Gas Emissions and Metallic Contents of Commonly Used Fuelwood in Nigeria

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Abstract

Gas emissions levels of NO, NO_2, SO_2, CO, and CO_2 from commonly used domestic fuel wood were investigated using Carbolite Muffler Furnace equipped with gas probes. Results after analysis showed gas levels in ppm in the range 0.1–29.6 for NO, 0.1–10.0 for NO_2, 1.2–21.0 for SO_2, 0–0.2 for CO, and 90–560 for CO_2. Analysis of the resulting wood ash showed metal levels in gkg^{-1} in the range 2.16–10.37 for Ca, 0.29–1.58 for Mg, 1.04–3.53 for Zn, and 0.24–0.84 for Al. Compared to the recommended short term exposure limits, the observed gas levels of SO_2 and NO_2 indicate environmentally unfriendly nature of some of the commonly used domestic fuel wood and the possible risk of respiratory, pulmonary and carcinogenic diseases that could be associated with their regular usage. The wood ash composition suggests it could serve a friendly utilization as soil additive for agricultural purposes for soils whose compositions show deficiency of these metals.

Keywords: gas emissions, fuel wood, metallic content, wood ash

1. Introduction

Many rural communities in developing countries still depend on a variety of forest wood resources for their indoor and outdoor domestic cooking, drying of harvested products and house warming among other uses (Robinson, 2011; Njiong & Johannes, 2011; Tanimowo, 2000). Gas and particulate matter emissions from domestic fuel wood usage are increasingly becoming a great source of concern because of high incidence of respiratory, pulmonary and carcinogenic diseases that have been associated with their regular usage (Environment Australia, 2002; Smith, 2002; Enwereji & Ezeama, 2009; Guggisberg et al., 2003; Diaz et al., 2007; Riojas-Rodriguez et al., 2001). A popular but unsubstantiated belief in most developing countries is that domestic cooking with fuel wood is faster and gives a better taste of the food. In local communities, wood ash has found a number of applications as a source of potash, liming and tannin extracting agent in poultry feeds, in water treatment, as degreaser or scouring powder and for traditional bone-setting therapy (Misra et al., 1993; Pitman, 2011; Suruchi & Pankaj, 2011). So far carbon emission levels and those of other pollutants resulting from the use of biomass and inefficient biomass stoves, including the utilization of the resulting ash, in developing countries have not been fully studied (Tanimowo, 2000; Enwereji & Ezeama, 2009; Pérez-Padilla et al., 1999).

The present study was carried out to estimate emission levels of NO, NO_2, SO_2, CO, and CO_2 in some commonly used fuel wood in Nigeria and analyze the essential metal content of the resulting wood ash which is being utilized in agriculture and domestic products preparations by rural community dwellers.

2. Materials and Method

2.1 Reagents

All reagents used were of analytical grade purity and were used without further purification except were otherwise stated.

Distilled deionized water was used all through the experiments.

EDTA, disodium salt (BDH Poole, England) was prepared as 0.1 M solution and standardized using 0.1 M $ZnSO_4$ following procedure described elsewhere (Mendham et al., 2004). Dilution was done as required.

Ammonia-ammonium chloride buffer (pH=10) was prepared and adjusted with dilute acid or ammonium hydroxide.

2.2 Apparatus

Muffler Furnace Carbolite RHF 1600 fitted with probes of single gas analyzers; 92, 93, 94, 96, and 97 located at Sheda Science and Technology Complex, Sheda, Abuja, Nigeria were used for ashing and for the analysis of NO, NO_2, SO_2, CO_2, and CO levels from burning wood samples respectively.

Electric drying oven, DHG 9023A, was used for drying the wood samples while pH meter, C175 Hanna Instruments Italy, was used for pH measurements.

2.3 Sample Collection

Commonly used fuel wood which are forest Down Wood Materials (DWM) of the following plants; orange (*Citrus spp.*), cassava (*Manihot spp.*), gmelina (*Gmelina aborea*), mango (*Mangiferia indica*), Indian bamboo (*Dracaena sandaeriana*), oil bean (*Recinus communis*), rowam (*Sorbus acuparia*), pear (*Pyrus communis*), guava (*Psdium guajava L.*) and iroko (*Chlorophora excelsa*), stacked for domestic use in different homes within 200 meters radius in communities in Afikpo North/South, Ivo, Abakaliki, Izzi, Ezza North, and Ohaukwu Local Government Areas of Ebonyi State Nigeria, were sampled at random for the Fine Woody Debris (FWD) of medium size (0.25–1.0 inch diameter). Six log samples of each plant which were of sound, freshly-fallen and intact quality with absence of decay were sampled, two each from top, middle and bottom of a pile. The six samples were reduced to small sizes and pulled together by type as composite samples for ease of transportation to the laboratory for analysis.

2.4 Sample Preparation and Analysis

2.4.1 Analysis of Gas Emissions

The composite wood samples were reduced to about 4 mm size using wood saw. The samples were oven-dried for 5 hours at 95 ^{o}C. Weighed dry samples were placed in porcelain containers, labeled correctly and transferred to the furnace. The temperature of the furnace was set at 350 ^{o}C and switched on with the meters of the various probe gas analyzers connected to the exhaust chimney of the furnace (Figures 1, 2 and 3). The samples were allowed to burn completely in the furnace and the gases produced were recorded in parts per million (ppm) by the probe meters of the analyzers which have the ability to draw in the gas produced. The process was repeated for consistent results making sure the furnace was flushed with nitrogen to remove any residual gases each time. The analysis method using the Muffler Furnace Carbolite RHF 1600 with the gas analyzer probes is reliable with about 95% confidence level.

2.4.2 Analysis of Ash Samples

The resulting wood ash from the analysis of gas emissions was analyzed for metallic contents. Mg, Ca, Zn, and Al found present were determined by EDTA complexometric titration following standard procedure (Mendham et al., 2004).

Figure 1. Muffler Furnace Carbolite RHF 1600 fitted with probes of single gas analyzers (Furnace is to the left of gas analyzers)

Figure 2. Single gas analyzers

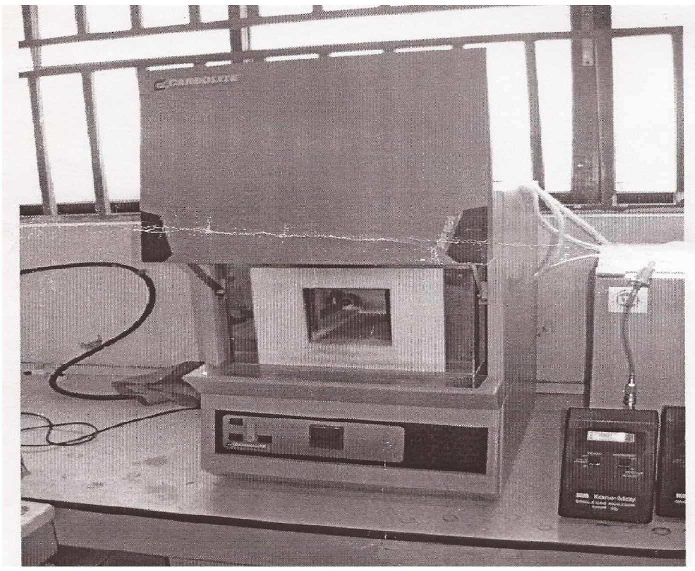

Figure 3. Muffler Furnace Carbolite RHF 1600 in open possition (a single gas analyzer is to the right)

3. Results and Discussion

Table 1 shows the results obtained for the emission of CO_2, CO, NO, NO_2, and SO_2 from the combustion of fuel wood samples collected from different communities in seven Local Government areas of Ebonyi State Nigeria and which were compared with the values for the recommended maximum emission limits for these gases in Michigan State USA (MDLRA, 1974). The particulate matter emission was not analyzed because of absence of the analyzer probe. Of all the fuel wood resources analyzed cassava appears to have the highest carbon footprint while pear and mango have the lowest. The low emission levels of CO generally observed from the combustion of the fuel wood samples studied indicate efficient combustion of the samples in the furnace which may not be the case when local biomass stoves are used under wet conditions of these forest resources. Cassava, just like orange, shows low levels of NO and NO_2 compared with the other wood resources even though it emitted higher levels of SO_2 than the maximum allowed limit and therefore the use of cassava as a fuel wood resource constitutes a serious hazard to health. Most of the observed fuel wood emissions of NO and NO_2 did not exceed the maximum allowed limits except for oil bean tree which gave a high emission level of NO_2. However, NO_2 emissions from these wood resources exceeded the short-term exposure limits except for Gmelina and Indian bamboo as shown in Table 1 and, for this reason, the use of these wood resources for cooking in a kitchen or enclosed environment is not a healthy practice. As observed by Chen et al. (2008), there is a significant adverse health effect of exposure to SO_2 and NO_2 on a daily basis as these gaseous pollutants can independently contribute to increase in daily mortality. Apart from the incidence of toxicity to humans, animals and plants, high levels of gas emissions from fuel wood utilization contribute to greenhouse gases with their attendant effects of global warming, ozone layer depletion, the phenomenon of acid rain, deforestation and desertification (Robinson, 2011; Chen et al., 2008; Najjar, 2011; Jayaratne & Verma, 2001; Moreira et al., 2008). The levels of gas emissions from fuel wood could also contribute to various birth complications among women (Boy et al., 2002). Table 1 also shows a significant variation in NO, NO_2 and SO_2 emission levels for each of the respective wood samples when compared for different locations. This is evident in the results for Gmelina, Mango and Cassava fuel wood samples. The observed emission levels for these gases are higher for wood samples from Abakaliki and Afikpo North, which are urban cities, than for the samples from Ivo and Ezza North which are rural communities. The observed higher emissions may therefore be attributed to anthropogenic factors related to soil contamination with N- and S- containing compounds in the urban cities studied. Invariably, these compounds or their derivatives are picked up as part of plant nutrients from the soil (Singh, 2001).

Table 1. Gas emission levels (in ppm) found in the fuel wood samples (mean of triplicate analysis ± SD)

Sample/Source	CO_2	CO	NO	NO_2	SO_2
Afikpo North					
Gmelina	260±0.001	0.1±0.013	0.5±0.012	1.1±0.002	1.2±0.018
Cassava	360±0.011	0.1±0.005	-	-	21.0±0.015
Indian bamboo	120±0.003	-	0.4±0.010	0.4±0.006	1.4±0.007
Ivo					
Gmelina	115±0.007	-	0.2±0.011	0.2±0.006	0.8±0.010
Mango	95±0.002	0.2±0.005	0.1±0.002	2.2±0.001	0.6±0.006
Iroko	110±0.001	-	0.8±0.010	3.2±0.003	-
Abakaliki					
Mango	285±0.018	-	1.8±0.015	2.4±0.001	1.2±0.013
Cassava	450±0.005	-	-	1.0±0.003	20.1±0.010
Oil bean	290±0.005	-	-	6.1±0.005	2.1±0.002
Pear	90±0.001	-	2.1±0.011	4.0±0.015	1.8±0.007
Ohaukwu					
Guava	102±0.005	-	-	2.1±0.003	4.0±0.013
Afikpo South					
Orange	250±0.002	-	-	-	0.7±0.006
Izzi					
Rowam	150±0.010	0.2±0.002	0.4±0.018	-	1.5±0.007
Ezza North					
Cassava	195±0.015	-	0.5±0.003	1.5±0.006	14.2±0.001
***STEL**	-	-	-	1.0	5.0
***MAC**	-	50.0	25.0	5.0	5.0

*STEL = Short-Term Exposure Limit, *MAC = Maximum Allowed Limits. *Source: (MDLRA, 1974).

Table 2 shows the results of the concentrations of the essential metals found in the ash samples of fuel wood under study. The results were compared with minimum and maximum limit values for minor elements and nutrients in the Nordic countries according to the Sweden Recommendations Draft (SRD) 2007 for forestry applications (Hugland and Expert Group, 2008). Many of the developing countries are known for their use of wood ash and household wastes for agricultural purposes (Pasquini, 2006). From the results of our analyses, metals found in the wood ash samples were all below the recommended limit values for forestry application and therefore can be utilized as additives for agricultural purposes on soils which are deficient on these minerals. However, for cassava and gmelina that have high concentrations of Zn closer to the limits, caution is required in their use. The general trends for major elements in wood ash obtained from component parts of plants as reviewed by Pitman (2011) is in the order; foliage branch > stem bark > stem wood. The observed percentage levels of Ca, Mg, Zn, and Al in the analyzed wood ash samples under study are; 0.2–1.0, 0.03–0.25, 0.1–0.35, and 0.01–0.09 respectively which are consistent with the general trends for these metals in stem bark and stem wood. Persistent use of wood ash as agricultural additive for a long time could result to high metal contents of the receiving soils, which could also lead to ground and surface water pollution through metal leaching (Singh, 2001). Low level metal intake from food grown on metal contaminated soils has been shown to lead to bioaccumulative toxicity, and there is so far no effective mechanism found for elimination of metals from the body (Clark, 1992). Table 2 also shows variation in metal concentration levels in ash samples of a particular plant from different locations. Soil is one of the repositories for anthropogenic wastes, and a major pathway of soil contamination is through atmospheric deposition of trace metals from point sources such as metaliferrous mining, quarrying and industrial activities (Singh, 2001). The largest ore bodies in the Benue Trough are distributed in the Abakaliki and Ishiagu districts (lower Benue) on the main axis of a major anticlinal structure known as the Abakaliki anticlinorium (Akande & Erdtmann, 1995). The communities under study are within the two districts and mining and quarrying of pyroclastics, limestone, sphererite and other mineral ores have been carried out mainly in Ivo, Ezza North and Abakaliki communities for the past two decades. However soil composition mapping of these communities have not been carried out and hence it will be difficult to relate soil composition with metal uptake by the plants studied. Moreover, it has been suggested that uptake of metals by plants is dependent on chemical form of the metals in the contaminated soil (Gundermann et al., 1995). Generally, the observed higher concentration levels of Ca, Mg, Zn, and Al in the ash samples of Cassava, Gmelina and Mango collected from Abakaliki, Ezza North and Ivo can be attributed to the impact of mining and quarrying activities in these communities over these years.

Table 2. Concentration of essential metals (in gkg^{-1}) found in fuelwood ash samples (mean of triplicate analysis ± SD)

Wood ash Sample/Source	**Ca^{2+}**	**Mg^{2+}**	**Zn^{2+}**	**Al^{3+}**
Afikpo North				
Gmelina	3.08±0.001	1.54±0.013	-	0.24±0.018
Cassava	3.93±0.007	1.74±0.005	1.19±0.015	0.86±0.015
Indian bamboo	5.63±0.018	1.23±0.001	1.04±0.002	0.14±0.001
Ivo				
Gmelina	6.49±0.003	0.29±0.001	3.16±0.010	0.72±0.005
Mango	5.51±0.006	1.31±0.001	-	0.69±0.002
Iroko	6.46±0.001	0.95±0.007	-	-
Abakaliki				
Mango	5.67±0.018	0.94±0.012	-	0.30±0.011
Cassava	5.42±0.015	2.31±0.010	2.18±0.007	-
Oil bean	6.22±0.013	0.42±0.001	1.98±0.005	0.59±0.006
Pear	10.37±0.002	1.77±0.003	-	0.07±0.015
Ohaukwu				
Guava	6.29±0.007	1.58±0.002	-	0.84±0.006
Afikpo South				
Orange	2.16±0.003	0.66±0.018	-	0.27±0.011
Izzi				
Rowam	3.08±0.010	0.35±0.005	1.91±0.013	0.30±0.007
Ezza North				
Cassava	2.48±0.002	0.41±0.001	3.53±0.005	-
*SRD 2007 (min.)	125.00	15.00	0.50	-
(max.)	-	-	7.00	-

*Min = minimum, max = maximum. Source: (Hugland and Expert Group, 2008).

4. Conclusion

Gas emissions levels of NO, NO_2, SO_2, CO, and CO_2 from commonly used domestic fuel wood in Nigeria, as well as the metal concentrations from their ashes, were investigated in this study. The observed gas levels when compared to short term exposure limits indicate environmentally unfriendly nature of commonly used domestic fuel wood and the possible risk of respiratory, pulmonary and carcinogenic diseases that could be associated with their regular usage. This study advocates for less use of fuel wood such as cassava stem and oil bean tree which gave high emission levels of SO_2 and NO_2. The study also confirms that fuel wood such as gmelina, orange and Indian bamboo burn efficiently with low emission of pollutant gases. The wood ash composition suggests a friendly utilization as soil additive for agricultural purposes depending on the composition of the target soil for application. However, caution is required about persistent ash utilization for a long time which could result to bioaccumulation of these metals in the food chain.

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