Science World Journal Vol. 16(No 4) 2021
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

COMPARATIVE STUDY ON THE CONCENTRATION OF HEAVY-DUTY TRUCKS AND SMALL MOTOR VEHICLES SOOT IN LAFIA METROPOLIS, NASARAWA STATE, NIGERIA

Nasirudeen M. Baba*, Friday Onwukwe and Muhammad E. Binin

Department of Chemistry, Faculty of Science, Federal University of Lafia, Lafia, Nasarawa State, Nigeria

*Corresponding Author Email Address: nasirudeenbaba@gmail.com

ABSTRACT
Soot samples from Heavy Duty Trucks (HDT) and Small Motor Vehicles (SMV) exhaust were investigated for the presence of some heavy metals using Flame Atomic Absorption Spectrophotometer. The results showed the Pb concentration in HDT ranges from 0.911±0.001 ppm to 0.069±0.008 ppm whereas, for the SMV it ranges from 0.456±0.000 ppm to 0.091±0.000 ppm. Almost all available Cd and Cr escaped leaving a non-detectable limit except for one of the SMV which showed a highly objectionable value of Cr 4.336±0.004 ppm. The concentration of Al ranges from 0.126±0.002 ppm to 0.093±0.001 ppm for the HDT; and 0.150±0.000 ppm to 0.057±0.001 ppm for the SMV. The Fe values ranges from 65.885±0.006 ppm to 27.834±0.009 ppm for HDT and 52.448±0.003 ppm to 2.418±0.001 ppm for the SMV. There is a clear indication that fragmented soot contributes to heavy metal pollution in Lafia Metropolis based on this study.

Keywords: Soot, Heavy Metals, Heavy Duty Truck and Motor Vehicles.

INTRODUCTION
Soot is formed after incomplete combustion of hydrocarbons and it is a powdery mass of fine particles of impure carbon (Canagaratna, 2010; Niranjan, 2017). Although the main source of environmental soot is the combustion of fossil based fuels and biomass burning at earth's surface, other sources include coal, charred wood, petroleum coke, and tars (Niranjan, 2017). Also, quartz/halogen bulbs with settled dust, cooking oil lamps, smoking of plant matter, fire places, candles, furnaces and local filed burning contributes to a small extent in soot production (Niranjan, 2017).
The poly aromatic hydrocarbons (PAHs) are the major carcinogenic compound among the hydrocarbons in the soot (Canagaratna, 2010; Niranjan, 2017). Vehicle exhaust contributes approximately 50% of urban particulate matter (PM) (Cassee, 2013; Kamboures, 2013) Soot (also known as black carbon) and carbon black (CB) have been used interchangeably, but both are physically and chemically distinct entities (Niranjan, 2017). Soot is known as an unwanted by-products derived from incomplete combustion of carbon containing materials. Whereas, carbon blacks are manufactured under controlled conditions in rubber, printing and painting industries for commercial purposes (Long, 2013; Niranjan, 2017).
Carbon black is produced by partial combustion of heavy petroleum materials such as coal tar and ethylene cracking tar (Apicella, 2003). Other subtypes are furnace black, acetylene black, lampblack, and thermal black. It has over 97% amount of elemental carbon (Jeong, 2013; Niranjan, 2017). However, both soot and carbon black affect cardiovascular system, respiratory system, and causes different kinds of cancer (Valavanidis, 2013).

Black carbon is the most energy-absorbing component of particulate matter and can absorb one million times more energy than CO_2 (Renee, 2016) The amount of energy stored in the atmosphere is measured as watts per square meter of Earth's surface. According to Renee (Renee, 2016), a 2013 study estimated black carbon's effect to be 1.1 watts per square meter per year, and is second only to carbon dioxide, which is responsible for 1.56 watts per square meter. In order words, black carbon is the second largest contributor to climate change after carbon dioxide (CO_2).
Thus, unlike CO_2, that can stay in the atmosphere for hundreds to thousands of years, black carbon, because it is a particle, remains in the atmosphere only for days to weeks before it returns to earth with rain or snow (Valavanidis, 2013). The United States is responsible for about 8 percent of global black carbon emissions, with most of it coming from diesel engines, biomass burning, including wildfires, residential heating and industry. The developing countries in Asia, Africa and Latin America emit more than 75 percent of global black carbon emissions (Renee, 2016). In gasoline exhaust emission, the pollutants of concern are carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2) and polycyclic aromatic hydrocarbons (PAHs); in diesel exhaust emission, the pollutants of concern are nitrogen oxides (NOx) and particulate matter (PM) (Lu, 2011). These pollutants vary between different internal combustion engines and depend on variables like ignition timing, load, speed, and air/fuel ratio (Ogur, 2014).

MATERIALS AND METHODS

Description of Study Area
Lafia town is the capital city of Nasarawa State. It lies within latitude 8º29˙30"N and longitude 8º31˙00"E. It is a 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.

Sample/ Sampling Protocol
Soot samples were collected in Lafia Metropolis from three locations; Bukan Sidi, College of Agric and Mararaba Akunza. Eighteen samples were collected. Sampling location was based on the population density, areas of industrial activities, and anthropogenic events. Soot samples from exhaust of Heavy Duty Trucks (HDT), Small Motor Vehicles (SMV), were randomly collected for 12 months (January to December 2019). 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 (Okorie, 2010).

Sample Digestion (Wet Digestion)
Sample digestion was done using 0.5g of potassium per manganate, hydrogen peroxide, 5ml of concentrated Nitric acid, and heating in an oven at 200ºC-300ºC a black residue which was washed with distil water thoroughly as described by (Atiku, 2011) with little modification.

Heavy Metal Analysis
Analysis of heavy metals in soot samples was done using Flame 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 (Atiku, 2011; Okorie, 2010). All reagents used in preparing the standards were of analytical grade.

RESULTS

Table 1: Mean concentration of heavy metals in soot samples from HDT

Sample Code	Element(ppm) Pb	Cd	Cr	Al	Fe
HDT1	0.468±0.006	BDL	BDL	0.097±0.0001	57.192±0.0045
HDT2	0.092±0.006	BDL	BDL	0.102±0.0003	27.834±0.0092
HDT3	0.911±0.011	BDL	BDL	0.093±0.0001	30.637±0.0028
HDT4	0.202±0.007	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±0.006	BDL	BDL	0.122±0.0001	65.885±0.0060
HDT7	0.069±0.008	BDL	BDL	0.102±0.0001	65.423±0.0029
HDT8	BDL	BDL	BDL	0.102±0.0001	61.656±0.0051
HDT9	0.139±0.002	BDL	BDL	0.089±0.0001	46.576±0.0056
RANGE	0.911-0.069	BDL	BDL	0.126-0.089	65.885-27.834
WHO	0.010	0.003	0.050	0.020	0.300

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

Table 2: Mean concentration of heavy metals in soot samples from SMV

Sample Code	Element (ppm) Pb	Cd	Cr	Al	Fe
SMV1	0.269±0.001	BDL	4.336±0.004	0.142±0.003	52.448±0.003
SMV2	0.456±0.004	BDL	BDL	0.150±0.004	38.418±0.009
SMV3	0.091±0.005	BDL	BDL	0.065±0.001	2.418±0.0012
SMV4	0.199±0.006	BDL	BDL	0.048±0.009	36.177±0.007
SMV5	0.140±0.003	BDL	BDL	0.077±0.001	37.990±0.004
SMV6	0.185±0.005	BDL	BDL	0.057±0.001	33.420±0.001
SMV7	BDL	BDL	BDL	0.073±0.007	4.573±0.0013
SMV8	BDL	BDL	BDL	0.089±0.003	20.352±0.007
SMV9	0.172±0.005	BDL	BDL	0.097±0.002	37.995±0.006
RANGE	0.456-0.091	BDL	4.336-BDL	0.150-0.057	52.448-2.418
WHO	0.010	0.003	0.050	0.020	0.300

Key: SMV = Soot of Motor Vehicles. WHO = World Health Organization Standard. BDL = Below Detection Limits

Table 3: Levene's Test of Equality of Error Variances

Element	F	Df1	Df2	Sig.
Pb	1.488	11	24	.200
Cd	-	-	-	-
Cr	2.154	11	24	.056
Al	3.286	11	24	.007
Fe	3.668	11	24	.004

Tests the null hypothesis that the error variance of the dependent variable is equal across groups. Design: Intercept+Direction+Distance+Direction*Distance

DISCUSSION

The results obtained in Tables 1 and 2 present the concentrations (ppm) of Pb, Cd, Cr Al and Fe in soot derived from Heavy Duty Trucks (HDT) and Small Motor Vehicles (SMV). Availability and flows of the trends for Pb is in order of HDT3>HDT1>HDT4>HDT2>HDT6>HDT7. The highest concentration in HDTs samples for Pb is 0.911±0.001 ppm and the lowest 0.069±0.008 ppm while for SMVs samples; SMV2>SMV1>SMV4>SMV6>SMV5>SMV3. The highest concentration obtained for the SMVs is 0.456±0.000ppm and lowest 0.091±0.000ppm respectively.

The results in this study revealed a concentration of Pb as 0.140±0.003ppm for SMV5 and this is in agreement with a reported value elsewhere, (Nwaedozie, 2018) for both gasoline and diesel engine as 0.14097±0.003ppm.

More so, the Tables 1 and 2 revealed both HDT and SMV results for Cd and Cr to be below detection limit (BDL) based on WHO standards of 0.003 and 0.050 respectively. (Nwaedozie, 2018) in their study reported Cd concentration in both gasoline and diesel engines as 0.044±0.036 mg/kg and 0.0403±0.037 mg/kg. In a similar study, (Bharathi, 2005) reported Cd was not detected in engine load of diesel exhaust and 2.8 μg/g was reported diesel fuel, and it compares well with this study. More so, Cd was not detected in this study which was also in agreement with a reported literature (Okorie, 2010). A research by (Safo-Adu, 2014) revealed Cr concentration as 0.115±0.016 $\mu g/m^3$. Thus, (Igbal, 2012) in a related study reported Cr concentration in vehicular soot at 3-9.8 mg/kg, and all these reported values agrees with the 4.336±0.004 ppm obtained for SMV1 in this study.

Aluminium, on the other hand showed a trend of HDT5>HDT6>HDT2 =HDT4 = HDT7 = HDT8 = HDT1>HDT3>HDT9 and recorded highest and lowest concentrations of 0.126±0.000ppm and 0.089±0.001ppm. The SMVs showed trends in Al concentration in order of SMV2>SMV1>SMV9>SMV8>SMV7>SMV5>SMV6>SMV3>SMV4 with the highest and lowest at 0.150±0.000ppm and 0.057±001ppm respectively. In a similar study, (Corbin, 2018) reported Al. In another development, (Jen-Hsiung, 2018) reported the values of Al for different blends of diesel engine exhausts as W20 = 20.6±2.3 μgN^{-3}, B30 = 19.1±23 μgN^{-3}, and A3 = 18.0±4.4 μgN^{-3}. The concentrations of Al obtained in this study were higher than the permissible limits (Nwaedozie, 2018).

Iron concentrations in HDTs are in the order of HDT6>HDT7>HDT4>HDT8>HDT1>HDT5>HDT9>HDT3>HDT2 with the highest concentration value as 65.885±0.006ppm and the lowest as 27.834±0.009ppm. More so, the SMVs revealed the trends in Fe concentrations in order of SMV1>SMV2>SMV9>SMV5>SMV4>SMV6>SMV8>SMV7>SMV3 , with the highest and lowest concentrations as 52.448±0.003ppm and 2.418±0.001ppm. In their study, (Nwaedozie, 2018) reported Fe concentrations for both gasoline and diesel engines as 1153.560±0.361 mg/kg and 796.816±0.522 mg/kg, and their values were higher than the values obtained in this study. More so (Kalagbor, 2019) reported that Fe has the highest concentration among the five heavy metals in their study and this compares well with this study. In another development Fe was reported as having the highest concentration in a similar study by (Verma, 2015) and this agrees with this study. The Fe concentration values in this study for both HDTs and SMVs are above WHO permissible limits (Nwaedozie, 2018).

As shown in Table 3, Levene's test was calculated for all the heavy metals for significance values. In the case of Fe and Al, the null hypotheses was rejected since their significant values are below 0.05 being .004 and .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 test of between subject effects revealed the interaction effect of the distance and direction on the dependable variable as follows: For Pb there is a partial eta squared of 0.791 which means that 79.1% of the variance of the dependable variable Pb can be attributed to the distance and direction. Since there is statistically significant interaction effect, individual significance is negligible. For Cr, it has a partial eta squared of 0.384 which means that 38.4% of the variance of the dependable variable Cr can be attributed to the distance and direction, no statistically significant interaction effect observed, hence individual significance. For Al, it has a partial eta squared of 0.503 which means that 50.3% of the variance of the dependable variable Al can be attributed to the distance and direction. Since there is a statistically significant interaction effect, therefore, the individual significance does not need a closer look. For Fe, it has a partial eta squared of 0.390 which means that 39.0% of the variance of the dependable variable Fe can be attributed to the distance and direction. Since there is a statistically significant interaction effect, hence individual significance is considered.

Conclusion

This present research considers particulate emissions which majorly rely on soot. The highest Pb concentration was obtained in the HDT compared to the SMV. Cadmium was below detection limits in both HDT and SMV, whereas the highest Cr concentration was obtained in the SMV. This study also revealed HDT as having the highest concentration of Al compared to SMV. More so, Fe was found to have the highest concentration in the HDT compared to the SMV. This Comparative study revealed that Cd and Cr concentrations are respectively lower than Pb, Al and Fe in the studied soot samples. The reduction was linked to fragmentation or volatilization of these metals into the atmosphere and surrounding air current, hence contributes to heavy metal pollution within the metropolis. The high values obtained for Al and Fe in the study can be attributed to the materials used in making the tailpipes. The differences in the values reported by the reviewed literatures and the values obtained in this study could be attributed to various factors such as methodology, gasoline and diesel sources, engine condition, and age of vehicles. This study has revealed that soot from HDTs and SMVs among others are sources of heavy metal pollution in Lafia Metropolis, and its adverse effects can be seen in heavy metal related ailments among the Lafia populace. There is need for the vehicles emission regulation by the state government to mitigate the soot pollution effects.

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