swirled to mix. The timer icon was touched, OK was also touched. Then a five (5) minutes reaction was run and there was no interruption in the cell during the reaction period. A second sample cell was filled with 10ml of sample (THE BLANK), the blank in the cell holder was placed when the timer beeped and zero button was touched and the display showed 0 mg/l $SO_4{}^{2-}$. The prepared sample was placed into the cell holder within five (5) minutes after the timer beeped. Read result was touched and the values appeared in mg/l SO^{2-}. (Oliveira *et al.,* 2019; Tariq *et al.,* 2020).

Extraction of Chloride ion (Cl^-) (Calcium Nitrate Salt Extraction Method)

Extraction Reagents:

Calcium nitrate, Deionized water

Preparation of Extraction Reagent 0.01 M $Ca(NO_3)_2.4H_2O$

Two hundred and thirty - six grams (236 g) Calcium nitrate $Ca(NO_3)_2.4H_2O$ was weighed into 1000 ml volumetric flask and brought to volume with deionized water.

Procedure for Extraction

Ten grams (10 g) of air dried sieved street dust was weighed into a 50 ml Erlenmeyer flask, 25 mg of 0.01 M $Ca(NO_3)_2.4H_2O$ washed charcoal and 25 ml extraction reagent was added and shaked for 15 minutes. The solution was filtered through whatmann no. 42 filter paper. The blank was prepared and the normal analysis for chloride was carried out (Wang *et al.,* 2022).

Procedure for Determination of Chloride ion (Cl^-) (Argentometric Titration Method (SM 4500 - Cl-B Using $AgNO_3$ and K_2CrO_4 Indicator) (Mohr's Method))

Preparation of the Reagents

Potassium Chromate Indicator Solution

Fifty grams (50 g) of K_2CrO_4 was dissolved in a little distilled water, $AgNO_3$ solution was added until a definite red precipitate was formed, and was allowed to stand for 12 hours, filtered and diluted to 1 L with distilled water.

Standard Silver Nitrate Titrant 0.0141 M (0.0141 N)

A mass of 2.395 g $AgNO_3$ was dissolved in distilled water and diluted to 1000 ml, and was standardized against NaCl by 1.00 ml = 500 µgcl$^-$ stored in a brown SO_4 bottle.

Standard Sodium Chloride 0.0141 M (0.0141 N)

The reagent was prepared by dissolving 842.0 mg Nacl (dried at 140 ºC) and diluted to 1 litre, 1.00 ml = 500 µgcl$^-$

Special Reagents for Removal of Interference

Aluminium Hydroxide Suspension

One hundred and twenty-five grams (125g) of Aluminium potassium sulphate $Alk(SO_4)$ was dissolved in 1 litre distilled water, and was warmed to 60º C and 55 ml of concentration ammonium hydroxide (NH_4OH) was added slowly with stirring and it was allowed to stand for about one hour (1hr) after which it was transferred to a large bottle and the precipitate was washed by successive additions with thorough mixing and decanting with distilled water, until it was free from chloride. The suspension occupied a volume of approximately 1 L when freshly prepared.

Procedure

Sample Preparation

A 100 ml sample was used, 3 ml of $Al(OH)_3$ suspension was added to remove color from the sample, mixed thoroughly and allowed to settle after which it was filtered. 1 ml of H_2O_2 was added and stirred for 1 minute to remove Sulphide, Sulphite or thiosulphate that is present in the sample.

Titration

Samples were directly titrated in the P^H range of 7 to 10. For adjustment, a P^H meter with a non -chloride type reference electrode was used. 1 ml of K_2CrO_4 indicator solution was added, and was titrated with standard $AgNO_3$ titrant to a pinkish yellow end point. End point was recognized. Standardized $AgNO_3$ titrant and established reagent blank value by the titration method outlined above. A blank of 0.2 to 0.3 ml is usual.

Calculation:

$$mgCl-/L = \frac{(A-B)- \times N \times 35450}{\text{ml Sample}} \quad \text{-------------} \quad \text{Equation 1}$$

A = ml titration for sample

B = ml titration for blank, and

N =Normality of AgNO3 (HACH, 2000; APHA, 2017).

Extraction of Nitrate ion (NO) (Potassium Chloride (KCl) Salt Extraction Method)

Reagents Used

Potassium chloride, deionized water.

Preparation of Extraction Reagent (2 M KCl)

A 2 M Potassium chloride were prepared by weighing 150 g Potassium chloride (KCl) into a 1000 ml volumetric flask and bring to volume with water.

Procedure for Extraction

Ten grams (10 g) of air dried and sieved dust was weighed into a 125 ml conical flask. 50 ml of extraction reagent was added and shaked on a reciprocating shaker for 15 minutes. After which the extract was filtered through whatmann No. 2 filter paper.

Procedure for Determination of Nitrate ion (NO^-) (Cadmium Reduction Colorimetric Spectrophotometric Method (HACH NitraVer ® method, Program 351 N)

Program '351 N, Nitrate LR' was selected and the START was touched. A 25 ml graduated mixing cylinder was filled with 15 ml of sample, the contents of one sachet Nitrate 6 reagent powder pillow was emptied into the cylinder, then stopper. The timer icon was gently touched OK was clicked. Then a three (3) minutes reaction time was commenced. The cylinder was shaked vigourously during the three (3) minutes reaction time. The timer icon was pressed as soon as the timer expired OK was clicked after which a two (2) minutes reaction period was conducted. 10ml of the sample was carefully poured at the expiration of the timer into a clean cuvette and ensured that Cadmium particles was not transferred to the cuvette. The content of one nitriver 3 nitrate reagent powder pillow (Prepared sample) was added to the sample cell. The timer icon was touched. And OK was pressed. After which A 30 seconds reaction time was conducted. The cuvette containing the sample was gently caped during the 30 seconds reaction time after which the present of nitrate developed a pink colour. The timer icon was clicked and OK was pressed and a 15 minutes reaction period was run. Another cuvette was filled with 10 ml of the original sample at the expiration of the timer (Blank preparation). The blank was inserted into the cell holder with the filled line that faced the right. ZERO was pressed to zero the blank after which the display showed 0.00 Mg/l NO^- -N. The cuvette containing the prepared sampled was wiped and inserted into the cell holder with the filled line that faced the right. READ was pressed and the result appeared in Mg/l NO_3 -N.

Calculation

Multiply the result in mg/L NO^- - N by 4.4 to get the total amount of NO^- (Nitrate) in the sample in mg/L. (HACH, 2000; APHA, 2017).

Procedure for Determination of Carbonate ion (CO_3^{2-}) (Acid Decomposition Gravimetric Method)

A 50 ml flask was weighed with the lid, and the weight recorded. Ten milliliters (10 ml) of 3 M HCl was added and the weight was also recorded. A quantity of dried dust ranging from 2 g to 5 g was transferred to the flask and the weight of the dust was recorded and transferred to the nearest 0.1 mg, effervesence was noticed. After it has subsided, the flask lid was replaced and placed in a shaker for 15 minutes, 3 blanks was included to determine water vapour loss. After 2 hours, the flask was weighed to the nearest 0.1 mg and the mass was noted. (Wang *et al.*, 2021; APHA, 2017; Querol *et al.*, 2007). Weight loss of CO_2 (g) = Initial weight (g) - Final weight (g) (Flask + Stopper + Acid + dust). CO $^{2-}$% =

$$\frac{\text{(g) CO Lost (0.2727) x 100}}{\text{(g) Air Dried dust}}$$

Procedure for the determination of Oxalate Ion ($C_2O_4^{2-}$) (Aqueous or Dilute Acid) Extraction Method/ Colorimetric Spectrophotometric Method)

Dust samples were collected using clean, non-reactive filters or vacuum devices and stored in sealed containers to avoid contamination. The samples are air - dried, finely homogenized, and a known mass is extracted with deionized water or dilute acid to solubilize oxalate ions. The extract is filtered to remove particulate matter. Oxalate concentration is then determined using a HACH DR spectrophotometer based on a colorimetric method, where oxalate reacts with specific reagents to form a colored complex. The absorbance is measured at the recommended wavelength and quantified by comparison with oxalate calibration standards. (HACH, 2007; Misiewicz *et al.*, 2023; Ichiyama *et al.*, 1985).

Statistical Analysis

The Mean, Standard Deviation, Analysis of Variance (ANOVA), Kaiser-Meyer-Olkin (KMO) and Bartlett's tests, Principal Component Analysis (PCA), and Pearson's Correlation Coefficient were conducted. Table 2: Shows the mean ± standard deviation (mg/kg) of heavy metals and ionic species across various sampling sites. The highest mean concentrations of Pb - (437.71 ± 143.28), Cu - (241.88 ± 70.63), and Ni - (161.16 ± 47.74) mg/kg were observed at ABS, while UPS recorded the highest Zn (387.85 ± 144.74) and Cd (21.31 ± 5.79) mg/kg. The lowest metal concentrations occurred at FFA (Zn - 10.96 ± 144.74; Ni - 3.99 ± 47.74), ULP (Pb - 10.48 ± 143.28), AKKS (Cd - 0.35 ± 5.79), and USC (Cu - 1.19 ± 70.63) mg/kg. For ionic species, URD showed the highest CO_3^{2-}, SO_4^{2-}, $C_2O_4^{2-}$ and Cl^- values, while UPS had the highest NO_3^-. EP recorded the lowest concentrations of all heavy metals and ionic species.

Table 2: Mean ± Standard Deviation of Heavy Metals and Ionic Species (mg/kg)

Sample Site	Zn	Pb	Cu	Ni	Cd	CO_3^{2-}	SO_4^{2-}	NO_3^-	$C_2O_4^{2-}$	Cl^-
URD	241.42± 144.74	300.99± 143.28	86.78± 70.63	25.82 ± 47.74	2.86 ± 5.79	112.64 ± 33.22	336.81 ± 108.94	16.85 ± 12.81	30.75 ± 8.45	143.72 ± 52.32
ABS	387.68± 144.74	437.71± 143.28	241.88± 70.63	161.16 ± 47.74	2.40 ± 5.79	102.02 ± 33.22	314.93 ± 108.94	13.36 ± 12.81	12.42 ± 8.45	123.64 ± 52.32
AKKS	222.39± 144.74	41.34± 143.28	30.63± 70.63	27.43 ± 47.74	0.35 ± 5.79	32.72 ± 33.22	104.61 ± 108.94	11.28 ± 12.81	4.30 ± 8.45	98.56 ± 52.32
UFG	138.82± 144.74	129.22± 143.28	110.94± 70.63	27.69 ± 47.74	3.82 ± 5.79	32.93 ± 33.22	102.68 ± 108.94	11.10 ± 12.81	7.03 ± 8.45	80.85 ± 52.32
USC	27.91± 144.74	31.53± 143.28	1.19± 70.63	0.39 ± 47.74	2.14 ± 5.79	36.68 ± 33.22	78.79 ± 108.94	5.99 ± 12.81	3.07 ± 8.45	5.96 ± 52.32
UPS	387.85± 144.74	187.86± 143.28	107.38± 70.63	81.49 ± 47.74	21.31 ± 5.79	52.79 ± 33.22	114.42 ± 108.94	48.29 ± 12.81	17.62 ± 8.45	13.46 ± 52.32
FSS	35.59± 144.74	20.25± 143.28	22.44± 70.63	11.79 ± 47.74	4.78 ± 5.79	51.53 ± 33.22	64.44 ± 108.94	5.51 ± 12.81	12.95 ± 8.45	13.04 ± 52.32
ULP	211.71± 144.74	10.48± 143.28	53.59± 70.63	17.71 ± 47.74	1.93 ± 5.79	82.92 ± 33.22	51.38 ± 108.94	7.31 ± 12.81	13.72 ± 8.45	8.35 ± 52.32
MRRH	46.56± 144.74	30.13± 143.28	51.63± 70.63	57.24 ± 47.74	3.42 ± 5.79	51.65 ± 33.22	46.65 ± 108.94	7.42 ± 12.81	8.48 ± 8.45	34.99 ± 52.32
FFA	10.96± 144.74	20.94± 143.28	13.59± 70.63	3.99 ± 47.74	2.53 ± 5.79	75.41 ± 33.22	45.87 ± 108.94	6.30 ± 12.81	6.66 ± 8.45	9.48 ± 52.32
EP	4.17± 144.74	1.10± 143.28	0.13± 70.63	1.54 ± 47.74	1.19 ± 5.79	0.02 ± 33.22	6.04 ± 108.94	0.03 ± 12.81	0.05 ± 8.45	9.79 ± 52.32

RESULTS AND DISCUSSION

Heavy Metals Distribution in Road Dust of the Study Area

Table 3. shows percentage contributions of heavy metals to road dust pollution in the study area with Zinc -(Zn) contributing 41.67 %, followed by lead (Pb) - 29.48 %, copper (Cu) - 17.54 %, nickel (Ni) - 10.13 %, and cadmium (Cd) - 1.19 %. Zn - (1710.86 mg/kg) was the most abundant heavy metal, while Cd - (48.73 mg/kg) was the least. The high Zn levels may results from brake lining wear, tyre abrasion, and corrosion of galvanized steel fences in the study area, with significant differences observed among the study sites ($P \leq 0.05$). The low Cd concentrations may arise from low open refuse burning and improper waste disposal (Querol *et al.*, 2007). The highest Zn - (387.85 mg/kg) and Cd -(21.31 mg/kg) levels occurred at UPS, whereas Pb - (437.71 mg/kg), Cu -(241.88 mg/kg), and Ni - (161.16 mg/kg) occur at ABS. The lowest concentrations were recorded at FFA, ULP, AKKS, and USC sites. The high Pb levels may likely results from vehicular emissions, while the presence Cu may arise from metal, electrical cable, microplastics deposit and traffic (Amato *et al.*, 2014; Ramirez *et al.*, 2018; Men *et al.*, 2018; Foti *et al.*, 2017; Ika *et al.*, 2024).(Table 3).

Table 3: Concentrations of Heavy Metals (mg/kg)

Sample sites	Code	Zn	Pb	Cu	Cd	Ni	Total	Percentage %
Unilag junction	URD	241.42	300.99	86.78	2.86	25.82	657.87	16.02
Abudu Street	ABS	387.68	437.71	241.88	2.40	161.16	1230.83	29.97
Akoka Street	AKKS	222.39	41.34	30.63	0.35	27.43	322.14	7.84
Unilag gate	UFG	138.82	129.22	110.94	3.82	27.69	410.49	10.00
Sport Centre	USC	27.91	31.53	1.19	2.14	0.39	63.16	1.54
Petrol Station	UPS	387.85	187.86	107.38	21.31	81.49	785.89	19.14
FSS Printing	FSS	35.59	20.25	22.44	4.78	11.79	94.85	2.31
Unilag park	ULP	211.71	10.48	53.59	1.93	17.71	295.42	7.19
Mariere hall	MRRH	46.56	30.13	51.63	3.42	57.24	188.98	4.60
Faculty of Arts	FFA	10.96	20.94	13.59	2.53	3.99	52.01	1.27
Epe (Control)	EP	4.17	1.10	0.13	1.19	1.54	8.13	0.20
Total		1710.86	1210.55	720.28	48.73	416.25	4106.67	100.00
Average		155.53	110.05	65.48	4.43	37.84	373.33	
%		41. 67	29.48	17. 54	1.19	10.13	4106.67	100.00

Significant differences were observed in Pb levels across the study sites ($P \leq 0.05$). There are significant variations in the levels of Copper among sampling sites ($P \leq 0.05$). Cadmium (Cd) may originate from diesel fuel, lubricating oils, tyre and brake wear, and batteries (Men *et al.*, 2020; Heidari *et al.*, 2021; Duan *et al.*, 2017) and displayed significant site differences ($P < 0.05$). Nickel (Ni) may likely comes from fuel combustion, waste incineration, and sewage, but no significant difference in Ni levels were observed between sites ($P \leq 0.05$). The metals follow the order Zn > Pb > Cu > Ni > Cd, with mean concentrations of 155.53, 110.05, 65.48, 37.84, and 4.43 mg/kg, respectively (Figure 2). This result is in agreement with previous studies (Ojiodu *et al.*, 2018; Ojiodu *et al.*, 2024 & 2026). The high Zn, Pb , Cu, and Ni levels is an indication of the ability of the dust to accumulation heavy metals, whereas the low concentrations of Cd suggest limited sources and the dust's reduced capacity to preferentially retain these metals. (Table 3).

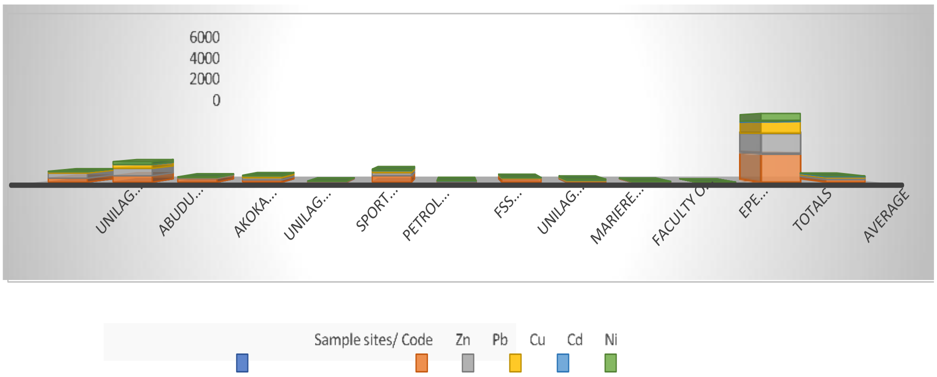

Figure 2: Distribution Of Heavy Metals in the Study Area

Abudu Street (ABS) - 1230.83 mg/kg is the most polluted site, while the least polluted is the Faculty of Arts (FFA) - 52.01 mg/kg, this may be due to traffic, vehicular, and commercial activities (Figure 3). The contributions of each site to heavy metal dust pollution follows the trend: ABS - 29.97% > UPS - 19.14 % > URD -16.02 % > UFG - 10.00 % > AKKS - 7.84 % > ULP - 7.19 % > MRRH - 4.60 % > FSS - 2.31 % > USC - 1.54 % > FFA -1.27 % > EP - 0.20% (Figure 3). These results is in agreement with global studies (Xu *et al.*, 2020; Wang *et al.*, 2022), which shows that heavy metal concentrations depend on the type and intensity of local activities.

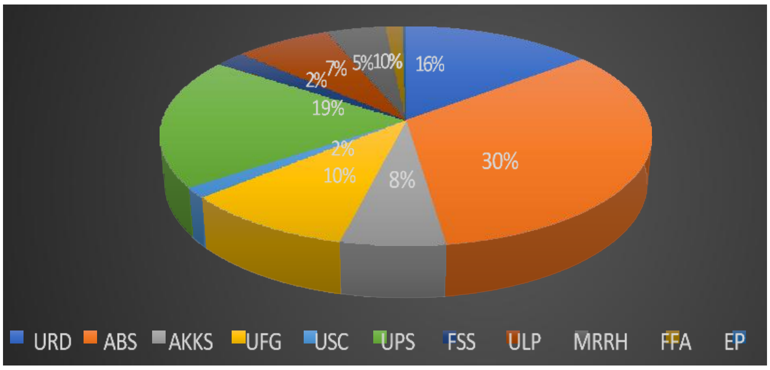

Figure 3: Percentage Contribution of Each Site to Heavy Metals Dust Pollution

The concentrations of heavy metals at all sites exceeded recommended limits set by World Health Organization/ Food and Agriculture Organization (WHO/FAO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) in Nigeria (WHO/FAO (2020); USEPA (2020); NESREA (2025); Ojiodu *et al.*, 2026), and were higher than the control site, which experiences minimal anthropogenic activity.

Ionic Species Distribution in Road Dust of the Study Area

Table 4 : shows the distribution of ionic species in road dust across the study area. Sulphate - (SO_4^{2-}) -1266.62 mg/kg was the most abundant ion while oxalate ($C_2O_4^{2-}$) - 116.05 mg/kg was the least. The high SO_4^{2-} levels may likely result from traffic and human activities, chemical and solvent usage, sewage, and waste disposal, whereas the low CO_3^{2-} concentrations may reflect low anthropogenic inputs from fossil fuel combustion, concrete dissolution, and agricultural runoff. The highest site concentrations were recorded at URD for SO_4^{2-}- (336.81 mg/kg), Cl^- - (143.72 mg/kg), CO_3^{2-}- (112.64 mg/kg), and $C_2O_4^{2-}$ - (30.75 mg/kg), while NO_3^-- (48.28 mg/kg). is highest at UPS. Similarly, lowest levels were observed at FFA - SO_4^{2-} - (45.87 mg/kg), FSS - (NO_3^-) - 5.51 mg/kg), AKKS - (CO_3^{2-}- 32.72 mg/kg), and USC - (Cl^- - 5.96 mg/kg; $C_2O_4^{2-}$ - 3.07 mg/kg (Figure 4).There is significant differences in SO_4^{2-} levels ($p < 0.05$), while $C_2O_4^{2-}$ levels showed no significant variation. The contribution of each site to ionic dust pollution followed the trend: URD > ABS > AKKS > UPS > UFG > ULP > MRRH > FSS > FFA > USC > EP. The degree of contribution of ionic species to dust pollution is in the order: SO_4^{2-} (47.14%) > CO_3^{2-} (23.42%) > Cl^- (20.16%) > NO_3^- (4.97%) > $C_2O_4^{2-}$ (4.32%), reflecting progressive accumulation in the samples (Table 4). There were decreases in concentrations of heavy metals and ionic species (January- June) (Tables 3 & 4). Figure 5. shows the distribution of heavy metals and ionic species in the study areas.

Table 4: Concentrations of Ionic Species (mg/kg)

Sample sites	Code	SO_4^{2-}	NO_3^-	Cl^-	CO_3^{2-}	$C_2O_4^{2-}$	Total	Percentage %
Unilag junction	URD	336.81	16.85	143.72	112.64	30.75	640.77	23.84
Abudu Street	ABS	314.93	13.36	123.64	102.02	12.42	566.37	21.07
Akoka Street	AKKS	104.61	11.28	98.56	32.72	4.30	251.47	9.36
Unilag gate	UFG	102.68	11.10	80.85	32.93	7.03	234.59	8.73
Sport Centre	USC	78.79	5.99	5.96	36.68	3.07	130.49	4.86
Petrol Station	UPS	114.42	48.29	13.46	52.79	17.62	246.58	9.18
FSS Printing	FSS	64.44	5.51	13.04	51.53	12.95	147.47	5.49
Unilag park	ULP	51.38	7.31	8.35	82.92	13.72	163.68	6.09
Mariere hall	MRRH	46.65	7.42	34.99	51.65	8.48	149.19	5.55
Faculty of rts	FFA	45.87	6.30	9.48	75.41	6.66	143.72	5.35
EP (Control)	EP	6.04	0.03	9.79	0.02	0.05	15.93	0.59
Total		1266.62	133.44	541.84	629.31	116.05	2687.26	100.00
Average		115.15	12.13	49.26	57.21	10.55	244.30	
%		47.14	4.97	20.16	23.42	4.32	2687.26	100.00

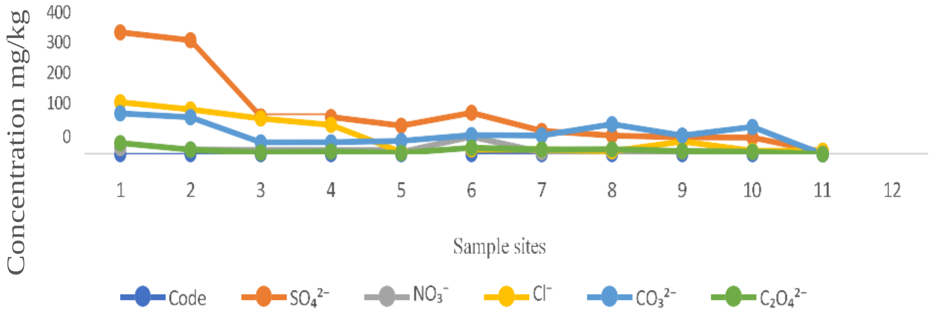

Figure 4: Distribution of Ionic Species at the Study Sites (mg/kg)

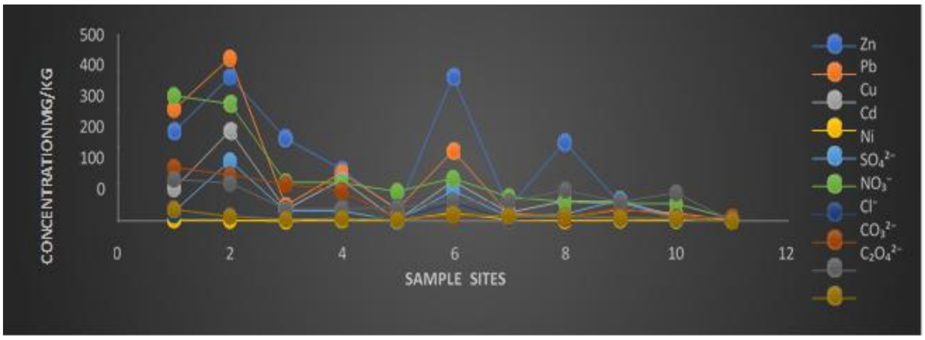

Figure 5: Distribution of Heavy Metals and Ionic Species at the Study Sites (mg/kg)

Source Apportionment

Using Principal Component Analysis (PCA) to Identify the Potential Sources of Heavy Metals and Ionic Species

The dataset was analyzed using factor analysis with principal component analysis (PCA) as the extraction method and orthogonal Varimax rotation (Table 6). The Kaiser-Meyer-Olkin (KMO) measure was 0.519, indicating that the data were adequate for Exploratory Factor Analysis (EFA). Bartlett's test of sphericity (χ^2 (45) = 113.252, $p < 0.05$) confirmed patterned relationships among variables (Table 5). The Scree plot supported the retention of three principal components. PCA classified the data into three principal components (PC1, PC2, and PC3), which together accounted for 90.78% of the total variance (Table 6). PC1 accounted for 59.50% of the total variance and was strongly loaded with Zn, Pb, Cu, Ni, SO_4^{2-}, and Cl^-. These elements primarily originates from traffic and vehicular emissions, chemical and solvent usage, waste burning, lubricating oils, diesel fuel, and tyre and brake wear (Men *et al.,* 2020; Heidari *et al.,* 2021; Duan *et al.,* 2017). PC 2 accounted for 20.28% of the variance and included Pb, SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-}, and $C_2O_4^{2-}$, which arise from both anthropogenic activities and organic sources, including plant and microbial contributions, textiles , microplastics, and construction materials (Men *et al.*, 2020; Martin *et al.,* 2020; Kohri *et al.,* 2019; Ika *et al.,* 2024). PC3 accounted for 11.01% of the variance and was primarily loaded with NO_3^-, derived from wastewater, and sewage disposal (Wang *et al.,* 2021; Rehman *et al.,* 2018).

Table 5: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	**0.519**
Approx. Chi-Square	113.252
Bartlett's Test of Sphericity Df Sig.	45
	0.000

Table 6: The Rotated Component Matrix (PCA - Based Approximation)

HM/IS	**PC1**	**PC2**	**PC3**
Zn	0.680	0.356	0.479
Pb	0.818	0.516	0.132
Cu	0.916	0.259	0.170
Ni	0.879	0.094	0.254
Cd	0.057	-0.024	1.000
SO_4^{2-}	0.643	0.737	-0.032
Cl^-	0.594	0.537	-0.221
NO_3^-	0.262	0.189	0.907
CO_3^{2-}	0.348	0.713	0.023
$C_2O_4^{2-}$	0.083	0.940	0.342
Eigenvalues	6.54	2.23	1.21
% of Variance	59.50	20.28	11.01
% of cumm. Variance	59.50	79.78	90.78
SOURCES	traffic/vehicular, chemical/solvent usage, burning of wastes, lubricating oil, diesel fuel, tire, and brake wear.	traffic/vehicular, chemical/solvent usage, Organic sources (plants, microbes), Textiles, microplastics,waste disposal Construction materials.	wastewater, and sewage disposal

Extraction Method: Principal Component Analysis

Cluster Analysis

The bi - plot suggests that there are three clusters groups. Clusters 1, 2, 3 are SO_4^{2-}, $CO_3^{2-}$and NO_3^- , Cu, Ni, Cd, C_2O^{2-} and Cl^-; Zn and Pb . This is observed in the dendogram (Figure 6). The 3D Rotated Component plot of heavy metals and ionic species in the study area is shown in (Figure 7).

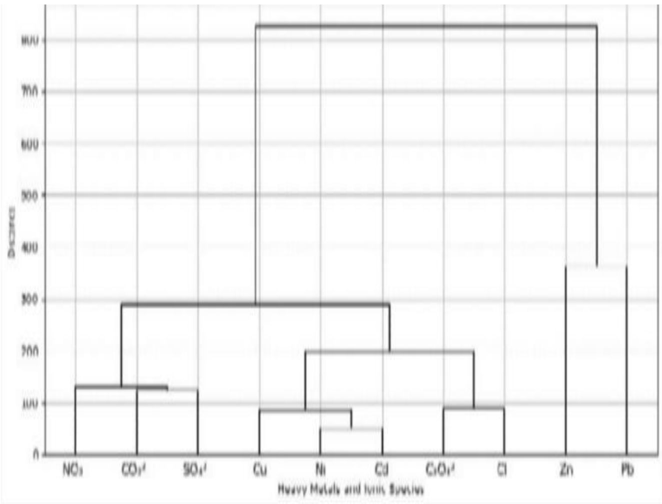

Figure 6. Dendogram of the Components

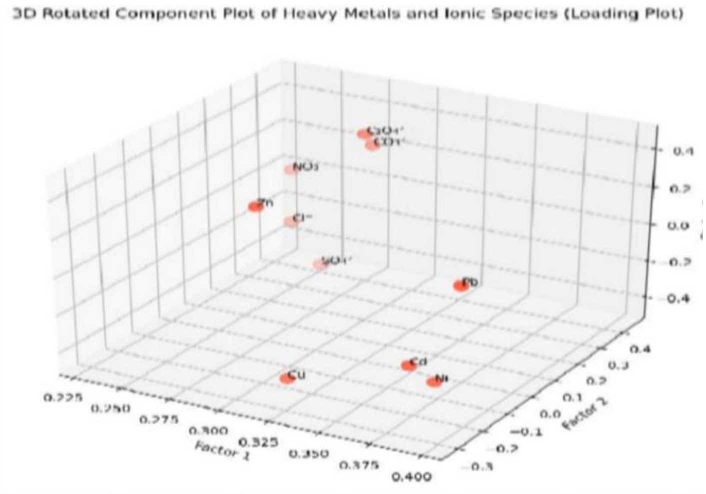

Figure 7: 3D Rotated Component of Heavy Metals and Ionic Species

Correlation Coefficient Analysis

Pearson's correlation analysis was conducted to assess the relationships between heavy metals, ionic species, and their possible pollution sources in road dust samples. Table 7, shows the correlation coefficients, significance levels, and total observations. The correlation coefficients ranged from -0.236 to 0.927, where the sign indicates the direction of the relationship and the magnitude reflects its strength. Most relationships among Zn, Pb, Cu, Cd, Ni, SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-}, and $C_2O_4^{2-}$ were positive, suggesting common anthropogenic sources and interdependence among the pollutants. The weakest correlations occurred between Cd and Cl^- and between Cd and CO_3^{2-}. Many positive correlations were statistically significant at the 0.05 level, indicating strong associations among the contaminants (Suresh *et al.,* 2012; Wang *et al.,* 2021; Enuneku *et al.,* 2017).

Table 7: Correlation Analysis

Heavy metals/Ionic species	Zn	Pb	Cu	Ni	Cd	SO_4^{2-}	Cl^-	NO_3^-	CO_3^{2-}	$C_2O_4^{2-}$
Zn	1.000									
Pb	0.768	1.000								
Cu	0.794	0.903	1.000							
Ni	0.758	0.796	0.907	1.000						
Cd	0.485	0.198	0.224	0.309	1.000					
SO_4^{2-}	0.672	0.927	0.736	0.601	0.014	1.000				
Cl^-	0.543	0.748	0.616	0.458	-0.236	0.858	1.000			
NO_3^-	0.729	0.429	0.412	0.456	0.926	0.306	0.104	1.000		
CO_3^{2-}	0.505	0.651	0.537	0.444	-0.004	0.728	0.482	0.203	1.000	
$C_2O_4^{2-}$	0.553	0.594	0.402	0.251	0.346	0.701	0.473	0.498	0.774	1.000
Mean	155.9	110.14	65.47	37.84	4.25	115.1	49.265	12.13	57.39	10.64
SD	144.74	143.280	452.32	12.81	33.22	8.45	70.63	47.74	5.79	108.9

CONCLUSION

This research results revealed that Zinc (Zn)- 1710.86 mg/kg has the highest concentration among the heavy metals, followed by lead (Pb)-1210.55 mg/kg, copper (Cu) - 720.28 mg/kg, nickel (Ni) - 416.25 mg/kg, and cadmium (Cd) - 48.73 mg/kg. The high levels of these metals may be due to activities such as vehicular emissions, waste incineration, construction operations, organic waste disposal, and the use of chemicals and solvents. Locations outside the study area, such as Unilag Junction, Abudu Street, Akoka Street, and the front gate, recorded higher contamination levels compared to areas within the campus such as the Faculty of Arts and the Sport Centre, where lower concentrations reflected reduced anthropogenic influence. Since, the concentrations of heavy metals is beyond the permissible standards set by WHO / FAO, USEPA and NESREA, the continuous accumulation of these contaminants in the dust may present serious long-term environmental and public health risk. Sulphate (SO_4^{2-}) - 1266.62 mg/kg was the most dominant ionic species, followed by carbonate (CO_3^{2-}) - 629.31 mg/kg, chloride (Cl^-) - 541.84 mg/kg, nitrate (NO_3^-) - 133.44 mg/kg, and oxalate ($C_2O_4^{2-}$) - 116.05 mg/kg. These ions are likely from sources such as fossil fuel combustion, sewage discharge, wastewater contamination, microplastic degradation, and chemical - related activities. The principal component analysis (PCA) identified three major factors accounting for 90.78% of the total variance, strongly associating the pollutants with human activities such as, traffic/ vehicular emission, chemical/ solvent usage, burning of wastes, lubricating oil, diesel fuel, tire, brake wear , oil leakage, construction materials, microplastic pollution, and other organic inputs.

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REFERENCES

Aguilera, A., Armendariz, C., Quintana, P., Garcia - Oliva, F., & Bautista, F. (2019). Influence of land use and road type on the elemental composition of urban dust in a Mexican metropolitan area, Polish Journal of Environmental Studies, 28; 1535 - 1547. https://doi.org/10.15244/pjoes/90358

Amato, F., Alastuey, A., De La Rosa, J., Gonzalez Castanedo, Y., Sánchez de la Campa, A.M., Pandolfi, M.,Lozano, A., Contreras González, J., & Querol, X. (2014). Trends of road dust emissions contributions on ambient air particulate levels at rural, urban and industrial sites in southern Spain, Atmos. Chem. Phys, 14; 3533 - 3544. https://doi.org/10.5194/acp-14-3533-2014

APHA. (2017). Standard Methods for the Examination of Water and Wastewater (23rd ed.). American Public Health Association.

Awang, S. E., Nurmaya, A., Sofatunida, T. H., & Fauzi., M. A. J. (2025). Analysis of illegal gold mining (PETI) impact on the environment with TDS, TSS, mercury and cyanide parameters in water and sediment of Cikaniki River. Aceh Int. J. Sci. Techn., 14(1), 74 - 83. https://doi.org/10.13170/aijst.14.1.43432

Budai, P., & Clement, A. (2018). Spatial distribution patterns of four traffic - emitted heavy metals in urban Road dust and the resuspension of brake - emitted particles: Findings of a field study, Transp. Res. D Transp. Environment, 62; 179 - 185. https://doi.org/10.1016/j.trd.2018.04.001

Duan, Z. B., Wang, J., Zhang, Y. X., & Xuan, B. (2017). Assessment of Heavy Metals Contamination in Road Dust from Different Functional Areas in Guiyang, Southwest, China , International Journal of Environment, Science and Education, 12; 27 - 439.

Enuneku, A., Biose, E., & Ezemon ye, L. (2017). Levels, distribution, characterization and ecological risk assessment of heavy metals in road side soils and earthworms from urban high traffic areas in Benin metropolis, Southern Nigeria, Journal of Environment, Chemical Engineering, 5(3); 2773. https://doi.org/10.1016/j.jece.2017.05.030

Foti, L.,Dubs, F., Gignoux, J. , Lata, J., Lerch, T. Z., Mathieu, J., Nold, F.,Nunan, N., Raynaud, X., Abaddie, L. & Barot, S. (2017). Trace element concentrations along a gradient of urban pressure in forest and lawn soils of the Paris region (France), *The* Science of the Total Environment, 598; 938 - 948. https://doi.org/10.1016/j.scitotenv.2017.04.099

Ghosh, S., and Das, S. (2014). Evaluation of Heavy Metals and Ionic Species in Road Dust from Kolkata, India, Journal: Environmental Science and Pollution Research, 21(10): 6617-6627.

HACH (2020). DR 6000 Spectrophotometer User Manual, HACH Company.

Hazem, A. S., Ibrahim, H., Saleh, E. A. Shalaby, Z. F., Ghatass, A.R., Shatat, Mohamed, E., & Esraa, H. A. (2025). Assessment of heavy metals in total suspended particles and deposited dust in different areas in Assiut city. Egypt Scientific Reports, 15, 32574 1. https://doi.org/10.1038/s41598-025-18697-1

Hegazy, A.M.S., & Fouad, U. A. 2019. Evaluation of lead hepatotoxicity; histological, histochemical and ultrastructural study. Forensic Med. Anat. Res. 02 (03): 70 - 79.

Heidari, M., Darijani, T., Alipour, V. "Heavy metal pollution of road dust in a city and its highly polluted suburb; quantitative source apportionment and source - specific ecological and health risk assessment", *Chemosphere,* 273; 2021,29656

Ichiyama, A., Nakai, E., Funai, T., Oda, T., & Katafuchi, R. (1985). Spectrophotometric determination of oxalate in urine and plasma with oxalate oxidase. Journal of Biochemistry, 98 (5), 1375 - 1385. https://doi.org/10.1093/oxfordjournals.jbchem.a135405

Ika, S., & Saiful, I. (2024). Microplastics in Landfill Environments: Distribution, Characteristics, and Risks from Gampong Jawa, Indonesia. Aceh International Journal of Science and Technology 13(2): 131-148. https://doi.org/10.10.13170/aijst.13.2.42344. Copyright: © 2024 by Aceh International Journal of Science and Technology.

Jiao, X., Yingze, T., Chunlei, Cheng., Chuang, W., Qiuju, L., Mei, L.,, Xiaofei, W., & Guoliang, S. (2020). Characteristics and source apportionment of ambient single particles in Tianjin, China", The close association between oxalic acid and biomass burning. Atmospheric Research. Science Direct, 237; 104843. https://doi.org/10.1016/j.atmosres.2020.104843

Jreije, M., Gorgy, K., & Helal, N. (2022). Assessment of heavy metals in urban dust using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and risk evaluation, Environmental Science and Pollution Research, 29(12); 17500 - 17515. https://doi.org/10.1007/s11356-021-18162-5

Kara, M. (2020). Assessment of sources and pollution state of trace and toxic elements in street dust in a metropolitan city. Environ. Geochem. Health, 42 (10): 3213.

Kohri, K., Moriyama, M.,& Kitamura, M. (2019). Dietary oxalate and kidney stone formation, Mechanisms and prevention strategies. Urological Research, 47(1): 37- 45.

Lu, X., Wu, X., Wang, Y., Chen, H., Gao, P., & Fu, Y. (2014). Risk assessment of toxic metals in street dust from a medium - sized industrial city of China, Ecotoxicology Environment Saf, 106: 154 - 163.

Lu, X., Zhang, X., Li, L. Y., & Chen, H.(2019). Assessment of metals pollution and health risk in dust from nursery schools in Xi'an, China, Environmental Research, 157;118 - 127. https://doi.org/10.1016/j.envres.2017.05.014 https://doi.org/10.1016/j.envres.2017.05.014

Martin, J., Cooper, P., & Collins, D. (2020). Biogenic oxalate production in fungi and lichens: Environmental and physiological roles, Fungal Biology Reviews, 34(2); 89 - 103. https://doi.org/10.1016/j.fbr.2020.01.002

Men, C., Liu, R., Xu, L., Wang, Q., Guo, L., Miao, Y., & Shen, Z.(2020). Source - specific ecological risk analysis and critical source identification of heavy metals in road Dust in Beijing China, Journal of Hazard Materials, 388. https://doi.org/10.1016/j.jhazmat.2019.121763

Men, C., Liu, R., Xu, F., Wang, Q., Guo, L., & Shen, Z.(2018). Pollution characteristics, risk assessment, and source apportionment of heavy metals in road dust in Beijing, China, The Science of the Total Environment, 612; 38 - 147. https://doi.org/ 10.1016/j.scitotenv.2017.08.123.

Misiewicz, B., Mencer, D., Terzaghi, W., & VanWert, A.L.(2023). Analytical methods for oxalate quantification: The ubiquitous organic anion. Molecules, 28(7), https://doi.org/10.3390/molecules28073206.

Mohamed, Y. H., Andrian, A. S., Ilia, V. Y., Georgy, M., Elizaveta ,Y. K., Mohammed, S. A., & Ahmed, K. S.(2023). Heavy metal contamination levels, source distribution, and risk assessment in fine sand of urban surface deposited sediments of Ekaterinburg, Russia Environ, Geochemical Health , 45(7); 438 - 4406. https://doi.org/ 10.1007/s10653-023-01494-y.

NESREA(2025). National Environmental Standards and Regulations Enforcement Agency. National environmental standards and regulations. NESREA Press.

Nguyen, M.H., Huynh., T, K,N., Ha, T. L., & Pham , T. T.(2023). Utilizing X - ray fluorescence (XRF) method to evaluate the content of metal elements in soil and their effects on the total phenolic and flavonoid contents of some medicinal plants, Environmental Monitoring and Assessment, 195(8); 963. https://doi.org/10.1007/s10661- 023-11585-z

Ogunyinka, S. E., & Adedeji, A. M. (2017). Assessment of Heavy Metal Contamination in Road Dust of Lagos, Nigeria, Environmental Science and Pollution Research, 24(6); 5619 - 5627.

Ojiodu ,C. C., Eruola, E. G. Olumaye de, E. G., Moses, D U., & Ikegwu, E. M. (2026). Appraising Heavy metals and Ionic species in road dust of Yaba College of Technology Campus and Environs. Fulafia Journal of Science & Technology, Vol. 10, No. 1. 172 - 187.

Ojiodu, C. C., Eruola, A. O., Olumayede, E. G., Moses, D. U., Ikegwu, E. M., & Ashiru, A.W. (2026). Potential Toxic Metals (PTMs) Pollution of underground water (Well water) in Ijora -Badia area of Lagos - State, Southwestern-Nigeria. FUDMA Journal of Sciences (FJS) Vol. 10 No. 1, January, 2026, pp 259 - 268. https://doi.org/10.33003/fjs-2026-1001-4547

Ojiodu, C. C., Olumayede, E.G., Eruola, A.O., Ashiru, A. W., Moses, D.O., Olaleru, S. A., & Oyebamiji, O.O. (2024). Characteristic distribution and Source apportionment of some heavy metals in street dust of Ikorodu area of Lagos state, Southwestern Nigeria, Fulafia Journal of Science and Technology(FJST), 8(2); 23 - 34 ISSN (Print): 2449- 6954 | ISSN (Online): 2636 - 4972. https://doi.org/ https://doi.org/10.62050/fjst2024.v8n2.323

Ojiodu, C. C., Olumayede, E. G., & Okuo, J. M. (2018). The level of heavy metals in the atmosphere of a microenvironment, Lagos state, southwestern - Nigeria using Moss plant (Dicranium scorparium) as Bioindicator, Science World Journal, 13(4); 69 - 74.

Oliveira, M., Pinto, E., Ferreira, I. M. P. L. V. O., & Correia, D. M. (2020). Cadmium, lead, and copper content of water and vegetables from urban markets in Portugal, Food Additives and Contaminants: Part B, 13(1); 9 - 14. https://doi.org/10.1080/19393210.2019.1657973

Pettucci, C., Zelenin, A., Culver, J. A., Gabriel, M., Kirkbride, K., Christison, T. T., & Gardell, S. J.(2016).Use of Ion Chromatography/Mass Spectrometry for Targeted Metabolite Profiling of Polar Organic Acids, Analytical Chemistry, 88(23); 11799 - 11803. https://doi.org/10.1021/acs.analchem.6b03165

Praveena, S. M.(2019). Characterization and risk analysis of metals associated with urban dust in Rawang (Malaysia),Arch. Environ. Contamination and Toxicology, 75; 415 - 423. https://doi.org/10.1007/s00244-018-0584-4

Querol, X., Viana, M., Alastuey, A., Amato, F., Moreno, T., Castillo, S., Pey, J., De la Rosa, J., De La Campa, A.S., Artíñano, B., & Salvador, P. (2007). Source origin of trace elements in PM from regional background, urban and industrial sites of Spain, Atmospheric Environment, 41; 7219 - 7231. https://doi.org/10.1016/j.atmosenv.2007.05.022

Rahman, M. S., Khan, M. D. H., & Jolly, Y. N., Kabir, J., Akter, S., & Salam, A.(2019). Assessing risk to human health for heavy metal contamination through street dust in the Southeast Asian Megacity: Dhaka, Bangladesh, The Science of the Total Environment, 660; 1610 - 1622. https://doi.org/10.1016/j.scitotenv.2018.12.425

Ramírez, O., de la Campa, A.S., Amato, F., Catacolí, R.A., Rojas, N.Y., & de la Rosa, J. (2018).Chemical composition and source apportionment of PM10 at an urban background site in a high - altitude Latin American megacity (Bogota,Colombia), Environmental Pollution, 233; 142 - 155. https://doi.org/10.1016/j.envpol.2017.10.045

Rehman, K., Fatima, F., Waheed, I., & Akash, M. S. H. (2018). Prevalence of exposure to heavy metals and their impact on health consequences. Journal of Cellular Biochemistry, *119*(1), 157-184.

Reyes, B.A., Bautista, F., Goguitchaichvili, A., Contreras, J.J. M., Owen, P.Q., Carvallo, C., & Battu, J.(2013). Rock-magnetic properties of topsoils and urban dust from Morelia (> 800,000 inhabitants), Mexico: Implications for anthropogenic pollution monitoring in Mexico's medium size cities, Geofis. Int. 52; 121 - 133.

Rodriguez, E., McDonough, W. F., & Reynolds, B. C.(2019). Applications of Laser Ablation ICP - MS in Environmental and Biological Samples, TrAC Trends in Analytical Chemistry, 112; 235-247. https://doi.org/10.1016/j.trac.2019.12.015

Saghatelyan, A., Sahakyan, L., Belyaeva, O. , & Maghakyan, N. (2014).Studying atmospheric dust and heavy metals on urban sites through synchronous use of different methods. J. of Atmos. Pollution, pp. 12 - 16.

Sahakyan, L., Maghakyan, N., Belyaeva, O., Tepanosyan, G.,Kafyan, M., & Saghatelyan, A. (2014). Heavy metals in urban dust: Contamination and health risk assessment: A case study from Gyumri, Armenia, Arabian Journal of Geoscience, 9; 142. https://doi.org/10.1007/s12517-014-1423-0

Shaapera, U., Nnamonu, U.L., & Eneji, I. S. (2023). Assessment of Heavy Metals in Ranaesculentaorgans from river Guma, Benue State Nigeria. Am. J. Anal. Chem, 4: 496 – 500

Shabbaj, I. I., Alghamdi, M.A., Shamy, M., Hassan, S. K., Alsharif, M. M., & Khoder, M. I. (2018). Risk Assessment band Implication of Human Exposure to Road Dust Heavy Metals in Jeddah, Saudi Arabia. International Journal of Environment. Res. Public Health. 15, 36.

Soltani, N., Keshavarzi, B., Moore, F., Tavakol, T., Lahijanzadeh, A.R., Jaafarzadeh, N., & Kermani, M.(2015). Ecological and human health hazards of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in road dust of Isfahan metropolis, Iran, The Science of the Total Environment, 505; 712 -723. https://doi.org/10.1016/j.scitotenv.2014.10.047

Suresh, H.N., Mahalingam, C.A., and Pallavi., (2012). Amount of chitin, chitosan and chitosan based on chitin weight in pure races of multivoltine and bivoltine silkworm pupae Bombyx mori L. International Journal of Science and Nature, 3(1): 214 - 216. ISSN 2229 - 6441.

Tanner, P., Lingma, H., & Yu, P. K. N.(2008). Fingerprinting metals in urban street dust of Beijing, Shanghai and Hong Kong, Environment Science and Technology, 42; 7111 - 7117. https://doi.org/10.1021/es800761e

Tariq, A., Lee, Y., Roosa, K., Blumberg, S., Yan, P., Ma, S., & Chowell, G. (2020). Real-Time Monitoring the Transmission Potential of COVID-19 in Singapore, BMC Medicine, 18(166); https://doi.org/10.1186/s12916-020-01615-9

Trujillo - Gonzalez, J. M., Torres - Mora, M. A., Keesstra, S., Brevik, E. C., & Jimenez - Ballesta, R.(2016). Heavy metal accumulation related to population density in road dust samples taken from urban sites under different land uses, The Science of the Total Environment, 553; 636 - 642. https://doi.org/10.1016/j.scitotenv.2016.02.101

(USEPA). (2020). United States Environmental Protection Agency. Regional screening levels (RSLs) for chemical contaminants at superfund sites. U.S. Environmental Protection Agency. https://www.epa.gov/risk.

Vallero, D. A. (2025). Fundamentals of air pollution (6th ed., Vol. 1). Academic Press.

Valotto, G., Rampazzo, G., Visin, F., Gonella, F., Cattaruzza, E., Glisenti, A., Formenton, G., & Tieppo, P. (2015). Environmental and traffic - related parameters affecting road dust composition: a multi – technique approach applied to Venice area (Italy). Atmospheric Environment. 2(8):596 - 608.

Wahab, N. A. A., Fairus, M. D., Norain I., Siti, M. S., & Nur, F. M. H. (2012). Heavy metal concentration of settled surface dust in residential building. The Malaysian Journal of Analytical Sciences, 16 (1), 18 - 23.

Wang, W., Xu, X., Zhou, Z., Dong, X., & Tian, T. A.(2022). Joint method to assess pollution status and source-specific human health risks of potential toxic elements in soils, Environmental Monitoring and Assessment, 194; 685. https://doi.org/10.1007/s10661-022-10378-5

Wang, Y., Guo, G., Zhang, D., & Lei, M.(2021).An integrated method for source apportionment of heavy metal(loid)s in agricultural soils and model uncertainty analysis, Environmental Pollution, 276; 116666. https://doi.org/10.1016/j.envpol.2020.116666

Wei, B., Jiang, F., Li, X., & Mu, S.(2009). Spatial distribution and contamination assessment of heavy metals in urban road dusts from Urumqi, NW China, Microchemical Journal, 93; 147 - 152. 10.1016/j.microc.2009.06.001.

Wise, S.S., Holmes, A.L., Ketterer, M.E., Hartsock, W.J., Fomchenko, E., & Katsifis, S.P. (2017). Chromium is the proximate clastogenic species for lead chromate - induced clastogenicity in human bronchial cells. Mutation Research, 560:79 - 89.

World Health Organization & Food and Agriculture Organization of the United Nations. WHO/FAO.(2020). Guidelines for the safe use of wastewater, excreta and greywater (3rd ed.).WHO Press.

Xu, Z., Mi, W. B., Mi, N., Fan, X. G., Zhou, Y., & Tian, Y. (2020). Characteristics and sources of heavy metal pollution in desert steppe soil related to transportation and industrial activities. Environment Science Pollution Research, 27(31): 1 - 14.

Yu, Y., Ma, J., Song, N., Wang, X., Wei, T., Yang, Z., & Li, Y. (2016). Comparison of metal pollution and health risks of urban dust in Beijing in 2007 and 2012. Environmental. Monitoring Assessment, 188: 1 - 11.

Zhang, C., Qiao, Q., Appel, E., & Huang, B. (2012). Discriminating sources of anthropogenic heavy metals in urban street dusts using magnetic and chemical methods, Journal Geochemical. Exploration. 60-75, 119 - 120. https://doi.org/10.1016/j.gexplo.2012.06.004

Zhao , Y., Miao,Q., Shi, H., Li, X, Yan, J., Yang, S., Hou C., Yu, C., Feng, W., & Hao, J. (2025). Inversion of soil salinization at the branch canal scale in the Hetao Ireogation District based on improved spectral \indices. Agricultural Water Management, Science Direct, 316: 109608.

Zhe, X., Wenbao, M., Nan, M., Xingang, F., Ying, T., Yao, Z., & and Ya - nan, Z.(2021). Heavy metal pollution characteristics and health risk assessment of dust fall related to industrial activities in desert steppes. Peer J. 9, pp. 1 - 26. https://doi.org/10.7717/peerj.10585