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Assessment of Gaseous Pollutants and Particulate Matter in Some Major Towns of Benue State – Nigeria

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ABSTRACT

Gaseous pollutants concentration and particulate matter (PM) was measured in three major towns in Benue State. Four (4) sites were chosen per town for study; at each of the site three major gaseous pollutants and particulate matter (PM) were determined using Crowcon gas monitors and Haz - dust monitor respectively. The result of PM concentration recorded ranges from 36 0.059µg/m3 to 109 0.056µg/m3, 98 0.037µg/m3 to 193 0.048µg/m3, 75 0.549µg/m3 to 214 0.126µg/m3 in Makurdi, Otukpo and Gboko town respectively. The concentration of CO ranges from 2.30 1.20ppm to 28.40 8.98ppm, 1.10 0.83ppm to 9.60 1.43ppm, 1.70 0.90ppm to 22.80 5.18ppm in Makurdi, Otukpo and Gboko respectively. The concentration of NO ranges from 0.27 0.11ppm to 0.42 0.15ppm, 0.19 0.11ppm to 0.42 0.25ppm, 0.20 0.08ppm to 0.83 0.17ppm in Makurdi, Otukpo and Gboko town respectively. The concentration of SO_2 ranges from 0.15 0.05ppm to 0.29 0.11ppm, 0.09 0.04ppm to 0.14 0.08ppm, 0.11 0.06ppm to 0.15 0.09ppm in Makurdi, Otukpo and Gboko town respectively. The settling velocity of PM in Makurdi, Otukpo and Gboko town was found to be 1.12 x 10-3m/s, 1.39 x 10-3m/s and 1.33 x 10-3m/s while the residence time for the particulate matter in the study towns was found to be 1.25 x 103s in Makurdi, 1.01 x 103s in Otukpo town and 1.05 x 103s in Gboko town. The stop distance of PM was 300m, 212.1m and 273m in Makurdi, Otukpo and Gboko town respectively. The results reveal that, concentration of gaseous pollutants and PM are higher than safety limit in some locations. Hence the quality of air in such study town of Benue State needs to be continuously monitored to ensure compliance with the recommended regulations.

Keywords Gaseous Pollutants, PM, Health/ Environmental Effects

INTRODUCTION

Air pollutants consist of gases and finely divided solid and liquid aerosols which have long been recognized as the most fatal harmful form of pollution due to increasing pollution levels as a result of urbanization and population growth [1]. This is a source of major concern to both modern and fast growing societies in the world to which Benue State cannot be an exception. Air pollution can be as result of natural or man-made activities and one of such activities is vehicular emission, which derives their energy from the combustion of fossil fuels [1]. In the process of combustion, vehicles emit into the environment exhaust gases, which create serious environmental and health concerns [2]. These emissions contain carbon monoxide (CO), oxides of sulphur (SOx), oxides of nitrogen (NOx), Ozone (O_3), hydrocarbons and particulate matter. Some of these gases are refers to as Green House Gases (GHGs) [3].

However, this situation is alarming and is predicated on the poor economic disposition of developing countries, poor vehicle maintenance culture and importation of old vehicles, which culminates in an automobile fleet dominated by a class of vehicles known as "super emitters" with high emission of harmful pollutants (Ibrahim, 2009). The increase in this traffic-related pollution is not based on the above factors only, but also on low quality fuel which may be due to the increase in illegal refineries in Nigeria, poor traffic regulation and lack of air quality implementation force among others (Okunola *et al.*, 2012; Ghauri *et al.*, 2007).

The impact and complexity of traffic-related air pollution in Nigeria today, alongside concurrent emissions from industrial and domestic sources therefore necessitates a new approach to the mitigation and management of air pollution. An assessment of the potential for increased vehicular pollution requires some basic information relating to traffic volume and the intensity of pollutant emissions on road corridors (Ojo *et al.*, 2012; Edokpa and Ede, 2013).

EXPERIMENTAL PROCEDURE

The concentration of particulate matter (PM_{10}) in some major towns of Benue were recorded using the particulate monitor (HAZ-DUST) which was placed on a tripod accessory within the height of an average human nasal region (i.e 1.4m above the ground), readings

were taken at five minutes interval for a period of thirty minutes. The unit was positioned so that the air intake is opposite bright light; this is to avoid fluctuation or erroneous data. The concentration measured is expressed in milligram per meter cube (mg/m_3). The concentration of PM measured is recorded in Table 1.

Gaseous Pollutants Sampling Using Gas Monitors

The concentration of carbon monoxide (CO), Nitrogen Oxide (NO) and Sulfur dioxide (SO_2) from selected locations in some major towns was recorded using Gasman instruments at five minutes interval for a period of thirty minutes, which was mounted on a tripod accessory of about 1.4m tall above the ground. The readings in Table 3 is recorded in parts per million (ppm) for one day each at four different places of the research town.

PM sampling using smeared microscope slides

For physical collection of PM, the samples were collected using dry deposition method (impaction method). The following apparatus were used in PM collection; four wooden stands per site (each measuring 1.4m tall) with a flat top made of ply wood measuring 25.0cm by 25.0cm, marked microscope slides lightly smeared with Vaseline petroleum jelly, clip pegs and dust wipers, each of the flat top had T- projection 15.0cm above the flat top with a nail whose head is cut off. This will enable it hold a microscope slide suspended with the help of a peg in a vertical position. The microscope is marked for identification and lightly smeared with white Vaseline to enable the particles sampled within the experimental period to be retained for subsequent laboratory analysis.

On each experimental site, the surface of the four stands was cleared with methylated spirit before they were taken to the fields and randomly placed. Two marked smeared microscope slides were used per wooden stand, one placed horizontally on a flat surface with the smeared surface facing vertically upward to collect particles settling down under the influence of gravity, while the other one was suspended vertically with the help of a clip peg on the T- projection and held firmly using platicine with the smeared surface facing the direction of the on coming wind so as to trap the particles that will impact on it horizontally. Eight slides per site were used within the period of experiment and at the end of 30 minutes, the slides were removed and quickly kept in a microscope slide box and immediately closed so as to prevent other particles from falling on the slides after the

experimental period. The above procedure was repeated on each identified site of the experiment.

Measurement of particle Size

The diameter/size of the captured particles is determined using the electronic microscope with graticles at Benue State University, Makurdi in the Biology Laboratory. The particle captured on the microscope slide is placed on the slide holder. The source of illumination is switch on immediately the microscope is powered from the wall socket and the knobs adjusted appropriately to magnify the images of the particulate matter captured on the microscope slides, hence the slides were examined to know the size of the particulate matter (PM). The mean diameter of PM is thus recorded in Table 2.

Determination of the Settling Velocity (V) of the Particulate Matter (PM)

The settling Velocity of the PM in all the study towns is computed using the given equation;

$$V_s = \frac{\rho_p d_{pg}^2 Cc}{18\eta\rho_a} \quad (1)$$

Where ρ, is the particle density (2.6 x 103kg/m3),

d_p is the particle diameter; Cc is the slip correction or Cunningham's correction factor, a dimensionless parameter; η is the air viscosity(1.8 x 10-5 pa.s) and is the density of air(1.25kgm-3). The result obtained is recorded in Table 4.

Determination of the Residence time (τ) of the Particulate Matter (PM)

The residence time (τ) of the PM in all the study towns are equally computed using equation given as;

$$\tau = \frac{h_s}{v_t} \quad (2)$$

Where h_s is the vertical height above the ground (i.e 1.4m), the result is recorded in Table 4.

Determination of Horizontal Stop distance (X) of the PM

The horizontal stop distance of PM is computed using equation given as;

$$X = V_o\tau \quad (3)$$

Where v_o is the wind speed. The result of the calculated horizontal stop distance of PM is the recorded in Table 4.

RESULTS AND DISCUSSION

The average mean concentration of PM and Gaseous pollutants measured at four sites each using HAZ- DUST monitor and gasman monitors respectively in three towns of Makurdi, Otukpo and Gboko is presented in Table 1- 4.

Table 1: Mean PM concentration measured in study site

S/N	Town	Site 1	Site 2	Site 3	Site 4	Overall Average
1.	Makurdi	0.036±0.059	0.068±0.058	0.079±0.045	0.109±0.056	**0.073±0.026**
2.	Otukpo	0.193±0.048	0.156±0.023	0.098±0.037	0.147±0.025	**0.149±0.034**
3.	Gboko	0.092±0.010	0.075±0.541	0.214±0.126	0.165±0.556	**0.137±0.059**

Table2: Mean PM diameter measured t study site

S/N	Town	Site 1	Site 2	Site 3	Site 4	Overall Average
1.	Makurdi	3.01	3.95	3.76	4.35	**3.768±0.308**
2.	Otukpo	4.95	3.66	3.55	4.65	**4.203±0.385**
3.	Gboko	3.52	4.02	4.83	4.09	**4.115±0.296**

Table 3: The Mean Concentration of pollutants measured per study site

S/N	Town/Pollutants	Site 1	Site 2	Site 3	Site 4	Average(µm)
1.	Makurdi: CO	2.30± 1.20	20.60± 6.30	4.40± 3.38	28.40± 8.98	13.93± 6.92
	NO	0.33± 0.13	0.29± 0.14	0.27± 0.11	0.42± 0.15	0.33± 0.04
	SO_2	0.15± 0.05	0.23± 0.27	0.29± 0.11	0.17± 0.09	0.21± 0.03
2.	Otukpo: CO	9.60± 1.43	3.70± 3.92	1.10± 0.83	2.80± 1.40	4.30± 2.02
	NO	0.19± 0.11	0.31± 0.16	0.19± 0.09	0.42± 0.25	0.28± 0.06
	SO_2	0.10± 0.04	0.12± 0.06	0.09± 0.04	0.14± 0.08	0.11± 0.01
3.	Gboko: CO	1.70± 0.90	10.20± 2.36	22.80± 5.18	1520± 4.84	12.48± 4.85
	NO	0.20± 0.08	0.25± 0.23	0.83± 0.17	0.48± 0.21	0.44± 0.16
	SO_2	0.12± 0.09	0.11± 0.06	0.15± 0.09	0.13± 0.06	0.13± 0.01

Site 1: SRS, ER, Tj Site 2: Lc, Mm, BR Site 3: Wm, AB, Dc Site 4: Sm, Rc, Rm

RS Junction, Lc = Living Faith Church Near Wurukum Market.

Wm = Wadata market, near Police Station, Sm = Saw mill, near Wurukum abattoir.

Otukpo: ER = Enugu round about, Mm Otukpo Main Market

AB = Ahmodu Bello way, Rc = Rail Way crossing

Gboko: Tj = Tofi Junction, Dc = Dangote Cement Company Plc Gboko

Rm = Rice mill Gboko - Aliade road, BR = Bristow round about.

Table 4: PM parameters per study town

S/N	Study Town	Settling Velocity (m/s)	Residence Time(s)	Horizontal Stop Dist.(m)	Wind Speed (m)
1.	Makurdi	$\mathbf{1.12 \times 10^{-3}}$	$\mathbf{1.25 \times 10^{3}}$	**300**	**0.24**
2.	Otukpo	$\mathbf{1.39 \times 10^{-3}}$	$\mathbf{1.01 \times 10^{3}}$	**212.1**	**0.21**
3.	Gboko	$\mathbf{1.33 \times 10^{-3}}$	$\mathbf{1.05 \times 10^{3}}$	**273**	**0.26**

The data collected in this research work were base on statistical analysis using graphs and bar charts presented in Figures 1-6. The result is discussed and compared with national ambient air quality standard (NAAQS) and World Health Organization (WHO).

Concentration of Particulate Matter (PM)

matter concentration per site in Makurdi town ranged from 36 0.059 at SRS junction to 109 0.045µg/m3 at saw mill area, for Otukpo town it was from 98 0.037 at Ahmodu Bello way to 193 0.048µg/m3 at Enugu round about and in Gboko town, it ranged from 75 0.549 at Bristow round about to 214 0.126µg/m3 at Dangote Cement Company plc (Table1). The result of the experiment shows that, the highest PM concentration per site is recorded at Gboko town, precisely at Dangote Cement Company (DCC) plc which is about 214 0.126µg/m3 which exceed the 150 µg/m3 WHO and NAAQ standard, Since DCC plc is a cement producing factory where dust particles are produced due to mining, crushing and grinding of raw materials (limestone and clay) and also, dust particles are produced as a result of continuous movement of vehicles (Trailer) around the vicinity of the company. Otukpo town has the maximum of 193 0.048µg/m3 (Enugu round about) which is still above the limit set by the regulatory bodies. This may be as a result of the unpaved road and street mostly found in the area.

But the mean average total concentration in all the towns is within the limit of 150 µg/m3 set by WHO and NAAQs. The average mean Concentration of PM is highest at Otukpo town (149 0.034µg/m3), followed by Gboko town (137 0.59µg/m3) and lastly Makurdi town (73 0.026µg/m3). The high concentration in Otukpo town is due to unpaved roads, streets

and other factors present. This may likely affect plant growth thereby preventing the photosynthesis of the plant [9]. The average mean concentration of PM is shown in Figure 1

PM Size/Diameter

Particle size is one of the most important parameters in describing the behaviour of aerosols. The mean particle size of PM in Table 2 show that, the particle size of PM in Makurdi ranged from 3.01 0.07µm (SRS Junction) to 4.35 0.04 µm (saw mill), Otukpo town, it ranged from 3.35 0.05µm (Ahmodu Bello way) to 4.95 0.07µm (Enugu round about) and Gboko town town ranged from 3.52 0.04µm (Tofi Junction) to 4.83 0.06µm (Dangote Cement). These particle sizes of PM are less than 10µm in size and can reach the thorax if inhaled, and may likely cause disease like chronic bronchitis, pneumonia, pulmonary tuberculosis, meningitis, pertusis etc. But the graph of average mean particle size of PM represented in Figure 2 shows that, the PM size in Otukpo town were 4.203 0.385µm been the largest when compare with other study locations of the research, where large particle size of PM will settle down faster due to the effect of gravity and will not be present for long to cause health effect and will be filtered in the nasal region. In Gboko town, the average mean particle size of PM recorded were 4.115 0.296 µm and Makurdi recorded the least particle size of PM to be 3.768 0.308µm. Small particle can be easily absorbed in the respiratory tract into the blood stream, hence nose to be more hazardous and can also remain suspended in the atmosphere for longer time; this can be transported by wind to other part of the town thereby causing harm to the climate and environment.

The Concentration of gaseous Pollutants

The mean concentration of CO measured in Makurdi town were from 2.30 1.20 (SRS) to 28.41 8.98ppm (Saw mill), in Otukpo town it ranged from 1.10 0.83 (Ahmodu Bello way) to 9.60 1.43ppm (Enugu round about) and in Gboko town it ranged from 1.70 0.90 (Tofi Junction) to 22.80 5.18ppm (Dangote Cement) where most of the places like Saw mill, Ahmodu Bello way, Dangote Cement exceed the 9ppm limit set by the regulatory bodies. But the average mean concentration of CO measured in the study town show that, Makurdi town recorded the highest Concentration of CO (13.93 6.92ppm), followed by Gboko town (12.48 4.85ppm) which exceed the limit of 9ppm for 8hrs mean time but below 35ppm 1hr average time set by NAAQs and WHO where Otukpo town recorded 4.30 2.02ppm which is still within the limit. These high values recorded were all along traffic related areas when the road became busy with vehicles. This shows that Benue state produces high

concentration of CO from vehicles; hence CO is anthropogenic source. Nitrogen oxide (NO) is a colorless gas, which during combustion of fuels; it oxidized to nitrogen dioxide (NO_2) in the air, this is commonly refers to as NOx. Table 3 show that, the measurement for concentration of NO ranged from 0.27 0.11 (Wadata Market) to 0.42 0.15ppm (Saw Mill) in Makurdi, while in Otukpo town, it ranged from 0.19 0.11(Enugu round about) to 0.42 0.25ppm (Rail way crossing) and in Gboko town, it ranged from 0.20 0.08 (Tofi Junction) to 0.48 0.21ppm (Rice Mill). But the average mean concentration of NO in the study town were 0.33 0.04ppm (Makurdi), 0.28 0.06ppm (Otukpo), 0.44 0.16ppm (Gboko). This clearly show that the quantity of NO measured in all the sampling site and the average mean concentration in the study towns exceed the 1hr average time of 0.1ppm standard set by NAAQs and WHO.

The concentration of SO_2 measured in Table 3 indicate that, Makurdi town ranged from 0.15 0.05 (SRS) to 0.29 0.11ppm (Wadata Market), in Otukpo town it ranged from 0.09 0.04 (Ahmodu Bello way) to 0.14 0.08ppm (Rail way crossing) and in Gboko town it ranged from 0.11 0.06 (Bristow round about) to 0.15 0.09ppm (Dangote Cement) where most of the places like SRS and Dangote Cement exceed the 24hr mean of 0.14ppm standard set by the regulatory bodies. But average Mean Concentration of SO_2 show that, Makurdi town recorded the highest concentration of SO_2 to be 0.21 0.03ppm, while Otukpo town recorded 0.11 0.01ppm and Gboko town recorded 0.13 0.01ppm. These indicate that, the concentration of SO_2 in Makurdi is higher than the 24hr mean of 0.14ppm standard. However, Otukpo and Gboko town are within the limit set by NAAQS. A similar study carried out in Lagos and the results obtained for SO_2 per minute were found to be higher than NESREA limits [10]. This was supported by Erica [11], who observed that the hourly SO_2 concentration in Abuja exceeded the Nigerian ambient air quality standard during all readings and in all locations. This study showed increasing trend and thus, posing a potential health effects to the population. In addition low quality of fuel, lack of traffic regulation and infrastructure, and lack of air quality enforcement contribute to the high levels of automobile emissions [12]. The findings indicate that the contributions of automobile emissions to the environmental problems in Benue State are obvious. Increased SO_2 emissions from motor cycles and vehicles will have effect on driving performance. In order to achieve optimum driving performance with minimum displacement many motor cycles use rich combustion, in which fuel is burned in excess. Hence the average concentration of gaseous pollutants is presented in Figure 3.

Settling Velocity of PM

Otukpo town recorded the highest settling velocity of 1.39 x 10-3m/s, followed by Gboko town with settling velocity of about 1.33 x 10-3m/s and Makurdi town with the least settling velocity of 1.12 x 10-3m/s as presented in Figure 4. The deposition of air pollutants on soils and surface water can cause alteration of the nutrient content of the soil in the vicinity of the plant. This changes the soil conditions and hence leads to an indirect effect of air pollutants on vegetation and plants. The impaction and sedimentation of particles result to soiling and damage to materials [13].

Residence Time of PM

The time taken for PM to stay in air before impacting on material surfaces is shown in the graph of Figure 5. This means that, the PM in makurdi town stay longer in air taking a time of 3.04 x 103s followed by Gboko town with a residence time of 2.56 x 103s and lastly, Otukpo town with a residence time of 2.45 x 103s. The lifetime of atmospheric aerosol particles depends on their properties (size, chemical composition, etc.) and on altitude range, too. In large quantities, this may likely cause impairment of visibility. Smaller particles are efficiently removed by coagulation with other particles. Therefore, their lifetime is very short (in a range of ten minutes to day). Similarly, the large particles spend only a short time in the atmosphere due to the sedimentation. Particles in the accumulation mode have the longest lifetime (7–10 days on average), as in this range, both the Brownian diffusion and sedimentation are less important. These particles removed from the atmosphere predominantly by wet deposition [14].

Stop Distance of PM

The stop distance of aerosol particles under the town of research is given in Figure 6. This means that, the highest stop distance of aerosol particle is in Makurdi town (300m), followed by Gboko town with stop distance of 212.1m and Otukpo town is the least with the stop distance of 273m. it implies that, the stop distance of aerosol particles can vary widely with the sizes and density of the particles most especially in the lung ways, light and small particles when inhaled flow with the air stream to the side of the lung, while large and

heavy particles continue towards the lung to collide and stick thereby increasing air way resistance (Kim, 2009).

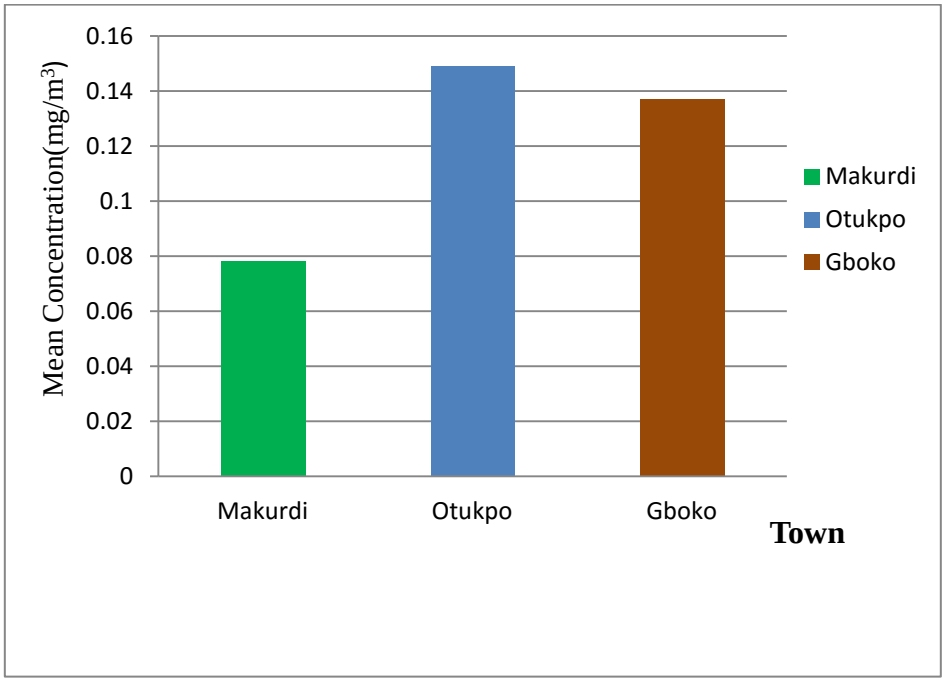

Figure 1: Average mean concentration of PM measured per town

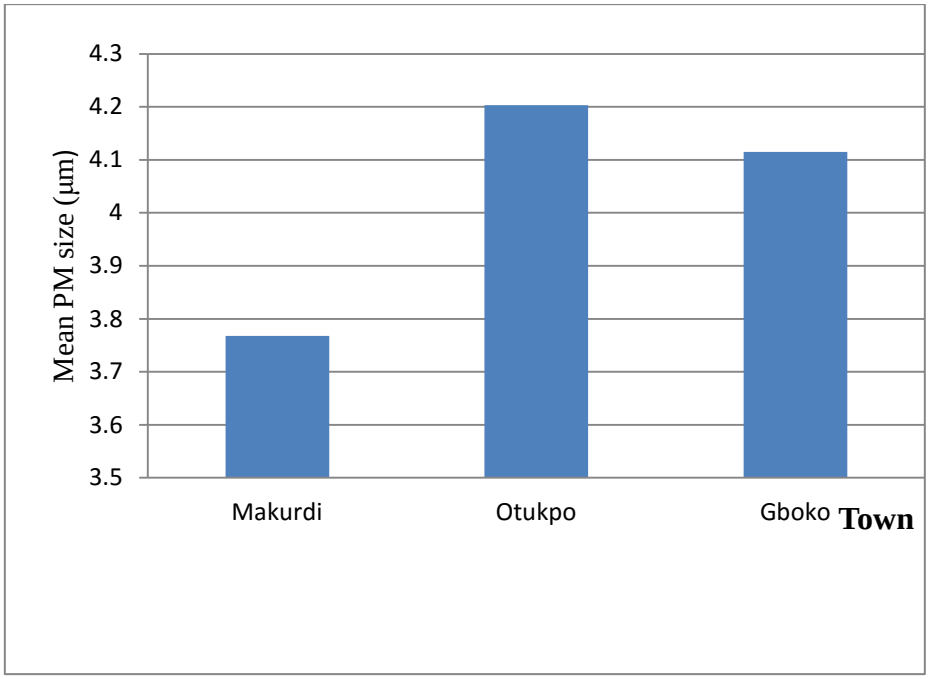

Figure2: Average mean size/diameter of PM per town

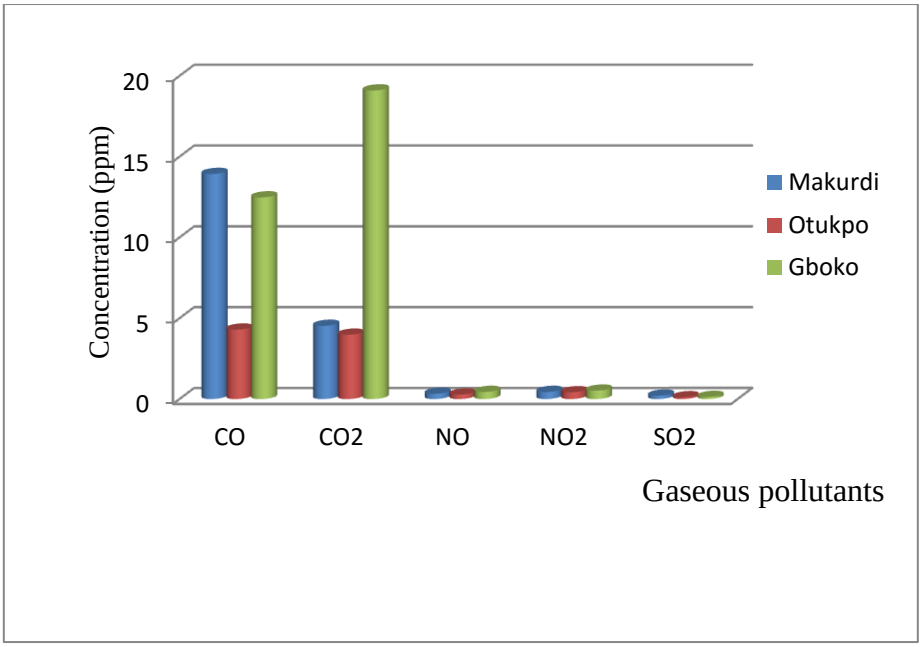

Figure3: Average mean concentration of pollutants measured per town

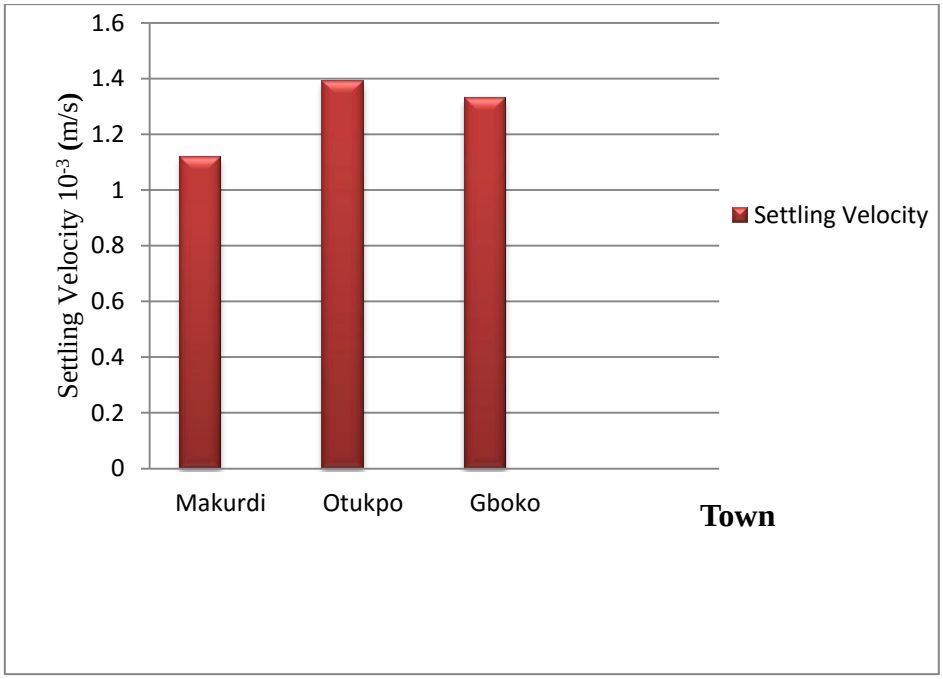

Figure 4: Settling velocity per study town

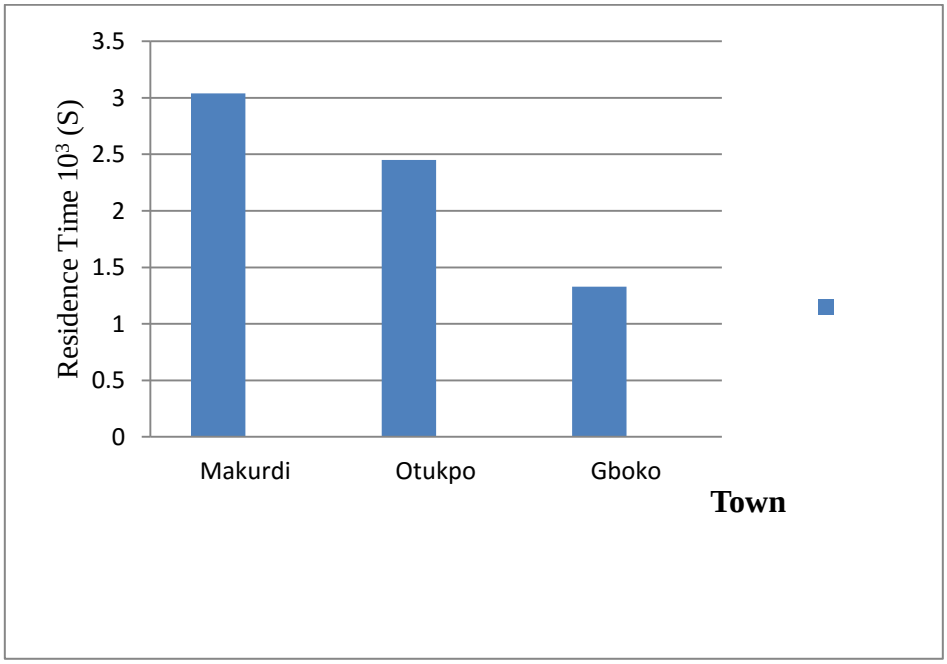

Figure 5: Residence time per study town

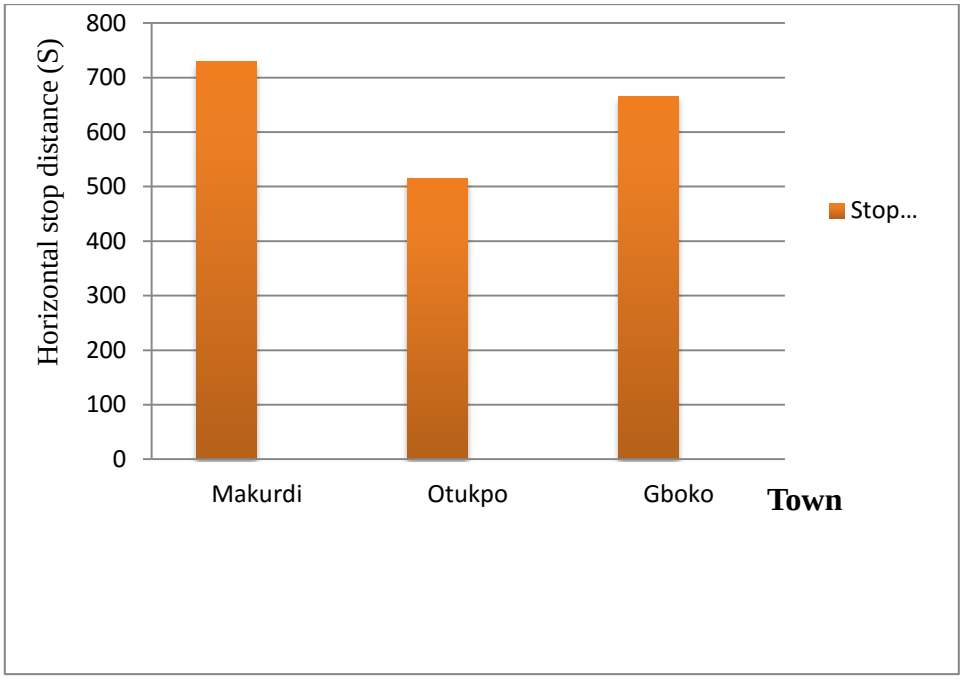

Figure 6: Horizontal stop distance per study town

CONCLUSION

The result of gaseous emissions and PM size distribution is higher than the recommended safety limit set by the regulatory bodies like National Ambient Air Quality Standard (NAAQs) and World Health Organization (WHO). This result may likely deteriorate environment and contribute to the pulmonary related health effects. In addition, the effect of gaseous emissions and particulate matter (PM) on animals, plant, structures and humans can be eliminated or minimized if the quality of air in Benue State is regularly monitored to adhere with the recommended limit.

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