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Effect of Biomass Blending and Desulphurization on Flue Gas Emissions of Nigerian Sub Bituminous Coal Briquettes

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ABSTRACT

The effect of blending, briquetting and desulphurization of coal and biocoal briquettes of Nigerian sub bituminous coal is discussed. The flue gas of the coal and biocoal samples were analyzed to study the emission characteristics of nitrogen oxide (NO2), sulphur dioxide (SO2) and carbon monoxide (CO) due to environment concern with the use of coal as either domestic or industrial fuel. Sub bituminous coal sample from eight coal mines and sites in five states in Nigeria were collected. The states and sites included Kogi (Ogboyoga, Okaba), Benue(Owukpa),Nassarawa (Lafia/Obi), Ebonyi (Afikpo) and Enugu (Okpara,Onyeama and Ezinmo).The samples were pulverized and blended with sawdust at various constituent ratios of 0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0 sawdust : coal. Cassava starch was used as binding material while calcium hydroxide was used as desulphurizing agent for the briquettes. Emission tests for various compositions of the briquettes were carried out and the O2, CO2, CO, NO2 and SO2 of the briquettes were compared. Results showed reduction in combustion emission withincrease in sawdust concentration with the reduction in smoke and noxious gas emission. Thesulphur dioxide range of the coal briquettes is between 0.018ppm and 0.028ppm which decreased to between 0.025and 0.005 ppm in biocoal briquettes. Same for nitrogen oxide which range between 0.034ppm and 0.038ppm but decreased to between 0.025 and 0.019 ppm and carbon monoxide range of between 0.3ppm and 0.48ppm which decreased to between 0.43ppm and 0.12 ppm in the biocoal briquettes. The 50:50 blends of sawdust to coal for Ogboyaga has the lowest carbon monoxide emission of 0.12 ppm; Okpara has the lowest sulphur dioxide emission of 0.005ppm while Onyeama has the lowest nitrogen oxide emission of 0.019 ppm. These are below the national ambient air quality standards which put sulphur dioxide at 1.4 x 10-1 ppm. The biocoal briquette emits less sulphur dioxide because it contains desulphurizing agent which fixes some of the sulphur that would have gone to the atmosphere to ash.

Keywords: biocoal briquettes, blending, flue gas emissions, sub - bituminous coal.

1.0: INTRODUCTION

Large quantity of coal is used in many developing Countries as the major fuel in domestic and industries applications as well as power generation. They burnt raw coal with high sulphur content to fulfill their energy demand**.** Densification of various ranks of coal for the purpose of making solid fuel has been a technology widely used in many Countries (Adekunle, 2004, Adekunle *et al.*, 2015 and brooks 2010). There have been several researches carried out on the production of fuel briquettes for both domestic and industrial applications from coal. One of the driving forces behind these researches is the need to address the environmental consequences and health hazards associated with the use of raw coal and coal briquettes. However, it has been shown that blending coal and biomass such as sawdust and other agricultural waste give rise to briquettes with better combustion properties and environmentally friendly compare to the conventional coal briquettes. These types of briquettes are known as biocoal briquettes (Dong and Sakomoto, 2004)

Biocoal briquetting is a solid fuel made up of coal, biomass and sulphur retention agent; it is prepared by compacting pulverized coal, biomass, binder, and sulphur fixation agent (Kim 2002). The high pressure involved in the process ensures that the coal and the biomass particles are sandwiched and bind together, as a result do not separate during transportation and storage. Biocoal briquette technology combines irrenewability fossil energy and renewable biomass, embodying both functions of synthetic utilization of energy and reduction of air pollution. During combustion, the combustion of the coal and the biomass gives a better combustion performance and reduces pollutant emission. It has a favourable ignition, better thermal efficiency, emits less dust and soot (Knosper and Walleser, 2004).

This technique has the advantages over coal briquette in the sense that any grade of coal can be used without carbonization (Knosper and Walleser, 2004). Furthermore, the presence of sulphur fixation agent otherwise known as desulphurizing agent ensures that most of the sulphur content of the coal is fixed into the ash instead of being liberated into the atmosphere as sulphur dioxide (Kwong *et al.*, 2004). The desulphurizing agent in the briquette reacts with the sulphur content of coal to fix about 60-80% of it into ash (Lu *et al.*, 1995). This implies that, by this technology, the pollution problems associated with burning of coal is to a great extent taken care of. Calcium hydroxide, calcium carbonate and calcium oxide are common desulphurizing agents.

Nigeria has potential for utilizing biocoal technology as a measure to address its energy problem associated with rural household energy demands and means of utilizing the large deposits of coal as well as means of managing agro wastes thereby creating avenues for substitutes for excessive use of fuel wood. Sawdust is one of the agro wastes that are available in abundance locally as a waste material from saw mills across the Country (Lu *et al.*,1995).
This research is aim at investigating the effect of sawdust blending and desulphurization on the flue gas emission of Nigerian sub bituminous coal and biocoal briquettes.

2.0: MATERIALS AND METHODS

2.1: Sources and preparation of Materials

Coal samples from eight mine sites in the following locations in Nigeria were obtained: Enug u (Okpara, Onyeama and Ezinmo), Ebonyi (Afikpo) Kogi(Odu Ogboyaga and Okaba), Nassarawa (Lafia/Obi) and Benue (Owukpa).The samples were taken in each of the locations and thereafter transferred and kept in polyethylene bags which were labeled appropriately. Figure1 shows map of Nigeria showing where coal samples were collected while Table1 sho ws the coordinates of where the coal samples were collected. Sawdust was collected from a saw mill and used as one of the composite blend. Calcium hydroxide was bought and used as desulphurizer. Cassava starch was obtained from open market and used as binder. The samples were dried and pulverized to 0.3mm particle size.

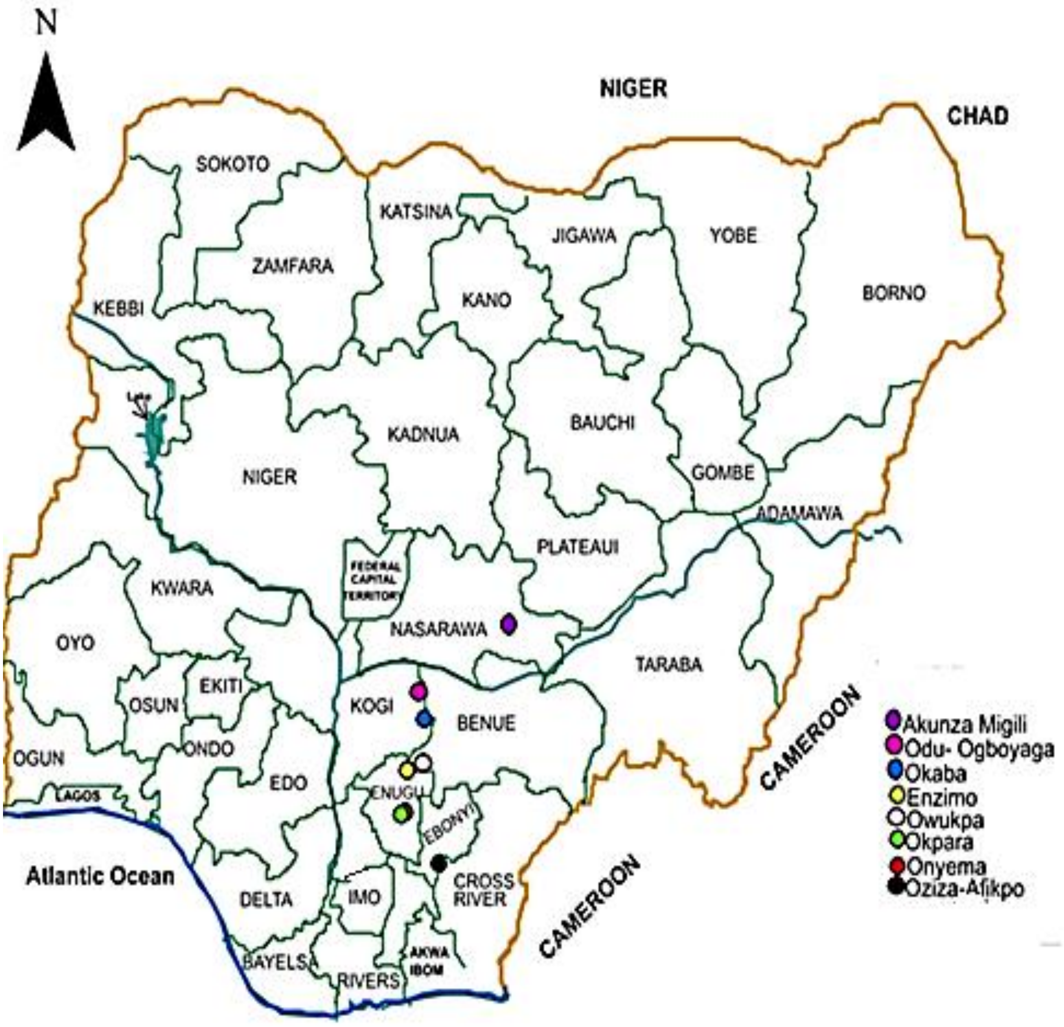

Fig.1: Map of Nigeria showing where Coal samples were collected

Table 1: Coordinates of coal sample locations

Sample Code	State	Mine Location	Type of Coal	Longitude	Latitude
OK	Enugu	Okpara	Sub-bituminous	7^o 27' 2.93''E	6^o 24' 23''N
ON	Enugu	Onyeama	Sub-bituminous	7^o 29' 41.13''E	6^o 26' 20.52''N
EZ	Enugu	Ezinmo	Sub-bituminous	7^o 31' 59.50''E	6^o 51' 59.24''N
AF	Ebonyi	Afikpo (Oziza)	Sub-bituminous	7^o 53' 54.84''E	5^o 54' 17.07''N
OG	Kogi	Ogboyaga (Odu)	Sub-bituminous	7^o 40' 0.29''E	7^o 40' 0.07''N
OB	Kogi	Okaba	Sub-bituminous	7^o 43' 59.20''E	7^o 22'58.55''N
LA	Nasarawa	Lafia/Obi (Akunza Migili)	Sub-bituminous	8^o 44' 0.02''E	8^o 21'56''N
OP	Benue	Owukpa	Sub-bituminous	7^o 39' 50.92''E	6^o 55'59.01''N

The eight coal samples were blended with sawdust at various mixing proportions of 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 and 100:0 sawdust: coal, 5% $Ca(OH)_2$ based on the mass of the coal that was added for desulphurization and 10% cassava starch gel based on the entire mass of the mixture was used as binder for all the samples as adopted by (Dong and Sakomoto, 2004). The samples were weighed using digital weighing balance with maximum load of 600g and accuracy of 0.1g. The different concentrations were loaded into the mould compartment of the manually operated hydraulic briquetting machine. A maximum of 16 briquettes were obtained at each operation of the machine under a total load of 57.4N. Biocoal briquettes of different mixing proportion as well as pure coal and sawdust briquettes were produced under this condition.

Plate 1: Sawdust sample

Plate 2: Pulverized coal sample

Plate 3: Samples of coal, sawdust and biocoal briquettes

3.0: MATERIALS AND METHODS

3.1: Emission Tests

The flue gas of the samples was analyzed to study the emission characteristics of NOx, SOx and CO due to environment concern with the use of coal as either domestic or industrial fuel.

The experimental apparatus was conducted by adopting the procedure adopted by (Patomok, (2008), it consists of electrically heated batch furnace, temperature controllers, a digital balance and flue gas analyzer. 5g of briquette was placed in a basket, which was linked with a digital balance positioned in the centre of the furnace along the vertical axis. The injected air was preheated to a temperature of 100^0C by a packed bed of alumina balls located at the bottom of the furnace. The change in the mass of briquette and the change in the concentration of SO_2, NO_2, CO, CO_2 and O_2 in the flue gas were continuously measured during the combustion process by the digital balance and the flue gas analyzer respectively. At the beginning of combustion, the electrical furnace was heated to 200^oC and was moved upward to heat the sample**.** The time - concentration history of SO_2, NO_2, CO, CO_2 and O_2 and the mass loss of sample were continuously measured by computer aided flue gas analyzer and the digital balance respectively.

The air was maintained at 10 lt/min. The emissions of combustion were monitored and recorded using a Testo 350 Flue Gas Analyzer.

4.0: RESULTS AND DISCUSSION

4.1: Results

Table 2 shows the flue gas emission of various coal samples, Figures 2 to 9 show the percentage concentration of flue gas emission of Okpara, Onyeama, Ezinmo, Afikpo, Ogboyaga, Okaba, Lafia/Obi, Owukpa biocoal briquettes while Table 3 shows the flue gas emission of sawdust and sawdust briquette.

Table 2: Flue gas emission test of raw coal

Sample name	O_2 (%)	CO_2 (%)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
Okpara Coal	19.27	3.18	0.3	0.035	0.027
Onyeama Coal	19.55	3.17	0.41	0.034	0.028
Ezinmo Coal	19.34	3.18	0.36	0.036	0.02
Afikpo(Oziza) Coal	19.3	3.19	0.48	0.04	0.018
Ogboyaga(Odu) Coal	19.34	3.18	0.34	0.038	0.028
Okaba Coal	19.66	3.17	0.34	0.034	0.028
Lafia/Obi(Ak. Mig.) Coal	19.81	3.19	0.35	0.038	0.027
Owukpa Coal	19.73	3.19	0.38	0.036	0.028

Description:

O_2 Oxygen
CO_2 Carbon dioxide
CO Carbon monoxide
NO_2 Nitrogen oxide
SO_2 Sulphur dioxide

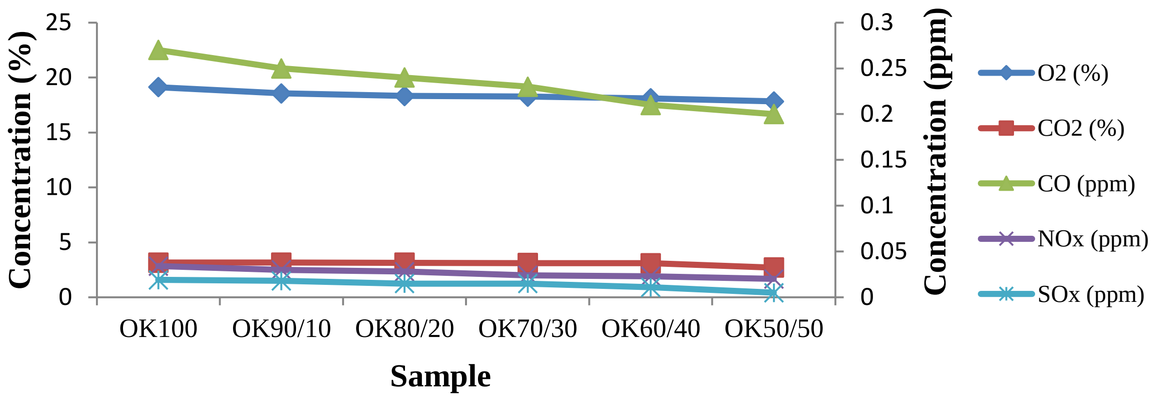

Fig. 2 : Plot of percentage concentration of flue gas emission of Okpara coal and biocoal briquettes

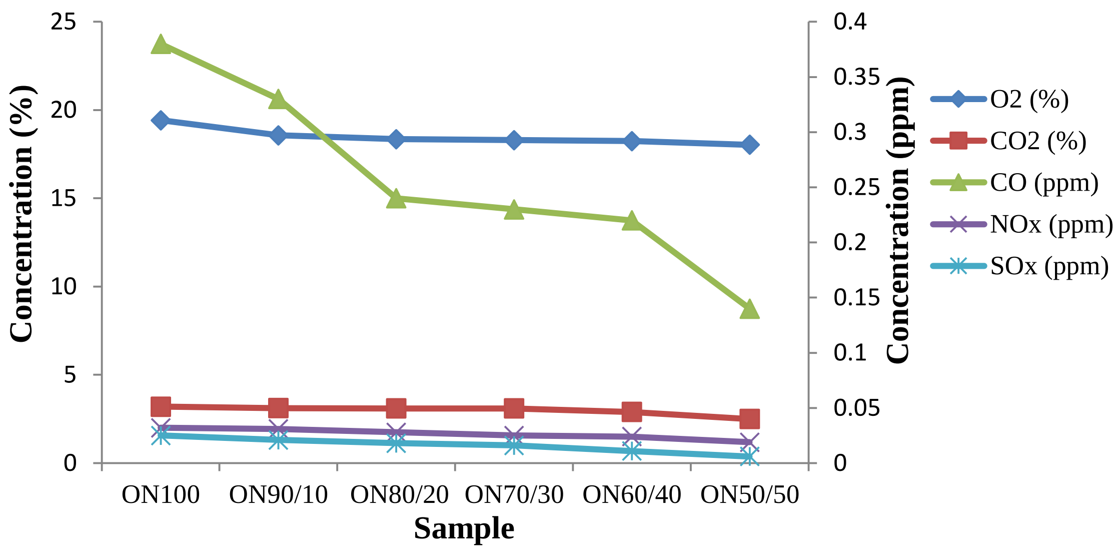

Fig. 3: Plot of percentage concentration of flue gas emission of Onyeama coal and biocoal briquettes

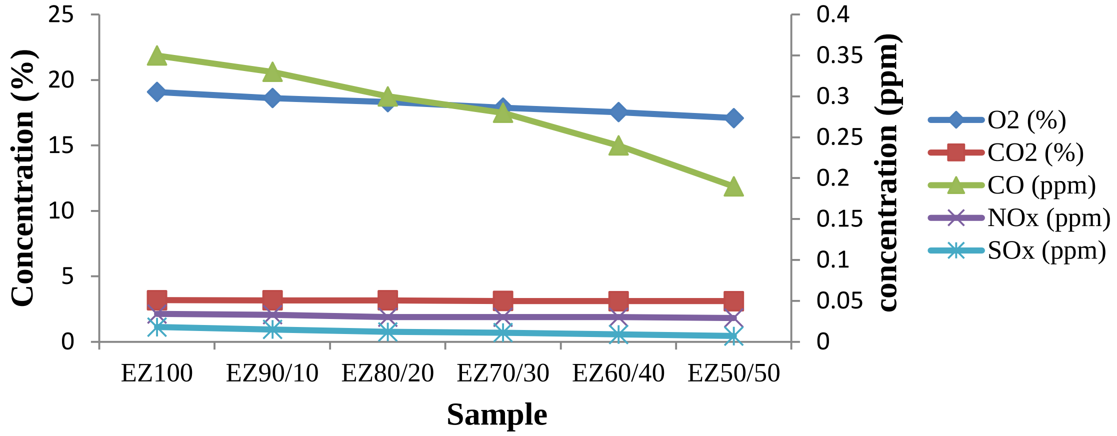

Fig. 4 : Plot of percentage concentration of flue gas emission of Ezinmo coal and biocoal briquettes

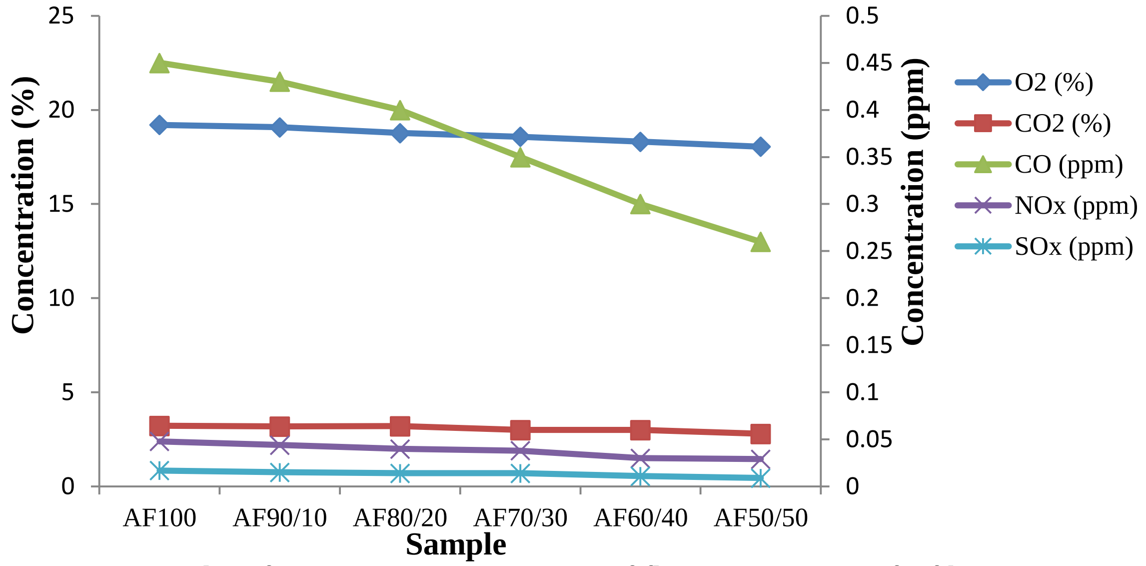

Fig. 5 : Plot of percentage concentration of flue gas emission of Afikpo (Oziza) coal and biocoal briquettes

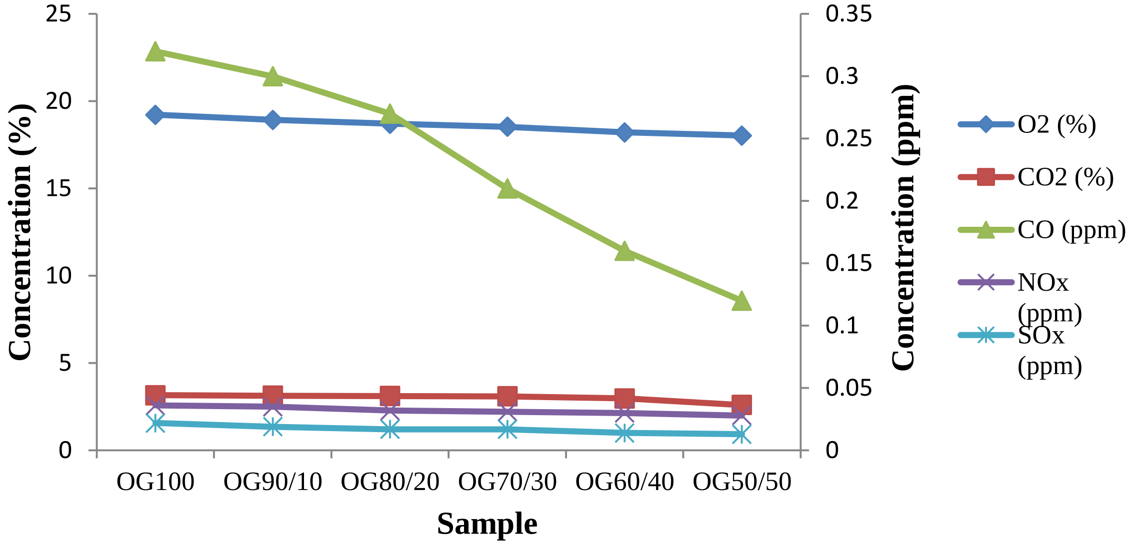

Fig.6 : Plot of percentage concentration of flue gas emission of Ogboyaga(Odu) coal and biocoal briquettes

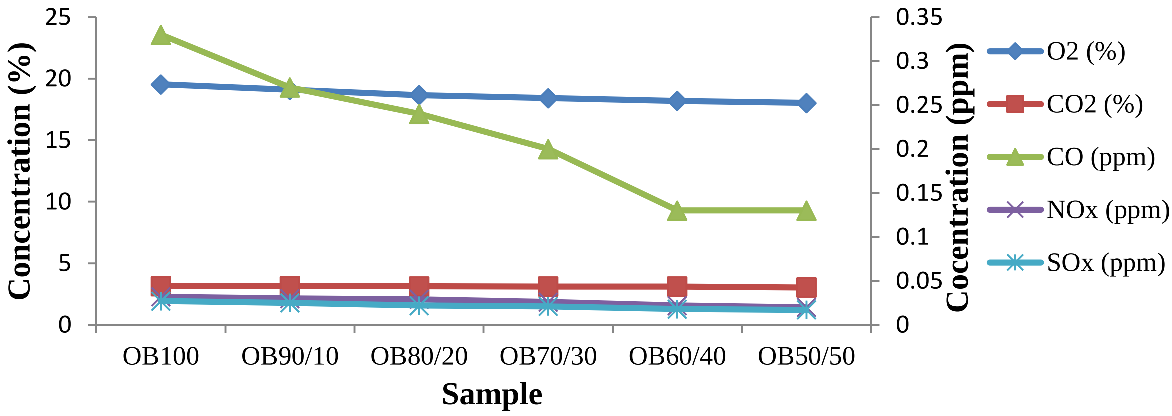

Fig. 7 : Plot of percentage concentration of flue gas emission of Okaba coal and biocoal briquettes

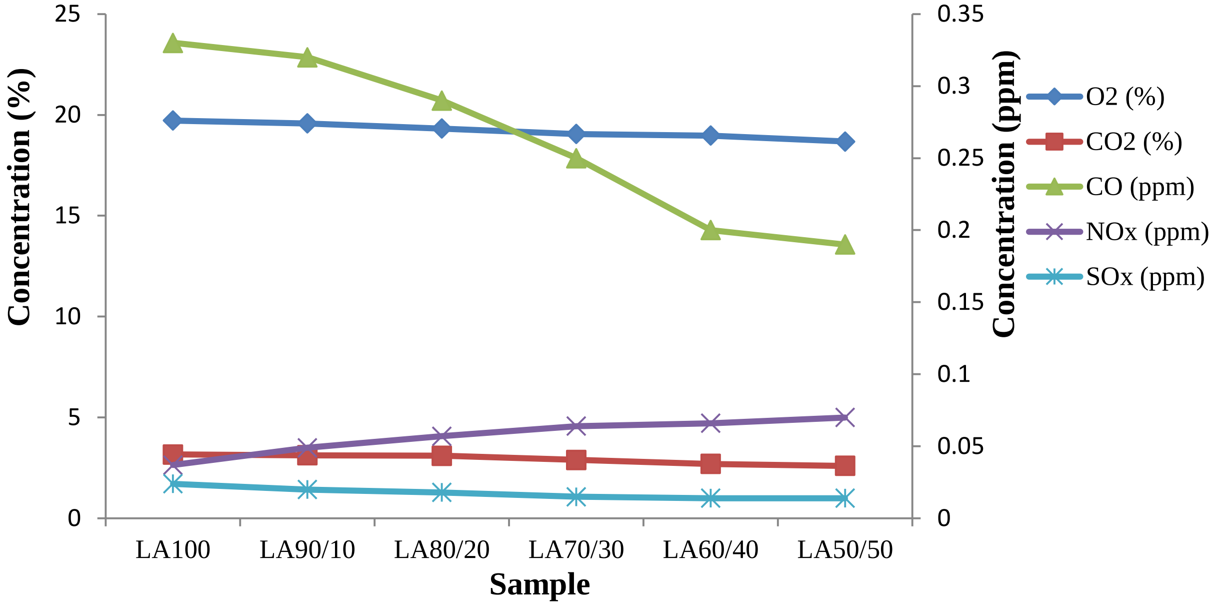

Fig.8 : Plot of percentage concentration of flue gas emission of Lafia/Obi (Akunza Migili) coal and biocoal briquettes

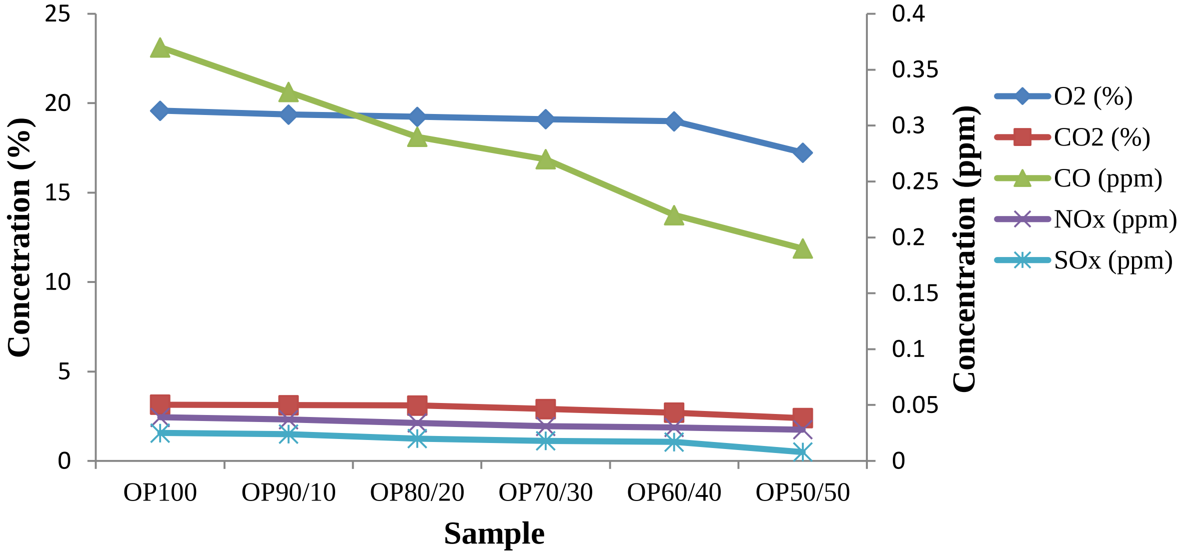

Fig.9: Plot of percentage concentration of flue gas emission of Owukpa coal and biocoal briquettes

Table 3: Flue gas emission of sawdust and sawdust briquette

SC	O_2 (%)	CO_2 (%)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
SD	17.35	3.44	0.25	0.08	0
SB100	16.35	3.44	0.25	0.08	0

SC Sawdust composition
SD Sawdust
SB Sawdust briquettes
O_2 Oxygen
CO_2 carbon dioxide
CO Carbon monoxide
NO_x Nitrogen oxides
SO_2 Sulphur dioxide

4.2: Discussion

4.2.1: Effect of Blending and Desulphurization on the Flue Gas Emission

In Table 2, the sulphur dioxide of the coal deposit, range between 0.02ppm for Ezinmo to 0.028ppm each for Onyeama, Ogboyaga, Okaba and Owukpa respectively. These decreased substantially in Figures 2- 9 with increase in sawdust concentration and addition of desulphurizing agent, calcium hydroxide in all the compositions to between 0.025ppm and 0.005ppm for biocoal briquette samples. The Onyeama coal briquette has the highest sulphur dioxide content of 0.028ppm while Okpara 50:50 biocoal briquette has the lowest with 0.005ppm (Figure 2). These are below the national ambient air quality standards which put sulphur dioxide at 1.4x 10-1 ppm (Ramesh et al.,) Sulphur content in coal is combustible and generates some energy by its oxidation to sulphur dioxide which is a major source of atmospheric pollution. It then follows that biocoal briquette emits less sulphur dioxide because it contains desulphurizing agent which fixes some of the sulphur that would have gone to the atmosphere to ash. During combustion, the desulphurizing agent effectively reacts with the sulphur content of the coal to form a solid compound instead of being released as oxides of sulphur to the atmosphere. However, it is widely accepted that biocoal briquette technology is one of the most promising technologies for the reduction of sulphur dioxide emission associated with burning of coal (Kim et al., 2002 and Somchai et al., 1988).

The nitrogen oxide range of the deposits is between the lowest at 0.034ppm for Onyeama and Okaba deposits and the highest of 0.038ppm each for Ogboyaga and Lafia/obi deposits, in Fig.2 - 9, the nitrogen oxide content decreased marginally in all the coal and biocoal briquettes with increase in sawdust concentration and addition of desulphurizing agent. The Onyeama 50:50 briquette has the lowest nitrogen oxide of 0.019ppm, while sawdust briquette has 0. 08ppm.They are below the national ambient air quality standards, which put nitrogen oxide at 0.53ppm Ramesh et al., 2009). The emissions are relatively low in all the biocoal briquettes as compared with the raw coal and 100% coal briquettes which make them better and more environmentally friendly solid fuel.

Carbon monoxide for the raw coal ranges between 0.3ppm for Okpara to 0.48ppm for Afikpo deposits. There were progressive decreases in the carbon monoxide content as the sawdust concentration increased from 100% coal briquettes to 50/50% biocoal briquettes and addition of desulphurizer. In all, they are below the national ambient air quality standards which put carbon monoxide at 6.67ppm (Patomok, 2008). Carbon monoxide is formed predominantly during incomplete combustion of fossil fuels and other materials containing carbon. Outdoors in ambient conditions, CO is not very dangerous for human beings because of its fast reaction to CO_2 with oxygen. However, indoors or within enclosed spaces it must be considered as very dangerous at a concentration of 700 ppm in the breathing air, it could lead to death within a few hours; the working place threshold value is 50 ppm (Xu et al., 2000). High carbon monoxide emission also reduce the oxygen carrying capacity of the blood to the body organs like the heart, brain and tissue, hence low carbon monoxide is desirable for domestic fuel which all the biocoal briquettes have in their qualities.

The concentration of carbon dioxide in all the samples range between 2.4% and 3.3%. It is produced during all combustion processes; it contributes considerably to the greenhouse effect through its ability to filter heat radiation. In ambient air, CO_2 concentration is 0.03%; at concentrations of over 15%, loss of consciousness will occur immediately, so the concentration range for these samples is well below the harmful level. The portion of oxygen that has not been consumed by the combustion process remains as part of the flue gas.

5.0: CONCLUSION

The study revealed that:

i. The level of harmful emission from 100% coal briquettes was considerably reduced in all biocoal briquettes

ii. The addition of sawdust and desulphurizer at various concentrations of biocoal briquettes resulted in reduction of harmful emission gases such as carbon monoxide, sulphur dioxide and nitrogen oxide.

iii. That biocoal technique and desulphurization are some of the means of reducing the emissions in coal combustion either for domestic or industrial applications.

iv. The research work is expected to contribute to the development of alternative or additional energy sources that is less pollutant in Nigeria which could reduce over dependence on firewood and petroleum products for domestic and industrial heat applications and also act as additional information and source of knowledge to studies on the blend of biomass with different deposits of coal in the country.

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