FULafia Journal of Science & Technology
ISSN (print) 2449-0954 \ ISSN (online) 2636-4972
https://lafiascijournals.org.ng/index.php/fjst
Sponsored By TETFUND TERTIARY EDUCATION TRUST FUND
Manuscript => Received: Dec., 2025; Accepted: Feb., 2026; Published: March, 2026 https://doi.org/10.62050/fjst2026.v10n1.695

APPRAISING HEAVY METALS AND IONIC SPECIES IN ROAD DUST OF YABA COLLEGE OF TECHNOLOGY CAMPUS AND ENVIRONS, LAGOS - NIGERIA

C. C. Ojiodu[1]*, A. O. Eruola[2], E. G. Olumayede[3], D. U. Moses[1] and E. M. Ikegwu[4]
[1]*College Central Research Laboratory, Yaba College of Technology, Yaba - Lagos, Nigeria*
[2]*Department of Chemical Sciences, Yaba College of Technology, Yaba - Lagos, Nigeria*
[3]*Department of Industrial Chemistry, Federal University, Oye - Ekiti, Nigeria*
[4]*Department of Statistics, Yaba College of Technology, Yaba - Lagos, Nigeria*
*Corresponding email: ojioducc@yahoo.com

ABSTRACT
This study reports 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 within Yaba College of Technology and its surrounding environment in Lagos State, Nigeria. 44 dust samples were collected from January to June 2025, four times a month across eleven locations. Road dust were swept using a hand brush into plastic parkers and transferred into sterile valves. Samples were sieved through a 75-µm stainless steel mesh, weighed, and digested with nitric (HNO_3) and sulphuric (H_2SO_4) acids. Heavy metal concentrations were determined with an inductively coupled plasma-optical emission spectrometer (ICP-OES), while ionic species were analyzed using standard Analytical methods and procedures. The percentage contributions of contaminants were: Zn - (60.63%), Pb - (22.42 %), Cu (8.75 %), Cd -(1.01 %), Ni - (7.19 %); and among ionic species: SO_4^- -(42.62 %), NO_3^- -(21.90 %), Cl^- -(12.07 %), CO_3^{2-} -(16.32 %), and $C_2O_4^{2-}$ -(7.09 %). Zinc -(1434.69 mg/kg), showed the highest metal concentration, whereas Cadmium - (23.89 mg/kg) had the lowest. Sulphate -(841.38) was the most abundant, while Oxalate- (139.89 mg/kg) was least. Principal Component Analysis (PCA) identified three components accounting for 86.68 % of the total variance, indicating anthropogenic influence. Pearson correlation analysis revealed significant positive relationship ($p < 0.05$) between metals and ionics species. Concentrations of Zn, Pb, Ni, and Cu exceeded limits set by the Federal Ministry of Environment, the European Communities, and United Nations Environmental Programme, confirming pollution in the study area.

Keywords: Pollution, Dust, Anthropogenic, Sample, Contamination, Heavy metals

INTRODUCTION
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 of Yaba College of Technology and neighboring areas in Lagos State, Southwestern Nigeria, are suspected to exceed permissible limits, posing significant environmental concerns. This makes the current study necessary. Dust is a collection of fine particles of solid matter, consisting of heavy metals, minerals, organic materials, ionic species, and anthropogenic pollutants. These pollutants originate from both natural processes and anthropogenic activities such as industrial emissions, fossil fuel combustion, vehicular exhaust, and urban construction (Shi *et al.*, 2022; Ali *et al.*, 2017). Dust plays a dual role as source and sink for heavy metals and ionic species in the environment, particularly in urban air and soil (Men *et al.*, 2020). There are various methods of sampling dust which include the use of: a plastic dustpan and a brush (Wei *et al.*, 2009; Aguilera *et al.*, 2019; Praveena, 2019) a plastic hand broom and dustpan (Soltani *et al.*, 2015), brushing 1 m^2 of previously delimited surface of asphalt (Reyes *et al.*, 2013) portable aspirator (Sahakyan *et al.*, 2014; Saghatelyan *et al.*, 2014), a brush and plastic hand shovel (Trujillo - Gonzalez *et al.*, 2016) , a vacuum cleaner (Yu *et al.*, 2016; Tanner *et al.*, 2008) portable high-pressure washer device with a piston fitted into a rigid, sealed rubber dome (Budai *et al.*, 2018).

Heavy metals may refer to any metallic substance with relatively high density such substances are toxic even at low concentrations. They are naturally occurring elements that are found in the earth's crust, they are mostly environmental, domestic and agricultural contaminants (Herawati *et al.*, 2000; He *et al.*, 2005). Examples of heavy metals include Zinc (Zn), Nickel (Ni), Copper (Cu), Mercury (Hg), Cadmium (Cd), Chromium (Cr), Thallium (Tl) and Lead (Pb). Heavy metals are group of non - biodegradable pollutants. They cannot be degraded or destroyed. Heavy metals are dangerous because they tend to bio-accumulate (Bawuro *et al.*, 2018). Heavy metals enter the human body through **i**nhalation, **i**ngestion and dermal contact (Faisal *et al.*, 2021; Zgłobicki *et al.*, 2021; Smith *et al.*, 2022). Heavy metals in dust originates from different sources such as industrial emissions, vehicular emissions, construction and demolition activities, agricultural practices (Zhang *et al.*, 2020; Tang *et al.*, 2020; Chen *et al.*, 2021). Lead

exposure is linked to respiratory problems, cardiovascular diseases, and neurological damage, including cognitive decline and an increased risk of neurodegenerative disorders like Alzheimer's and Parkinson's (Landrigan *et al.*, 2020). Cadmium modifies epigenetics (DNA methylation, histone changes) and activates cancer pathways (NF-κB, MAPK), increasing risks of lung, prostate, and kidney cancers (IARC, 2021). Long-term excessive exposure has been linked to immune dysfunction and neurological disorders due to disruption of essential trace element homeostasis (King *et al.*, 2021). Chronic inhalation of nickel compounds can cause respiratory complications including lung fibrosis and significantly elevates risks for lung and nasal cancers, as classified by the International Agency for Research on Cancer (IARC, 2020). Acute copper poisoning, typically from industrial environments, manifests as gastrointestinal distress, hepatic injury, and neurological symptoms including dizziness and cognitive impairment (Linder, 2020).

Ionic species are charged atoms or molecules, classified as cations (e.g. Zn^{2+}, Pb^{2+}) or anions (e.g. SO_4^{2-}, NO_3^{2-}, Cl^-, CO_3^{2-}, $C_2O_4^{2-}$). They are in particulate matter and contribute to environmental degradation (Xu *et al.*, 2020). Sulphates results from fossil fuel combustion contribute to acid rain (Wang *et al.*, 2022). Nitrates, formed from nitrogen oxides, impact respiratory health (Wang *et al.*, 2021). Chlorides originates from sea salt and industry, contribute to soil salinity (Zhao *et al.*, 2025) Carbonates stem from construction materials (Lu *et al.*, 2017) and oxalates, formed through photochemical reactions, are indicators of biomass burning (Jiao*et al.*, 2020). Several analytical techniques may be employed to analyzing heavy metals and ionic species which 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 with Mass Spectrometry (IC-MS) (Pettucci *et al.*, 2016) and Laser Ablation ICP-MS) (Rodriguez *et al.*, 2019).

Yaba College of Technology, established in 1947 is located in Yaba, Lagos State, stands as Nigeria's premier polytechnic institution. Situated in a busy commercial and educational district, the campus is bordered by major roads like Herbert Macaulay Way and lies about 7 kilometers from Lagos Island. Yaba College of Technology campus hosts academic buildings, laboratories, hostels, offices, recreational facilities, and green spaces, blending historic and modern architecture that reflects its evolution over time. Although, numerous studies have examined heavy metals and ionic species in dust in Lagos State, across Nigeria and other parts of the world (Wang et al., 2021; Chen et al., 2022; Owoeye & Owoeye, 2020; Ghosh & Das, 2014; Ogunyinka& Adedeji, 2017) there is limited literature(s) specifically focused on Yaba area. Notably, no existing research has been conducted on road dust of Yaba College of Technology campus and its surrounding environment in Lagos State, Nigeria. Yaba College of Technology Campus and Environs was chosen for the present study due to several factors: its strategic urban setting and the presence of diverse anthropogenic activities around it; it's proximity to major traffic routes and commercial zones; it's symbolic and institutional importance; accessibility and suitability for practical sampling; it's representativeness of urban dust composition; and it's relevance to public health and environmental quality (Hu *et al.*, 2020; L.A.S.G, 2020; Benhaddya *et al.*, 2016; Men *et al.*, 2019; Chen *et al.*, 2022; Lu *et al.*, 2014; Rahman *et al.*, 2019). Therefore, the objectives of the present study were to: (1) assess and evaluate the levels of heavy metals and ionic species in road dust of Yaba College of Technology Campus and Environs; (2) determine the degree of accumulation and characteristic distribution of the heavy metals and ionic species; (3) determine whether there is a significant difference in the levels of heavy metals and ionic species from one location to another within the study area; (4) determine the potential sources of heavy metals and ionic species.

MATERIALS AND METHODS

Study Area and Sampling Location

This study was conducted on road dust of Yaba College of Technology Campus and Environs, Lagos - State, Southwestern - Nigeria. (N $6^0$30' 58.75884 and E 3^0 22' 34.51656 and N $6^0$32' 1.21668 and E 3°22' 6.62484). The study area include: Yabatech front gate roundabout, Hollywood hostel, Back gate library, Food village, First bank roundabout, Automobile, Yabatech Junior school, Military hospital Gate, Jibowu filling station, Shomolu market and Epe - Ijebu ode road were used as control site (Figure 1).

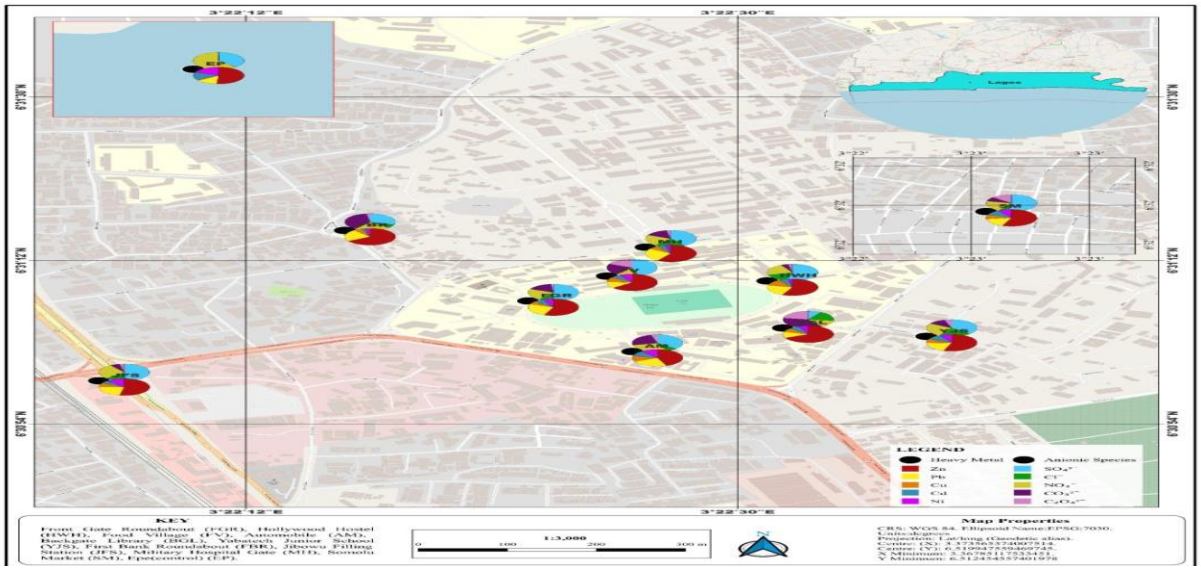

Figure 1: GIS Map showing the sites and concentrations of heavy metals and ionic species in the study area

Table 1: Sampling sites, characteristics and coordinates of Yaba College of Technology campus and environs, Lagos State, Southwestern - Nigeria

S/N	Location	Codes	Co-ordinates		Site description
			Latitude	Longitude	
1	Front gate roundabout	FGR	N6^{0}31'7.5504	E3^{0}22'22.33342	A major road with few traffic/vehicular activities.
2	Hollywood hostel	HWH	N6^{0}31'9.75396	E3^{0}22'31.08576	It is a residential area where student come to rest with generator emission
3	Food village	FV	N6^{0}31'10.28676	E3^{0}22'25.21036	A commercial area where various foods are cooked and sold. Photocopy and Printing activities also takes place
4	Automobile	AM	N6^{0}31'1.98048	E3^{0}22'26.14188	It is a mechanic workshop with high welding mechanic, galvanized metals and steel activities.
5	Backgate library	BGL	N6^{0}31'4.575	E3^{0}22'31.65672	It is a major road with high traffic and few vehicular activities.
6	Yabatech junior School	YJS	N6^{0}31'3.64584	E3^{0}22'36.90768	It is a commercial area, in front of it is a major road with high vehicular activities.
7	First bank roundabout	FBR	N6^{0}31'15.31272	E3^{0}22'15.62412	It is an area with high traffics/vehicular activities.
8	Jibowu filling station	JFS	N6^{0}30'58.75884	E3^{0}22'6.62484	This is a site with fuel emissions and a major road connected with high vehicular activities.
9	Military hospital gate	MH	N6^{0}31'13.47132	E3^{0}22'26.63076	It is a commercial area with different medical health departments such as (dentist, X-ray etc) with high vehicular activities.
10	Somolu market	SM	N6^{0}32'1.21668	E3^{0}22'34.51656	It is an area that has high vehicular activity and market areas.
11	Epe (control)	EP	N6^0.03052	E3^0.64452	It is a residential area with low anthropogenic activities.

Selection of Sampling Sites and Locations

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

Sampling and Sample Collection

Dust samples were collected from eleven sites within the study area, at least 100 m apart, four times a month (January-June), 2025. Samples were collected in the morning when dust has settled well throughout the night and before heavy morning traffic movement that can disrupt the dust. The samples were randomly collected from both sides of the road by sweeping surface dust into plastic waste packers using plastic brush and transferred into pre- labeled polythene bag (Aguilera *et al.*, 2019; Praveena, 2019; Rahman *et al.*, 2019). All irrelevant materials such as cigarette ends, papers, plastics etc. were carefully handpicked. Thereafter, samples collected at each location were filtered through 75 µm stainless steel sieve. The samples were taken to the laboratory for further treatment and analysis.

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 glassware 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 glassware was 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 e.g. Sulfaver 4 powder pillow, Potassium chromate indicator solution, Standard silver nitrate titrant 0.014M (0.014N), Standard sodium chloride 0.014M (0.014N), Aluminium hydroxide suspension (special reagent for remover of interference), Phenolphthalein indicator solution, Hydrogen peroxide 30 %, Nitraver 6 reagent powder pillow, nitraver 3 nitrite reagent powder pillow, Saturated $NaHCO_3$, NaOH , Distilled water , Hydrochloric acid, Bamboo powder, Sulfuric acid, Acetic acid, Phosphoric acid, Nitric acid, Calcium nitrate, ammonium acetate, Potassium chloride, De-ionized water, concentrated ammonium hydroxide (NH_4OH), used for the laboratory analysis were of analytical grade and purchased from Lazco Scientific in Lagos, Lagos State. Nigeria. Laboratory analysis was conducted in the Analytical Chemistry Laboratory of the College Central Research Laboratory, Yaba College of Technology, Yaba - Lagos, Nigeria.

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

Extraction reagents: 0.5M ammonium acetate, 0.25M acetic acid.

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

Procedure for Extraction

10 g of air dried sieved dust was weighed into an extraction vessel, 25 ml of extraction reagent was pipetted into the vessel and shaken for 30 minutes with shaker. About 0.15 g or ¼ teaspoon of powdered charcoal was added and shaken for an additional 3 minutes. 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(SO_4^{2-}) (Spectrophotometric - Turbidimetric Method)

The Spectrophotometer was turned on and allowed to run a full system check. The hack programs was touched and selected at 680 nm (for Sulphate). 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 minutes reaction was run and there was no interruption in the cell during the reaction period.

A second sample cell was filled with 10 ml 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_4^{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 0.01M $Ca(NO_3^-)_2.4H_2O$

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

10 g of air dried sieved street dust was weighed into a 50 ml Erlenmeyer flask, 25 mg 0.01M of $Ca(NO_3)_2.4H_2O$ 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: 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 h, filtered and diluted to 1 L with distilled water.

Standard Silver nitrate titrant 0.0141M (0.0141N): 2.395 g of $AgNO_3$ 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 0.0141M (0.0141N): 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: 125 g of aluminium potassium sulphate Alk(SO_4) was dissolved in 1 litre distilled water, and was warmed to 60 ºC and 55 ml of concentration ammonium hydroxide (NH_4OH) was added slowly with stirring and it was allowed to stand for about one hour (1 h) 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 pH range of 7 to 10. For adjustment, a pH 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:

$$mgCl^- / L \frac{(A-B)\,x\,N\,x\,35450}{ml\ sample}$$

A = ml titration for sample
B = ml titration for blank, and
N = Normality of $AgNO_3$ (HACH, 2000; APHA, 2017).

Extraction of Nitrate ion (NO_3^-) (Potassium Chloride (KCl) Salt Extraction Method)

Reagents used: Potassium chloride, deionized water.

Preparation of Extraction Reagent (2M KCl)

2M 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:

10 g of air dried and sieved dust was weighed into a 125 ml conical flask. 50 ml of extraction reagent was added and shaken 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_3^-) (Cadmium Reduction Colorimetric Spectrophotometric Method (HACH NitraVer® method, Program 351N)

Program '351N, 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 shaken 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. 10 ml of the sample was carefully poured at the expiration of the timer into a clean cuvette and ensured that Cadmium particles were 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 0.00Mg/l NO_3^- -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_3^- -N by 4.4 to get the total amount of NO_3^- (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. 10 ml of 3M HCl was added and the weight was also recorded. 2 g to 5 g of dried dust was transferred to the flask and the weight of the dust was recorded and transferred to the nearest 0.1 mg, the effervescene 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 h, 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).

$$CO_3^{2-}\% = \frac{(g)\,CO_2\ Lost\,(0.2727)}{(g)\,Air\ Dried\ Dust}\,x100$$

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

Descriptive and inferential statistical analyses were applied to the dataset, including the calculations of mean and standard deviation, Analysis of Variance (ANOVA), Kaiser Meyer Olkin (KMO) and Bartlett's tests, Principal Component Analysis (PCA), and Pearson's correlation analysis. Table 2 shows the mean ± standard deviation (mg/kg) of heavy metals and ionic species measured at the various sampling locations. Among the sites, AM exhibited the highest mean concentrations of Zn, Pb, Cu, and Ni, with values of 273.49 ± 66.98, 106.99 ± 32.42, 58.18 ± 14.40, and 30.81 ± 7.48 mg/kg, respectively. In contrast, the control site EP recorded the lowest concentrations of these metals. JFS showed the highest mean levels of Cd, Cl^-, and NO_3^-, whereas the control site EPE had the lowest value. The greatest SO_4^{2-} concentration was observed at SC, while EP recorded the minimum. FV exhibited the highest CO_3^{2-} concentration, and BGL recorded the highest $C_2O_4^{2-}$, with EP consistently showing the lowest levels for these ions.

Table 2: Mean and standard deviation of heavy metals and ionic species in the study area

Sample Site	Zn	Pb	Cu	Ni	Cd	CO_3^{2-}	SO_4^{2-}	NO_3^-	$C_2O_4^{2-}$	Cl^-
FGR	115.91	52.38	10.80	14.41	2.12	40.38	124.38	54.37	4.29 ±	22.26±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
AM	273.49	106.99	58.18	30.81	2.65	11.95	142.44	58.33	7.71 ±	40.66 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
BGL	100.39	19.38	14.87	10.59	1.48	45.13	94.59	24.10	36.67 ±	5.79 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
HWH	78.50	42.04	19.38	17.99	2.42	33.17	49.63	36.39	5.69 ±	9.53 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
FV	111.72	19.75	11.45	11.90	1.85	57.82	13.23	21.65	35.23 ±	29.55 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
YJS	95.14	33.78	13.41	17.12	2.18	13.80	45.47	32.30	5.93 ±	25.60 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
MH	122.74	41.87	10.01	4.71±	1.50	50.48	40.51	30.47	3.33 ±	9.39 ±
	±66.98	±32.42	±14.40	7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
FBR	141.32	59.29	20.46	14.44	2.29	13.55	112.54	65.31	7.11 ±	29.48 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
JFS	256.53	112.34	29.20	22.35	3.80	40.54	111.86	59.71	8.26 ±	53.88 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
SM	134.78	41.52	19.16	24.22	2.41	15.34	100.69	39.93	25.62 ±	12.19 ±
	±66.98	±32.42	±14.40	±7.48	±0.66	±17.24	±42.93	±15.89	13.17	15.39
EP	4.17±66.98	1.10±32.42	0.13±14.40	1.54±7.48	1.19±0.66	0.02±17.24	6.04±42.93	9.79±15.89	0.05±13.17	0.03±15.39

RESULTS AND DISCUSSIONS

Distribution of Heavy Metals in Dust of the Study Area

Tables 3 and 5 showed the percentage contributions of heavy metals and ionic species to pollution in the study area: Zn- 60.63%, Pb -22.42%, Cu -8.75%, Cd -1.01%, Ni-7.19%, SO_4^{2-} - 42.62%, NO_3^{2-} -21.90%, Cl^- -12.07%, CO_3^{2-} -16.32%, $C_2O_4^{2-}$ -7.09%. The most abundant heavy metal is Zn -1434.69 mg/kg while the least is Cd-23.89 mg/kg. The presence of Zn may arise from wearing of brake lining; corrosion of galvanized steel safety fence, wearing of tyres in the area, etc. There were significant difference in the levels of Zn in the study sites ($P \leq 0.05$). The low Cd concentrations may be as a result of burning of refuse in open space, agricultural activities such as application of pesticide and fertilizer, improper industrial waste disposal and smoking of tobacco (Querol *et al.*, 2007). The highest concentrations of Zn - 273.49 mg/kg, Pb -106.99 mg/kg, Cu- 58.18 mg/kg, and Ni-30.81 mg/kg respectively were recorded at AM. The highest concentrations of Cd-3.80 mg/kg was recorded at JFS. The least concentrations of Zn-78.5 mg/kg, Pb -19.38 mg/kg, Cd- 1.48 mg/kg, Cu-10.01 mg/kg, Ni - 4.71 mg/kg were recorded at HWH, BGL, BGL, MH, MH respectively (Table 3). Pb levels could be attributed to emissions from traffic/ vehicular activities. There were significant difference in the levels of Pb($P \leq 0.05$). The presence of Copper may be due to manufacturing of electrical cables, mining of metal, production of cans and the use of pesticides, combustion of fossil fuels, smelting of metals, vehicular emission, traffic congestion and industrial processes that uses these metals or their compounds (Table 3) (Amato *et al.*, 2014; Ramírez *et al.*, 2018; Men *et al.*, 2018; Foti *et al.*, 2017). There were significant differences in the levels of Cu in the study sites ($P \leq 0.05$). Presence of Cadmium might be due to the use of diesel

fuel, lubricating oil, tyre and brake wear, batteries, plastic and building materials (Men *et al.*, 2020; Heidari *et al.*, 2021; Duan *et al.*, 2017). There is no significant difference in levels of Cd in the study sites ($p > 0.05$). The concentration of Nickel at JFS may be as a result of fuel combustion from generators, diesel oil, fuel oil, incineration of waste and sewage as well as frequent burning of solid waste in the surroundings. There were no significant difference in the levels of Ni in the study sites ($p > 0.05$).The characteristic distribution and accumulation of heavy metals in the study area follows the trend: Zn > Pb> Cu > Ni > Cd. with the mean concentrations of - 130.43, 48.22, 18.82, 15.43 and 2.17 mg/kg respectively (Table 3). The results obtained in this study is similar to studies carried out by the following researchers (Jeong *et al.*, 2019; Ojiodu *et al.*, 2018; Xu *et al.*, 2020; Wang *et al.*, 2021). The levels of accumulation of heavy metals are as follows: AM- 19.95% > JFS-17.93 %> FBR- 10.05% > SM- 9.39% > FGR- 8.27% > MH- 7.64% > YJS-6.83% > HWH - 6.78% > FV -6.62% > BGL- 6.62% > EP- 0.34% (control) (Table 3). The high significant levels of Zn and Pb is an indication of their concentrations while the low concentrations of Copper, Nickel and Ni suggest low contributing factors to their spread and as well as dust inability to preferentially accumulate these metals. Zinc showed the highest concentration in road dust across the study areas when compared with levels reported globally. Although, the concentrations of Zn, Pb, Cu, Ni, and Cd in the study area are comparable to those recorded in some locations in Nigerian , they are generally higher than values reported from many cities worldwide (Table 4). These variations may be as a result of differences in vehicular and human activities such as waste burning and dumping, as well as disparities in environmental management practices, road-cleaning frequency, and local meteorological factors including rainfall, temperature, and wind speed which influence the distribution of heavy metals and ionic species. Heavy metal levels in the study area exceeded the permissible limits set by the Federal Ministry of Environment (FME), the European Communities (EC, 2006), and the United Nations Environment Programme (UNEP). Concentrations were also higher than those at the control site, likely because the control area experiences minimal anthropogenic influence (Table 3).

Table 3: Concentrations of heavy metals at the study sites (mg/kg)

Sample Sites/Codes	Zn	Pb	Cu	Ni	Cd	Average	%
FGR	115.91	52.38	10.80	14.41	2.12	195.60	8.27
AM	273.49	106.99	58.18	30.81	2.65	472.12	19.95
BGL	100.39	19.38	14.87	10.59	1.48	146.71	6.20
HWH	78.50	42.04	19.38	17.99	2.42	160.33	6.78
FV	111.72	19.75	11.45	11.90	1.85	156.67	6.62
YJS	95.14	33.78	13.41	17.12	2.18	161.65	6.83
MH	122.74	41.87	10.01	4.71	1.50	180.83	7.64
FBR	141.32	59.29	20.46	14.44	2.29	237.81	10.05
JFS	256.53	112.34	29.20	22.35	3.80	424.22	17.93
SM	134.78	41.52	19.16	24.22	2.41	222.08	9.39
EP(Control)	4.17	1.10	0.13	1.54	1.19	8.13	0.34
Total	**1434.69**	**530.44**	**207.05**	**169.73**	**23.89**	**2500.04**	**100**
Average	130.43	48.22	18.82	15.43	2.17	227.28	9.09
%	60.63	22.42	8.75	7.19	1.01	100.00	

Table 4: Comparison of heavy metals concentrations of the study area with other selected cities of the world (mg/kg)

City	Pb	Zn	Cu	Cd	Ni
Yaba College of Technology, Campus and Environs. (This study)	530.44	1434.69	207.05	23.89	169.73
Ikorodu (Ojiodu *et al.*, 2024)	533.34	2869.69	33.35	0.692	178.706
Ketu - Mile 12 (Ojiodu *et al.*, 2023c)	322.99	1767.09	1623.133	4.078	69.811
Oshodi - Isolo (Ojiodu *et al.*, 2023a)	1031.73	1445.43	242.77	6.99	78.47
Ikeja (Ojiodu *et al.*, 2023b)	1043.73	2449.53	328.97	33.10	88.09
Central China / Arid Desert (China) (Zhe *et al.*, 2021)	91.55	222.82	20.00	0.39	-
Shijiazhuang (China) (Kui *et al.*, 2019)	154.78	496.17	91.06	1.86	40.99
Xian(China) (Li *et al.*, 2015)	97.4	169.2	46.6	0.72	29.3
Shanghai (Korea) (Li *et al.*, 2015)	295	735	197	1.23	84
Chengdu (Korea) (Li *et al.*, 2015)	375	1117	244	4.4	88.1
Guizhou(Korea) (Duan *et al.*, 2017)	67.81	185.98	129.80	0.62	61.07
Shihwa (Japan) (Jeong *et al.*, 2017)	612	1824	992	2.22	164
Delhi (India) (Suryawanshi *et al.*, 2016)	120.7	284.5	191.7	2.64	36.4
South Africa (Olowoyo *et al.*, 2016)	754.3	304.6	157.2	2.54	74.3

The most polluted site is the Automobile workshop AM- 472.126 mg/kg while the least polluted site is Backgate library BGL-146.71 mg/kg. This could be due to traffic/vehicular, chemical /solvent usage, burning of wastes, lubricating oil, diesel fuel, tire, and brake wear, carbonate materials, construction materials, glass manufacturing, water treatment for pH regulation, and pharmaceutical applications, etc. (Figure 1). The trend and contributions of each site to dust pollution is as follows: AM > JFS > FBR- > FGR > SM > BGL > FV > MH> HWH > YJS (Tables 3 & 5).

Distribution of ionic species in dust of the study area

Sulphate SO_4^{2-} - (841.38 mg/kg) was the most abundant, while $C_2O_4^{2-}$ -(139.89 mg/kg) was the least. The high levels of SO_4^{2-} in the dust may be attributed to human and industrial activities such as chemical and solvent usage, sewage and agricultural runoff, concrete weathering, fossil fuel combustion, mining, and natural geological processes. Conversely, the low concentration of $C_2O_4^{2-}$ may results from limited natural production by plants, fungi, bacteria, and wastewater inputs. Statistical analysis revealed significant differences in SO_4^{2-} and NO_3^- levels across study sites ($p < 0.05$), whereas $C_2O_4^{2-}$ levels showed no significant variation. JFS - (13.89 %) recorded the highest pollution likely due to vehicular and human activities, while YJS- (6.24%) was the least . Maximum concentrations of SO_4^{2-} - (142.44 mg/kg), Cl^- -(53.88 mg/kg), NO_3^- - (65.31 mg/kg), CO_3^{2-} - (57.82 mg/kg), and $C_2O_4^{2-}$ - (36.67 mg/kg) occurred at AM, JFS, FBR, FV, and AM respectively, whereas minimum levels were observed at FV, MH, FV, AM, and MH (Table 5). The contributions of ionic species to dust pollution and accumulation follow the trend: $SO_4^{2-} > NO_3^- > CO_3^{2-} > Cl^- > C_2O_4^{2-}$. There were progressive increases in accumulation of heavy metals and ionic species (Tables 3 & 5). Contribution (ionic species) of each site to pollution follows the trend: AM > JFS > FBR > SM > FGR > MH > YJS > HWH > FV > BGL > EP (control) (Table 5).

Table 5: Concentrations of ionic species at the study sites (mg/kg)

Sample Sites	SO_4^{2-}	Cl^-	NO_3^-	CO_3^{2-}	$C_2O_4^{2-}$	Average	%
FGR	124.38	22.26	54.37	40.38	4.29	245.68	12.45
AM	142.44	40.66	58.33	11.95	7.71	261.09	13.23
BGL	94.59	5.79	24.10	45.13	36.67	206.28	10.45
HWH	49.63	9.53	36.39	33.17	5.69	134.41	6.81
FV	13.23	29.55	21.65	57.82	35.23	157.48	7.98
YJS	45.47	25.60	32.30	13.80	5.93	123.10	6.24
MH	40.51	9.39	30.47	50.48	3.33	134.18	6.80
FBR	112.54	29.48	65.31	13.55	7.11	227.99	11.55
JFS	111.86	53.88	59.71	40.54	8.26	274.25	13.89
SM	100.69	12.19	39.93	15.34	25.62	193.77	9.81
EP(Control)	6.04	0.03	9.79	0.02	0.05	15.93	0.81
Total	841.38	238.36	432.35	322.18	139.89	1974.16	100.02
Average	76.49	21.67	39.30	29.29	12.72	179.47	9.09
%	42.62	12.07	21.90	16.32	7.09	100	

Table 6: KMO and Battlet's test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.750
Approx. Chi-Square		106.52
Bartlett's Test of Sphericity	Df	45
Sig.		0.000

Source Apportionment Using Principal Component Analysis (PCA) to Identify the potential sources of heavy metals and ionic species

Principal Component Analysis (PCA) is a widely applied multivariate technique that uses eigenvalues to partition datasets and identify potential emission sources based on patterns within the submitted data. In this study, the dataset was subjected to factor analysis using the PCA extraction method coupled with an orthogonal Varimax rotation (Table 7). The Kaiser Meyer Olkin (KMO) values for all individual variables (Pv > 0.70) exceeded the acceptable threshold of 0.50, and the KMO value of 0.750 confirmed the adequacy of the dataset for Exploratory Factor Analysis (EFA). Bartlett's test of sphericity, $\chi^2(45) = 106.52$, $p < 0.05$, indicated significant patterned relationships among the variables (Table 6).

The Scree plot supported the retention of three principal components. PCA identified three components-PC1, PC2, and PC3 which together accounted for 86.68 % of the total variance (Table 7). PC1 accounted for 62.89 % of the total variance and exhibited high loadings of Zn, Pb, Cu, Cd, Ni, SO_4^{2-}, Cl^-, and NO_3^-. These constituents are typically linked to vehicular emissions; solvent and chemical use, waste burning, lubricating oil, diesel combustion, as well as tire and brake wear (Men *et al.*, 2020; Heidari *et al.*, 2021; Duan *et al.*, 2017). PC2 accounted for 14.98 % of the total variance and was loaded with $C_2O_4^{2-}$, which is sourced from organic sources such as plant and microbial emissions, textile processes, and metal finishing operations (Men *et al.*, 2020; Martin *et al.*, 2019). PC3 accounted for 8.81 % of the total variance and was primarily loaded with CO_3^{2-}, originating from construction materials, glass production, water treatment additives, and certain pharmaceutical applications (Rodriguez *et al.*, 2019; Jiang *et al.*, 2019).

Table 7: The rotated component matrix (PCA-based Approximation) for data of heavy metals and ionic species in road the study area

Heavy metals and Ionic species	Factors		
	PCI	**PC2**	**PC3**
Zn	**0.962**	0.050	0.108
Pb	**0.973**	-0.228	0.037
Cu	**0.847**	0.112	-0.270
Cd	**0.854**	-0.124	0.078
Ni	**0.857**	0.215	-0.319
SO_4^{2-}	**0.769**	0.050	-0.187
Cl^-	**0.842**	-0.106	0.231
NO_3^{2-}	**0.848**	-0.219	-0.075
CO_3^{2-}	-0.011	0.248	**0.698**
$C_2O_4^{2-}$	-0.066	**0.954**	0.291
Eigenvalues	6.918	1.648	0.969
% of Variance	62.89	14.98	8.81
% of cumm. Variance	62.89	77.87	86.68
Sources	traffic/vehicular, chemical/solvent usage, burning of wastes, lubricating oil, diesel fuel, tire, and brake wear	Organic sources (plants, microbes, decomposition textile manufacturing and metal processing)	Geogenic/carbonate materials, construction materials, glass manufacturing, water treatment for pH regulation, and pharmaceutical applications including antacids and calcium supplements soil dust

Cluster Analysis

The bi-plot suggests that there are three clusters groups for the heavy metals and ionic species in the study area. Clusters 1, 2, 3 are Zn, Pb, Cu, Cd, Ni, SO_4^{2-}, Cl^-, NO_3^-, $C_2O_4^{2-}$ and CO_3^{2-} (Figure 2). This is observed in the dendogram (Figure 2). The 3D Rotated Component Plot of heavy metals and ionic species in the study area is shown in (Figure 3).

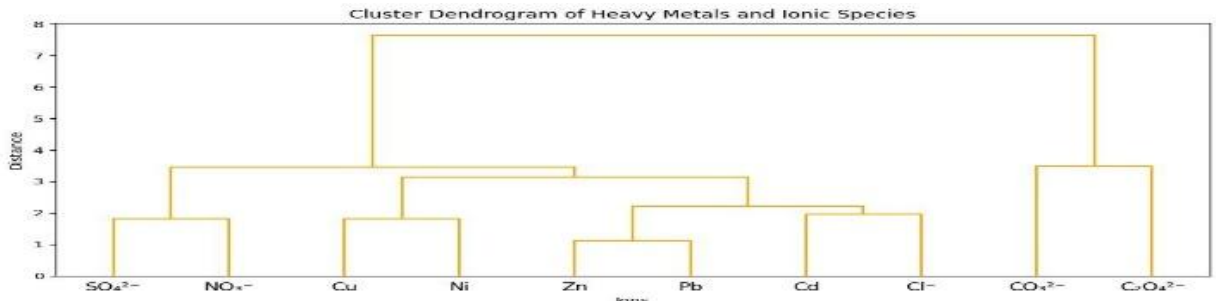

Figure 2: Dendogram of the components

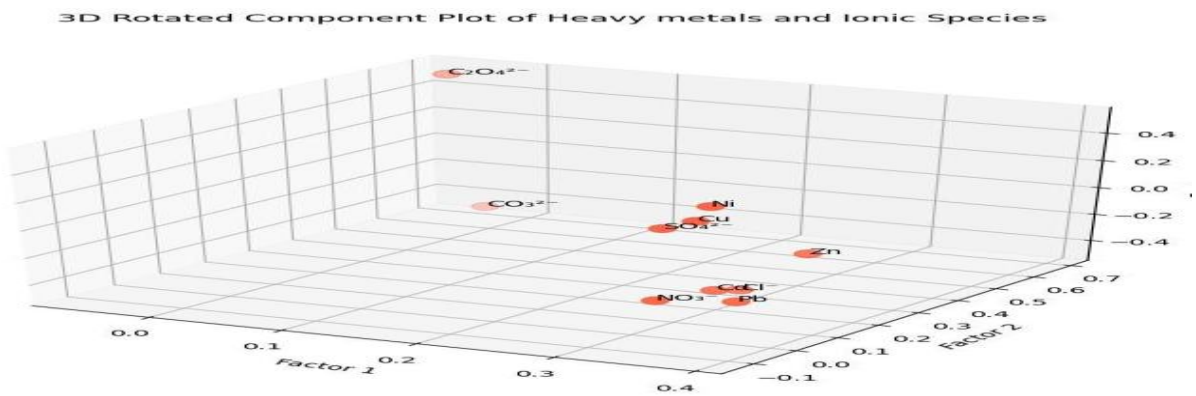

Figure 3: 3D rotated component of heavy metals and ionic species

Table 8: Correlation analysis among the heavy metals and ionic species in study area

Heavy metals and Ionic species	Zn	Pb	Cu	Ni	Cd	SO_4^{2-}	Cl^-	NO_3^-	CO_3^{2-}	$C_2O_4^{2-}$
Zn	1.000									
Pb	0.932	1.000								
Cu	0.844	0.792	1.000							
Ni	0.673	0.676	0.817	1.000						
Cd	0.709	0.823	0.532	0.708	1.000					
SO_4^{2-}	0.626	0.668	0.607	0.584	0.449	1.000				
Cl^-	0.804	0.793	0.567	0.530	0.782	0.367	1.000			
NO_3^-	0.652	0.809	0.549	0.530	0.667	0.798	0.627	1.000		
CO_3^{2-}	-0.255	-0.333	-0.498	-0.663	-0.313	-0.485	-0.171	-0.516	1.000	
$C_2O_4^{2-}$	-0.225	-0.508	-0.205	-0.138	-0.348	-0.221	-0.256	-0.583	0.350	1.000
Mean	143.05	52.93	20.69	16.85	2.27	85.53	23.83	42.26	32.22	13.98
SD	66.98	32.42	14.40	7.48	0.66	42.93	15.39	15.89	17.24	13.17

*Correlation is significant at the 0.05 level (2-tailed)

Correlation Coefficient Analysis

Pearson's correlation analysis was conducted to assess the relationship between heavy metals ionic species, and their potential pollution sources in the road dust. Table 8 presents the correlation coefficients, their significance levels, and the number of observations. The coefficients range from –0.663 to 0.932, where the sign reflects whether the association is positive or negative, and the absolute value indicates the strength of the relationship. Strong and positive correlations were observed among Zn, Pb, Cu, Cd, Ni, SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-}, and $C_2O_4^{2-}$, suggesting that these pollutants may originate from related sources. The weakest correlation occurred between $C_2O_4^{2-}$ and Cl^-, The high values of the correlation coefficient between the heavy metals and ionic species suggests common sources and mutual dependence (Suresh *et al.*, 2012). The presence of Ni was from automotive paint coatings, whereas Pb, Cd, Cu, and Zn were from vehicular emissions, industrial processes, chemical/solvent usage, and the abrasion of tires and metal alloys. The metals and ions exhibited significant positive correlations at the 0.05 level (Wang *et al.*, 2021; Enuneku *et al.*, 2017).

CONCLUSION

Zinc (Zn)- 1434.69 mg/kg recorded the highest concentration making it the most dominant heavy metal in the study area, followed by lead (Pb) - 530.44 mg/kg, copper (Cu) - 207.05 mg/kg, nickel (Ni) - 169.73 mg/kg, and cadmium (Cd) at 23.89 mg/kg. These values were higher and surpassed recommended environmental safety limits, indicating strong anthropogenic influence. Major contributors include vehicular emissions industrial operations, waste burning, and the use of various chemicals. Sulphates (SO_4^{2-}) -841.38 mg/kg is the most abundant ionic species followed by nitrate (NO_3^-) - 432.35 mg/kg, chloride - (Cl^-) -238.36 mg/kg, carbonate- (CO_3^{2-}) - 322.18 mg/kg, and oxalate ($C_2O_4^{2-}$) - 139.89 mg/kg. The dominance of sulphates suggests influences from fossil fuel combustion, industrial discharges, solvent use, and underlying geological conditions.

Principal Component Analysis (PCA) identified three components accounting for 86 % of the total variance, linking the presence of the heavy metals and ionic species to traffic emissions, organic sources, and industrial or construction activities. There are positive correlations among the pollutants suggesting common sources and mutual dependence. The findings reveal significant impacts of human activities on dust pollution and metal accumulation, with the automobile workshop area identified as the most polluted site. These results is in agreement with global research and highlights the need for targeted pollution control and improved environmental management to safeguard public health within Yaba College of Technology and surrounding communities in Lagos State.

Conflict of interest: The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements: Due acknowledgement is hereby given to the Management of Yaba College of Technology for the use of the College Central Research Laboratory and Nigerian Educational Trust Fund (TETFund) for supporting this research.

REFERENCES

Aguilera, A., Armendariz, C., Quintana, P., Garcia-Oliva, F. and 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.

Ali, M. U., Liu, G., Yousaf, B., Abbas, Q., Ullah, H., Munir, M. A. M. and Fu, B. (2017). Pollution characteristics and human health risks of potentially (eco)toxic elements (PTEs) in road dust from metropolitan area of Hefei, China. *Chemosphere*, 181, 111- 121.

Amato, F., Alastuey, A., De La Rosa, J., Gonzalez Castanedo, Y., Sánchez de la Campa, A.M., Pandolfi, M., Lozano, A., Contreras González, J. and 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.

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. and 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. DOI: 10.13170/aijst.14.1.43432

Bawuro, A., Voegborlo, R. and Adimado, A. (2018). Bioaccumulation of heavy Metals in some tissues of fish in Lake Geriyo, Adamawa State, Nigeria. *Journal of Environment and Public Health*, 1, 1 - 7.

Benhaddya, M. L., Boukhelkhal, A., Halis, Y. and Hadjel, M. (2016). Human health risks associated with metals from urban soil and road dust in an oilfield area of Southeastern Algeria. *Arch. Environ. Contam. Toxicol.*, 70, 556 - 557.

Budai, P. and 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. Env.*, 62, 179 - 185.

Chen, H., Lu, X., Wang, J. and Qu, L. (2021). Heavy metal pollution in urban road dust: A case study in Xi'an, China. *Env. Pollution*, 286, 117577.

Chen, W., Zhang, X., Zhang, J., Duan, N., Gong, X., Liu, S., Zhan, C., Chen, W. and Xing, X. (2022). Characteristics, sources and health risk of heavy metals in road dust in a typical county town, central China. *Applied Sciences*, 12(24), 12958.

Duan, Z. B., Wang, J., Zhang, Y. X. and Xuan, B. (2017). Assessment of heavy metals contamination in road dust from different functional areas in Guiyang, Southwest, China. *Int. J. of Env., Sci. and Education*, 12, 427 - 439.

European Commission (EC). Regulation No. 1881/2006. *JO L.*, 364, 5 - 24.

Enuneku, A., Biose, E. and Ezemonye, 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.

Faisal, M., Wu, Z., Wang, H., Hussain, Z. and Azam, M. I. (2021). Human health risk assessment of heavy metals in the urban road Dust of Zhengzhou Metropolis, China, *Atmosphere*, 12(9), 1213.

Foti, L., Dubs, F., Gignoux, J., Lata, J., Lerch, T. Z., Mathieu, J., Nold, F., Nunan, N., Raynaud, X., Abaddie, L. and 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.

Ghosh, S., and Das, S. (2014). Evaluation of heavy metals and ionic species in road dust from Kolkata, India. *Journal of Environmental Science and Pollution Research*, 21(10), 6617-6627.

HACH (2000). DR6000 Spectrophotometer User Manual. *HACH Company*.

Hach Company (2007). *DR 2800 Spectrophotometer Procedures Manual* (Rev. ed.). Hach Company — General procedures and principles for spectrophotometric analyses using Hach DR instruments, including sample measurement, calibration, and wavelength selection for colorimetric determinations.

Hazem, A. S., Ibrahim, H., Saleh, E. A. Shalaby, Z. F., Ghatass, A.R., Shatat, Mohamed, E. and 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

He, Z. L., Yang, X. E. and Stoffella, P. J. (2005). Trace elements in agro - ecosystems and impacts on the environment, *Journal of Trace Elements in Medicine and Biology*, 19(2), 125 - 140.

Heidari, M., Darijani, T. and Alipour, V. (2021). 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, 29656.

Herawati, N., Suzuki, S., Hayashi, K., Rivai, I. F. and Koyama, H. (2000). Cadmium, Copper and Zinc levels in rice and soil of Japan, Indonesia, and China by soil type. *Bulletin of Environment, Contamination and Toxicology*, 64(1), 33 - 39.

Hu, B., Shao, S., Ni, H., Fu, Z., Hu, L., Zhuo, Z., Min, X., She, S., Chen, S., Huang, M., Zhuo, L., Li, Y. and Shi, Z. (2020). Current status, spatial features, health risks, and potential driving factors of soil heavy metal pollution in China at province level. *Environmental Pollution*, 266, 114961.

IARC (2021). Cadmium and its compounds. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, 129, 1- 37.

IARC (2020). Nickel and nickel compounds. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, 124, 1-40.

Ichiyama, A., Nakai, E., Funai, T., Oda, T. and 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

Jeong, H.Y., Lee, J. H., Kim, K. T., Kim, E.S. and Ra, K. T. (2019). Identification on metal pollution sources in road dust of industrial complex using magnetic property around Shihwa Lake Basin. *J. of Korean Soc. Mar. Env.. Energy*, 22, 18 - 33.

Jiang, H., Patel, S. and Kumar, R. (2019). Carbonate Ions in Human Environmental Exposure, *Env. Health Perspectives*, 127(6), 067005.

Jiao, X., Yingze, T., Chunlei, Cheng., Chuang, W., Qiuju, L., Mei, L., Xiaofei, W. and 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. and 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.

King, J. C., Shames, D. M., and Lowe, N. M. (2021). The role of zinc in human health and disease. *Advances in Nutrition*, 12(5), 1673 - 1685.

Kui, C. and Chang, L. (2019). Street dust heavy metal pollution source apportionment and sustainable management in a typical city - Shijiazhuang, China. *International Journal of Environment Res. Public Health*, 2625, 1-16.

L.A.S.G. (2020). Lagos State Government, Lagos Urban Challenges: Tackling the City's Growth and Environmental Sustainability. Lagos State Ministry of Urban Planning.

Landrigan, P. J., Fuller, R., Fisher, S., Suk, W. A., Sly, P., Chiles, T. C. and Bose-O'Reilly, S. (2020). Pollution and children's health. *Science of the Total Environment*, 728, 138-147.

Li, X. (2015). Levels and spatial distribution of heavy metals in urban dust in China. *Chinese Journal of Geochemistry*, 34, 498 - 506.

Linder, M. C. (2020). Copper and human health: Biochemistry, genetics, and strategies for prevention, *Biometals*, 33(3), 331 - 340.

Li, Q., Sun, Y. and Zhang, Y. (2021). Comparative analysis of chloride determination methods in urban street dust. *J. of Env. Sci.*, 115, 121-128. https://doi.org/10.1016/j.jes.2021.06.004/

Lu, X., Zhang, X., Li, L. Y. and Chen, H. (2017). 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/

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

Martin, J., Cooper, P. and Collins, D. (2020). Biogenic oxalate production in fungi and lichens: Environmental and physiological roles. *Fungal Biology Reviews*, 34(2), 89 - 103.

Men, C., Liu, R., Wang, Q., Guo, L., Miao, Y. and Shen, Z. (2019). Uncertainty analysis in source apportionment of heavy metals in road dust based on positive matrix factorization model and geographic information system. The *Science of the Total Environment*, 652, 27-39.

Men, C., Liu, R., Xu, F., Wang, Q., Guo, L. and 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.

Men, C., Liu, R., Xu, L., Wang, Q., Guo, L., Miao, Y. and 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.

Misiewicz, B., Mencer, D., Terzaghi, W. and VanWert, A. L. (2023). Analytical methods for oxalate quantification: The ubiquitous organic anion. *Molecules*, 28(7), 3206. https://doi.org/10.3390/molecules28073206

Mohamed, Y. H., Andrian, A. S., Ilia, V. Y., Georgy, M., Elizaveta ,Y. K. and Mohammed, S. A. and 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. doi: 10.1007/s10653-023-01494-y

Nguyen, M. H., Huynh, T. K. N., Ha, T. L. and 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. and 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., Damazio, O. A. and Oshin, T. T. (2023a). Assessment and source apportionment of heavy-metals (Zn, Pb, Cu, Ni, Cd) on street dust of Oshodi-Isolo Area, Lagos State, Southwestern Nigeria. *Nig. J. of Environment Science and Techn.* (NIJEST), 7(2), 203 - 216.

Ojiodu, C. C., Eruola, A. O., Damazio, O. A. and Oshin, T. T.(2023b). Characteristic distribution and source apportionment of heavy metals (Zn, Pb, Cu, Ni and Cd) on street dust of Ikeja Area of Lagos State, Southwestern Nigeria. *Nigerian Journal of Environment Science and Technology* (NIJEST), 7(2), 217 - 231.

Ojiodu, C. C., Moses, D. U., Damazio, O. A. and Oshin, T. T. (2023c). Appraising heavy metals distribution in Street Dust of Ketu - Mile 12 Area of Lagos State, South-western Nigeria. *Nigerian Journal of Environment Science and Technology*, 7(2), 277 - 290.

Ojiodu, C. C., Olumayede, E. G., Eruola, A. O., Ashiru, A. W., Moses, D. O., Olaleru, S. A. and 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 Sci. and Techn.*, 8(2), 23-34.

Oliveira, M., Pinto, E., Ferreira, I. M. P. L. V. O. and 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/

Olowoyo, J. O., Mugivhisa, L. L. and Magoloi, Z. G. (2016). Composition of trace metals in dust samples collected from selected high schools in Pretoria, South Africa. *Applied Environment, Soil Sciences*, 1 - 9.

Owoeye, O. and Owoeye, O. (2020). Heavy Metal Contamination of Dust in Urban and Industrial Areas in Lagos, Nigeria. *Environmental Monitoring and Assessment*, 192(8), 1- 9.

Pettucci, C., Zelenin, A., Culver, J. A., Gabriel, M., Kirkbride, K., Christison, T. T. and Gardell, S. J. (2016). Use of ion chromatography/mass spectrometry for targeted metabolite profiling of polar organic acids. *Analytical Chemistry*, 88(23), 11799 - 11803.

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.

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. and Salvador, P. (2007). Source origin of trace elements in PM from regional background, urban and industrial sites of Spain. *Atmospheric Environment*, 41, 7219 - 7231.

Rahman, M. S., Khan, M. D. H. and Jolly, Y. N., Kabir, J., Akter, S. and Salam, A. (2019). Assessing risk to human health for heavy metal contamination through street dust in the Southeast Asian Megacity: Dhaka, Bangladesh. *The Sci. of the Total Env.*, 660, 1610 - 1622.

Ramírez, O., de la Campa, A. S., Amato, F., Catacolí, R. A., Rojas, N. Y. and de la Rosa, J. (2018). Chemical composition and source apportionment of PM_{10} at an urban background site in a high - altitude Latin American megacity (Bogota, Colombia). *Environmental Poll.*, 233, 142 - 155.

Reyes, B. A., Bautista, F., Goguitchaichvili, A., Contreras, J. J. M., Owen, P. Q., Carvallo, C. and Battu, J. (2013). Rock-magnetic properties of top soils 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. and 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. and Maghakyan, N. (2014). Studying atmospheric dust and heavy metals on urban sites through synchronous use of different methods. *Journal of Atmospheric Pollution*, 2, 12 - 16.

Sahakyan, L., Maghakyan, N., Belyaeva, O., Tepanosyan, G., Kafyan, M. and 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.

Shi, J., Zhao, C., Wang, Z., Pang, X., Zhong, Y., Han, X. and Ning, P. (2022). Chemical Composition and Source Apportionment of $PM_{2.5}$ in a Border City in Southwest China, *Atmosphere*, 13:7. https://doi.org/10.3390/atmos13010007/

Soltani, N., Keshavarzi, B., Moore, F., Tavakol, T., Lahijanzadeh, A. R., Jaafarzadeh, N. and 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.

Smith, A. L., Jones, M. E. and Roberts, D.(2022). Dermal exposure to heavy metals: Implications for human health. *Journal of Environmental Health*, 84(9), 24 -31.

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. *Int. J. of Sci. and Nature*, 3(1), 214 - 216.

Suryawanshi, P. V., Rajaram, B. S., Bhanarkar, A. D. and Chalapati Rao, C. V. (2016). Determining heavy metal contamination of road dust in Delhi, India. *Atmósfera*, 29, 221- 234.

Tang, J., Liu, X. and Liu, Y.(2020). Distribution and risk assessment of heavy metals in street dust from an industrial city in China. *Environmental Science and Pollution Research*, 27, 12555-12567.

Tanner, P., Lingma, H. and Yu, P. K. N. (2008). Fingerprinting metals in urban street dust of Beijing, Shanghai and Hong Kong. *Environment Science and Technology*, 42, 7111 - 7117.

Tariq, A., Lee, Y., Roosa, K., Blumberg, S., Yan, P., Ma, S. and 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. and 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.

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

Wang, W., Xu, X., Zhou, Z., Dong, X. and 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.

Wang, Y., Guo, G., Zhang, D. and 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.

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

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

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

Zgłobicki, W. and Telecka, M.(2021). Heavy Metals in Urban Street Dust: Health Risk Assessment (Lublin City, E Poland). *Appl. Sci.*, 11(9), 4092.

Zhang, R., Chen, L. and Huang, J. (2020). Determination of carbonate in arid soil dust via gravimetric CO_2 evolution method. *Geoderma Regional*, 22, e00331.

Zhang, X., Li, Y. and Wang, L. (2021). Epigenetic effects of cadmium exposure. *Environmental Epigenetics*, *7*(1), dvab017.

Zhao , Y., Miao,Q., Shi, H., Li, X, Yan, J., Yang, S., Hou C., Yu, C., Feng, W. and 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 Journal*, 9, 1 - 26.