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CONCENTRATIONS OF POTENTIALLY TOXIC ELEMENTS IN DUST FROM UNIVERSITIES IN SOUTH-WEST, NIGERIA

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ABSTRACT

Respected as hubs of learning and intellectual development, universities are places where staff and students come together to share knowledge. However, concealed within these establishments may be a possible health hazard such as contaminated dust. Hence, this study determined potentially toxic elements (PTEs) in the dusts of Federal, State and private universities in Southwest, Nigeria. The dust samples were collected from various parts of the universities, including classrooms, laboratories, offices, creche and workshops. The samples were prepared by acid digestion and the PTEs were analysed using Microwave Plasma Atomic Emission Spectroscopy (MP AES). The findings showed differences in dust concentrations between State, private, and Federal universities. The PTE concentrations of As (ND to 0.0926 mg/kg), Hg (ND to 0.0141 mg/kg), Pb (0.361 to 12.0 mg/kg), Cu (0.0745 to 26.1 mg/kg), Ni (0.217 to 5.63 mg/kg) and Mn (0.566 to 16.7 mg/kg) were below the permissible limits of FAO/WHO soil guideline value. The concentration of PTEs was higher at Federal universities, which were mostly found in State capitals with high traffic and population density, than in State and private universities. Arsenic and mercury were below detection limit in most of the samples, whereas lead, copper, nickel and manganese were found in various concentrations in all the universities. Strong relationships between lead, nickel, and manganese indicated shared sources of emissions, potentially related to construction and transportation. To protect the health and welfare of university communities and advance environmental sustainability, it is recommended that universities should conduct routine PTE concentration monitoring, put mitigation plans in place to lower emissions, launch awareness campaigns and conduct additional research to identify regional sources of contamination.

Keywords: Potentially toxic elements, Universities, Dust, South-west Nigeria, MPAES

INTRODUCTION

In the modern world, the need to protect people's health and well-being is intricately linked to the quest for knowledge. Despite being revered as places of higher learning, universities may pose possible health risks associated with environmental pollutants [1]. Universities are not just places of learning but also thriving communities where staff, teachers, and students come together to study and share knowledge. However, there may be hidden threat of the dust in these institutions containing potentially toxic elements such as lead, arsenic and mercury [2].

PTE is an adopted group name for metals and metalloids associated with toxicity [3]. Upon exposure to these pollutants, since the body has no way of getting rid of them, they accumulate in the body tissues, cells and other parts of the body [1]. Some of the toxic health effects associated with exposure to PTEs include gingivitis, nervous system disorder, blood and bone diseases, kidney failure, tremors, and cardiovascular diseases.

Among the several PTEs, Arsenic (As), mercury (Hg), and lead (Pb) are among the World Health organization’s list of most toxic elements [4]. As, Hg, and Pb are naturally occurring elements found in the earth's crust and can be released into the environment through a variety of sources, including industrial processes, pesticides and herbicides, mining and the burning of fossil fuels. Exposure to As and Hg can occur through the ingestion of contaminated water or food or through inhalation or dermal exposure to arsenic-containing dust or fumes [5]. Exposure to arsenic and mercury can be dangerous and can have serious health effects. Acute exposure to high levels of arsenic can cause symptoms such as nausea, vomiting, diarrhoea, and difficulty breathing. Long-term exposure can lead to a variety of health problems, including cancer, cardiovascular disease, and neurological disorders [6]. Acute exposure to high levels of mercury can cause symptoms such as tremors, numbness, and difficulty walking, and long-term exposure can lead to a variety of health problems, including kidney damage, neurological disorders, and developmental problems in children [7].

Most people believe that universities are secure places where people may grow both intellectually and personally [8]. Contamination by heavy metals in schools is not a recent issue [9]. It has received international recognition and sparked concern in a number of regions.

University no doubt is a community on its own being characterized by various activities ranging from classroom, and laboratory work to administrative activities [10]. Offices, lecture rooms,

laboratories, technical workshops, and shopping complexes situated in universities indicate the variations in different activities.

Dust from universities showed that there was possible heavy metal pollution in universities [11]. Meanwhile, occupational exposure to several chemicals in laboratories may induce oxidative stress and have implications for genome instability [12]. Dust can contain heavy metals that may have been introduced to the environment through a variety of sources, such as laboratory or industrial processes (such as water production), transportation, and the use of pesticides and herbicides.

Studying heavy metals in university dust can help identify sources of contamination and determine the potential health risks to students, faculty and staff [13]. It can also help to identify necessary remediation efforts to reduce or eliminate heavy metal contamination in the university environment. In addition to the potential health risks, the presence of heavy metals in university dust can also impact the quality of the environment and the overall sustainability of the university [14]. By understanding the sources and levels of heavy metals in university dust, universities can take steps to reduce their environmental impact and improve the overall health and well-being of the campus community.

Numerous institutions are located in Nigeria, a nation renowned for its rich traditions and diversity of cultures, with a notable concentration in the South-West area [15]. This area is known for its distinctive fusion of rural and urban environments, where old traditions and modern technology coexist. However, in the context of heavy metal pollution, this particular combination of settings and behaviours also pose specific issues [16]. The causes of heavy metal pollution that afflict other areas, such as industrial activity, vehicle emissions, and garbage disposal, are not unaffected in the South-West of Nigeria. Furthermore, the climate of the area, which comprises of wet and dry seasons, affects the movement and dispersion of pollutants, which may contribute to the concentration of heavy metals in dust [17].

The relationship between heavy metals and culture in this area is also greatly influenced by socioeconomic and cultural variables. Heavy metal used in crafts, ceremonies, or traditional medicine may raise the general level of pollution [18]. The region's cultural and nutritional customs heavily rely on the use of locally obtained food and water, both of which may be affected by heavy metal contamination.

Assessment of heavy metals (Cr, Pb, Cd, Cu, and Zn) in indoor dust samples from four tertiary institutions in Ondo State, Nigeria showed that Cu had the highest concentrations (0.18–0.31 mg/kg) while Cd had the lowest concentrations (ND–0.02 mg/kg) [19]. Also, Federal College of Agriculture had the highest metal concentration, while those from Ondo State College of Health Science Technology had the lowest concentrations. The investigation of the indoor dust in the University of Agriculture Makurdi, Nigeria showed that the dust loading in all the College buildings was less than 18 g/m^2 per month being South African National Standard (SANS) threshold limit [20]. The pattern of the concentrations of the heavy metals was Cu < Mn < Zn < Fe.

The contamination of heavy metals in road dust of the University of Nigeria, Enugu Campus, Southeastern Nigeria was assessed by Ichu et al [21]. The results showed increased enrichment of heavy metal at a distance of 1 m from the curb than near the curb implying high levels of source pollution complexes such as human activity, vehicular emissions and lithogenic occurrences.

In spite of the health risks of heavy metals and the complexities of the university environment, limited studies exist on heavy metals in the Nigerian university environment. Moreover, in the few existing literature, sampling of dust samples from Nigerian universities were not categorized according to the type of activities involved and inorganic pollutants such as mercury which had been classified as hazardous had not been studied. Hence, this study aims to fill existing knowledge gaps by sampling based on different sections in the universities. With a focus on various Departments and activities inside these establishments, the primary aim is to close information gaps by offering in-depth insights into the amounts and causes of heavy metal contamination in Nigerian universities [22]. Hence, evaluating the possible health concerns that students, teachers, and staff may face by looking at the levels of lead, mercury, and arsenic in campus dust. This research hopes to make a substantial contribution to the knowledge of environmental health in academic contexts and lay the groundwork for upcoming initiatives which may be to monitor, control, and reduce heavy metal pollution in learning spaces.

MATERIALS AND METHODS

Materials

All reagents used were of Analytical grade. These include sodium borohydride ($NaBH_4$, (Merck, Kenilworth, NJ, USA), sodium hydroxide (NaOH, (Merck)), 37% hydrochloric acid (HCl, (Merck)), 30% hydrogen peroxide (H_2O_2, (Merck)), 65% nitric acid (HNO_3, (Merck)), and deionized water from a Millipore purifier (Merck) with a resistance of 18.2 MΩ.cm. Additionally, the standardized reference using mercury ICP (Merck), traceable to NIST Standard Reference Material® (SRM) $Hg(NO_3)_2$ in 10% nitric acid, equalled 1000 mg/L Hg.

Sampling

Five categories of Indoor dust samples were collected from each institution. These categories are based on the different activities carried out in the university environment. The categories were offices, laboratories, workshops, classrooms and creche.

Indoor samples were collected by brushing the surfaces of fans, table tops, air conditioner filters, carpets, and exposed surfaces.

Collected samples in each category for each institution were thoroughly mixed to form a pool sample for such categories. For example, dust samples collected in offices for administrative purposes in a university were pooled together and thoroughly mixed to form the sample from administrative offices for such institutions. Six each of federal, state, and private universities in the South West were sampled. Dust samples were obtained in the university environments based on activities carried out in the area. Diverse characteristics of universities throughout Nigeria were sampled for a study conducted during a strike action in the universities. The institutions encompassed private and public higher education in Nigeria. The private universities were Chrisland University in Ogun, Anchor University in Lagos, Wesley University in Ondo, Afe Babalola University, Ado-Ekiti (ABUAD), and Oduduwa University in Osun. The Federal Universities were Adeyemi University in Ondo, University of Ibadan (UI) in Oyo, University of Lagos (Unilag) and Obafemi Awolowo University (OAU) in Osun. The State universities were University of Medical Sciences (UniMed) in Ondo, Osun State University (OSU) in Osun, and Tai Solarin University of Education (TASUED) in Ogun.

Their administrative and funding structures determined the classification of universities as private, State or Federal. Federally-funded universities feature a vast array of programmes and

sizable student bodies, whereas private universities, which are typically administered by private entities, have more limited class sizes and higher tuition fees. Government-run State universities generally prioritise the academic requirements of the inhabitants of the given state.

Classrooms, laboratories, workshops, creches, and offices, among other locations, were sampled during the sampling process at these universities. During the strike, each location was selected based on its accessibility and convenience. Offices, which catered to the administrative and faculty requirements, and classrooms, which were for teaching and learning activities, were the primary locations. Laboratories and workshops were centres for experiments, research, and practical training, whereas creches offered a distinctive milieu as learning facilities for children.

To ensure the safety and accessibility of the environments sampled, the sampling process was carried out exclusively during daylight hours, from 10 am to 4 pm. The sampling locations exhibited variability in proximity to main roads, with certain sites being situated in closer proximity to facilitate accessibility, while others were more isolated, thereby offering a diverse array of contexts within the university environments. The availability of these particular sites throughout the strike period significantly impacted the selection process, underscoring the need for resourcefulness and flexibility when choosing sampling locations amidst limiting conditions. Reflecting the diverse operations and characteristics of these academic establishments in Nigeria, the study offers a glimpse into university infrastructure and life during a specific era.

Sample digestion

Sample digestion was done using the EPA METHOD 3050B method. Dust sample (1.0 g) was digested with *aqua regia* (HCl: HNO_3, 3: 1 v/v) and covered with a watch glass. The beaker with the sample mixture was allowed to digest on a hot plate at 90 ^{O}C for 2 to 3 hours until no brown fumes were seen and the solution was evaporated to near dryness [23]. The resulting solution was then removed from the hot plate, allowed to cool, and filtered through a Whatman filter paper (No 42) into a volumetric flask and made up to mark with de-ionized water. This was done in triplicates and transferred to cleaned dried plastic bottles before analysis.

Analytical Procedure for Mercury/Arsenic Analysis using MP-AES 4100 (Hydride Generation Method)

A mercury analysis was determined by hydride generation method using MP-AES 4100 [24] with the reaction chamber of multimode sample introduction system (MSIS), nebulizer pressure of 160 kPa, viewing position at the zero-point, pump rate of 15 rpm and the gas used to produce plasma was nitrogen, which was the in-situ product of the N-generator.

Sodium borohydride was freshly prepared by weighing 2.0 g of $NaBH_4$ and gradually mixing 1.0% NaOH solution into it until a volume of 100 mL was reached. This is the reductant solution. Further, a 1000 µL aliquot was obtained from the preparation of the standard mercury solution of 1000 mg/L and diluted with solvent HNO_3 to a volume of 100 mL (Hg concentration of 10.00 mg/L). Afterwards, the mercury series standard solution was further prepared, by serially pipetting 10, 20 and 50 mL, of the main standardized content, as each was dissolved with 100 mL of solvent in order to obtain a metallic concentration of 1.00, 2.00 and 5.00 mg/L respectively.

The MP-AES system was configured under the conditions specified for the operation of the instrument [24, 25]: A Multimode Sample Introduction System was activated within the reaction chamber. A solution of sodium borohydride ($NaBH_4$) containing 1.0% was employed as the reductant. At 253.652 nanometers, the wavelength was set. Twenty seconds were allotted for stabilisation, and thirty seconds were chosen for sample absorption. 15 revolutions per minute was the operating pace of the pump. A manual operation was required for the injection apparatus. An upper limit of 0.995 was imposed on the calibration correlation coefficient. Constantly 0.75 litres per minute was dispensed through the nebulizer. The RAW method was utilised to achieve calibration fit, while automatic background correction was activated.

The optimization of the nebulizer pressure, viewing position, and pump speed were performed in an initi al system using a standard solution of mercury at 5.00 mg/L. The optimization was then carried out through the use of MP-Expert software (MP-4100, Agilent).

The concentrations of Cu, Mn, Ni, and Pb in the digest were determined using an Agilent 4100 MP-AES with a stream of Nitrogen supplied from an Agilent 4107 Nitrogen Generator [25, 26]. The operating conditions for the instrument were detailed as follows: The pump speed was set at 15 revolutions per minute, and the EGCM setting was on high. The calibration correlation coefficient limit was established at 0.995, and blank subtraction was activated. The read time was fixed at 3 seconds, with a total of 4 replicates for each measurement. The sample uptake

time was 30 seconds, and the stabilization time was 20 seconds. The fast pump running feature was turned on, and automatic background correction was enabled.

For specific elements, the wavelength labels were set as follows: 327.395 nm for Copper (Cu), 259.372 nm for Manganese (Mn), 232.003 nm for Nickel (Ni), and 283.305 nm for Lead (Pb). The nebulizer flow times were also tailored for each element: 0.7 L/min for both Copper (Cu) and Nickel (Ni), 0.9 L/min for Manganese (Mn), and 0.75 L/min for Lead (Pb). Lastly, the viewing position was set at 0.

For the determination of, Cu, Mn, Ni, and Pb, an intermediate calibration standard of 10 mg/L was prepared from an AccuStandard multi-element calibration standard of 1,000 mg/L single standard solution in 3% (v/v) HNO_3. Subsequently, serial working calibration standards of 0.2, 0.5, 1.0, 2.0 and 4.0 mg/L were prepared and used for the calibration.

Quality Assurance and Quality Control

De-ionized water that was ultra-pure (18.2 MΩ resistivity) was used to prepare all of the solutions. Nitric acid of analytical grade (68–70% m/v). Every standard was prepared to a volume of 1% (v/v) HNO_3. Method calibration was carried out, and the Initial Calibration Blank and Initial Calibration Verification (ICB & ICV) solutions were done. For every 10 samples, the Continuing Calibration Blank and Continuing Calibration Verification (CCB & CCV) solutions were analysed.

RESULTS AND DISCUSSION

Arsenic was not detected in the sample locations except in TASUED classroom, OAU Security post, and Adeyemi workshop, which had As concentrations of 0.093 ± 0.007, 0.086 ± 0.003, and 0.018 ± 0.005 mg/kg respectively. The result obtained from a similar study in the Islamic Republic of Iran was in the range of 0.2 mg/kg to 8.8 mg/kg which was much higher than was obtained in this study [27]. Arsenic can be from natural or anthropogenic sources. Some natural sources include volcanic eruptions, weathering of arsenic-containing minerals and forest fires while anthropogenic sources include pesticides, herbicides, insecticides, wood preservatives, disposal of arsenic-containing waste, mining and smelting [4]. Another source of As is smoke exhaust from power plants and waste incineration. Arsenic can also be easily emitted during waste incineration which can then be transported by air into various parts of the environment including enclosed spaces such as offices and can also be carried by humans during movement into large-capacity

spaces such as classrooms [28]. The samples in TASUED were collected two weeks after the entire University was fumigated, hence this might have contributed to the concentration reported. However, the concentration is below the permissible limits of FAO/WHO soil guideline value (20 mg/kg) [5].

Mercury concentration in all 56 samples and locations ranged from ND to 0.014 ± 0.002 mg/kg. The result showed that mercury was only detected in dust from two sample locations which are OAU Workshop with a concentration of 0.014 ± 0.002 as the highest concentration and ADEYEMI Workshop with 0.006 ± 0.007 mg/kg as the lowest detected concentration. Burning of mercury-containing products such as electronic devices, batteries, light bulbs and thermometers is the major anthropogenic source of mercury.

Lead is one of the most abundant heavy metals as well as one of the most dangerous to human health [29]. Past studies have shown that vehicle emissions such as from the usage of lubricant oils, car components, wear of tyres, brake pads and engines are the main contributors of lead in indoor dusts [30]. The result from this study shows that lead concentrations ranged from 0.361 ± 0.02 mg/kg (Adeyemi Workshop) to 11.9 ± 0.2 mg/kg (ABUAD workshop). This concentration range was lower than what was reported in classroom dust samples from Islamic Republic of Iran which ranged from 9 mg/kg to 971 mg/kg [27]. It was stated that the wide range was because some schools were near and some far from the main streets which are prone to heavy traffic. The use of lubricating oil for some machines and equipment and the emission produced during the use of this equipment as well as the settling in of lead emitted from vehicles could be the reason why the dust samples collected from ABUAD workshop had the highest lead concentration.

Studies have shown that Cu is widely used in car radiators, automotive brake wire, antioxidants and additives in lubricating oil, paint, pigment and coating [31]. The result of this study showed that Cu concentration ranged from 0.075 ± 0.007 mg/kg (OAU Workshop) to 26.1 ± 0.9 mg/kg (ABUAD workshop), a concentration range lower than what was reported in a study carried out in dust from university campuses in Xi'an China which ranged from 40.7 mg/kg to 220.2 mg/kg [32]. It was reported that three campuses had the highest Cu concentration and two of these three campuses were close to shops focusing on car detailing, repair and decoration while there was no similar shop around the third campus. It was further concluded that the cutting, painting, polishing and grinding involved in detailing, repairing, and decorating cars release dust

containing Cu into the local environment. The abrasion and corrosion of the Cu-containing metal parts in vehicles as well as the leaking and depletion of lubricating oil can lead to Cu being emitted into the environment. Therefore, it was believed that the dust samples from two of the three campuses had high Cu concentrations because of the nearby automobile detailing/repair/decoration activities. The third campus which also had a high Cu concentration was believed to have been due to the extensive use of Cu-containing paints, pigments and coatings by students and teachers in their art creations. The low Cu concentration reported in this present study could be as a result of the absence of an automobile repair shop and very little or no use of Cu-containing paints and pigments.

Nickel concentration ranged from 0.217 ± 0.02 mg/kg (OAU Workshop) to 5.63 ± 0.09 mg/kg (ABUAD workshop). This concentration is lower than what was obtained in dust samples from university campuses in Xi'an China which was in the range of 16.9 mg/kg to 55.2 mg/kg [32]. The burning of residual and fuel oils, nickel mining and refining, and municipal waste incineration are the major anthropogenic sources of nickel in the environment [33]. The main source of nickel in the dust samples may be as a result of the emission of fuel oils from power plants used for electricity supply in the university compound.

Manganese is the 5th most abundant metal. Its alloys make up drinking cans to enhance corrosion resistance. Inhalation exposure to manganese may cause sperm damage and pneumonia [34]. Industrial emission, fossil fuel combustion and erosion of manganese-containing soils are the main sources of manganese. Manganese concentration in this study ranged from 0.552 ± 0.03 mg/kg (OAU Workshop) to 16.8 ± 0.4 mg/kg (ABUAD workshop). This concentration was lower than what was reported from university campuses in Xi'an China which ranged from 309.2 mg/kg to 815.1 mg/kg [32]. A wide difference was observed between Mn and the other five metals. The trend can be explained as mercury < arsenic < copper < nickel < lead < manganese. High concentration of manganese is due to its abundance in the atmosphere.

Although arsenic and mercury concentrations were low in most of the universities, it is important for the universities to monitor and control levels of arsenic and mercury in the environment to protect the health and well-being of the campus community. Universities should implement measures to reduce the release of arsenic and mercury into the environment and to prevent accidental exposure to these substances [4]. This may involve using alternative products and technologies that do not contain arsenic or mercury, implementing proper waste management

practices, and regularly monitoring and testing the air, water and soil for the presence of these substances. Universities should also have procedures in place to respond to accidental releases of arsenic and mercury and to provide medical care to anyone who may have been exposed [9]. By taking these precautions, universities can help to protect the health and well-being of their students, faculty and staff, and minimize the risk of negative impacts on the environment.

The concentrations of the PTEs in each university dust samples are presented in Table 1.

Table 1: The concentrations of PTEs in University dust samples

	Ni (mg/kg)	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Mn (mg/kg)	Hg (mg/kg)
ANCHOR office	4.61 ± 0.02	2.49 ± 0.001	ND	7.34 ± 0.001	8.78 ± 0.008	ND
ANCHOR cafeteria	2.36 ± 0.01	1.33 ± 0.008	ND	3.72 ± 0.003	7.18 ± 0.005	ND
ANCHOR security house	2.10 ± 0.003	1.13 ± 0.004	ND	3.30 ± 0.04	6.36 ± 0.3	ND
ANCHOR walkway	2.39 ± 0.02	1.27 ± 0.07	ND	4.15 ± 0.05	7.96 ± 0.02	ND
ANCHOR medical priote	1.45 ± 0.04	0.513 ± 0.02	ND	2.57 ± 0.03	4.01 ± 0.007	ND
ABUAD Classroom	1.37 ± 0.002	0.429 ± 0.01	ND	1.75 ± 0.02	4.42 ± 0.09	ND
ABUAD office	1.99 ± 0.003	1.97 ± 0.04	ND	1.87 ± 0.03	4.21 ± 0.04	ND
ABUAD Laboratory	0.967 ± 0.005	0.476 ± 0.002	ND	1.39 ± 0.002	4.52 ± 0.03	ND
ABUAD workshop	5.63 ± 0.09	26.1 ± 0.9	ND	11.9 ± 0.2	16.8 ± 0.4	ND
ADEYEMI crèche	2.41 ± 0.001	0.648 ± 0.02	ND	4.40 ± 0.08	5.60 ± 0.02	ND
ADEYEMI classroom	3.17 ± 0.007	0.805 ± 0.001	ND	5.72 ± 0.008	6.01 ± 0.3	ND
ADEYEMI laboratory	2.29 ± 0.003	0.918 ± 0.004	ND	3.82 ± 0.002	5.06 ± 0.06	ND
ADEYEMI office	3.10 ± 0.02	0.409 ± 0.03	ND	5.99 ± 0.07	7.77 ± 0.3	ND
ADEYEMI workshop	0.254 ± 0.002	0.115 ± 0.003	0.018 ± 0.005	0.361 ± 0.02	0.775 ± 0.002	0.006 ± 0.007
Chrisland University (CLU) classroom	1.72 ± 0.02	0.784 ± 0.006	ND	2.77 ± 0.003	6.64 ± 0.02	ND
CLU Office	1.43 ± 0.01	0.806 ± 0.008	ND	2.34 ± 0.02	5.04 ± 0.03	ND
FUNAB Classroom	2.69 ± 0.02	1.83 ± 0.02	ND	4.31 ± 0.008	10.9 ± 0.006	ND
FUNAB Office	3.36 ± 0.04	1.93 ± 0.007	ND	3.65 ± 0.2	13.8 ± 0.8	ND
LASU Office	0.845 ± 0.008	0.551 ± 0.002	ND	1.35 ± 0.002	2.29 ± 0.007	ND

	Ni (mg/kg)	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Mn (mg/kg)	Hg (mg/kg)
LASU Corridor	1.08 ± 0.002	2.12 ± 0.03	ND	1.65 ± 0.04	2.99 ± 0.02	ND
LASU Laboratory	2.51 ± 0.04	3.68 ± 0.04	ND	2.43 ± 0.05	7.08 ± 0.002	ND
LASU classroom	2.02 ± 0.01	1.60 ± 0.02	ND	3.33 ± 0.008	5.95 ± 0.06	ND
UNILAG classroom	2.21 ± 0.003	2.05 ± 0.09	ND	7.76 ± 0.006	5.90 ± 0.04	ND
UNILAG office	0.437 ± 0.001	0.357 ± 0.006	ND	0.555 ± 0.001	0.566 ± 0.003	ND
UNILAG sport centre	1.92 ± 0.05	1.17 ± 0.03	ND	2.47 ± 0.02	4.83 ± 0.01	ND
UNILAG hall	0.974 ± 0.003	0.690 ± 0.01	ND	1.54 ± 0.003	3.48 ± 0.02	ND
UNILAG rest room	0.929 ± 0.02	0.535 ± 0.002	ND	1.70 ± 0.007	2.59 ± 0.004	ND
OAU Classroom	2.43 ± 0.04	1.40 ± 0.02	ND	4.27 ± 0.002	13.9 ± 0.8	ND
OAU Laboratory	0.734 ± 0.007	0.437 ± 0.02	ND	1.01 ± 0.004	3.80 ± 0.06	ND
OAU Security post	1.72 ± 0.06	1.21 ± 0.06	0.086 ± 0.003	2.65 ± 0.03	9.93 ± 0.05	ND
OAU Office	1.27 ± 0.005	0.575 ± 0.004	ND	2.12 ± 0.0022	5.51 ± 0.02	ND
OAU Workshop	0.217 ± 0.02	0.075 ± 0.007	ND	0.366 ± 0.02	0.552 ± 0.03	0.014 ± 0.002
Osun State University Classroom	1.23 ± 0.002	0.519 ± 0.03	ND	2.05 ± 0.02	3.47 ± 0.001	ND
Osun State University Laboratory	1.36 ± 0.07	0.523 ± 0.02	ND	2.19 ± 0.004	5.42 ± 0.02	ND
Osun State University Office	1.11 ± 0.006	0.314 ± 0.001	ND	1.57 ± 0.08	3.81 ± 0.06	ND
Osun State University Security post	1.39 ± 0.005	0.632 ± 0.002	ND	2.60 ± 0.03	7.48 ± 0.007	ND
Oduduwa University office	5.27 ± 0.09	1.95 ± 0.05	ND	9.01 ± 0.04	11.6 ± 0.7	ND
Oduduwa University classroom	2.10 ± 0.003	1.29 ± 0.01	ND	2.78 ± 0.05	8.01 ± 0.02	ND
Oduduwa University laboratory	1.49 ± 0.02	0.601 ± 0.02	ND	2.22 ± 0.02	7.44 ± 0.3	ND

	Ni (mg/kg)	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Mn (mg/kg)	Hg (mg/kg)
TASUED classroom	2.37 ± 0.02	0.795 ± 0.003	0.093 ± 0.007	4.68 ± 0.02	6.63 ± 0.001	ND
TASUED office	2.33 ± 0.04	0.667 ± 0.004	ND	4.47 ± 0.005	6.25 ± 0.003	ND
UI classroom	2.71 ± 0.005	2.65 ± 0.006	ND	3.52 ± 0.008	8.94 ± 0.2	ND
UI office	2.52 ± 0.02	1.38 ± 0.06	ND	3.80 ± 0.004	7.40 ± 0.07	ND
UI laboratory	2.26 ± 0.05	1.75 ± 0.01	ND	3.60 ± 0.09	8.53 ± 0.02	ND
UI workshop	2.38 ± 0.03	2.22 ± 0.02	ND	3.59 ± 0.03	10.5 ± 0.006	ND
UI Sport Arena	2.94 ± 0.008	2.96 ± 0.02	ND	4.58 ± 0.02	10.3 ± 0.05	ND
UI office	2.95 ± 0.007	3.52 ± 0.005	ND	4.66 ± 0.005	11.9 ± 0.004	ND
UI workshop	4.27 ± 0.08	13.5 ± 0.7	ND	4.80 ± 0.02	12.4 ± 0.02	ND
UNIMED classroom	1.01 ± 0.001	0.259 ± 0.003	ND	1.66 ± 0.007	2.97 ± 0.02	ND
UNIMED laboratory	2.51 ± 0.02	3.25 ± 0.05	ND	4.17 ± 0.001	5.89 ± 0.03	ND
UNIMED crèche	1.38 ± 0.04	0.512 ± 0.002	ND	2.29 ± 0.03	2.13 ± 0.001	ND
UNIMED office	1.96 ± 0.02	0.288 ± 0.02	ND	3.66 ± 0.02	5.82 ± 0.04	ND
WESLEY classroom	1.34 ± 0.06	0.207 ± 0.01	ND	2.25 ± 0.006	3.67 ± 0.05	ND
WESLEY workshop	2.38 ± 0.002	0.373 ± 0.03	ND	4.58 ± 0.04	7.05 ± 0.02	ND
WESLEY laboratory	2.93 ± 0.07	0.544 ± 0.001	ND	5.30 ± 0.07	8.50 ± 0.003	ND

Correlation among the PTEs

The result of the correlation among the PTEs is shown in Table 2. Correlations between the heavy metals in university dust samples have been shown by the correlation data, which may point to common sources or accumulation patterns. The strong positive correlation of 0.9077 between Pb and Ni was one notable finding. The observed significant correlation could potentially be attributed to common anthropogenic activities that release Pb and Ni at the same time, including construction operations within the institution or vehicle emissions [35]. These metals might have also come from paint or comparable building supplies utilized in the infrastructure, suggesting parallel patterns of deposition [36].

Furthermore, the strong positive correlation of 0.8237 between Mn and Ni may have indicated comparable causes, such as wear and tear on machinery or even similar pathways in stormwater runoff following rainstorms [37].

The modest relationship between Cu and Pb that was found might have resulted from their simultaneous use in certain of the equipment and electrical devices located on campus.
Conversely, the poor correlations that As had with other metals, particularly with Mn (0.644), would have pointed to different, potentially natural sources of As, like leaching from subterranean rocks or the application of specific pesticides in the surrounding green spaces [38].

On the other hand, Hg displayed an odd pattern, demonstrating negative associations with every other PTEs. The observed negative association, particularly with Mn at -0.3025, could potentially be attributed to conflicting deposition dynamics. For example, whereas Mn may have had frequent and diffuse sources such as adjacent industry or soil disturbance, Hg may have been mostly injected during specialized academic investigations. Also, this might have been because Hg was below detection limits in most of the samples while Mn was detected. However, the relationships seen between heavy metals in dust samples from universities suggest possible sources and patterns of deposition. Nevertheless, more research is needed to determine the precise sources. Understanding these links may be essential for direct mitigation efforts and provide information for campus policy decisions.

Table 2: Correlations between the PTEs

	Ni	Cu	As	Pb	Mn	Hg
Ni	1					
Cu	0.615006	1				
As	-0.03403	-0.05049	1			
Pb	0.907729	0.604034	0.000174	1		
Mn	0.823696	0.57039	0.064421	0.718	1	
				-	-	
Hg	-0.29621	-0.08161	0.017782	0.25596	0.30248	1

COMPARISON OF FEDERAL, STATE AND PRIVATE UNIVERSITIES

Comparison between Classroom dust from Federal universities (FUNAB, UniLag, OAU, UI, and Adeyemi University) and State Universities (LASU, OSU, TASUED and UniMed)

For Federal universities, Ni concentrations ranged from 2.21 ± 0.003 mg/kg (UNILAG) to 3.17 ± 0.007 mg/kg (Adeyemi Uni), which is higher than what was obtained for State Universities which ranged from 1.01 ± 0.001 mg/kg (UniMed) to 2.37 ± 0.02 mg/kg (TASUED).

For Federal universities, Cu concentrations ranged from 0.805 ± 0.001 mg/kg (ADEYEMI) to 2.65 ± 0.006 mg/kg (UI) compared with State universities which ranged from 0.259 ± 0.003 mg/kg (UniMed) to 1.60 ± 0.02 mg/kg (LASU).

In dust samples collected for Federal universities, As was below the detection limit, hence not detected (ND) in all while As concentration in dust from state universities ranged from ND (LASU, OSU & UniMed) to 0.093 ± 0.007 mg/kg (TASUED).

Mercury was not detected in all dust samples collected from Federal universities as well as in dust samples collected from State universities. The reason for this is that mercury is one of the expensive metals and cannot be disposed inappropriately.

For Federal universities, manganese concentration was high ranging from 5.90 ± 0.04 mg/kg (UNILAG) to 13.9 ± 0.8 mg/kg (OAU) compared to what was obtained in State universities which is in the range of 2.97 ± 0.02 mg/kg (UniMed) to 6.63 ± 0.001mg/kg (TASUED).

The concentration of Pb obtained in dust collected from Federal universities which ranged from 3.52 ± 0.008 mg/kg (UI) to 7.76 ± 0.006 mg/kg (UniLag) is higher compared to what was obtained

in dust from State universities which ranged from 1.66 ± 0.007 mg/kg (UniMed) to 4.68 ± 0.02 mg/kg (TASUED).

Conclusively, the concentration of the metals found in this study is higher in dust from Federal universities than in dust from State universities except Arsenic which was detected in only one state university (TASUED). The reason for the concentration of five heavy metals being higher in samples from Federal universities may be because they are mostly situated in State capitals with high population (of students and other inhabitants) and traffic.

Comparison between private universities (Anchor University, Chrisland University, Wesley University, ABUAD, and Oduduwa University) and Federal universities (FUNAB, UniLag, OAU, UI, and Adeyemi University):

Nickel **c**oncentration in classroom dust from private universities ranged from 1.34 ± 0.06 mg/kg (Wesley Uni) to 2.10 ± 0.003 mg/kg (Oduduwa University), a concentration range which is lower than what was obtained from Federal universities which was in the range of 2.21 ± 0.003 mg/kg (UNILAG) to 3.17 ± 0.007 mg/kg (Adeyemi university). This slight concentration difference can be due to the fact that these private universities are less populated compared to Federal universities, hence there is less waste to be incinerated [39].

The Cu concentration detected in dust from private universities ranged from 0.207 ± 0.01 mg/kg (Wesley Uni) to 1.29 ± 0.01 mg/kg (Oduduwa University) is low compared to what was obtained for Federal universities which ranged from 0.805 ± 0.001 mg/kg (ADEYEMI) to 2.65 ± 0.006 mg/kg (UI).

The result of this study showed that As was not detected in all dust samples collected from the four sampled private universities and also corroborated with what was obtained in classroom dust collected from the Federal universities studied.

The reason for the low Pb concentration in classroom dust from private universities which ranged from 1.75 ± 0.02 mg/kg (ABUAD) to 2.78 ± 0.05 mg/kg (Oduduwa University) compared to that of Federal Universities at 3.52 ± 0.008 mg/kg (UI) to 7.76 ± 0.006 mg/kg (UniLag) may be because Federal universities are more populated with and many car owners [40].

The was no detection of Hg in classroom dust from private universities similarly in classroom dust from Federal universities.

Manganese concentration for private universities ranged from 3.67 ± 0.05 mg/kg (Wesley Uni) to 8.01 ± 0.02 mg/kg (Oduduwa University). This concentration is low compared to the concentration obtained for Federal universities sampled in this study which ranged from 5.90 ± 0.04 mg/kg (UNILAG) to 13.9 ± 0.8 mg/kg (OAU). OAU is popular for its works of art, hence the high concentration of Mn which was detected in classroom dust from OAU may be because of the presence of Mn in the soil or clay used for artworks [41].

Comparison between State Universities (LASU, OSU, TASUED, and UniMed) and Private universities (Anchor University, Chrisland University, Wesley University, ABUAD, and Oduduwa University):

Nickel concentration range of 1.01 ± 0.001 mg/kg (UniMed) to 2.37 ± 0.02 mg/kg (TASUED) was obtained for State universities. This concentration range is higher than the concentration that was detected in classroom dust collected from private universities which ranged from 1.34 ± 0.06 mg/kg (Wesley Uni) to 2.10 ± 0.003 mg/kg (Oduduwa University). The reason for this difference may be because of the fumigation done in TASUED prior to the sampling for this study [42]. Moreover, sampling was done during strike, indicating less cleaning action in most State and Federal universities.

Copper concentrations in classroom dust from State universities, being in the range of 0.259 ± 0.003 mg/kg (UniMed) to 1.60 ± 0.02 mg/kg (LASU), was higher than those of private universities at 0.207 ± 0.01 mg/kg (Wesley Uni) to 1.29 ± 0.01 mg/kg (Oduduwa University). Investigation has shown that LASU is surrounded by a couple of car repair workshop, hence this could be the reason for it having the highest Cu concentration in this category [43].

Lead concentration in State universities which ranged from 1.66 ± 0.007 mg/kg (UniMed) to 4.68 ± 0.02 mg/kg (TASUED) is higher than was detected in private universities at 1.75 ± 0.02 mg/kg (ABUAD) to 2.78 ± 0.05 mg/kg (Oduduwa University). Since the major source of Pb in the environment is from car emissions, the reason for this difference is because State universities are more populated making it possible for the number of car users to be high [44].

Comparison between As concentration in classroom dust from State universities with private universities showed that As was not detected in all other sample locations except TASUED (0.093 ± 0.007).

From 2.97 ± 0.02 mg/kg (UniMed) to 6.63 ± 0.001 mg/kg (TASUED) was the concentration range for Mn in classroom dust from State universities. This concentration range is low compared to what is reported in dust from private universities to be 3.67 ± 0.05 mg/kg (Wesley Uni) to 8.01 ± 0.02 mg/kg (Oduduwa University).

Mercury was not detected in classroom dust from State universities and similarly in classroom dust from private universities.

This study highlights the environmental consequences and possible sources of contamination by offering a comparison of the metal concentrations in classroom dust across different kinds of institutions. Federal colleges are mostly located in State capitals with possibly higher population densities, traffic volumes, and student populations, hence, they may have higher concentrations of most PTEs than State universities. While this may be the case, other factors including the age of the structures, the kind of infrastructure, and upkeep procedures may also be important. According to Muller et al. [45], older buildings may have construction materials that release more metals into the environment.

Major sources of Arsenic in dust are industrial activities, agricultural practices other activities that may lead to arsenic emission [46]. The existence of arsenic in the dust from TASUED, a State university, but not in the dust from Federal or other State universities may be a result of fumigation which was carried out in the institution a few weeks prior to sampling. The comparison of Federal and private universities emphasizes the effect of population density on metal concentrations; it is claimed that fewer students in private universities means less waste to be burned. This assertion can be supported by research from Chang and Cockerham [47] who revealed that waste incineration can cause the release of different heavy metals into the environment.

The fluctuations in Pb concentrations in dust samples from Federal, State and private institutions may be because of vehicular emissions which is the main source of Pb in the environment. For this assertion to be supported, a thorough traffic analysis in the vicinity of these universities would be helpful. The observation that LASU, a State institution, has elevated copper concentrations, potentially as a result of adjacent auto repair shops, serves as an example of how certain local activities might affect metal concentrations [33].

CONCLUSION

This investigation reported the existence of potentially toxic elements in dust samples obtained from Universities and emphasizes the possible health hazards linked to these impurities. The dust samples had variable concentrations of PTEs. The results of the correlation analysis showed a connection between the PTEs, pointing to potentially similar origins or patterns of accumulation especially of Mn and Ni, Mn and Pb, Pb and Ni, Pb and Cu, Cu and Ni and Cu and Mn. A significant positive association was observed between lead and nickel, which could be attributed to similar human activities including building and car emissions [48]. A high positive association was also seen between manganese and nickel, suggesting possible similar sources or soil [49].

The impact of local activities and population density on dust metal concentrations was noticed through comparisons among Federal, State, and private university ownership. State and private universities typically had lower metal concentrations than Federal institutions, which are typically found in state capitals with denser populations and heavier traffic. Localized sources of contamination may be the cause of the arsenic found in the dust of a State university. Therefore, constant monitoring of the university environment for potentially toxic elements is recommended.

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