



Elemental Composition of Total Wet Particulate Matter Deposition in the Selected Industrial Areas within Lagos State

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Abstract The total deposition particulate matter (PM) was studied with seventeen selected Industrial Areas within Lagos state in the wet season (May-June 2015) to determine effects of seasonal changes and EIA of industrial activities on particulates generation. The samples were collected with deposition gauges (0.2 diameters by 0.15 m depth) which were placed at the sampling locations for a period of a month. The PMs deposited were characterized using Energy dispersive X-ray Fluorescence (EDXRF). The sources of the heavy metals were evaluated using Enrichment Factor (EF) Analysis. Factor Analysis (FA) was used to determine the correlations between the sources of the heavy metals. Twenty one elements (Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ge, As, Sr, Zr, Pb, Kr, Ta, Rb, Mo and Cd) were characterized in the PM collected at all the sample sites. The iron elemental ration ranged from 0.0001 – 0.985. The EF ranged from 0.0004 – 217.27 including the control experiment. The FA using Principal Component Analysis (PCA) techniques reveal six factors loading with 84.04% cumulative.

Keywords Deposition Gauges, EDXRF, Elemental ratio, Enrichment Factor, Factor analysis

1. Introduction

Clean air is considered a basic requirement for human health and well-being. Various chemicals are emitted into the air from both, natural and anthropogenic sources. In spite of the introduction of cleaner technologies in industry, energy production and transport, air pollution remains a major health risk and tighter emission controls are being enforced by many governments. According to the most recent update of the World Health Organization (WHO) air quality guidelines; many studies were published that had investigated the effects of air pollution on human health. Particulate matter pollution is nowadays one of the problems of the most concern in great cities, not only because of the adverse health effects, but also for reducing atmospheric visibility and its effects to the state of conservation of various cultural heritages [1]. On a global scale, particulate matter (PM) also influences directly and/or indirectly the Earth's radiation energy balance, and can subsequently impact on global climate change [2].

Wet deposition constitutes an important natural pathway for the removal of atmospheric pollutants. However, contamination of rainwater by atmospheric pollutants is of growing concern on both regional and global scale [3-4]. The composition of the rainwater plays an important role in the transport of the soluble components of the atmosphere, which helps in understanding the contribution of atmospheric polluting agents from different sources. The chemical composition of the rainwater varies from one site to another and from one region to another, due to the influence of local sources [5].

The existing published articles in Lagos State are on single industrial area. In this work, seventeen industrial areas are considered within Lagos State with aim of determining the elemental composition of total wet



particulate matter deposition in the selected industrial areas. The objectives of the study include sites identification, particulates characterization, elemental ratio determination, enrichment factor determination and factor analysis.

2. Materials and Method

2.1. Sampling Site and Sampling Procedures

Sampling site

The industrial areas selected in Ikeja LGA were Agidingbi Industrial Area (AGIA), Ojota Industrial Area (OJIA), Oregon Industrial Area (ORIA), and Ikeja Industrial Area (IKIA). The selected industrial areas at Apapa LGA were Ijora Industrial Area (IJIA), Tin Can Island Industrial Area (TIIA), Redline Industrial Area (RLIA), and Creek Road Industrial Area (CRIA). Two industrial areas selected at Oshodi/Isolo LGA were Ilasameja Industrial Area (ILIA) and Matori Industrial Area (MAIA). Ilupeju Industrial Area (IPIA) was selected at Mushin LGA. The industrial areas selected in Agege LGA were Oba Akran Industrial Area (OAIA) and Henry Car Industrial area (HCIA). Odogunyan industrial area (ODIA) was selected at Ikorodu LGA. Charley boy Industrial Area (CBIA) was selected at Kosofe LGA. The selected industrial areas from Surulere LGA and Ajeromi/Ifelodun LGA were Eric Moore Industrial area (EMIA) and Julius Berger Industrial Area (JBIA), respectively Fig.1, while Lagos State University Epe was selected at Epe LGA as control experiment.

Sampling Map

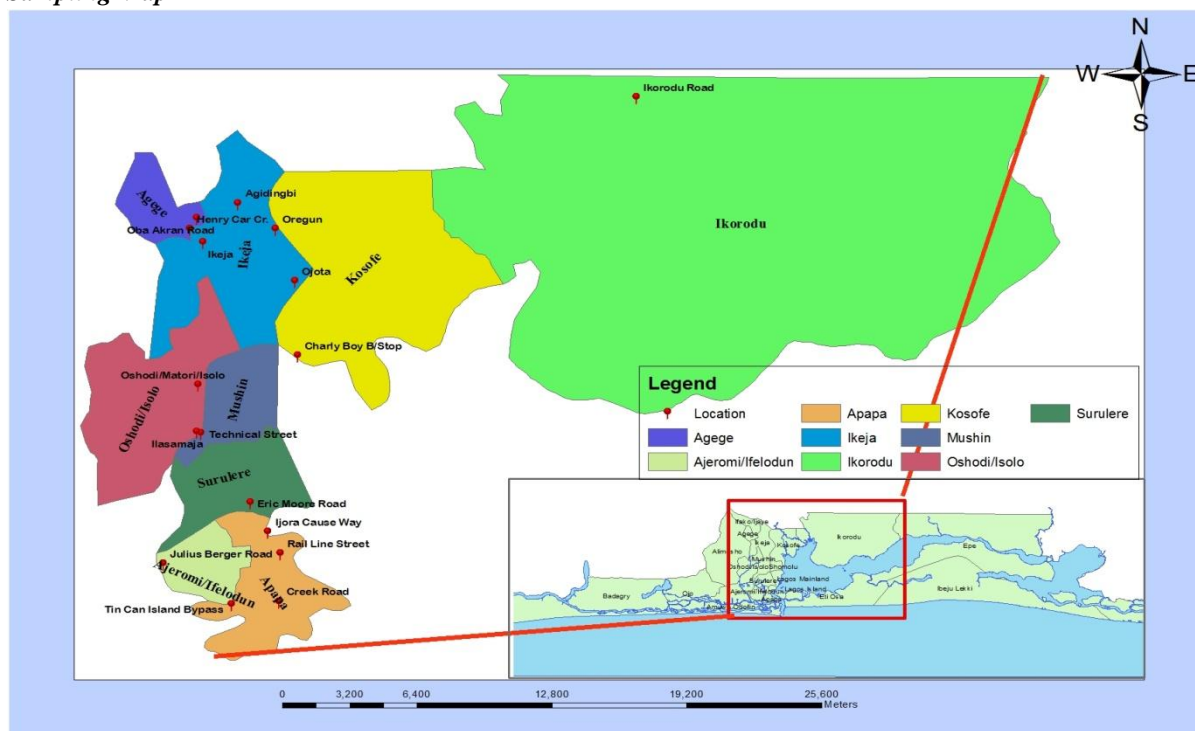


Figure 1: Selected Industrial Areas within Lagos State

Sampling procedure

The sampling period covered wet and dry seasons that are typical of Lagos State climates. May to June 2015 was chosen as study period for the wet season while the study period for the dry the season was December 2015 to January 2016. It was assumed that the wet and dry seasons were at their peak at these chosen periods. The deposition flux measurement was carried out using deposition gauges. Three deposition gauges (0.2m diameter by 0.15m depth) were deployed permanently to each sampling spot in the selected industrial area for a period of one month [6]. Some sampling spot were located in residential areas, which are in close proximity to the industries, in cases where access was denied to the industries. The deposited particulate matter was characterized for heavy metals using Energy Dispersive X-ray



Fluorescence Spectrometry (EDXRF). The EDXRF was used for this analysis due to its high sensitivity, which measure to parts per million of a gram in a sample. It is also multi-elemental detector equipment.

Sample preparation

The analyzed samples were dried, pulverized and pelletized. The pelletization of the samples were done with steel molds, pellets and an hydraulic press, aluminum foil was used as the binder to hold the sample particles together after removal from the molds. This was followed up by irradiation of samples. The irradiated samples were placed in the sample chamber. The sample chamber had the source X-ray tube and the Si-PIN photodiode detector connected, which are at angle 45° to it respectively, the source X-ray tube was maintained at a voltage of 25kV and a current of $50\mu\text{A}$ and each of the samples is irradiated for 1000sec. The electronic system detects the real time taken. The real time (RT) is actually the time it takes the electronic system to acquire, and, the X-ray photon signals reflected from the fluorescing atoms in the samples to detect the photon energy, which is usually more than the preset 1000 seconds. The lifetime (LT) is the pre-set time of 1000/sec calibrated for the specific sample by the operator. The dead time (DT) is actually the differences between the real time and the lifetime.

$$\text{The \% DT is} = \frac{RT-LT}{RT} \times 100 \quad 1$$

Where: RT = Real time (seconds), LT = Life time (seconds) and DT = Dead time (seconds)

If DT is much less than 15%, we obtain a considerably accurate spectrum of X-ray energy. To ensure a below 15% percentage dead time, the geometry of the sample chamber, the source X-ray tube and the Si-PIN photodiode detector have to be rearranged in such a way as to make sure the dead time is just about 5% for precision. The X-ray source tube will eject beams of X-radiation onto the sample, thereby irradiating the samples.

Elemental Ratio, Enrichment Factor and Factor Analysis

The elemental ratios were determined by selecting a marker element from the characterized results of the particulates sampled. This is usually done by selecting the highest occurring element from the characterized elements (Kothai et al., 2011). The elemental ratio was calculated using equation 2:

$$ER = \left(\frac{C_x}{C_{ref}} \right)_{\text{aerosol}} \quad 2$$

where C_x and C_{ref} are the concentrations of the element x and the reference element from the characterized results. The sources of the heavy metals in particulate matter study were evaluated using the enrichment factor (EF) analysis. The enrichment factor (EF_x) for an element x is defined as:

$$EF_x = \frac{[C_x/C_{ref}]_{\text{aerosol}}}{[C_x/C_{ref}]_{\text{crust}}} \quad 3$$

Where C_x and C_{ref} are the concentrations of the element x and the reference element, while $(C_x/C_{ref})_{\text{aerosol}}$ and $(C_x/C_{ref})_{\text{crust}}$ are the proportions of the element concentrations in the particulate matter and in the Earth's crust respectively.

The EFs were calculated by obtaining crustal elements data from literature [7]. An element will be chosen as indicator based on the type of industries located in these areas for enrichment factor to be used. Therefore, Iron (Fe) was chosen because it is the conventional element for the main source of the Earth's crust [8-9]. Crustal element data were taken from Taylor and McLennan [7].

3. Results and Discussion

Characterization of the deposition samples

The particulate matter obtained at the sampling spots were pooled together and then characterized for the presence of heavy metals such as Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ge, As, Sr, Zr, Pb, Kr, Ta, Rb, Mo and Cd in the wet season. The concentrations of each metal at the selected sampling industrial areas are discussed and presented in Table 1. The United State Environmental Protection Agency (USEPA) and the WHO have respectively set $35 \mu\text{g}/\text{m}^3$ and $25 \mu\text{g}/\text{m}^3$ as standard. The mean concentration of Chlorine (Cl) an anion was



highest at JBJA ($120.14 \times 10^6 \mu\text{g}/\text{m}^3$) and the standard deviation ($95.34 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest value was detected at OJIA ($22.93 \times 10^6 \mu\text{g}/\text{m}^3$) with the standard deviation ($1.63 \times 10^6 \mu\text{g}/\text{m}^3$). The concentration was found to be higher than the stipulated values as documented by USEPA and that of WHO at both JBJA and OJIA. In addition, these average concentrations of Cl were higher at both JBJA and OJIA when compared with studies where $20.60 \mu\text{g}/\text{m}^3$ was reported [10]. Potassium (K) a cation was detected from the characterized sample. The average concentration was highest at IJIA with concentration ($110.24 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($20.28 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest concentration ($8.32 \times 10^6 \mu\text{g}/\text{m}^3$) was found at ODIA with standard deviation ($8.35 \times 10^6 \mu\text{g}/\text{m}^3$). The average concentrations were higher than that of USEPA and WHO standard at IJIA and ODIA. The K concentrations were also higher than value ($3.07 \mu\text{g}/\text{m}^3$) reported by Fatma *et al.*, [10]. The concentration of Calcium (Ca) from the characterized wet sample are higher at ORIA with mean concentration ($636.44 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($585.08 \times 10^6 \mu\text{g}/\text{m}^3$) while that of ODIA was the lowest with concentration ($37.54 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($17.89 \times 10^6 \mu\text{g}/\text{m}^3$). The values obtained at ORIA and ODIA were higher than the standards proposed by USEPA and WHO. In addition, these values are higher than ($19.97 \mu\text{g}/\text{m}^3$) reported for an industrial area [10]. Titanium (Ti) was characterized from wet samples and has its highest mean concentration value at EMIA. The mean concentration value of Ti at EMIA ($128.75 \times 10^6 \mu\text{g}/\text{m}^3$) with standard deviation ($24.6 \times 10^6 \mu\text{g}/\text{m}^3$) while that of JBJA was the lowest with mean concentration of ($33.96 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($2.86 \times 10^6 \mu\text{g}/\text{m}^3$). The average concentrations at EMIA and JBJA were higher than the concentration ($0.809 \mu\text{g}/\text{m}^3$) reported by Gitari, Kinyua, Kamau and Gatebe [11]. In addition, both JBJA and EMIA have their respective concentrations higher than USEPA and WHO standards. The mean concentration of Vanadium (V) in the characterized wet samples was the highest at CRIA ($7.58 \times 10^6 \mu\text{g}/\text{m}^3$) with standard deviation ($1.35 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest at JBJA ($2.11 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($0.41 \times 10^6 \mu\text{g}/\text{m}^3$). The average concentrations were much higher than the USEPA and WHO standards. They were equally higher than $0.0072 \mu\text{g}/\text{m}^3$ that was reported by Kothai *et al.* [12]. The highest mean concentration ($5.66 \times 10^6 \mu\text{g}/\text{m}^3$) for Chromium (Cr) was at ODIA with standard deviation ($1.36 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest was recorded at IJIA ($1.87 \times 10^6 \mu\text{g}/\text{m}^3$) with the standard deviation ($0.38 \times 10^6 \mu\text{g}/\text{m}^3$) respectively. They are higher than the recommended standard value by USEPA and WHO and they were higher than the mean concentration ($0.026 \mu\text{g}/\text{m}^3$) reported by Kothai *et al.*, [12]. Manganese (Mn) recorded the highest mean concentration at MAIA ($79.75 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($27.80 \times 10^6 \mu\text{g}/\text{m}^3$) while lowest mean concentration ($12.61 \times 10^6 \mu\text{g}/\text{m}^3$) was detected at JBJA with and standard deviation ($3.88 \times 10^6 \mu\text{g}/\text{m}^3$). The average concentrations at MAIA and JBJA were higher than that of USEPA and WHO standards. $0.041 \mu\text{g}/\text{m}^3$ was recorded for industrial area elsewhere by Kothai *et al.*, [12], and the concentration was much lower than the characterized concentrations for Mn. Iron (Fe) was predominantly high in all the selected industrial area. However, MAIA has the highest mean concentration ($1113.94 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation of ($88.78 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest mean concentrations ($363.95 \times 10^6 \mu\text{g}/\text{m}^3$) was at JBJA with a standard deviation ($62.25 \times 10^6 \mu\text{g}/\text{m}^3$). The average concentrations at both locations were higher than the recommended by USEPA and WHO standards. The characterized average concentrations at the locations were also higher than ($1.9 \mu\text{g}/\text{m}^3$ and $6.025 \mu\text{g}/\text{m}^3$) as reported by Kothai *et al.*, [12] and Gitari *et al.*, [11] respectively. The highest mean concentration of Nickel (Ni) was at HCIA ($10.12 \times 10^6 \mu\text{g}/\text{m}^3$) and the standard deviation ($5.36 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest value was detected at MAIA ($3.64 \times 10^6 \mu\text{g}/\text{m}^3$) with the standard deviation ($1.05 \times 10^6 \mu\text{g}/\text{m}^3$). These concentrations were found to be higher than the stipulated average concentration values by USEPA and WHO [13-15]. In addition, the concentrations of Ni at HCIA and MAIA are higher when compared with reported value ($0.0023 \mu\text{g}/\text{m}^3$) by Kothai *et al.*, [12]. Copper (Cu) was detected from the characterized sample. The concentration was highest at OAIA with concentration value ($6.26 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($4.33 \times 10^6 \mu\text{g}/\text{m}^3$) while the lowest concentration ($1.71 \times 10^6 \mu\text{g}/\text{m}^3$) was found at IKIA and standard deviation ($1.03 \times 10^6 \mu\text{g}/\text{m}^3$). These values are higher than stipulated average concentrations by USEPA and WHO [13-15]. Both the highest and the lowest concentrations value here are higher than ($0.019 \mu\text{g}/\text{m}^3$) the value reported by Kothai *et al.*, (2011). The concentration of Zinc (Zn) from the characterized wet sample are higher at AGIA with mean concentration ($109.44 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($11.00 \times 10^6 \mu\text{g}/\text{m}^3$) while that of OAIA was the lowest with concentration value of ($8.72 \times 10^6 \mu\text{g}/\text{m}^3$) and standard deviation ($4.33 \times 10^6 \mu\text{g}/\text{m}^3$). The average concentration at AGIA and OAIA were higher than the standards values by USEPA and WHO and they



were higher than ($0.084\mu\text{g}/\text{m}^3$) and ($0.247\mu\text{g}/\text{m}^3$) respectively which were reported for an industrial area [11-12]. Germanium (Ge) was characterized from wet samples and has its highest mean concentration value at CRIA. The mean concentration value of Ge at CRIA was ($3.98 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($2.88 \times 10^6\mu\text{g}/\text{m}^3$) while that of AGIA was the lowest with mean concentration ($1.16 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($0.61 \times 10^6\mu\text{g}/\text{m}^3$). These average concentration values are higher than the recommended values by USEPA and WHO and they are equally higher than ($0.0051\mu\text{g}/\text{m}^3$) that was reported for an industrial area [12]. The mean concentrations of Arsenic (As) in the characterized wet samples were higher at LSUE ($1.46 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($0.65 \times 10^6\mu\text{g}/\text{m}^3$) and lowest at IJIA with mean concentration ($0.16 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($0.23 \times 10^6\mu\text{g}/\text{m}^3$). These average concentrations values are found to be higher than the recommended values by USEPA and WHO and they are much higher than ($0.0054\mu\text{g}/\text{m}^3$) that was reported for an industrial area by Kothai *et al.*, [12]. The mean concentration for Strontium (Sr) was the highest at OAIA ($96.01 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($131.00 \times 10^6\mu\text{g}/\text{m}^3$) and MAIA ($1.11 \times 10^6\mu\text{g}/\text{m}^3$) with the standard deviation ($0.17 \times 10^6\mu\text{g}/\text{m}^3$) respectively. The average concentration at these two industrial areas OAIA and MAIA were higher than the recommended value by USEPA and WHO. Also, both OAIA and MAIA have their values higher than reported value for an industrial area reported for an industrial area [12]. The mean concentration of Zirconium (Zr) was highest at AGIA ($722.01 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($73.30 \times 10^6\mu\text{g}/\text{m}^3$) while the lowest value was detected at LSUE ($0.75 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($0.04 \times 10^6\mu\text{g}/\text{m}^3$). AGIA and LSUE concentrations were higher than the USEPA and WHO standard. Their concentrations are equally higher when compared with other studies elsewhere [11]. Lead (Pb) was detected from the characterized sample. The concentration was highest at OJIA with concentration ($69.61 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($39.07 \times 10^6\mu\text{g}/\text{m}^3$) while the lowest concentration ($8.03 \times 10^6\mu\text{g}/\text{m}^3$) was found at LSUE with standard deviation ($8.35 \times 10^6\mu\text{g}/\text{m}^3$). Both OJIA and LSUE have their concentrations higher than the standard value by USEPA and WHO. The reported concentration ($0.024\mu\text{g}/\text{m}^3$) for an industrial area was much lower than characterized concentration of Pb [12]. The concentration of Krypton (Kr) from the characterized wet sample are higher at ILIA with mean concentration ($1.94 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($1.53 \times 10^6\mu\text{g}/\text{m}^3$) while that of CRIA and IJIA were the lowest with concentrations ($0.26 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($0.37 \times 10^6\mu\text{g}/\text{m}^3$). These average concentrations values are higher than the stipulated values by USEPA and WHO. Tantalum (Ta) was characterized from wet samples and has its highest mean concentration value at HCIA. The mean concentration at HCIA was ($70.51 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation of ($21.45 \times 10^6\mu\text{g}/\text{m}^3$) while that of IKIA was the lowest with mean concentration ($0.20 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation of ($15.15 \times 10^6\mu\text{g}/\text{m}^3$). The average concentration at HCIA and IKIA were higher than the standard by USEPA and WHO [13-15]. The mean concentrations of Rubidium (Rb) in the characterized wet samples were higher at IKIA ($24.12 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($0.37 \times 10^6\mu\text{g}/\text{m}^3$) while was lowest at OJIA with mean concentration ($1.22 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($0.47 \times 10^6\mu\text{g}/\text{m}^3$). These average concentrations values are higher than the standard by USEPA and WHO. They are higher than the reported ($0.011\mu\text{g}/\text{m}^3$) for an industrial area [12]. The mean concentration for Molybdenum (Mo) was the highest at OAIA ($88.68 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($122.25 \times 10^6\mu\text{g}/\text{m}^3$) and JBIA ($2.08 \times 10^6\mu\text{g}/\text{m}^3$) with the standard deviation ($0.44 \times 10^6\mu\text{g}/\text{m}^3$) respectively. Both OAIA and JBIA concentrations were higher than the standard values of USEPA and WHO respectively. Kothai *et al.*, [12] reported ($0.053\mu\text{g}/\text{m}^3$) for industrial are which was lower to the characterized concentration. Cadmium (Cd) was characterized from wet samples and has its highest mean concentration value at EMIA. The mean concentration value of Cd at EMIA was ($499.98 \times 10^6\mu\text{g}/\text{m}^3$) with standard deviation ($20.53 \times 10^6\mu\text{g}/\text{m}^3$) while that of IKIA was the lowest with mean concentration ($2.87 \times 10^6\mu\text{g}/\text{m}^3$) and standard deviation ($77.15 \times 10^6\mu\text{g}/\text{m}^3$). The average concentration value at EMIA and IKIA were higher than the standard by USEPA and WHO. The two are higher than average concentration ($1.20\mu\text{g}/\text{m}^3$) that was reported by Farahmandkia *et al.*, [16].



Table 1: Concentrations of Characterized particulate matter for the wet season ($\mu\text{g}/\text{m}^3$) 10^6

	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Ge	As	Sr	Zr	Pb	Kr	Ta	Rb	Mo	Cd
HClA	69.01	67.05	184.24	108.83	6.52	2.20	30.76	1012.64	10.82	5.41	52.02	3.01	ND	3.33	494.44	59.33	ND	70.51	3.51	4.19	461.34
OAlA	34.94	38.18	365.44	58.01	3.98	3.66	33.41	550.29	6.51	6.26	8.72	2.10	ND	96.01	198.91	43.78	ND	24.40	2.09	88.68	308.42
JBIA	120.14	61.54	474.10	33.96	2.11	2.50	12.61	363.95	5.23	2.29	16.91	1.84	ND	1.91	236.42	21.03	0.71	39.37	1.56	2.08	356.80
AGIA	72.20	51.09	212.23	93.67	5.81	3.03	35.56	853.01	6.04	4.40	109.44	1.16	ND	2.10	722.01	64.90	ND	42.80	1.86	2.79	418.09
IKIA	41.93	86.20	40.43	44.07	4.60	2.52	26.36	672.19	6.18	1.71	17.22	2.05	ND	1.87	358.69	23.96	0.20	24.12	2.60	2.87	302.06
OJIA	22.99	31.49	257.30	35.81	3.67	3.43	16.90	396.44	6.38	2.91	11.82	1.71	ND	2.44	223.96	69.61	ND	26.29	1.22	2.16	284.48
ORIA	45.60	65.22	636.44	72.09	5.18	3.50	22.87	669.39	5.62	3.13	20.04	1.42	ND	3.32	449.28	29.88	ND	21.59	1.86	2.94	374.45
ODIA	45.42	8.32	37.64	59.76	4.31	5.66	47.74	891.88	5.68	3.27	80.87	2.72	ND	1.25	445.94	24.91	ND	26.29	1.82	2.58	305.45
CBIA	49.65	48.66	248.63	105.29	6.78	4.20	24.64	1013.02	6.81	5.68	43.96	1.93	ND	2.84	509.27	43.96	ND	28.35	2.33	2.16	453.47
ILIA	46.95	54.36	47.54	41.65	4.07	2.71	19.84	657.59	3.98	1.90	20.48	1.49	ND	1.71	356.31	22.44	ND	23.35	1.61	2.42	297.99
MTIA	57.27	14.97	41.82	77.28	3.95	5.22	79.75	1113.94	3.64	5.22	44.19	1.44	ND	1.11	413.79	31.94	ND	24.92	1.42	2.86	305.26
ILIA	38.40	41.90	122.74	66.17	4.90	2.76	18.46	668.14	5.94	4.70	32.03	1.90	0.75	1.55	437.64	16.31	1.94	38.29	1.79	2.37	341.22
EMIA	67.29	59.73	207.98	128.75	6.84	3.56	24.63	892.27	8.74	5.79	56.40	2.52	ND	2.91	600.14	61.07	ND	54.69	3.71	4.15	499.98
CRIA	44.42	58.30	551.03	83.61	7.58	3.61	21.17	688.76	7.07	3.31	26.61	3.98	ND	3.12	367.24	36.27	0.26	47.73	2.87	3.99	495.13
IJIA	52.14	110.24	399.34	65.59	2.95	1.87	19.71	764.66	6.73	3.96	14.46	2.23	0.16	3.66	265.64	38.98	0.26	41.83	2.61	3.75	383.62
RDIA	51.53	51.71	222.94	41.51	3.69	3.15	13.61	501.94	8.18	2.26	16.23	3.24	ND	2.44	231.23	34.92	ND	42.73	2.07	2.67	312.51
TCIA	62.26	53.71	582.02	35.91	2.76	3.88	14.23	484.21	5.82	2.87	19.62	2.02	0.60	2.37	143.08	19.45	0.94	27.85	1.63	2.23	339.14
LSUE	61.46	74.14	373.29	59.80	4.02	3.33	17.12	646.72	4.00	4.03	40.28	1.59	1.46	2.87	0.75	8.03	1.88	22.01	2.35	2.81	321.95

Elemental Ratio

The elemental ratio of the elements found in the particulate collected during the wet season was calculated across the selected industrial areas with reference to Iron (Fe) [12]. The highest elemental ratio of chlorine (Cl) for the particulate collected during the wet season was determined at JBIA to be 0.318 while the lowest value was determined at CBIA to be 0.049 Table 2. For values lower than 1.00 could be traced to sources emitting iron, such as soil entrainment, which is a major source of particulates to the ambient air locations. Values beyond that could suggest the emitting of chlorine and this indicates the presence of wood smoke from burning. Therefore, Emission of iron is suggested. Potassium (K) elemental ratio was also determined across the selected areas. The highest value 0.162 was found at JBIA and the lowest value 0.007 was found at ODIA. All values are lower than the reported values, and then iron emission is suggested. The elemental ratio for (Ca) for wet season was calculated across the selected industrial areas and the highest was determined at ORIA to be 1.359 while the lowest value was determined at MAIA to be 0.038. The highest value is higher than the value reported therefore suggesting emission of calcium while the lower value is suggesting emission of iron. Titanium (Ti) elemental ratio was also determined across the selected areas. The highest value 0.144 was found at EMIA and the lowest value 0.063 was found at IPIA. Values are lower than the reported values thereby suggesting the emission of iron. The elemental ratio for (V) for wet season was calculated across the selected industrial areas and the highest was determined at CRIA to be 0.011 while the lowest value was determined at MAIA to be 0.004. Values are lower than the reported values thereby suggesting the emission of iron. Chromium (Cr) elemental ratio was also determined across the selected areas. The highest value 0.006 was found at ORIA and the lowest value 0.002 was found at HClA. Values are lower than the reported values thereby suggesting the emission of iron. The elemental ratio for manganese (Mn) for wet season was calculated across the selected industrial areas and the highest was determined at MAIA to be 0.073 while the lowest value was determined at CBIA to be 0.024. Values are lower than the reported values thereby suggesting the emission of iron. Nickel (Ni) elemental ratio was also determined across the selected areas. The highest value 0.019 was found at OJIA and the lowest value 0.003 was found at MAIA. The values are much lower and it suggests that iron is emitted. The elemental ratio for (Cu) for wet season was calculated across the selected industrial areas and the highest was determined at OAlA to be 0.011 while the lowest value was determined at IKIA to be 0.002. Since the values are lower than the reported values, emission of iron is suggested. Zinc (Zn) elemental ratio was also determined across the selected areas. The highest value 0.128 was found at AGIA and the lowest value 0.017 was found at OAlA. Since the values are lower than the reported values, emission of iron is suggested. The elemental ratio for (Ge) for wet season was calculated across the selected industrial areas and the highest was determined at RLIA to be 0.008 while the lowest values were determined at both MAIA and AGIA to be 0.001 and since it is also much lower than the reported values, emission of iron is suggested. Arsenic (As) was detected only in four of the selected industrial areas including the control experiment. These are Ilupeju Industrial area (ILIA), Ijora industrial area (IJIA), Tincan Island industrial area (TIIA) and Lagos State University Epe Campus (LSUE). The highest value 0.002 was found at LSUE while the lowest value 0.0001 was found at IJIA. This is lower than the reported values, emission of iron is suggested. The elemental ratio for (Sr) for wet season was calculated across



the selected industrial areas and the highest was determined at OAIA to be 0.160 while the lowest value was determined at MAIA to be 0.0001 since it is also much lower than the reported values, emission of iron is suggested. Zirconium (Zr) elemental ratio was also determined across the selected areas. The highest value 0.895 was found at AGIA and the lowest value 0.001 was found at LSUE. The ratio value was higher at AGIA; therefore, emission of zirconium is suggested while emission of iron is suggested at LSUE. The elemental ratio for Lead (Pb) for wet season was calculated across the selected industrial areas and the highest was determined at OJIA to be 0.172 while the lowest value was determined at LSUE to be 0.013 since it is also much lower than the reported values, emission of iron is suggested. Krypton (Kr) was detected only in seven of the selected industrial areas including the control experiment. These are Julius Berger Industrial area (JBIA), Ikeja industrial area (IKIA), Ilasamaja Industrial area (ILIA), Creek Road Industrial Area (CRIA), Ijora Industrial Area (IJIA), Tincan Island industrial area (TIIA) and Lagos State University Epe Campus (LSUE). The highest value 0.003 was found at ILIA while the lowest value 0.0001 was found at IJIA. This is lower than the reported values, emission of iron is suggested. The elemental ratio for Tantalum (Ta) for wet season was calculated across the selected industrial areas and the highest was determined at JBIA to be 0.129 while the lowest value was determined at MAIA to be 0.023. Fig. 39 has the details and since it is also much lower than the reported values, emission of iron is suggested. Rubidium (Rb) elemental ratio was also determined across the selected areas. The highest value 0.004 was found at RLIA and the lowest value 0.001 was found at MAIA. These values are lower than the reported values, emission of iron is suggested. The elemental ratio for Molybdenum (Mo) for wet season was calculated across the selected industrial areas and the highest was determined at OAIA to be 0.148 while the lowest value was determined at CBIA to be 0.002. Since the values are lower at the both the highest and the lowest industrial locations than the reported values, emission of iron is suggested. Cadmium (Cd) elemental ratio was also determined across the selected areas. The highest value 0.985 was found at JBIA and the lowest value 0.275 was found at MAIA and the value is higher at JBIA, emission of cadmium is suggested while emission of iron is suggested at MAIA.

Enrichment Factor

Calculation of enrichment factor (EF) values helps in determining whether a certain element has additional or anthropogenic sources other than its major crustal sources. Sources of metal in particulate include both natural and anthropogenic processes (Salwa and Mamdouh, 2016). Iron (Fe) was used as a reference element for an EF evaluation with respect to crustal abundance, assuming that the contribution of its anthropogenic source to the atmosphere is negligible (Wuet *et al.*, 2007). According to norms, when $EF < 10$ is taken as an indication of crustal-derived trace metals source in the atmosphere and these are termed the Non-Enriched Elements (NEEs). In contract, an EF value of > 10 is considered to indicate non-crustal source or anthropogenically-derived trace metal source, and these are referred to as anomalously enriched elements (AEEs) (Cheng *et al.*, 2005). The Enrichment factor for Cl, Zn and Zr in all the selected industrial areas are >10 . This means that their sources were anthropogenic except LSUE which was the control experiment. Cr, Ni and Sr also showed that their sources are anthropogenic at Industrial areas such as LSUE, JBIA, OJIA, RLIA and OAIA while the sources of all other elements are crustal derived since their $EF < 10$.

Table 2: The Iron Elemental ratio for wet seasons

	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Ge	As	Sr	Zr	Pb	Kr	Ta	Rb	Mo	Cd
HCIA	0.068	0.067	0.185	0.108	0.006	0.002	0.030	1.000	0.011	0.005	0.051	0.003	ND	0.003	0.487	0.059	ND	0.070	0.003	0.004	0.457
OAIA	0.064	0.070	0.660	0.105	0.007	0.007	0.058	1.000	0.012	0.011	0.017	0.004	ND	0.160	0.378	0.080	ND	0.047	0.004	0.148	0.564
JBIA	0.318	0.162	1.270	0.095	0.006	0.007	0.034	1.000	0.016	0.007	0.048	0.005	ND	0.005	0.652	0.065	0.003	0.129	0.004	0.006	0.985
AGIA	0.086	0.060	0.251	0.109	0.007	0.004	0.041	1.000	0.007	0.005	0.128	0.001	ND	0.002	0.855	0.076	ND	0.051	0.002	0.003	0.495
OJIA	0.063	0.081	0.568	0.095	0.009	0.008	0.044	1.000	0.019	0.008	0.033	0.005	ND	0.006	0.620	0.172	ND	0.079	0.004	0.006	0.771
ORIA	0.068	0.105	1.359	0.106	0.008	0.006	0.034	1.000	0.008	0.005	0.029	0.002	ND	0.006	0.623	0.040	ND	0.032	0.003	0.004	0.594
IKIA	0.064	0.128	0.060	0.064	0.007	0.004	0.039	1.000	0.009	0.002	0.026	0.003	ND	0.003	0.554	0.036	0.000	0.034	0.004	0.004	0.455
ODIA	0.051	0.007	0.042	0.073	0.006	0.007	0.051	1.000	0.008	0.003	0.082	0.004	ND	0.001	0.562	0.027	ND	0.034	0.002	0.004	0.392
CBIA	0.049	0.048	0.247	0.104	0.007	0.004	0.024	1.000	0.007	0.006	0.043	0.002	ND	0.003	0.503	0.043	ND	0.028	0.002	0.002	0.448
IPIA	0.075	0.085	0.075	0.063	0.006	0.005	0.031	1.000	0.006	0.003	0.031	0.003	ND	0.003	0.560	0.035	ND	0.039	0.003	0.004	0.470
MAIA	0.052	0.013	0.038	0.071	0.004	0.005	0.073	1.000	0.003	0.005	0.039	0.001	ND	0.001	0.378	0.029	ND	0.023	0.001	0.003	0.276
ILIA	0.054	0.062	0.191	0.100	0.007	0.004	0.028	1.000	0.010	0.006	0.048	0.003	0.001	0.002	0.679	0.022	0.003	0.055	0.003	0.004	0.521
EMIA	0.077	0.068	0.240	0.144	0.008	0.004	0.027	1.000	0.009	0.006	0.062	0.003	ND	0.003	0.710	0.068	ND	0.059	0.004	0.005	0.567
CRIA	0.066	0.086	0.833	0.120	0.011	0.005	0.031	1.000	0.010	0.005	0.040	0.006	ND	0.005	0.552	0.054	0.000	0.070	0.004	0.006	0.720
IJIA	0.068	0.145	0.545	0.085	0.004	0.003	0.026	1.000	0.009	0.005	0.019	0.003	0.000	0.005	0.352	0.052	0.000	0.052	0.003	0.005	0.503
RLIA	0.108	0.106	0.519	0.083	0.008	0.007	0.028	1.000	0.019	0.005	0.033	0.008	ND	0.005	0.514	0.080	ND	0.098	0.004	0.006	0.674
TIIA	0.129	0.111	1.205	0.074	0.006	0.008	0.029	1.000	0.012	0.006	0.041	0.004	0.001	0.005	0.295	0.040	0.002	0.058	0.003	0.005	0.702
LSUE	0.096	0.114	0.570	0.092	0.006	0.005	0.026	1.000	0.006	0.006	0.065	0.002	0.002	0.004	0.001	0.013	0.003	0.034	0.004	0.004	0.496



Table 3: Enrichment Factor for Wet Season

	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Ge	As	Sr	Zr	Pb	Kr	Ta	Rb	Mo	Cd
HCIA	46.51	0.26	0.35	1.25	2.92	1.31	1.84	1.00	7.67	4.83	35.56	0.01	0.00	0.32	102.21	0.01	0.00	0.06	1.44	0.01	6.44
OAIA	43.78	0.27	1.25	1.21	3.35	3.98	3.51	1.00	8.66	9.75	11.55	0.01	0.00	15.30	79.39	0.01	0.00	0.04	1.56	0.32	7.94
JBIA	217.27	0.63	2.41	1.10	2.72	4.27	2.04	1.00	11.59	5.89	33.15	0.02	0.00	0.50	136.88	0.01	0.00	0.01	0.31	0.00	0.02
AGIA	58.83	0.23	0.48	1.26	3.12	2.16	2.49	1.00	5.21	4.58	89.04	0.00	0.00	0.24	179.44	0.01	0.00	0.04	0.90	0.01	6.97
OJIA	42.90	0.31	1.08	1.10	4.32	4.76	2.64	1.00	13.46	7.26	22.84	0.02	0.00	0.57	130.16	0.02	0.00	0.07	1.46	0.01	10.85
ORIA	46.49	0.41	2.58	1.22	3.55	3.64	2.04	1.00	5.87	4.22	20.00	0.01	0.00	0.55	130.74	0.00	0.00	0.03	1.11	0.01	8.37
IKIA	43.55	0.50	0.11	0.74	3.12	2.25	2.34	1.00	6.50	2.10	17.90	0.01	0.00	0.30	116.30	0.00	0.00	0.00	0.00	0.21	0.00
ODIA	35.10	0.03	0.08	0.84	2.58	4.20	3.06	1.00	5.52	2.27	57.09	0.01	0.00	0.14	118.07	0.00	0.00	0.03	0.91	0.01	5.52
CBIA	33.47	0.19	0.47	1.21	3.08	2.50	1.47	1.00	4.80	4.98	30.11	0.01	0.00	0.27	105.66	0.01	0.00	0.02	0.95	0.00	6.30
IPIA	51.57	0.33	0.14	0.73	2.96	2.78	1.87	1.00	4.59	2.44	21.17	0.01	0.00	0.25	117.61	0.00	0.00	0.03	1.07	0.01	6.62
MAIA	35.40	0.05	0.07	0.82	1.67	2.91	4.41	1.00	2.39	4.24	27.16	0.00	0.00	0.10	79.47	0.00	0.00	0.02	0.53	0.01	3.88
ILIA	37.07	0.24	0.36	1.15	3.42	2.42	1.70	1.00	6.89	5.36	33.51	0.01	0.00	0.21	142.59	0.00	0.00	0.00	0.22	0.00	0.01
EMIA	52.69	0.26	0.46	1.66	3.53	2.57	1.65	1.00	6.75	5.80	43.30	0.01	0.00	0.31	149.19	0.01	0.00	0.05	1.67	0.01	7.98
CRIA	44.82	0.33	1.58	1.38	4.89	3.20	1.87	1.00	7.13	4.51	27.39	0.02	0.00	0.44	115.89	0.01	0.00	0.00	0.39	0.00	0.01
IJIA	46.17	0.56	1.03	0.99	1.84	1.63	1.55	1.00	6.26	4.46	12.98	0.01	0.00	0.47	73.85	0.01	0.00	0.00	0.24	0.00	0.01
RLIA	73.63	0.41	0.99	0.96	3.51	4.18	1.68	1.00	13.74	4.13	23.04	0.02	0.00	0.51	107.85	0.01	0.00	0.09	1.83	0.01	9.49
TIIA	88.34	0.43	2.29	0.86	2.61	4.83	1.78	1.00	8.55	5.31	28.09	0.01	0.00	0.47	61.98	0.00	0.00	0.00	0.24	0.00	0.01
LSUE	8.11	0.01	0.03	0.01	0.82	139.69	0.03	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Factor Analysis

The data obtained for the wet seasons were subjected to Factor analysis (FA) to interpret relationships between variables and the technique use for this was Principal Component Analysis (PCA). The main reason for using PCA is to account for the total variation among the variables in p-dimensional space by forming a new set of orthogonal and uncorrelated composite variables. Each of the new members of the set of variates is a linear combination of the original set of measurements [17]. The correlation coefficient is a measure of linear correlation between two variables and giving a value between +1 and -1. Where '1' is total positive correlation, '0' is no correlation, and '-1' is total negative correlation. This is widely used in the sciences as a measure of the degree of linear dependences between two variables. Therefore, the correlation factors for various metals were derived [18].

Correlation matrix of metals

The wet season correlation revealed that elements displayed both negative and positive matrix. Ti has a very strong correlations with V, Fe, Cu, and Sr in that $r = 0.83, 0.78, 0.74$ and 0.72 respectively (Table 4). Ti also has moderate correlations with Ni, Zn, Pb, Ta and Cd where $r = 0.50, 0.57, 0.51, 0.57$ and 0.67 respectively. V has a moderate correlations with Fe, Sr and Cd where $r = 0.58, 0.67$ and 0.51 . Cr has a moderate correlation of $r = 0.63$ with Mn while Mn has moderate correlation of $r = 0.69$ with Fe. Furthermore, Fe has a moderate correlations of $r = 0.59, 0.62$ and 0.65 with Cu, Zn and Sr respectively. Ni has a moderate correlations of $r = 0.64$ and 0.60 with Ger and Pb respectively. Cu has a moderate correlation of $r = 0.53$ Cd. Zn has a moderate correlation of $r = 0.69$ with Sr. Ger has a moderate correlation of $r = 0.50$ with Ta. As has a very strong correlation of $r = 0.91$ with Kr, Sr has a moderate correlation of $r = 0.51$ with Pb while Ta has strong correlation ($r = 0.79$) with Cd. The positive correlations found between metals could indicate a common source or chemical similarity, while the negative correlation could indicate that the metals originated from different sources possess non-chemical similarity. The elements have good correlations among themselves and they are typically associated with exhaust and non-exhaust sources [19]. The communalities for the wet season were inserted in diagonal of the correlation matrix (Table 5). As regards the eigenvalues, in the wet season, six factors were extracted, as the eigenvalues are greater than one (Table 6). Factor I accounted for 28.674% of the total variance with high loading of Cl, while factor II accounted for 16.638% of the total variance with high loading of K. Similarly, factor III accounted for 12.863% of the total variance with high loading of Ca while factor IV accounted for 11.987% of the total variance with high loading of Ti. Factor V accounted for 7.632% of the total variance with high loading of V while factor VI accounted for 6.228% of the total variance with high loading of Cr. The available data from the wet season resulted in six principal components with eigenvalues greater than one explaining 84.02% of the variance. Using the values of the respective loadings (Table 7), there are reasonable interpretations between the six components in the wet season, for the interpretation of the wet season to be simplified as representing certain source of air pollution, a varimax rotation was applied. The aim of this was to find variable that have an interpretation in terms of different source of air pollution. Considering the correlation



loadings of the rotated component, it was observed that in the wet season (Table 7) that the first component has very strong correlation with Ti (0.90), and Sr (0.81), strong correlation with V (0.77), Fe (0.77), and moderate correlation with Ni (0.56), Cu (0.66), Zn (0.66), Pb (0.68), Ta (0.63) and Cd (0.65). Second component has moderate correlation with K (0.67), Ta (0.63) and weak correlation with Ca (0.57) and Ni (0.57). Third component has a moderate correlation (0.89) with Zr and Mo. Fourth component has a weak correlation (0.57) with As and Kr while the sixth component also has correlation with Ger (0.68). Further component transformation (Table 8) revealed that the first component has a very strong correlation of 0.83 with Cl; second component has a weak and moderate correlation (0.52) with K and (0.63) with Ti respectively.

Third component has moderate correlation (0.74) with K. Fifth component has a very strong correlation (0.86) with Ca while component six has a very strong correlation (0.84) with V. This indicates that concentration of deposited particle and contamination in the selected study areas are most likely originated surfaces and crustal particle as well as anthropogenic sources particularly from vehicle emissions and industrial activities [10, 20-21].

4. Conclusions

Particulate Matter was collected at industrial area to know the impact of their emissions in the ambient air. EDXRF technique has been used to determine the concentration levels of heavy metals in the filter samples containing only few hundred μg of total dust load. Elemental composition of the characterized samples of the particulate matter revealed that only Ca was emitted during the wet season. Concentrations of crustal and sea salt derived elements found in high levels. The EF analysis showed very high enrichment for elements Cl, Cr, Ni, Zn, Sr, Zr and Cd were found to be enriched in the samples, which indicate their nature of origin could be from any anthropogenic sources and has been confirmed by PCA studies.

Table 4: Wet Season Correlation matrix^a

Elements	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Ger	As	Zr	Sr	Pb	Kr	Ta	Rb	Mo	Cd	
Cl	1.00																					
K	0.21	1.00																				
Ca	0.21	0.35	1.00																			
Ti	0.09	0.03	-0.10	1.00																		
V	-0.19	-0.02	-0.09	0.83	1.00																	
Cr	-0.22	-0.79	-0.16	0.10	0.09	1.00																
Mn	-0.08	-0.55	-0.48	0.29	0.10	0.63	1.00															
Fe	-0.03	-0.15	-0.46	0.78	0.58	0.34	0.69	1.00														
Ni	0.01	0.23	0.03	0.50	0.49	-0.31	-0.24	0.17	1.00													
Cu	-0.05	-0.19	-0.08	0.74	0.45	0.22	0.40	0.59	0.31	1.00												
Zn	0.22	-0.31	-0.37	0.57	0.44	0.33	0.44	0.62	0.08	0.34	1.00											
Ger	-0.09	0.06	0.10	0.18	0.38	0.00	-0.16	0.03	0.64	-0.02	-0.10	1.00										
As	0.01	0.18	0.17	-0.17	-0.21	-0.07	-0.27	-0.18	-0.33	0.04	-0.04	-0.21	1.00									
Zr	-0.24	-0.15	0.13	-0.07	-0.10	0.06	0.09	-0.19	0.05	0.43	-0.25	0.00	-0.10	1.00								
Sr	0.06	-0.17	-0.36	0.72	0.67	0.10	0.36	0.65	0.32	0.34	0.69	-0.03	-0.53	-0.23	1.00							
Pb	-0.11	-0.09	-0.10	0.51	0.43	-0.08	0.11	0.25	0.60	0.41	0.31	0.10	-0.55	0.12	0.51	1.00						
Kr	0.14	0.13	0.19	-0.22	-0.24	-0.17	-0.34	-0.29	-0.32	-0.01	-0.11	-0.16	0.91	-0.13	-0.44	-0.61	1.00					
Ta	0.37	0.10	0.11	0.57	0.40	-0.27	-0.11	0.25	0.71	0.39	0.30	0.50	-0.15	-0.13	0.35	0.48	-0.05	1.00				
Rb	-0.14	0.39	-0.30	-0.11	0.08	-0.25	-0.02	0.01	0.08	-0.31	-0.14	0.05	-0.11	-0.06	0.04	-0.13	-0.14	-0.45	1.00			
Mo	-0.24	-0.16	0.12	-0.06	-0.09	0.07	0.11	-0.17	0.05	0.44	-0.24	0.01	-0.11	1.00	-0.22	0.12	-0.14	-0.12	-0.06	1.00		
Cd	0.28	-0.03	0.37	0.67	0.51	0.04	-0.07	0.31	0.40	0.53	0.33	0.29	-0.06	-0.07	0.36	0.39	-0.01	0.79	-0.71	-0.07	1.00	

a. This matrix is not positive definite.

Table 5: Wet and Dry Season Communalities

Elements	Initial	Wet Extraction
Cl	1.000	0.632
K	1.000	0.849
Ca	1.000	0.584
Ti	1.000	0.951
V	1.000	0.801
Cr	1.000	0.876
Mn	1.000	0.784
Fe	1.000	0.860
Ni	1.000	0.844
Cu	1.000	0.940
Zn	1.000	0.727
Ger	1.000	0.817
As	1.000	0.934
Zr	1.000	0.955
Sr	1.000	0.835
Pb	1.000	0.721
Kr	1.000	0.901
Ta	1.000	0.860



Rb	1.000	0.875
Mo	1.000	0.950
Cd	1.000	0.948
W	1.000	NT
Po	1.000	NT
Ac	1.000	NT
Na	1.000	NT
Si	1.000	NT
P	1.000	NT
S	1.000	NT

Extraction Method: Principal Component Analysis
NT: Not Detected

Table 6: Wet Season Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.022	28.674	28.674	6.022	28.674	28.674	4.723	22.492	22.492
2	3.494	16.638	45.311	3.494	16.638	45.311	2.819	13.422	35.914
3	2.701	12.863	58.174	2.701	12.863	58.174	2.796	13.316	49.231
4	2.517	11.987	70.161	2.517	11.987	70.161	2.770	13.193	62.424
5	1.603	7.632	77.794	1.603	7.632	77.794	2.522	12.008	74.432
6	1.308	6.228	84.021	1.308	6.228	84.021	2.014	9.589	84.021
7	0.893	4.252	88.273						
8	0.819	3.898	92.170						
9	0.564	2.685	94.855						
10	0.382	1.817	96.672						
11	0.270	1.286	97.957						
12	0.174	0.829	98.787						
13	0.153	0.728	99.515						
14	0.067	0.321	99.836						
15	0.027	0.127	99.963						
16	0.006	0.030	99.993						
17	0.002	0.007	100.000						
18	1.278 x 10 ⁻¹⁶	6.085 x 10 ⁻¹⁶	100.000						
19	6.822 x 10 ⁻¹⁸	3.249 x 10 ⁻¹⁷	100.000						
20	-1.041 x 10 ⁻¹⁶	-4.958 x 10 ⁻¹⁶	100.000						
21	-1.813 x 10 ⁻¹⁶	-8.635 x 10 ⁻¹⁶	100.000						

Extraction Method: Principal Component Analysis

Table 7: Wet Season Component Matrix^a

Elements	Component					
	1	2	3	4	5	6
Cl	0.039	0.344	-0.376	0.170	-0.249	-0.529
K	-0.230	0.666	-0.102	-0.327	0.414	-0.252
Ca	-0.250	0.570	0.204	0.345	-0.189	-0.034
Ti	0.900	0.140	-0.098	0.102	0.308	-0.027
V	0.769	0.140	-0.039	-0.112	0.288	0.305
Cr	0.228	-0.702	-0.002	0.341	-0.273	0.375
Mn	0.431	-0.764	-0.037	0.088	-0.010	-0.071
Fe	0.770	-0.329	-0.279	0.004	0.283	0.015
Ni	0.562	0.570	0.287	-0.294	0.058	0.179
Cu	0.661	-0.071	0.286	0.487	0.405	-0.125
Zn	0.660	-0.251	-0.437	0.134	0.021	-0.138
Ger	0.271	0.422	0.231	-0.180	-0.128	0.681
As	-0.447	0.139	-0.355	0.569	0.484	0.176
Zr	-0.050	-0.155	0.889	0.250	0.218	-0.165
Sr	0.813	-0.135	-0.228	-0.257	0.000	-0.193
Pb	0.681	0.137	0.332	-0.227	-0.162	-0.225
Kr	-0.465	0.227	-0.377	0.570	0.381	0.144
Ta	0.631	0.632	-0.027	0.176	-0.175	0.005
Rb	-0.206	-0.130	-0.039	-0.758	0.489	0.028
Mo	-0.037	-0.166	0.886	0.247	0.220	-0.161
Cd	0.646	0.486	-0.032	0.497	-0.213	0.015

Extraction Method: Principal Component Analysis
a. 6 components extracted.

Table 8: Wet Season Component Transformation Matrix

Component	1	2	3	4	5	6
1	0.827	0.280	-0.138	0.407	0.008	0.232
2	-0.120	0.521	0.742	-0.077	-0.119	0.378
3	-0.259	0.010	-0.010	0.347	0.862	0.265
4	0.068	0.629	-0.349	-0.592	0.305	-0.185
5	0.471	-0.477	0.398	-0.518	0.350	0.030
6	-0.095	-0.160	-0.387	-0.300	-0.167	0.835

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization



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