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EVALUATION OF GREENHOUSE GAS CONCENTRATIONS AT WOOD-BASED BURNT BRICK SITES IN SELECTED LOCAL GOVERNMENT AREAS OF BENUE STATE, NIGERIA

Agera S.I.N[1], Agbidye F.S[1] and Ogwuche J.A[2*]

[1]Department of Forest Production and Products, University of Agriculture, Makurdi, Nigeria.
[2]Department of Geography Benue State University Makurdi, Nigeria.

ABSTRACT: *This study evaluated the concentrations of the greenhouse gases CO, CO_2, NO_2, SO_2, CH_4 and NH_3 at sixteen wood-based burnt brick sites selected from eight purposively sampled Local Government Areas (LGAs) of Benue State. The six greenhouse gases were monitored for two years, from 2012 to 2013, using CROWCON Gasman Digital Gas Meters. Descriptive and inferential statistics were employed in analyzing collected data. Results indicate that the concentrations of each of the greenhouse gases were significantly much higher during the dry season compared to their wet season concentrations ($p<.0.5$). There were also significant differences in the inter-local government concentrations of the assessed gases within the same period. The use of fuelwood to burn bricks is believed to have principally resulted in the observed significantly higher concentrations of the greenhouse gases during the dry season, from the months of November to March, and corresponds with the season of active wood-based burnt bricks production. The production of perforated bricks can reduce the volume of fuelwood used since the bricks are hollow and can be cured faster, and thus save energy cost as well as reduce greenhouse gas emissions. Greener alternative energy sources (like solar, wind, liquefied hydrogen gas and hydro) should be used in firing bricks as this can reduce greenhouse gas emissions from burning wood at brick sites.*

KEYWORDS: Greenhouse, Gas Concentrations, Burnt Brick, Energy, Nigeria.

INTRODUCTION

Worldwide, biomass burning is estimated to produce 40 percent of the carbon dioxide, 32 percent of the carbon monoxide, and 50 percent of the highly carcinogenic poly-aromatic hydrocarbons produced by all sources (Levine, 1990). Compared to natural gas, our cleanest burning fuelwood, burned in stoves produces 1,100 times the carbon monoxide, 50 times the sulfur oxides and 1,687 times the potent carcinogen benzo(a)pyrene to produce the same amount of heat energy (Cooper, 1980). Anthropogenic release of carbon monoxide (CO), carbon dioxide (CO_2) Nitrous oxide (NO_2), sulphur dioxide (SO_2), methane (CH_4) and ammonia (NH_3) as well as other greenhouse gases is the main driver of climate change. This is without undermining the natural release of greenhouse gases.

There is a well-established link between climate change and economic development (Sanderson and Islam 2003; IPCC 2007). While population growth puts demands on natural resources and leads to development of natural areas, economic development also contributes to the increase in greenhouse gases. In India, the brick industry produces about 22% of the CO_2 emissions of the construction sector and requires about 27% of the energy used in building materials production (PA, 2007). This is because the small and medium scale sectors are predominant and are generally more polluting than modern large-scale industries.

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Higher levels of atmospheric carbon dioxide (CO_2) may, for example, alter the chemistry of rivers, lakes streams, and artificial reservoirs (dams) which will have effects on the ecosystems. Pressure on the aquatic environment as a result of atmospheric warming includes increases in water temperature, decrease in salinity and changes in hydrography (Nye, 2010). Burned fossil fuels release carbon that has been sequestered for thousands of years. The net addition of carbon dioxide (CO_2) to the atmosphere is of concern since it is the main greenhouse gas believed to be responsible for climate change. Burning also liberates some chemicals which negatively impact on our physical environment and human health. The effect on air quality and human health is one of the major issues linked with burning of biomass for energy. Burnt brick production, according to Morton (1990), involves five processes which have significant impact on the environment, especially in the production and increase of the concentrations of greenhouse gases. The processes include land clearing, soil excavation and preparation, shaping of bricks, drying and firing. This study evaluated the dry and wet season concentrations of the greenhouse gases CO, CO2, NO_2, SO_2, CH_4 and NH_3 at wood-based burnt brick sites in eight Local Government Areas of Benue State, Nigeria.

The Study Area

The study was carried out in Benue State, Nigeria, between April and December, covering the two seasons in Nigeria – wet and dry. Benue State is made up of twenty three Local Government Areas (LGAs) that make up the geo-political zones (A, B, and C). Zones A and B are homes for the commercial wood-based clay bricks production because of the abundance of clay deposits there. Out of the 14 LGAs that make up Zones A and B, 8 were selected for this study, based on their ranking in terms of abundance of clay deposits as well as massive production of burnt bricks. The selected LGAs include Buruku, Gboko, Gwer West, Konshisha, Kwande, Makurdi, Ushongo and Vandeikya (Figure 1).

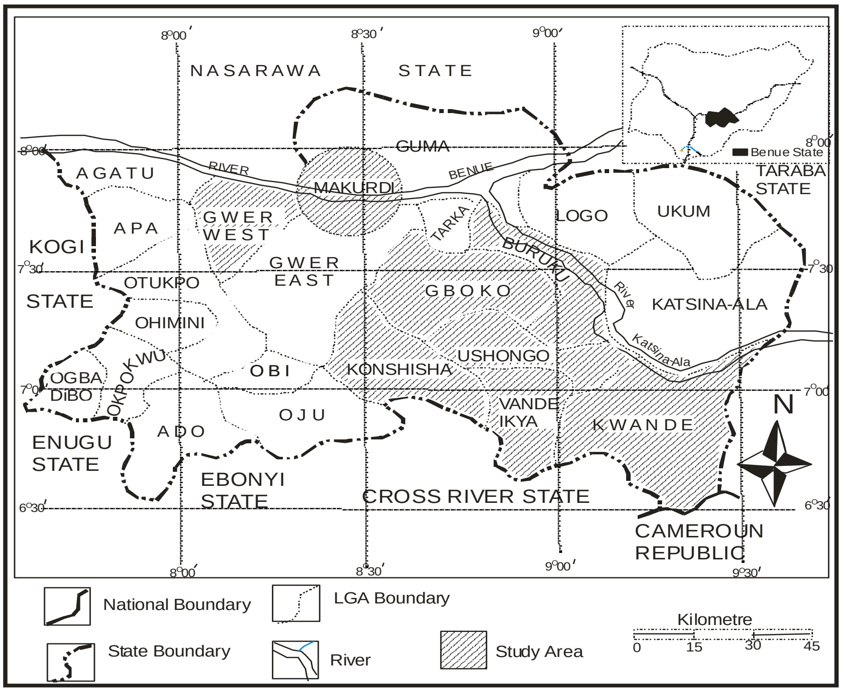

Fig. 1: Map of Benue State showing the studied Local Government Areas

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METHODOLOGY

The greenhouse gases (CO, CO_2, NO_2, SO_2, CH_4 and NH_3) were monitored in 2012 and 2013, using CROWCON Gasman digital gas meters. The concentration of each of the above greenhouse gases was concurrently assessed using six gas-specific meters. On each days of assessment, twenty assessments were done for each parameter every morning, afternoon and evening. For each session (morning, afternoon and evening) the mean of each parameter was obtained by dividing the observations for that session by 20, while the daily mean for each parameter was obtained by dividing the means for the three sessions by 3. Assessments were done ten times a month during the dry and wet seasons for two years (2012 and 2013). The mean air quality parameters for the two years were then calculated, tabulated and presented in a Table and presented in graphs and charts. Data were subjected to descriptive and inferential statistics. Differences in the concentrations of gases were assessed using coefficient of variation, Fisher's LSD, and student T-test. Post-mortem analysis using the least significant difference and Duncan multiple range test were employed to separate significant means.

RESULTS

Data on carbon monoxide (CO), carbon dioxide (CO_2) Nitrous oxide (NO_2), sulphur dioxide (SO_2), methane (CH_4), ammonia (NH_3) and particulates (Pts) were tabulated in the dry and wet seasons for 2012 and 2013. The analyzed data were summarized and presented as mean figures of the selected gasses by local government areas and seasons in Table 1. Figures 1, 2, 3, 4, 5 and 6 are trend graphs depicting the mean monthly and seasonal concentrations of CO, CO_2, NO_2, SO_2, CH_4 and NH_3, respectively. Details of the results are presented in Table 1, and discussed below.

Carbon monoxide (CO)

From table 1, the mean concentration of CO in the study area ranged from 3.14±0.38 ppm to 5.07 ± 0.48. Ushongo and Gboko LGAs have the lowest and highest concentration of CO within the two years of study (2012 and 2013) respectively. The cumulative mean monthly concentrations of CO for 2011/2012 are presented graphically in Figure 1. Buruku, Ushongo and Vandeikya LGAs have mean CO concentrations that did not differ significantly. Mean dry and wet season concentrations of CO for 2012 and 2013 were 4.84 ±8.37ppm and 2.09 ±0.11 ppm respectively. The concentration of CO in the dry season was significantly higher than that of the wet season ($p<0.5$) [Figure 1]

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Table 1: Mean Air Quality Parameters in the Study Area by Season and Government Area (2012/2013)

Local Government Area/Season	Carbon monoxide (CO) [ppm]	Carbon dioxide (CO_2) [ppm]	Nitrogen Dioxide (NO_2) [ppm]	Sulphur dioxide (SO_2) [ppm]	Methane (CH_4) [ppm]	Ammonia (NH_3) [ppm]
Buruku	3.50 ± 8.00^{b}	5.35 ± 0.77^{ab}	0.11 ± 0.01^{a}	0.07 ± 0.01^{a}	0.40 ± 0.08^{b}	0.64 ± 0.06^{ab}
Gboko	5.07 ± 0.48^{d}	7.61 ± 0.73^{c}	0.12 ± 0.01^{a}	0.10 ± 0.01^{b}	0.05 ± 0.01^{a}	0.89 ± 0.11^{c}
Gwer	4.21 ± 0.53^{c}	6.31 ± 0.79^{b}	0.09 ± 0.01^{a}	0.08 ± 0.02^{a}	0.69 ± 0.02^{e}	0.62 ± 0.04^{ab}
Konshisha	3.86 ± 0.49^{b}	5.79 ± 0.74^{ab}	0.29 ± 0.08^{ab}	0.09 ± 0.02^{a}	0.49 ± 0.02^{c}	0.58 ± 0.04^{a}
Kwande	3.76 ± 0.46^{b}	5.63 ± 0.69^{ab}	0.08 ± 0.01^{a}	0.08 ± 0.00^{a}	0.39 ± 0.08^{b}	0.65 ± 0.06^{bc}
Makurdi	3.97 ± 0.61^{b}	5.95 ± 0.92^{ab}	0.54 ± 0.01^{b}	0.08 ± 0.00^{a}	0.57 ± 0.03^{d}	0.60 ± 0.05^{ab}
Ushongo	3.14 ± 0.38^{a}	4.72 ± 0.58^{a}	0.08 ± 0.01^{a}	0.08 ± 0.01^{a}	0.39 ± 0.07^{b}	0.68 ± 0.05^{bc}
Vandeikya	3.77 ± 0.46^{b}	5.66 ± 0.69^{ab}	0.07 ± 0.01^{a}	0.07 ± 0.01^{a}	0.39 ± 0.07^{b}	0.66 ± 0.06^{bc}
SEASON						
Dry	4.84 ± 8.37^{b}	9.71 ± 0.19^{b}	0.29 ± 0.04^{b}	0.11 ± 0.01^{b}	0.64 ± 0.03^{b}	0.96 ± 0.03^{b}
Wet	2.09 ± 0.11^{a}	3.14 ± 0.16^{a}	0.09 ± 0.10^{a}	0.06 ± 0.01^{a}	0.26 ± 0.03^{a}	0.46 ± 0.01^{a}

Means on the same column with similar superscript are not significantly different

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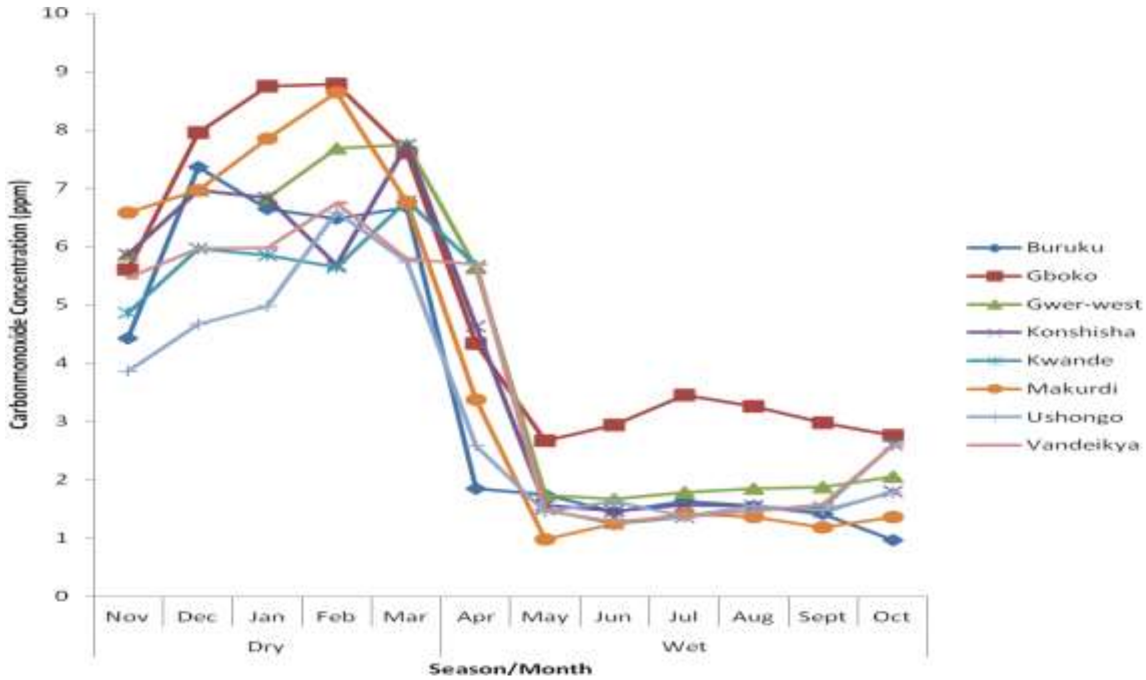

Figure 1: Mean Concentration of Carbon Monoxide in the Atmosphere at Brick Sites in Benue State by Month and Season (2012/2013)

Carbon dioxide (CO_2)

The mean CO_2 concentration for 2012 and 2013 followed the same trend as that of CO as indicated in Figure 2. Ushongo and Buruku LGAs have mean CO_2 concentrations of 4.72 ±0.58 ppm and 5.35±0.77 ppm respectively, which did not differ significantly from each other. Mean concentrations of CO_2 for Konshisha, Kwande and Makurdi LGAs show no significant differences between these means, even though they differed significantly with those of Ushongo, Buruku, and Vandeikya LGAs. Gwer-West and Gboko LGAs have mean CO_2 concentrations which differ significantly from each other as well as with Ushongo and Buruku, and Konshisha, Kwande and Makurdi LGAs. Dry and wet season mean values of CO_2 differ significantly from each other, being higher during the dry season ($P < 0.5$)[Table1]..

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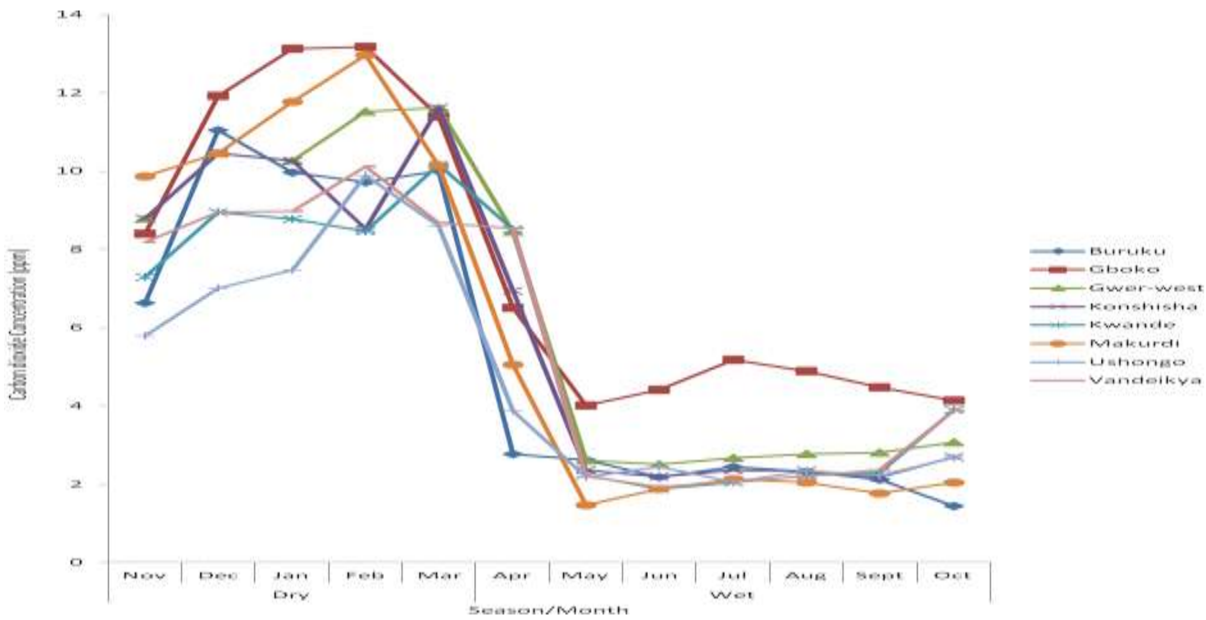

Figure 2: Mean Concentration of Carbon Dioxide in the Atmosphere at Brick Sites in Benue State by Month and Season (2012/2013

Nitrous oxide (NO_2)

From Table 1, the cumulative mean values for concentration of NO_2 for 2012 and 2013 ranged from 0.11 ± 0.1 ppm to 0.54 ± 0.01 ppm. Buruku and Makurdi LGAs have the lowest and highest mean concentration of 0.11 ±0.01 ppm and 0.54 ± 0.01 ppm, respectively. Mean concentration of NO_2 for Buruku, Gboko, Gwer west, Kwande, Ushongo and Vandeikya LGAs do not differ significantly from each other. Konshisha and Makurdi LGAs have mean NO_2 concentrations which are significantly different from that of other LGAs. Dry season and wet season means of NO_2 for 2012 and 2013 differ significantly from each other.

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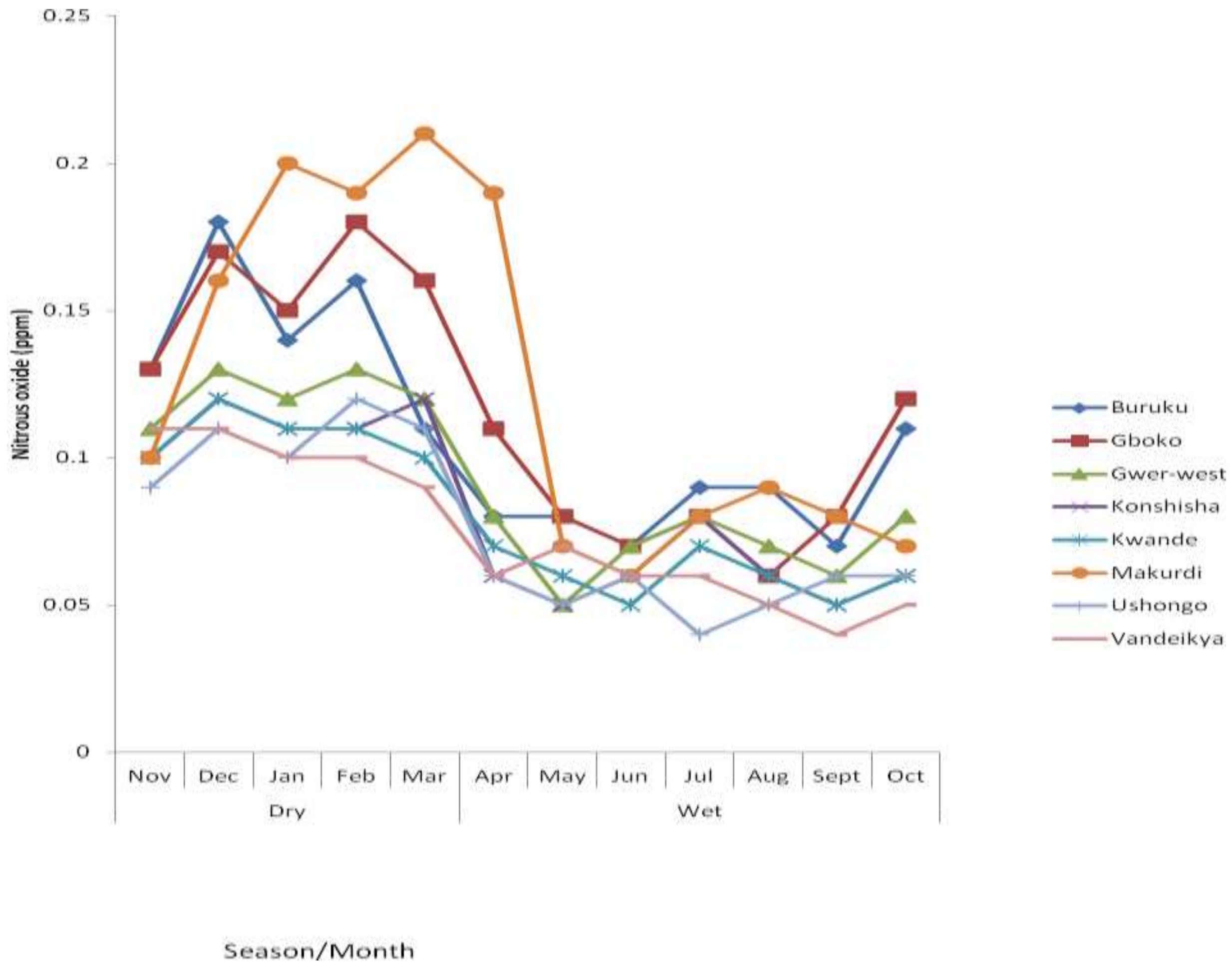

Figure 3: Mean Concentration of Nitrous Oxide in the Atmosphere at Brick Sites in Benue State by Month and Season (2012/2013)

Sulpur dioxide (SO_2)

From table1, Buruku and Vandeikya LGAs have the lowest mean SO_2 concentrations between 2012 and 2013 (both 0.07 ± 0.01 ppm). The mean range of SO_2 concentration within the period was 0.07 ± 0.01 ppm to 0.10 ppm. The mean concentration of SO_2 for Buruku and Vandeikya LGAs do not differ significantly from each other, but differ significantly with mean values for Gwer-West, Konshisha, Makurdi and Ushongo LGAs. From figure 4, Gboko LGA has the highest mean value of SO_2 concentration (0.10±0.01ppm) which differs significantly from all mean concentration of SO_2 from other LGAs sampled. Mean dry season and wet season concentrations of SO_2 differ significantly from each other, being higher in the dry season.

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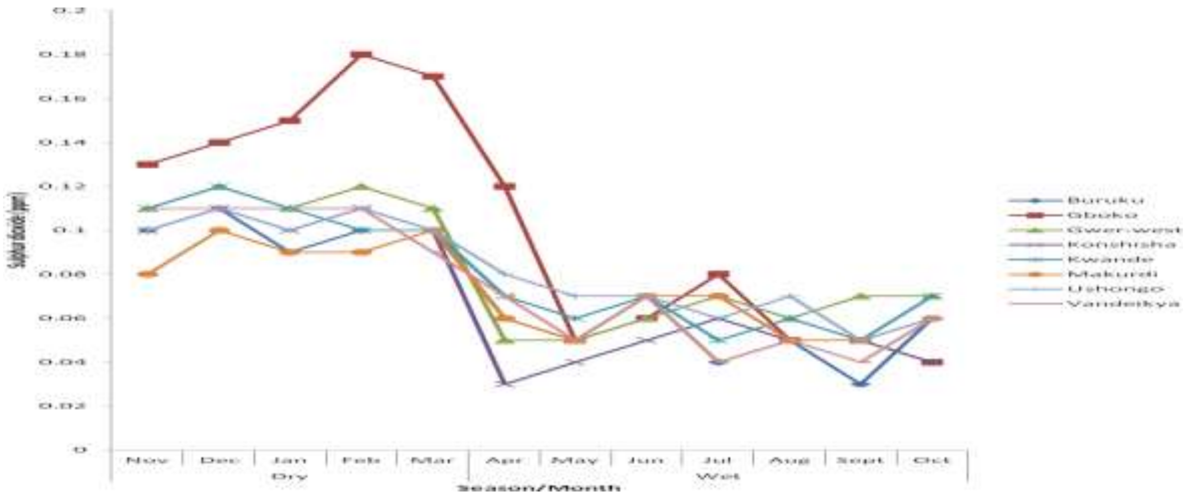

Figure 4: Mean Concentration of Sulphur Dioxide in the Atmosphere at Brick Sites in Benue State by Month and Season (2012/2013)

Methane (CH_4)

From table1, Kwande, Ushongo and Vandeikya LGAs have mean CH_4 concentrations which are not significantly different from each other. The mean CH_4 concentrations ranged from 0.39±0.07 to 0.69±**0**.02ppm. Buruku LGA has a mean methane concentration of 0.40±0.08 which differ significantly from those of Kwande, Ushongo and Vandeikya LGAs. Gboko and Kwande LGAs have mean CH_4 concentrations which do not differ significantly from each other, even though they differ significantly with mean CH_4 concentrations for Kwande, Ushongo and Vanveikya as well as those of Buruku and Gboko and Konshisha LGAs. Gwer-West LGA have the highest mean concentration of CH_4 (0.69±0.02ppm) which differ significantly with the concentrations for other LGAs. Mean concentrations of CH_4 in 2012/2013 for wet and dry seasons were 0.64±0.03ppm and 0.46±0.01 respectively (Figure 5). The seasonal mean concentrations differ significantly between the two seasons.

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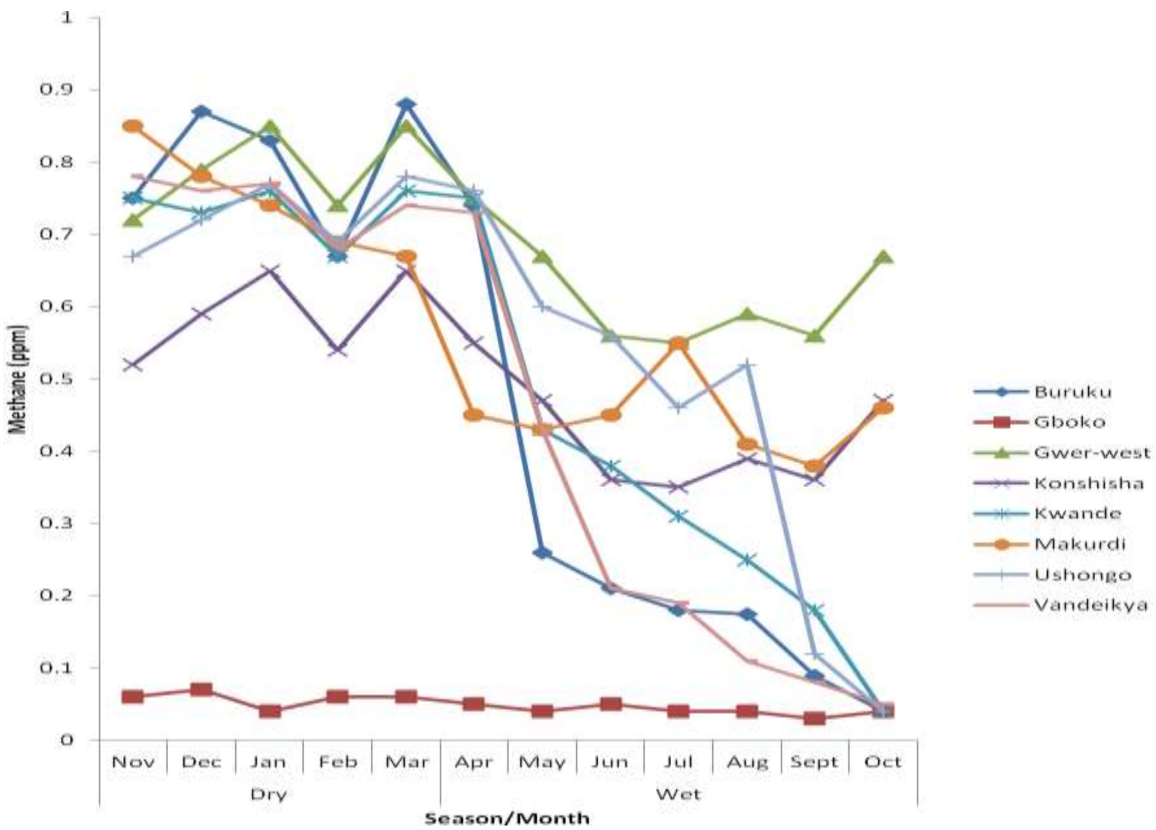

Figure 5: Mean Concentration of Methane in the Atmosphere at Brick Sites in Benue State by Month and Season (2012/2013)

Ammonia (NH_3)

The mean concentration of NH_3 for the 2012/2013 study period ranged from 0.58±0.04ppm to 0.89±0.11ppm corresponding to concentrations for Kwande and Gboko LGAs respectively (Table 1). Konshisha and Makurdi LGAs have mean Ammonia concentrations which represent the lowest concentrations of ammonia, which are not significantly different from each other, but differ significantly from those of Buruku and Gwer West LGAs. Kwande, Ushongo and Vandeikya LGAs have mean ammonia concentrations which do not differ significantly, and are significantly higher than those than those of Konshisha and Makurdi, Buruku and Gwer-West and Gboko LGAs. Gboko LGA has the highest concentration of ammonia which differs significantly and higher than all the mean concentrations of ammonia for the other LGAs. The coefficient of variation and Fisher's LSD value for the eight Local Government Areas were 0.169 and 0.089, respectively, and shows significant seasonal differences in the concentration of ammonia.

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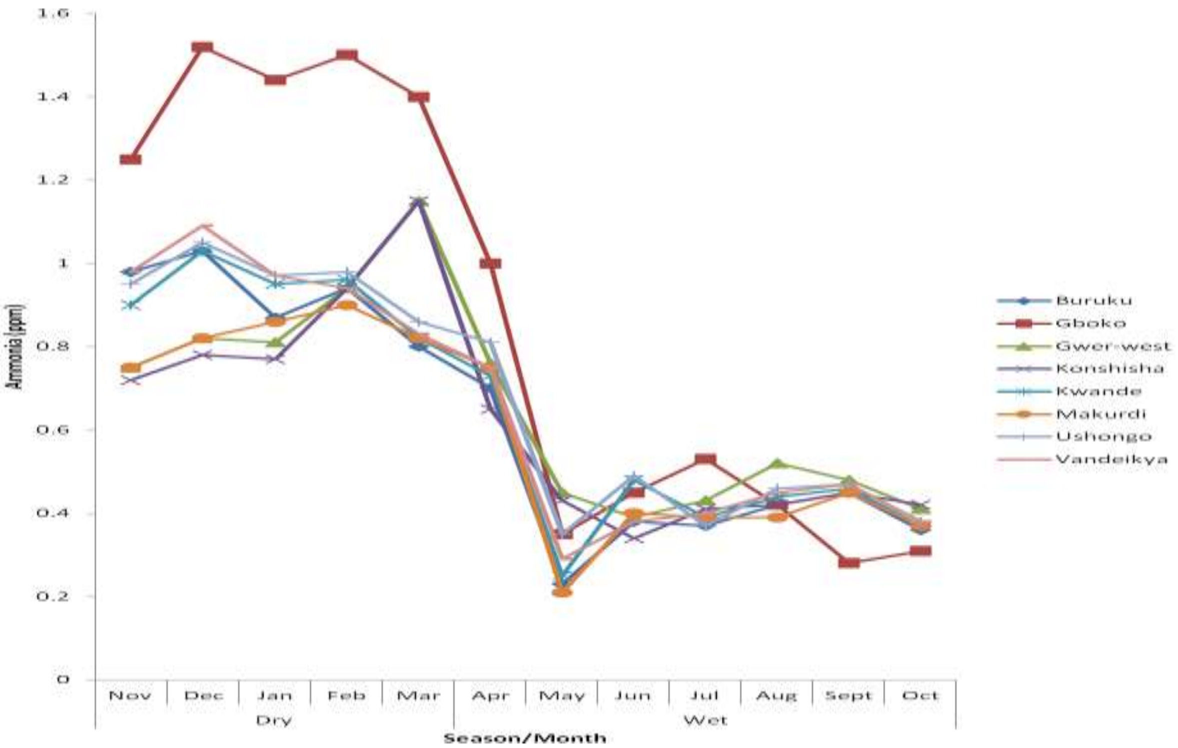

Figure 6: Mean Concentration of Ammonia in the Atmosphere at Brick Sites by Month and Season (2012/2013)

Discussion

The general trend of these graphs is that the observed parameters had a lower concentration in the wet season when burnt bricks production did not occur. The graphs also showed significant differences between dry and wet season air quality parameters assessed, with figures for the dry season being much higher. The concentrations of CO, CO_2, NO_2, SO_2, CH_4 and particulates were higher for the months of November, December, January, February and March. These parameters showed a sharp decline from April, through May, June, July, August, September and October for the years 2012 and 2013.

Assessment of atmospheric carbon dioxide concentrations at brick sites in the dry and wet seasons indicate that there were significant differences in the concentrations of carbon dioxide between the two seasons, the concentrations being relatively much higher in the dry season than in the wet season. The increased CO_2 concentrations coincide with the period of active burnt brick production (November to March); these concentrations decreased at the onset of the rainy season (April to October). The same trend is observed for other green house gases investigated (carbon monoxide, sulphur dioxide, methane, ammonia and nitrous oxide) [$P<0.05$]. Anthropogenic release of these gases investigated, as well as other greenhouse gases is the main driver of climate change. This is without undermining the natural release of greenhouse gases. There is a well established link between climate change and economic development (Sanderson and Islam 2003; IPCC 2007). While population growth puts demands on natural resources and leads to development of natural areas, economic development also contributes to the increase in greenhouse gases.

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In countries like China and India , clay brick manufacturing is transforming into more energy-efficient production methods now than it was a few decades ago (National Institute of Standards and Technology, 2007). This modern brick manufacturing process adapts many practices intended to conserve resources and promote sustainability. For instance, the many brick plants use renewable materials within the brick-making process. Lubricants made from waste by-products derived from processing organic materials can be used in forming of bricks. Heat required for dryer chambers usually is supplied from the exhaust heat of kilns to maximize thermal efficiency. Water used in brick production is recycled and reused. Automation of the brick production processes results in even less energy being used.

Additionally, many brick plants now use alternative energy sources and waste products such as methane gas from landfills and sawdust. Natural gas is the most frequently used fuel for firing bricks globally, but waste materials utilization enables brick plants to reduce their consumption of fossil fuels as well as provide a beneficial means of disposal for potential wastes. Brick manufacturers can also improve their efficiency by using sawdust and petroleum coke as a burnout material in the clay or shale mixture, producing lower-weight units with reduced raw materials. Brick manufacturers also use more energy-efficient brick and install energy-efficient lighting. The use of 100% fly ash to make bricks without any firing in kilns means that 100% fly ash bricks are made without cement or any other binder, and without kiln firing or autoclave curing; this curing approach to fly ash bricks uses much less energy than either kiln firing or autoclave curing (Liu, 2009)

Burning of woody biomass releases hazardous substances into the atmosphere (UCS, 2010). Such effluents from biomass combustion include carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), Methane (CH_4) and particulate matter (PM). Pollution is generated from 100% use of the woody biomass, even if only a portion of the released energy is harnessed (ALA 2010).

Higher levels of atmospheric carbon dioxide (CO_2) may for example alter the chemistry of rivers, lakes streams, and artificial reservoirs (dams) with disastrous effect on the ecosystems. Pressure on the aquatic environment as a result of atmospheric warming includes increases in water temperature, decrease in salinity and changes in hydrography (Nye, 2010).Burned fossil fuels release carbon that has been sequestered for thousands of years. The net addition of carbon dioxide (CO_2) to the atmosphere is of concern since it is the main greenhouse gas believed to be responsible for climate change. Burning also liberates some chemicals which negatively impact on our physical environment and human health. The effect on air quality and human health is one of the major issues linked with burning of biomass for energy

As an air pollutant, short-term concentrations of NO_2 exceeding 200µg/m^3 make it a toxic gas which causes significant inflammation of the airways. WHO's guideline value of 40µg/m^3 (annual mean) was set to protect the public from the health effects of gaseous NO_2 (USEPA, 2007). NO_2 is the main source of nitrate aerosols, which form an important fraction of $PM_{2.5}$ and, in the presence of ultraviolet light, of ozone. The major sources of anthropogenic emissions of NO_2 are combustion processes (heating, power generation (including use of woody biomass), and engines in vehicles and ships). Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2 at high concentrations.

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A SO_2 concentration of 500µg/m^3 should not be exceeded since people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes. SO_2 is a colourless gas with a sharp odour.produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulfur. The main anthropogenic source of SO_2 is the burning of sulfur-containing fossil fuels for domestic heating, power generation and motor vehicles. SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. Hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels. When SO_2 combines with water, it forms sulphuric acid, which is the main component of acid rain which is a cause of deforestation.

Carbon monoxide (CO) is the second major combustion particulate pollutant, next only to carbon dioxide. Carbon monoxide is poisonous and it affects the cardio-vascular system. Direct emissions of carbon monoxide are from fossil fuel and biomass burning; indirect production is through photochemical reactions in the atmosphere**.** 70% of global CO emissions are from human activities When inhaled, CO binds with hemoglobin in the blood (displacing O_2), and forming carboxyhemoglobin [COHb]. High levels of carboxyhemoglobin cause poor oxygenation of cells/tissues around the body. CO-hemoglobin affinity (binding) is 250 times stronger than O_2-hemoglobin affinity.

Methane gas is believed to have a greater global warming potential compared to carbon dioxide. Relatively, dry wood fuels can produce CO_2 when combusted. Other gases produced by burning wood include: carbon monoxide, methane, butane, ethylene, and other toxic gases (Partnership for Policy Integrity, 2014). During the burnt brick-producing season (November to March), significantly, higher concentrations of methane are released into the atmosphere than during the wet season (April to October). This result is in consonance with that of Partnership for Policy Integrity (2014) and Spath and Mann (2004) .

CONCLUSION

The mean concentrations of the assessed greenhouse gases (CO, CO_2, SO_2, NO_2, CH_4, and NH_3) were significantly higher for the dry season than for the wet season. There were also significant differences in the concentrations of these gases between the selected LGAs in Benue State. The use of fuelwood to cure bricks produces significantly higher concentrations of the greenhouse gases (CO, CO_2, SO_2, NO_2, CH_4, and NH_3). The high concentrations of these greenhouse gases within the dry season months of November to March correspond with the season of active wood-based burnt brick production. The burning of fuelwood produce a lot of carbon dioxide which had a high potential of dissolving in nearby water bodies thus decreasing water pH levels, increasing water acidity and the rate of photosynthesis in aquatic ecosystems.

RECOMMENDATIONS

1. Greener alternative energy sources (solar, wind, liquefied hydrogen gas) should be used in firing bricks. This can reduce greenhouse gas emissions from burning wood at brick sites.

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2. Prototypes of the Otukpo Burnt Bricks Industry in Zone C of Benue State, which do not use fuelwood need to be established in each of the other Geo-political Zones (A and B) of Benue State, since these zones are main commercial producers of conventional burnt bricks within the state This can reduce the proliferation of brick industries and attendant greenhouse gas emissions potential of wood-based brick industries

3. Production of perforated bricks can reduce the volume of fuelwood used since the bricks are hollow and can be cured faster, and thus save energy cost as well as reduce greenhouse gas emissions.

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