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INVESTIGATION OF PARTICULATE MATTER CONCENTRATIONS AT WOOD-BASED BURNT BRICK SITES IN BENUE STATE, NIGERIA

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ABSTRACT: *Burning of wood globally produces more particulate matter (PM) than fossil fuels and this could pollute the environment and result in serious human ill-health The study assessed particulate matter concentrations in eight purposively selected Local Government Areas (LGAs] of Benue State. Two brick sites were selected in each of the eight sampled LGAs. Particulate matter (PM) concentrations were monitored for two years (2012 and 2013), using CROWCON Gasman Digital Particulate Meters. The study revealed that concentrations of particulate matter were significantly much higher during the dry season compared to wet season concentrations. The increased dry season concentrations of particulate matter coincided with the season of burnt brick production in the dry season. The study recommends the development, enforcement and monitoring of air quality guidelines on PM especially for industries at levels to reduce health risks to a minimum.*

KEYWORDS: Particulate Matter, Wood-based burnt brick, Air pollution, Health Impact

INTRODUCTION

Biomass burning represents the largest source of air pollution in many rural areas of the developed and developing countries (Curtis, 2002). Worldwide, burning biomass produces 20 percent of the particulates produced by all sources (Levine, 1990). Wood heat offers financial savings for strained industrial budgets, however, like all energy sources, wood has constraints which include its adverse impact on air quality. Even highly efficient wood energy systems emit more particulate matter (PM) compared with fuel oil. The kind of wood and the manner in which it is burned influence particulate emissions. Bark and wet wood add PM, so using debarked wood chips or wood pellets and keeping fuel out of the weather reduce emissions. Wood also needs to burn at over 538ºC for complete combustion to take place. Wood stoves and outdoor wood open cast brick kilns burn at lower temperatures and the resulting incomplete combustion causes higher PM emissions. The properties of wood (pith, moisture content, specific gravity, and extractive content) may influence the burning characteristics and amount of particulate emissions (Ola, 2003). This study sets out to evaluate the dry and wet season concentrations of particulate matter at wood-based brick sites in selected 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

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as massive production of burnt bricks. The selected LGAs include Buruku, Gboko, Gwer West, Konshisha, Kwande, Makurdi, Ushongo and Vandeikya (Figure 1).

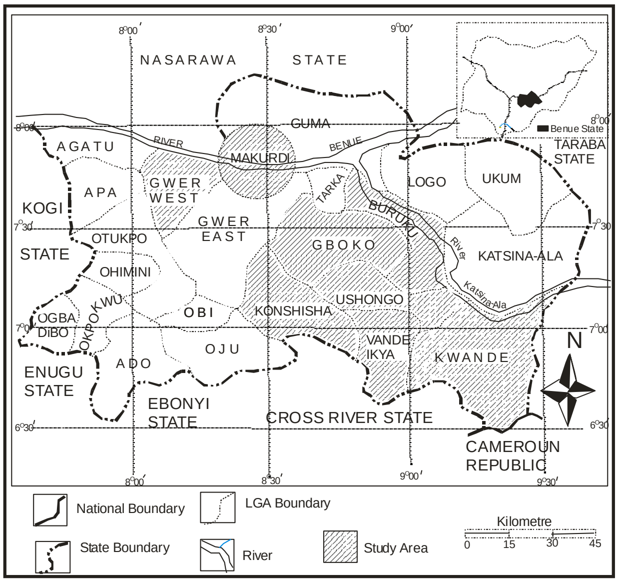

Fig. 1: Map of Benue State showing the studied Local Government Areas

METHODOLOGY

Eight Local Government Areas (LGAs) were purposively selected in Benue State, due to the abundance of clay deposits and burnt brick production sites. The LGAs include Buruku, Gboko, Gwer-West, Makurdi, Konshisha, Kwande, Ushongo and Vandeikya. Two brick sites were selected in each of the eight sampled LGAs, making a total of 16. Concentrations of particulate matter were monitored for two years (2012 and 2013), using CROWCON Gasman Digital Gas Meters. On each days of assessment twenty assessments of PM were done every morning, afternoon and evening and for the two seasons – wet and dry. For each session (morning, afternoon and evening) the mean Pm was obtained by dividing the observations for that session by 20. The daily mean PM 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). Descriptive and inferential statistics were employed in the analysis of data collected.

RESULTS

Table 1 shows that the mean concentration of particulate matter (PM) for the years 2012/2013 ranged from 1.84±0.42 ppm to 4.31±0.56 ppm. The concentration of PM for Buruku was significantly different from the concentration of PM for Kwande and Ushongo (Table 1). Kwande and Ushongo did not exhibit any significant differences in their concentration of PM. Also, Makurdi and Konshisha did not show significant differences in the concentrations of their PM ($p > 0.05$). However, the mean concentration of PM for Makurdi and Konshisha Local Government Areas exhibited significant differences with the values of PM for Ushongo and Kwande Local Government Areas. The concentration of PM for Gboko Local

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Government Area exhibited a significant difference (p<0.05) when compared with PM values for all other surveyed Local Government Areas. The mean dry season values of PM were significantly higher than the wet season values of PM for all surveyed Local Government Areas.

The mean value of particulate matter for all the surveyed Local Government Areas were significantly higher (p<0.05) for the dry season (November to March) than for the wet season (April to October). Mean concentrations of particulate matter (PM) differed significantly between the Local Government Areas. For example, the mean value of particulates for Buruku Local Government Area was lowest (1.84±0.42) while it was highest for Gboko Local Government Area (4.310.56). The cumulative mean value of PM for all surveyed Local Government Areas for 2012/2013 was 5.56±0.19 for the dry season while that of the wet season was 1.31±0/1. These values for the dry season and wet season differed significantly from each other (p < 0.05) (Table 1).

TABLE 1: MEAN CONCENTRATION OF PARTICULATE MATTER AT BRICR SITES IN BENUE STATE BY LOCAL GOVERNMENT AREA AND SEASON (2012/2913)

Local Government Area/Season	Particulate Matter(PM) [ppm
Buruku	1.84±0.42a
Gboko	4.31±0.56d
Gwer	2.79±0.56b
Konshisha	3.96±0.69c
Kwande	2.45±0.39ab
Makurdi	3.97±0.72c
Ushongo	2.37±0.38ab
Vandeikya	2.96±0.49b
SEASON	
Dry	5.56±0.19b
Wet	1.31±0.17a

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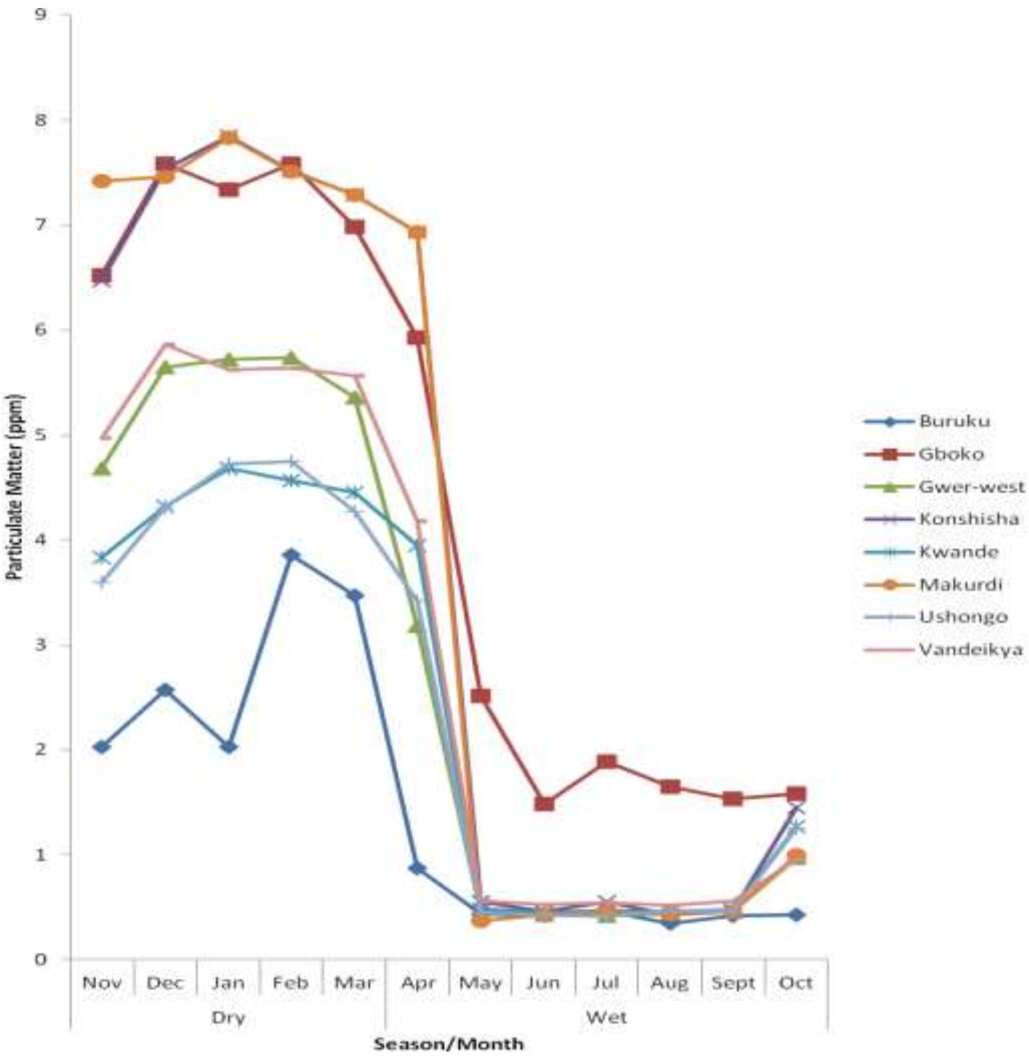
FIGURE 18: MEAN CONCENTRATION OF PARTICULATES IN THE STUDY AREA BY MONTH AND SEASON (2012/2013



DISCUSSION

The mean values of particulate matter (pm) in the eight studied Local Government Areas ranged were lowest and highest for Buruku and Gboko rThe mean values of particulate matter (pm) in the eight studied Local Government Areas ranged from 1.84±0.42ppm to 4.31±0.56ppm, representing the lowest and highest concentrations of PM. Gboko and Makurdi Local Government Areas had the highest levels of particulate matter. Higher levels of particulate matter were observed to be significantly higher for all Local Government Areas between the months of November to March (dry season). These elevated levels of particulate

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matter coincided with the active season for burnt brick production. The significantly higher levels of particulate matter ($p<0.05$) for Gboko Local Government Area (LGA) was likely to have been accentuated by cement production and other industrial activities within the LGA. Makurdi LGA also had very high levels of particulate matter in the dry season (November to March), most probably because of brick production as well as a relatively higher level of industrialisation within Makurdi Local Government Area. (Figure 1)The elevated PM levels are likely to have resulted

Particulate matter may be coarse, (>2.5 µm diameter) fine (<2.5 µm diameter), or ultrafine (<0.1 µm diameter). Particle size determines deposition properties and which particles can enter the lungs. The fractional abundance of different chemical elements determines the chemical properties of the particulates. The quantum of emissions changes on daily, weekly, seasonal, and annual cycles. The timing of emissions affects their transport, dilution, and human exposure to outdoor air pollution (Pennise, 2011) Coarse particulates are formed from mechanical processes– like weathering, volcanic activities, wind-blown soil, sea salt spray, pollen, soil excavation (mining) Fine particulates are formed from combination of smaller particles and condensation of vapors into particles that then grow Ultra-fine particulates are formed from condensation of vapors during very high temperature combustion (motor vehicles, diesel, organic vapors, fly ash) as well as from combination and growth of atmospheric particles. Whereas coarse and fine particulates are visible with the naked eyes, ultra-fine particulates are not visible. Four major sources of particulate emissions include: (a) Fuel combustion (including woody biomass burning (b) Industrial production (c) Non-industrial sources (road dust, cropland wind erosion, construction) and (d) Transportation (Pennise (2011). The intensity of these four activities (a) to (d) all increase at brick sites in the dry season in the study area, giving rise to a higher rate of particulate emissions compared to the wet season.

Outdoor air pollution is carcinogenic to humans, with the particulate matter component of air pollution most closely associated with increased cancer incidence, especially cancer of the lungs. Outdoor air pollution is correlated to increase in cancer of the urinary tract/bladder (USEPA, 2012). Ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide per year in 2012; this mortality is due to exposure to small particulate matter ((PM_{10} and $PM_{2.5}$).PM affects more people than any other pollutant. The major components of PM are sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.

Exposure to high concentrations of small particulates may result to increased mortality or morbidity, both daily and over time; however when concentrations of small and fine particulates are reduced, related mortality will also go down – presuming other factors remain the same. Small particulate pollution have health impacts even at very low concentrations – indeed no threshold has been identified below which no damage to health is observed. Therefore, the WHO 2005 guideline (WHO, 2006) limits aimed to achieve the lowest concentrations of PM possible.

Koenig (1990) noted increases in incidences of asthma and other respiratory diseases and declines in lung function among children exposed to woodsmoke. Lung-function declines

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were especially great during wintertime wood burning periods and in children who lived in smoke trapping valleys. As much as 90 percent of the winter particulate levels were produced by wood burning Zelikoff (1994). Wood-fired power plants produce higher levels of particulate matter than coal and gasoline. But particulate matter is the easiest emission to control and can be managed by using pollution-control devices like scrubbers, filters, and catalytic converters (Zamora *et. al.*, 2011).

Inhalation of particulate dust containing Cr in high oxidation states (IV) and (VI) is associated with malignant growth in the respiratory tract and painless perforation in nasal septum among trivalent and hexavalent states being the most stable and common in terrestrial environments (Rai and Pal, 2002). Hexavalent chromium is the form considered to be the greatest threat because of its high solubility, its ability to penetrate cell membranes and its strong oxidizing ability. Hence, Cr (+6) is more toxic than Cr (+3) because of its high rate of absorption on living surface.

The primary health impacts from chromium are damage to the gastrointestinal, respiratory, and immunological systems, as well as reproductive and developmental problems. Chromium VI is a known human carcinogen, and depending on the exposure route, can increase the rate of various types of cancers. Occupational exposure to chromium VI, which often occurs through inhalation, has been linked to increased rates of cancer in the respiratory system

There are serious risks to health not only from exposure to PM, but also from exposure to ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). As with PM, concentrations are often highest largely in the urban areas of low- and middle-income countries. Ozone is a major factor in asthma morbidity and mortality, while nitrogen dioxide and sulfur dioxide also can play a role in asthma, bronchial symptoms, lung inflammation and reduced lung function.

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The health effects of inhalable PM are well documented (WHO, 2013) They are due to exposure over both the short term (hours, days) and long term (months, years) and include:

(a) respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions;

(b) mortality from cardiovascular and respiratory diseases and from lung cancer..

CONCLUSION

Particulate matter (PM) was recorded to be present at all brick sites during the dry and rainy seasons. The concentration of PM was higher for Gboko and Makurdi Local Government Areas in the dry season.. There were also significant inter-local government differences observed in the concentration of particulate matter. The elevated dry season concentrations of PM were significantly different and higher than the wet season concentrations of PM. The highest concentration of PM coincided with the season of active burnt bricks production implying that burnt bricks were responsible for the increased levels of PM.

RECOMMENDATIONS

The following measures aimed at reducing the health effects of air pollution in brick sites are recommended:

i. The development, enforcement and monitoring of Air Quality Guidelines especially for PM10 and /or PM 2.5 levels for industries in Federal, States and Local Government Areas is essential to reduce health risks to a minimum..

ii. Structural adjustment changes like reducing energy consumption, especially that based on combustion sources (wood, grasses et cetera), changing modes of transport, land use planning) as well as behavioural changes by individuals.

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