SMOKE TOXICITY OF SOME FIREWOOD SAMPLES USED IN ANAMBRA STATE.

C. O. Ifediora and T. U. Onuegbu

Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

(drcynthia0@gmail.com/ +2348060944226), (tu.onuegbu@unizik.edu.ng/ +2348035089803)

ABSTRACT

The toxicity of smoke from firewood samples to its users has been investigated. The aim of this research is to evaluate the smoke toxicity of selected firewood samples from Umuoji, in Idemili North Local Government Area of Anambra State. The components of the smoke samples were analyzed using a flue gas analyzer; Testo 350XL, the gases emitted while burning these woods were identified. The wood ashes were digested using APHA standard methods and analyzed using Agilent A200 series Atomic Adsorption Spectrophotometer. From the findings of the study, the result of the analysis shows that wood smoke is made up of VOC/Hydrocarbons (2134ppm – 27340ppm), oxides of Sulphur (2ppm – 54ppm), Carbon monoxide (28ppm – 956ppm), Carbon dioxide (20.59ppm – 20.80ppm), oxides of Nitrogen (0.1ppm – 0.8ppm) and Hydrogen gas (18ppm -100ppm) in proportions higher than the threshold limit values (TLV) acceptable by the world health bodies, except for the oxides of nitrogen which shows danger only in the inhalation of N_2O_4 while the heavy metal analysis of their wood ash showed presence of Lead (0.19ppm – 1.19ppm), Zinc (7.51ppm – 14.60ppm), Copper (0.89ppm – 2.36ppm), Chromium (0.35ppm – 0.58ppm) and Cadmium (0.15ppm – 0.58ppm) whose proportions are higher than the threshold limit values (TLV) acceptable by the world health bodies. Data obtained in this study were subjected to descriptive statistical analysis using ANOVA and by Friedman non – parametric statistical test. The best wood in relation to smoke toxicity are Acacia, Gmelina, and African bread fruit and are recommended for wood fuel, while Bamboo, Avocado, and African star apple should be rarely used. In relation to heavy metal content, Gmelina, African star apple and Bamboo woods are preferred to the other wood samples.

INTRODUCTION.

According to the United Nations Development Program[1], the share of various energy sources in the total primary energy supply in Nigeria are made up of oil, (10.4%) gas, (6%) hydro, (0.6%) and commercial renewable energy, (83%). The greater portion of the commercial renewable energy is wood, while other agricultural wastes constitute the remaining smaller portion. The over-dependence on fuel wood for energy is chiefly because of its relatively low prices and easy accessibility.[2] Other reasons are constraints in the supply of the conventional fuels and the growing population with a larger segment still falling below incomes that cannot afford the cost of conventional fuels[2]. This observation was buttressed by another recent data published by The Solar Cooking Archive[3], which put the estimate of Nigeria's fuel wood consumption as percentage of energy at about 87%. Therefore, majority of the Nigerian rural people have been using and will continue to use the dried biomass fuels for energy for many years to come. Nigeria is a country with large fuel wood deficit zones mainly in the north, while in some southern areas production exceeds consumption[4]. These areas supply the deficit zones. Therefore, a balance between annual re-growth and consumption has to be struck on a national level. According to the Forest Resources Assessment (FRA) Report for Nigeria in 2005[5], total wood removals from forests in 2005 amounted to 86,626,797 m^3, and removals for wood fuel from forests in the year 2005 were 72,710,935 m^3, the difference being made up by industrial round wood, which accounted for 13,915,862m^3. However, wood may also come from areas outside forests like shrub land, savannah and grassland as no data are available on these sources in Nigeria, a reasonable estimate has to be made, based on figures from neighbouring countries. The Forest Resource Assessment of 2005 however, presents data on the growing stock on other wooded land[5] which concluded that the growing stock on "other wooded land" is about 7% of the growing stock in forests, the same percentage to be true for Nigeria by interpolation. Adding 7% to 86,626,797 m^3 gives us 92,690,673 m^3 as the total harvest of wood from forest and other wooded lands combined. In Nigeria, the shares of fuel wood proper and wood for making charcoal are not known. We assume it to be about the same as in Chad that is 78 and 22%, respectively of all the wood used energetically[6]. Firewood is a source of energy derived by burning wood materials like logs and twigs and is common among the rural dwellers. It is a traditional source of energy, which has remained the major source of fuel for over half of the world's population[7]. Nigeria's daily firewood consumption stands at 266 million kg[8]. 72 per cent of Nigerians depend solely on fuel wood for cooking [9]. Smoke emanating from firewood used for cooking is the third greatest killer of women and children in Nigeria[10]. The organization stated that 93, 300 deaths occur in Nigeria yearly as a result of smoke from traditional biomass stoves. After malaria and HIV/AIDS, smoke is the biggest killer of mostly women and children[10]. In addition to this health problem, 90 percent more wood is used than is necessary leading to wastage. This has cost poor families and institutions more money that could be used to improve education, health, and nutrition. Also, an estimated 72 per cent of Nigeria's population depends solely on firewood for cooking[9]. Wood has been used as fuel for millennia. Firewood is one of the oldest natural renewable resources. It is basically wood that is used for fuel. Firewood was the primary fuel source used around the world. It was not until the 1800s that coal took its place as the most abundantly used energy resource. By 1857 the oil industry began using crude oil, which soon after became the most used fossil fuel in the world. With the increase of coal and oil as fuel sources, firewood has become a secondary type of energy source. Firewood is also known as "cord wood" because in the United States it is sold by a unit called the cord. In contrast to civilizations in relatively arid regions (such as Mesopotamia and Egypt), the Greeks, Romans, Celts, Britons, and Gauls all had access to forests suitable for using as fuel. Over the centuries there was a partial deforestation of climax forests and the evolution of the remainder to coppice with standard woodland as the primary source of wood fuel.

MATERIALS AND METHODS.

Wood Smoke Analysis

Sample Collection.

Ten fire wood samples majorly used by rural settlers in cooking were collected from fire places in Umuoji, village Idemili North LGA of Anambra state, Nigeria. The villagers were able to give the local or common names of the fire woods while the botanic names were obtained with the aid of a forest officer.

Wood Samples selected and identified by name by forest officer were:

1. Bamboo wood. *(achara)*
2. Avocado Pear wood. *(ube oyibo)*
3. Breadfruit wood *(ukwa)*
4. Iroko wood. *(orji)*
5. Oil bean wood. *(Ukpaka)*
6. Gmelina wood.
7. Mango wood.
8. Acacia wood.
9. Bush Mango wood. *(Ogbono)*
10. African Star apple wood. *(Udara)*

Equipment / Apparatus

1. Name of Equipment. Flue gas analyzer.

   Make of Equipment. Testo.

   Model Number. 350XL

2. Heat testing furnace (Budpest KGYV) main voltage = 3x380 V, Temperature = 950 °C.
3. Atomic Absorption Spectrophotometer, Agilent AA200 / 240.
4. Kjeldal Flask, Water bath, Beakers, Filter papers, Volumetric flask
5. Atomic Absorption Spectrophotometer

Sample Preparation.

These wood samples were separately cut into pieces (2mm X 2mm X 2mm) to increase the surface area as well as reduce ignition time since it would be decomposed by pyrolysis.

Analysis of Flue Gases

The Electric furnace was switched on and temperature gradually increased till it reached 600 degrees Celsius. The pieces of wood were then introduced into the furnace and allowed for about 30 minutes to decompose. The Flue gas analyzer was then connected to the furnace stack through the probes, the probe removes hot sample gas from stack and transported it to the Analyzer Box. A thermocouple is integrated for a flue gas temperature measurement, and readings are taken from the control unit of the flue gas analyzer. The Control Unit displayed all flue gas measurements up to 6 parameters simultaneously on one screen. For C_xH_y measurements, 15 minutes will be needed for the sensor to reach stable operating temperature. This procedure was adopted for all the wood species.

Elemental Analysis of Firewood Ash.

To further evaluate the toxicity of wood smoke, the wood using the Atomic Absorption Spectrophotometer (AA200/240 series).

Method

Each wood ash sample (2.0g) was transferred into a Kjeldahl flask; 20 ml of concentrated nitric acid (HNO_3) was added to the sample pre-digested by heating gently for 20mins. More acid was added and digestion was continued for 30 mins. Digestion was stopped when a clear digest was obtained. The solution was filtered after cooling through Whatman paper number 42mm into 50ml volumetric flask and made to the mark with distilled water. The resulting solution was transferred into a polythene bottle and analyzed for heavy metals using the atomic absorption spectrophotometer AAS. Reagent blanks were prepared in a similar manner for every batch of sample. All solutions were analyzed for heavy metals using Atomic absorption Spectrophotometer. When the sample solutions were aspirated into the flame of the AAS, the instrument gave the concentration of each element.

Analysis of a mixture of metal standards (Pb, Zn, Cu, Cr, Cd) prepared from the stock solutions was also carried out as part of the analytical data quality assurance. Evaluation of accuracy and precision of the analytical instrument was performed by triplicate analysis of the standards.

RESULTS AND DISCUSSION

Table 1 The Composition of smoke from different firewood and their concentrations.

GAS DETECTED / FIREWOOD SAMPLE	NO_X (ppm)	SO_X (ppm)	CO_2 (%)	CO (ppm)	C_ZH_Y/VOC (ppm)	H_2
Bamboo	0.50	2.00	20.06	157	27340	45.0
Avocado	0.00	4.00	20.69	174	7380	72.0
African Bread Fruit	0.00	54.00	20.59	956	2290	18.0
Iroko	0.10	2.00	20.70	115	2198	100.0
Oil Bean	0.80	0.00	20.70	28	2410	57.0
Gmelina	0.20	8.00	20.50	113	2742	49.0
Mango	0.70	3.00	20.60	125	2134	70.0
Acacia	0.40	2.00	20.63	109	2191	20.0
Wild Mango (*ogbono*)	0.70	15.00	20.80	213	8021	25.0
African Star Apple	0.80	10.00	20.70	200	7101	50.0

Identified Toxic Gases in Wood Smoke

Gases analyzed for by the Flue gas analyzer during the Pyrolysis of the wood samples are;

1. VOC → Volatile Organic compounds,
2. C_zH_y → Hydrocarbons.
3. SO_x → Oxides of Sulphur.
4. CO → Carbon monoxide.
5. CO_2 → Carbon Dioxide.
6. NO_x → Oxides of Nitrogen.
7. H_2 → Hydrogen Gas

The CzHy/VOC concentrations from different wood samples are shown in Fig 1.

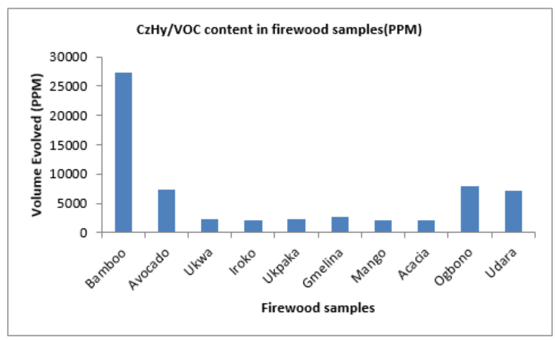

Figure 1 Plot of C_zH_y/VOC content of the firewood samples.

Fig 1 showed that Bamboo evolved the highest content of hydrocarbons and / or volatile organic compounds (27340 ppm). The flue analyzer grouped the result of CzHy/VOC content together. From literature[11] the least safest expossure limit for hydrocarbons and VOCs are those of Phenyl isocyanate, Pentaborane, methyl byphenylisocyanate, Methylene bis (4-cyclo-hexyl-isocyanate),Hexamethyldiisocyanate, Tetranitomethane,Toulene-2,4-

diisocyanateall at 0.005ppm, while the highest safest exposure are that of Dichlorodifluoromethane, Cyclofluorane, Dimethoxymethane, Dimethoxy ether, Liquified petroleum gas all at 1000ppm in an 8 hour working exposure. The smoke from these firewood samples are all above these limits and hence very toxic to human health. From this result, the order of deleteriousness is: Bamboo (27340 ppm) > Ogbono (Wild Mango) (8021ppm) > Avocado Pear (7380ppm) > Udara (7101ppm) > Gmelina (2742ppm) > Ukpaka (Oil Bean) (2410ppm) > Ukwa (Breadfruit)(2290ppm) > Iroko (2198ppm) > Acacia (2191ppm) > Mango (2134ppm).

The SOx oxides concentrations from different wood samples are shown in Fig 2.

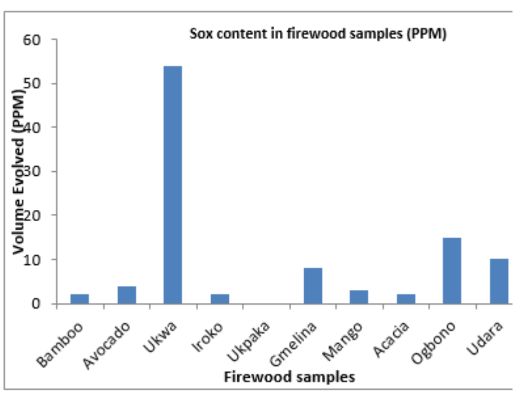

Figure 2: Plot of SO_x content of the firewood samples.

Figure 2 showed that African bread fruit contained the highest level of oxides of sulphur while Oil bean showed no presence of sulphur. The threshold limit values for human exposure to the oxides of sulphur are 0.5ppm and 5.8ppm for SO_2 and SO_3 respectively[12]. Figure 2 confirmed that the exposure to smoke from bread fruit (Ukwa), Wild mango (Ogbono), African Star Apple (Udara) and Gmelina firewoods as extremely dangerous due to their high SO_x concentrations. The Carbon monoxide concentrations from different wood samples are shown in Fig 3.

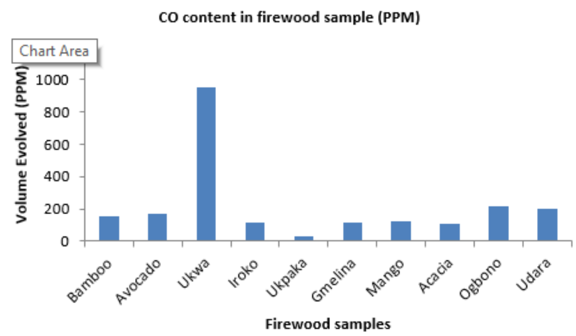

Figure 3: Plot of CO content of the firewood samples.

The Carbon monoxide concentrations from different wood samples are shown in Fig 3. This showed that all fire wood samples had a high level of CO above the Threshold Limit Value (TLV) of 35ppm[13], and exposure to this is very dangerous to health. The firewood with the highest concentration of CO is breadfruit (956ppm) while the wood with the lowest output is Ukpaka (28ppm).

The Carbon dioxide concentration of the smoke from the wood samples are shown in figure 4.

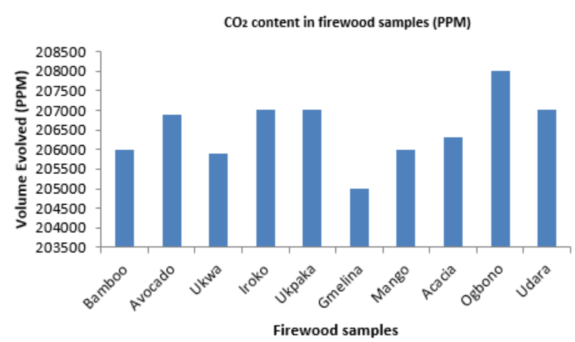

Figure 4: Plot of CO_2 content of the firewood samples.

The Carbon dioxide concentrations evolved are highly above 5000ppm which is the acceptable threshold limit value of the World Health organization, [14]. These results confirm that most of the woods used in the area of study constitute health risk in terms of CO_2 emission. Wild mango had the highest concentration of carbon dioxide while Gmelina arborea had the lowest value.The Nitrogen oxide composition of the smoke from the firewood samples are depicted in figure 5.

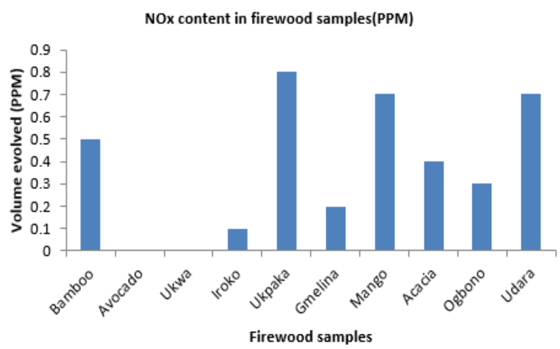

Figure 5: Plot of NO_x content of the firewood samples.

Avocado Pear and Bread fruit (Ukwa) showed no presence of oxides of Nitrogen, Other wood samples are in quantities within the WHO approved Threshold limit value (TLV) except for N_2O_4 which poses a threat. The TLV of the oxides of nitrogen, NO_2, N_20, NO, N_2O_3, N_2O_4, N_2O_5, are; 1ppm, 50ppm, 25ppm, 3ppm, 0.5ppm, 2ppm respectively [15]. The hydrogen concentration of the smoke from the firewood samples are shown in figure 6.

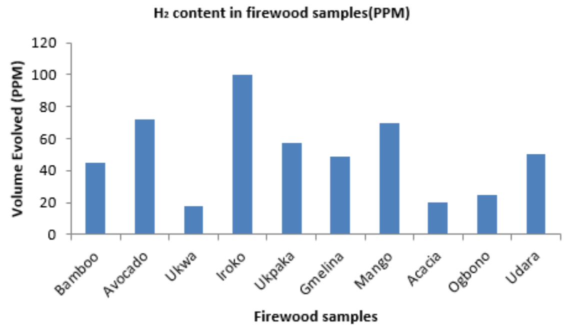

Figure 6. Plot of Hydrogen gas levels identified in the firewood smoke.

The trend for hydrogen evolution by wood was Iroko > Avocado > Mango > Oil bean > African Star Apple > Gmelina > Bambo > Wild Mango > Acacia > Bread fruit.

Hydrogen gas is not toxic at all. However, it can displace oxygen and thus can be an asphynxant in large quantities. There are no specific exposure limits for Hydrogen. Hydrogen is a simple asphyxiant (SA). Oxygen levels should be maintained above 19.5%.The most significant hazard associated with this gas is inhalation of oxygen-deficient atmospheres.

Heavy metals analysis (wood ash)

Table 2 Elemental compositions of ash from different firewood and their concentrations. (PPM)

SAMPLE	LEAD (Pb) (ppm)	ZINC (Zn) (ppm)	COPPER (Cu) (ppm)	CHROMIUM(Cr) (ppm)	CADMIUM(Cd) (ppm)
Avocado	0.19	13.10	1.13	0.53	0.53
Iroko	0.60	8.96	0.99	0.58	0.58
Ukwa	0.93	14.60	1.17	0.44	0.12
Ukpaka	0.93	8.69	2.36	0.45	0.09
Bamboo	1.29	7.51	1.37	0.38	0.09
Gmelina	0.91	8.50	1.22	0.32	0.15
Mango	0.87	10.10	2.14	0.35	0.45
Acacia	1.19	13.40	0.95	0.48	0.18
Ogbono	0.89	11.31	0.89	0.54	0.51
Udara	0.94	8.94	1.01	0.34	0.35

Table 2 showed the heavy metal analysis of wood ash and their concentrations in PPM. Comparing these results with the thresh hold limit values for an 8 hour working condition from World Health and Safety bodies showed that wood smoke could cause deleterious effects to firewood users.

Figure 7 showed the concentration of lead in the ash of the firewood samples.

Lead was identified in samples of fire wood ash in alarming proportions ppm – 1.29 ppm). The permissible exposure limit, (PEL) (the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-h workday or a 40-h workweek.) is 0.005ppm (50 micrograms/m^3)[16].

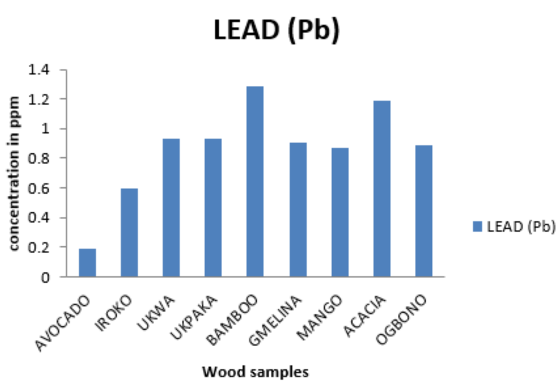

Figure 7. Plot of Lead levels in wood sample ash

From Figure 7, the concentration of lead (0.19 – 1.29) ppm is far greater than the PEL of 0.0059ppm (50 micrograms/m^3) and can cause deleterious impact to the health of the firewood user.

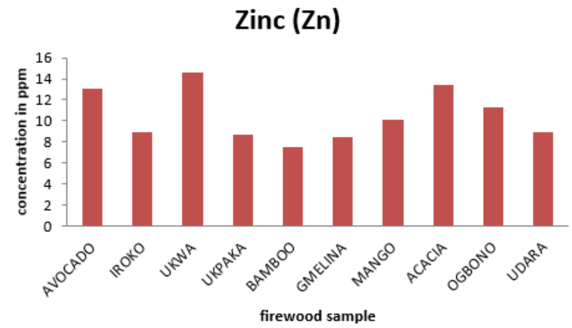

Figure 8. Plot of Zinc level in wood sample ash

From Figure 8, the concentration of zinc (8.5 – 14.6) ppm is far greater than the PEL of 2.19 ppm (5mg/m^3) and can cause deleterious impact to the health of the firewood user.

It is noteworthy that the trend of concentration was Ukwa > Acacia > Avocado > Ogbono > Mango > Iroko > Udara > Ukpaka > Gmelina > Bamboo.

The concentrations of copper in the ash of the firewood samples are outlined in figure 9

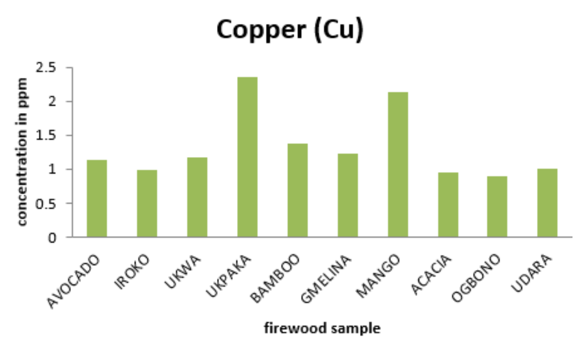

Figure 9 Plot of copper in wood sample ash

The PEL of copper is 0.036 ppm (0.1mg/m^3) for 8h workday or 40 h work/week [17]. From the fig 1.9, the concentration of copper (0.89 – 2.36) ppm is greater than the PEL of 0.036 ppm (0.1mg/m^3) and can cause deleterious impact to the health of the firewood user. The trend of concentrations of copper in the wood ash samples were *Ukpaka* > Mango >

Bamboo > Gmelina > *Ukwa* > Avocado > *Udara* > Iroko > Acacia > *Ogbono.*

The concentrations of chromium in the wood ash samples are depicted in figure 10.

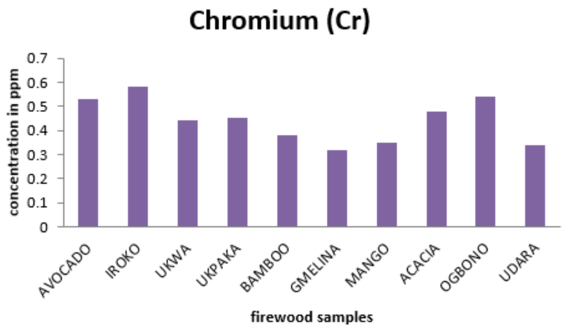

Figure 10 A plot of Chromium in wood sample ash

The legal airborne permissible exposure limit, *NIOSH REL TWA* (PEL) for Chromium is 0.24 PPM (0.5mg/m^3) averaged over an 8-hour workshift **[18]**.

From figure 10, the concentration of Chromium (0.32 – 0.58) ppm is far greater than the PEL of 0.24 ppm (0.5 mg/m^3) and can cause deleterious impact to the health of the firewood users.

The trend of deleteriousness of Chromium in wood is Iroko > *Ogbono* >Avocado > Acacia > *Ukpaka* > *Ukwa* > Bamboo > Mango > *Udara* > Gmelina.

Chromium III is much less toxic than chromium (VI). The respiratory tract is also the major target organ for chromium (III) toxicity, similar to chromium (VI).

The concentrations of cadmium in the wood ash samples are depicted in figure 11.

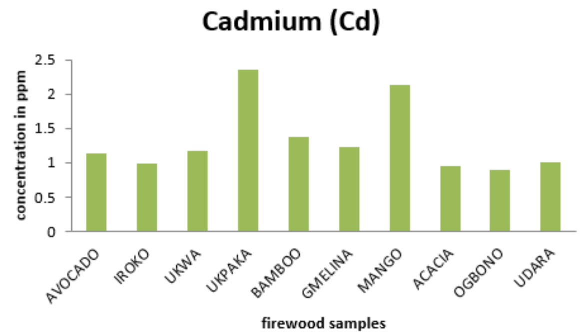

Figure 11. A plot of Cadmium in wood sample ash

OSHA sets a PEL of 5 micrograms/m^3 (0.00109 ppm**)** **[19]** for respirable dust of cadmium. From the graph, the concentration of Cadmium (0.12 – 0.58) ppm is far greater than the PEL of 0.00109 ppm (0.005 mg/m^3) and can cause deleterious impact to the health of the firewood user.

CONCLUSION

Indoor air pollution from wood smoke disproportionately affects women and children and is the cause of significant global mortality and morbidity. This is a neglected area of global disease that affects a large proportion of the world's population.

The study investigated the smoke components of ten Nigerian firewood samples and the elemental composition of the ashes derived from the pyrolysis of these wood fuels and the following conclusions were drawn.

1. Toxic gases were identified during the pyrolysis of the firewood samples.

Gases identified were.

a. Volatile organic compounds/Hydrocarbons. 2134ppm – 27340ppm.

b. Oxides of sulphur. 2ppm – 54ppm.

c. Carbon monoxide. 28ppm – 956ppm.

d. Carbon dioxide. 20.59% – 20.80%.

e. Oxides of Nitrogen 0.1ppm – 0.8ppm.

f. Hydrogen gas. 18ppm - 100ppm.

Heavy metals identified from the ashes were:

a. Lead 0.19ppm – 1.29ppm

b. Zinc 8.50ppm – 14.6ppm

c. Copper 0.89 ppm – 2.36ppm

d. Chromium 0.32 ppm – 0.58ppm

e. Cadmium 0.12ppm – 0.58ppm

2. The concentration values of the identified gases and heavy metals were higher than the threshold limit values (TLV) given by the World health bodies, Except for the oxides of Nitrogen which showed a danger in the inhalation of N_2O_4. Inhalation and contact with these gases are harmful to human health.

REFERENCES

1. UNDP (2002). World Energy Assessment. United Nations Development Programme, United Nation Department of Economic and Social Affairs and World Energy Council. New York: UNDP

2. Adedayo, A. (2005). "Gender roles in forest resources utilization and its impact on rural environment in Kwara State, Nigeria." Environmental sustainability and conservation in Nigeria.

3. The Solar Cooking Archive (2011). Fuelwood as percentage of energy consumption in developing countries. Retrieved on 23th August, 2012 from: http://solarcooking.org/fuelwood.htm

4. Ogbonna DO (1991). Energy Challenge and Ecological Balance in the Sahel and Semi-Arid Zone of Nigeria. A Paper Presented at The International Workshop on Ecology and Society in the History of the Sahel and Savanna, Centre for trans-Saharan Studies, University of Maiduguri.

5. FAO (2005). Global Forest Resources Assessment 2005. FAO Forestry Paper 147: Progress towards sustainable forest management. ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E00.pdf. [last accessed 20-05-2017].

6. Kituyi E (2002). “Towards Sustainable Charcoal Production and Use: A Systems Approach.” Proceedings of a Regional Workshop on Woodfuel Policy and Legislation in Eastern and Southern Africa. RELMA, Nairobi, Kenya.

7. FAO (2001). “The Role of Wood fuel in Africa by D. Gustafon. In: N Wamukonye (Ed) Proceeding of a High-Level Regional meeting on Energy and Sustainable Development.” 10-13 January 2001. Nairobi, Kenya. Food and Agriculture Organization of the United Nations, Rome. pp. 99-101.

8. Saraki B 2013, June 5, Nigerians use 266 million kg of firewood daily Premium Times https://www.premiumtimesng.com/news/13

7723-nigerians-use-266-million-kg-of-firewood-daily-senator-saraki.html

9. NBC-CNB-NCC Collaborative survey (2011) :2010 Annual Socio – Economic Survey Report, Nigerian Electricity Regulatory Commission, Present Licenses.

10. WHO (2016). Ambient (Outdoor) Air Quality and Health. Fact sheet updated September 2016, World Health Organisation.

11. Helmenstine, A. (2020). "Smoke Chemistry and Chemical Composition.". ThoughtCo, Aug, 27, 2020, https://www.thoughtco.com/smoke-chemistry-607309

12. Jayjock, M., et al. (2001). "Quantitative level of protection offered to workers by ACGIH threshold limit values occupational exposure limits." AIHA Journal 62(1): 4.

13. Oikawa, D., et al. (2012). "Recommendations for occupational safety and health: Compendium of policy documents and statements Recommendations for occupational safety and health: Compendium of policy documents and statements, 1992." Journal of occupational health 54(5): 370-375.

14. Friedman, D. (2015). "Toxicity of carbon dioxide gas exposure, CO2 poisoning symptoms, carbon dioxide exposure limits, and links to toxic gas testing procedures." InspectAPedia http://www.inspectapedia.com/hazmat/CO2 gashaz. htm# reviewers. Accessed on 15.

15. NRC (National Research Council) Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 13 (2012)

16. NRC (National Research Council) Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 14 (2013)

17. Occupational Safety and Health Administration [OSHA],1988 https://www.cdc.gov/niosh/pel88/7440-50.html

18. CDC - NIOSH Pocket Guide to Chemical Hazards - Chromium metal https://www.cdc.gov/niosh/npg/npgd0141.html

19. 1910.1027 – Cadmium | Occupational Safety And Health Administration http://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1027