Concentration of Vehicular and Generators Soot in Lafia Metropolis, Nasarawa State, Nigeria

F. Onwukwe, M. B. Nasirudeen, and M. E. Binin

ABSTRACT

The concentrations of Pb, Cd, Cr, Al and Fe in Heavy Duty Trucks (HDT), Power Generating Plants (PGP), Motor Vehicles (MV) and Small Generator (SG) Soot derived from the College of Agriculture, Bukan Sidi and Mararaba Akunza in Lafia City, Nigeria, were assessed for the level of contamination using Atomic Absorption Spectrophotometer (AAS). The results indicated that the ranges of heavy metal concentrations in soot (mg/kg) were: Pb (0.0911 ± 0.001 to 0.069 ± 0.008) for the HDTs, (0.775 ± 0.008 to 0.002 ± 0.000) for the PGPs, (0.456 ± 0.000 to 0.091 ± 0.000) for the MVs and (0.837 ± 0.000 to 0.027 ± 0.000) for the SGs. The concentrations of Cd and Cr in the HDTs and PGPs were below the detection limits of the AAS. More so, Cd and Cr in MVs were below the detection limits of the AAS except for one of the MVs which gave a highly objectionable Cr concentration of 4.336 ± 0.004 above WHO permissible limits for emissions into air and water. Al concentrations across the soot samples ranges from (0.126 ± 0.002 to 0.093 ± 0.001) for HDT, (0.170 ± 0.001 to 0.097 ± 0.000) for PGPs, (0.150 ± 0.000 to 0.057 ± 0.001) for MVs; and (1.348 ± 0.000 to 0.518 ± 0.000) for SGs. Iron concentrations ranges from (65.885 ± 0.006 to 27.834 ± 0.009) for HDTs, (62.663 ± 0.004 to 11.422 ± 0.019) for PGPs, (52.448 ± 0.003 to 2.418 ± 0.001) for MV, and (129.433 ± 0.008 to 9.129 ± 0.002) for the SGs. The results revealed that the concentration of Pb, Al and Fe in the HDTs, PGPs, MVs and SGs are above the WHO permissible limits for emissions into air and water. Cd, Cr, Al and Fe concentrations were higher in concentrations in SGs. The presence of heavy metals in the sampled soot portends their transfer to the food chain, especially as crop and vegetable cultivation in and around Lafia city.

Keywords: heavy metal, power generator, small generator, soot, vehicles/heavy duty truck.

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I. INTRODUCTION

Soot formation is the conversion of a hydrocarbon fuel molecule containing few carbon atoms into carbonaceous agglomerate containing some millions of carbon atoms in an extremely complicated process [1], [2]. The process is gaseous-solid phase transition where the solid phase exhibits no unique chemical and physical structure [2]. Soot is known as an unwanted byproducts derived from incomplete combustion of carbon containing materials [3]. Heavy metals from vehicular emissions possess threats to the humans and the environment due to their adverse effects on the environment leading to the contamination of air, water, and soil [4]. Heavy metal refers to any metal and metalloid element that has a relatively high density ranging from $3.5 - 7.9 \text{ gcm}^{-3}$ and is toxic or poisonous at low concentrations [5]. They are elements with atomic number 21 or higher, for example, scandium and above [6]. They are discharged into the environment in the form of air, water, or soil contaminants through several activities like agriculture, power generation, automobile emission, industrial discharge, seepage of municipal landfills, septic tank effluents, and extensive use of agrochemicals, etc. [6], [7]. In Nigeria, Heavy Duty Trucks (HDT), automobiles, power plants, and generator sets are the largest industrial and domestic sources of air pollution [8].

These pollutants vary between different internal combustion engines and depend on variables like ignition timing, load, speed, and air/fuel ratio [9].

In gasoline exhaust emission, the pollutants of major concern are carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO₂) and polycyclic aromatic hydrocarbons (PAHs); in diesel exhaust emission, the pollutants of major concern are nitrogen oxides (NO_x) and particulate matter (PM) [10].

Lafia Metropolis depends on Heavy Duty Trucks (HDT), for transportation of goods and animals, and Generators for both households and commercial power supply. Heavy metals from vehicular emissions possess threats to the humans and the environment due to their adverse effects on the environment leading to the contamination of air, water, and soil [4]. Lead (Pb) is used as anti-knock additive in conventional gasoline fuels. Leaded gasoline exhaust not only infects the air we breathe, but also responsible for adding Pb to the environment [10]. It is observed that Lafia Metropolis is hot, and the roofs of houses within the metropolis are corroded and rusty due to soot effects. This study is aimed at determining the concentration of some heavy and trace elements such as Pb, Cd, Cr, Al, and Fe in the soot of heavy-duty trucks, motor vehicles, and generators.

II. STUDY AREA

Lafia town is the capital city of Nasarawa State. It lies within latitude 8°29'30"N and longitude 8°31'00"E. It is home to both Federal and State Higher institutions of learning. There are so many agricultural and mining, business and educational activities going on in the city and its environs which involve the use of heavy-duty trucks, motor vehicles, and generators.

III. SAMPLE/ SAMPLING PROTOCOL

Soot samples were collected in Lafia Metropolis from three locations; Bukan Sidi, College of Agric and Mararaba Akunza. Thirty six samples were collected. Sampling location was based on the population density, areas of industrial activities, and anthropogenic events. Soot samples from the exhaust of Heavy Duty Trucks (HDT), Motor Vehicles (MV), Power Generating Plants (PGP), and Small Generators (SG) were randomly collected. Plastic containers and spatula were used to collect the soot samples for digestion and metal analysis. The containers for the sample collection were thoroughly washed with detergent and dried to eliminate adsorption as described by [6], [11], [12]. The sampling was done twice per day for a period of three months and treated as bulk.

IV. HEAVY METAL ANALYSIS

Analysis of heavy metals in soot samples was done using Atomic Absorption Spectrophotometer (MRC Instruments, Model PG 990 and AA500) equipped with Perking Elmer HGA 850 Graphite Furnace auto sampler with a computer interface for operation and readings display, Varian Spectra AAS.

V. QUALITY CONTROL AND STATISTICAL TREATMENT OF DATA

The data under different amendments were subjected to ANOVA test for assessing the significance of differences in heavy metal concentrations in soot derived from vehicular and generators. All the statistical tests were performed using SPSS software (SPSS Ins., version 12) [13]. Whereas precision and accuracy of analysis were assured through repeated analysis of samples against National Institute of water resources Kaduna, Nigeria Standard Reference Material (SRM 1410) for all the heavy metals. The results were found within $\pm 2\%$ of the certified value [14].

VI. RESULTS

TABLE I: CONCENTRATION OF HEAVY METALS IN SOOT SAMPLES FROM HEAVY DUTY TRUCKS

Sample Code	Element (mg/kg)				
	Pb	Cd	Cr	Al	Fe
HDT1	0.468±0.0006	BDL	BDL	0.097±0.0001	57.192±0.0045
HDT2	0.092±0.0006	BDL	BDL	0.102±0.0003	27.834±0.0092
HDT3	0.911±0.0011	BDL	BDL	0.093±0.0001	30.637±0.0028
HDT4	0.202±0.0007	BDL	BDL	0.102±0.0001	63.863±0.0028
HDT5	BDL	BDL	BDL	0.126±0.0002	47.179±0.0004
HDT6	0.083±0.0006	BDL	BDL	0.122±0.0001	65.885±0.0060
HDT7	0.069±0.0008	BDL	BDL	0.102±0.0001	65.423±0.0029
HDT8	BDL	BDL	BDL	0.102±0.0001	61.656±0.0051
HDT9	BDL	BDL	BDL	0.089±0.0001	46.576±0.0056
WHO	0.010	0.003	0.050	0.020	0.300

Key: HDT = Heavy Duty Truck. WHO = World Health Organization Standard, BDL = Below Detection Limit.

TABLE II: CONCENTRATION OF HEAVY METALS IN SOOT SAMPLES FROM POWER GENERATING PLANTS

Sample Code	Element (mg/kg)				
	Pb	Cd	Cr	Al	Fe
PGP1	0.002±0.0009	BDL	BDL	0.114±0.0002	42.539±0.0054
PGP2	0.191±0.0004	BDL	BDL	0.142±0.0003	11.422±0.0187
PGP3	0.352±0.0008	BDL	BDL	0.170±0.0006	62.663±0.0041
PGP4	0.775±0.0014	BDL	BDL	0.114±0.0002	43.650±0.0052
PGP5	BDL	BDL	BDL	0.097±0.0000	42.189±0.0152
PGP6	0.187±0.0009	BDL	BDL	0.134±0.0003	42.316±0.0105
PGP7	0.074±0.0003	BDL	BDL	0.118±0.0009	44.221±0.0061
PGP8	0.065±0.0006	BDL	BDL	0.114±0.0002	59.458±0.0040
PGP9	BDL	BDL	BDL	0.106±0.0007	31.264±0.0533
WHO	0.010	0.003	0.050	0.020	0.300

Key: PGP = Power Generating Plant. WHO = World Health Organization Standard. BDL = Below Detection Limit.

TABLE III: CONCENTRATION OF HEAVY METALS IN SOOT SAMPLES FROM MOTOR VEHICLES

Sample Code	Element (mg/kg)				
	Pb	Cd	Cr	Al	Fe
MV1	0.269±0.0013	BDL	4.336±0.0042	0.142±0.0003	52.448±0.0033
MV2	0.456±0.0004	BDL	BDL	0.150±0.0004	38.418±0.0088
MV3	0.091±0.0005	BDL	BDL	0.065±0.0001	2.418±0.0012
MV4	0.199±0.0006	BDL	BDL	0.048±0.0009	36.177±0.0074
MV5	0.140±0.0003	BDL	BDL	0.077±0.0011	37.990±0.0043
MV6	0.185±0.0005	BDL	BDL	0.057±0.0012	33.420±0.0012
MV7	BDL	BDL	BDL	0.073±0.0007	4.573±0.0013
MV8	BDL	BDL	BDL	0.089±0.0003	20.352±0.0069
MV9	0.172±0.0005	BDL	BDL	0.097±0.0002	37.995±0.0061
WHO	0.010	0.003	0.050	0.020	0.300

Key: MV = Motor Vehicles. WHO = World Health Organization Standard, BDL = Below Detection Limit.

TABLE IV: CONCENTRATION OF HEAVY METALS IN SOOT SAMPLES FROM SMALL GENERATORS

Sample Code	Element (mg/kg)				
	Pb	Cd	Cr	Al	Fe
SG1	0.485±0.0004	0.180±0.0006	0.019±0.0002	0.696±0.0013	56.887±0.0147
SG2	0.427±0.0005	0.108±0.0005	0.226±0.0001	0.603±0.0002	39.949±0.0024
SG3	0.335±0.0002	0.258±0.0001	0.218±0.0002	0.719±0.0005	20.138±0.0026
SG4	0.347±0.0006	0.214±0.0004	-0.037±0.0001	0.886±0.0014	14.349±0.0024
SG5	0.717±0.0003	0.204±0.0009	0.243±0.0003	0.518±0.0007	29.867±0.0033
SG6	0.324±0.0001	0.134±0.0009	0.107±0.0004	1.334±0.0008	82.191±0.0086
SG7	0.587±0.0004	0.079±0.0009	0.097±0.0006	1.272±0.0019	129.433±0.0084
SG8	0.066±0.0002	0.063±0.0007	0.046±0.0002	0.761±0.0008	27.937±0.0037
SG9	0.768±0.0004	0.133±0.0030	0.086±0.0003	0.796±0.0025	9.129±0.0021
WHO	0.010	0.003	0.050	0.020	0.300

Key: SG = Small Generator. WHO = World Health Organization Standard.

VII. DISCUSSION

From the results obtained in Tables I-IV, Pb concentration in the studied Soot samples varied in the range of HDT>SG>PGP>MV with values above the [15] permissible limits for emissions into air and water. In this study, the highest peak for Pb was observed in HDT (0.911±0.001 mg/kg) followed by SG (0.837±0.000 mg/kg) and PGP (0.775±0.008 mg/kg). MV showed the least representation of 0.456±0.000 mg/kg.

Similar research in Ghana by [12] revealed the value obtained for Pb to range from 0.09 to 0.16mg/kg; and it compares well with this study. According to [16] in the impact of automobile exhaust fumes on concentration levels of lead on bread in Port Harcourt City, Nigeria, there is a correlation in the concentration of lead in bus terminals and the volume of vehicular counts. A study by [17] in the determination of Heavy Metals in Soot from Petroleum Vehicles Exhaust Tailpipes in Kaduna Metropolis reported an average concentration value for Pb in gasoline engine as 14.097±0.644 mg/kg and 11.278±0.028 mg/kg for diesel engine with the gasoline engine having the highest value. The values are higher when compared with this study.

From the Tables I-IV results obtained for Cd in HDT, PGP, and MV were below the detection limit of the AAS. Hence highest value for SGs is 0.258±0.0001 mg/kg while the lowest is 0.054±0.0008 mg/kg. In their study, [18] reported cadmium was not detected in engine load of diesel engine exhaust and 2.8µg/g was reported for diesel fuel, and it agrees with this study. A similar study by [8] in Assessment of some selected Heavy Metals in Soot from the Exhaust of Heavy Duty Trucks and Power Generating Plants in Idah Local Government Area of Kogi State, Nigeria revealed that Cd has an average discharge in the soot samples as 0.3964ppm.

More so, Cr from the result showed MVI have a higher concentration value of 4.336 ±0.004 mg/kg. While the HDTs and PGPs have concentration values below the detection limit of the AAS and below [15] limits for emissions into air and water. The SGs have Cr values above [15] limits with the exception of SG4 which is below the limits. In a related study by [19] in Heavy Metals and Black Carbon Assessment of PM₁₀ Particulates along Accra-Tema Highway in Ghana, chromium mean concentration was reported as 0.115±0.016 µg/m³, and it agrees with the values obtained in SGs in this study. Cr was found to be below the detection limit of the Spectrophotometer in a similar study by [12], and this compares well with the values obtained for all HDTs, PGPs, and MVs in this study.

As presented in Tables I-IV above Al showed a wide range of differences across the parameters. The highest Al peaks across the soot samples is 1.348±0.000 mg/kg for SGs, 0.170±0.000 mg/kg for PGPs, 0.150±0.000 mg/kg for MVs and 0.126±0.000 mg/kg for HDTs. A similar study by [20] revealed the presence of Al and other metals in irregular combinations. In their research [21] suggested a relationship between aluminum exposure and neurodegenerative diseases, including dialysis encephalopathy, amyotrophic lateral sclerosis, and Parkinsonism dementia in Kii Peninsula and Guam. Alzheimer disease due to aluminum exposure has also being suggested in their study.

The Fe concentration recorded higher values of 129.433±0.008 mg/kg for SGs, 65.885±0.006 mg/kg for the HDTs, 62.663±0.004 mg/kg for the PGPs, and 52.448±0.003 mg/kg for the MVs. Concentration values obtained in all the soot samples are above the [15] permissible limits for emission into air and water. A similar study by [17] in Determination of Heavy Metals in Soots from Petroleum Vehicles Exhaust Tailpipes, Kaduna Nigeria, reported iron emission as the most significant with 1153.560±0.361 mg/kg and 796.816±0.522 mg/kg as mean concentrations for gasoline engine vehicle and diesel engine vehicle. Their report agreed with this study. In a Toxicological Mechanisms of Environmental soot study, [3] reported that iron among other heavy metals in their study contributes to the reactive oxygen species (ROS)-mediated DNA damage.

Using a multivariate test, the Levene's test was calculated for all the heavy metal. In the case of Fe, Cd, and Al, the null hypotheses were rejected since their significant values are below 0.05 being 0.004, 0.009, and 0.007, respectively. However, the error variance of the dependent variables is not equal across groups. Pb and Cr on the other hand accept the null hypothesis since their significance value is greater than 0.05. A 3(Direction: College of Agric vs Bukan Sdi vs Mararaba Akunza) × 4(1 km vs 2 km vs 4 km) between subject ANOVA was conducted to study concentration differences in 5 heavy metals which are Lead, Chromium, Iron, Cadmium and Aluminium.

For Pb, there was significance main effect of direction $F(2,24) = 485.70$, $p = 0.001$, partial $\eta^2 = 0.976$ such that Mararaba Akunza ($M = 161.86$, $SD = 8.83$) had significantly higher concentration than Bukan Sidi ($M = 129.87$, $SD = 17.50$) and Bukan Sidi had more significant concentration than College of Agric ($M = 131.28$, $SD = 12.45$). The main effect for distance was also significant $F(3, 24) = 206.47$, $p = 0.001$, partial $\eta^2 = 0.963$. The interaction effect of both distance and direction was significant $F(6, 24) = 15.16$, $p = 0.001$ partial $\eta^2 = 0.791$.

For Cr, there was no significance main effect of direction $F(2, 24) = 0.126$, $p = 0.882$ partial $\eta^2 = 0.010$ such that Mararaba Akunza (M = 57.23, SD = 5.81) had significantly higher concentration than Bukan Sidi (M = 56.51, SD = 6.51) and Bukan Sidi had more significant concentration than College of Agric (M = 56.81, SD = 17.50). The main effect for distance was also significant $F(3, 24) = 26.69$, $p = .001$ partial $\eta^2 = 0.769$. The interaction effect of both distance and direction was not significant $F(6, 24) = 2.49$, $p = 0.051$ partial $\eta^2 = .384$.

For Iron, there was significance main effect of direction $F(2, 24) = 204.64$, $p = 0.001$ partial $\eta^2 = 0.945$ such that Bukan Sidi (M = 64.16, SD = 3.72) had significantly higher concentration than College of Agric (M = 41.17, SD = 4.14) and College of Agric had more significant concentration than Mararaba Akunza (M = 37.22, SD = 8.26). The main effect for distance was also significant $F(3, 24) = 16.64$, $p = 0.001$ partial $\eta^2 = .670$. The interaction effect of both distance and direction was significant $F(6, 24) = 2.56$, $p = 0.047$ partial $\eta^2 = 0.390$.

For Cadmium, there was significance main effect of direction $F(2, 24) = 3.91$, $p = 0.034$ partial $\eta^2 = 0.246$ such that College of Agric (M = 0.50, SD = 0.08) had significantly higher concentration than Bukan Sidi (M = 0.45, SD = 0.24) and Bukan Sidi had more significant concentration than Mararaba Akunza (M = 0.39, SD = 0.14). The main effect for distance was also significant $F(3, 24) = 16.97$, $p = .001$ partial $\eta^2 = .680$. The interaction effect of both distance and direction was significant $F(6, 24) = 5.64$, $p = 0.001$ partial $\eta^2 = 0.585$.

For Aluminum, there was significance main effect of direction $F(2, 24) = 41.53$, $p = 0.001$ partial $\eta^2 = 0.776$ such that College of Agric (M = 0.50, SD = 0.08) had significantly higher concentration than Bukan Sidi (M = 0.45, SD = 0.24) and Bukan Sidi had more significant concentration than Mararaba Akunza (M = 0.39, SD = 0.14). The main effect for distance was also significant $F(3, 24) = 80.03$, $p = 0.001$ partial $\eta^2 = .909$. The interaction effect of both distance and direction was significant $F(6, 24) = 4.04$, $p = 0.006$ partial $\eta^2 = 0.503$.

VIII. CONCLUSION

From the results obtained, soot samples showed that the concentration of heavy metals from the sampling locations exceeded permissible limits set by W.H.O respectively. Variations in heavy metal concentrations as derived from Tables I–IV tend to be a consequence of a wide range of vehicular, generators usage and human activities in the Lafia Metropolis. A comparison of the diesel engine exhaust and the gasoline engine exhaust in the study showed that diesel engine exhaust has the highest concentration of Pb compared to gasoline engine exhaust. However, cadmium, chromium, aluminum, and iron concentrations were found to be higher in the gasoline engine exhaust compared to the diesel engine exhaust. Based on the results obtained in this study, it is concluded that Lafia Metropolis is suffering the soot pollution effects from Heavy Duty Trucks (used in transportation of animals, agricultural produce, and petroleum products, etc.), Power Generating Plants (used in Banks, Telecommunication Base Transmission Stations (BTS), Petrol Stations, and other industrial activities), Motor

Vehicles (used for personal and commercial purposes); and the Small Generator (used in homes, offices, and businesses due to epileptic power supply within the metropolis). The emitted heavy metals in the soot find their ways into the water bodies, plant vegetations, and infect the air within the metropolis. Soot pollution as a major contributor to climate change can be felt in the hotness of Lafia Metropolis. Much precaution has to be taken especially the choice of area of residence. Above all, proper awareness must be in place on the effects of soot.

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