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ATMOSPHERIC DYNAMICS OF AIR POLLUTION DISPERSION AND SUSTAINABLE ENVIRONMENT IN JOS-NIGERIA

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Abstract: The basic properties of chlorine were used to determine the dispersion patterns of the recent Jos explosion. The dynamic aerosols content model was used to affirm the eight kinds of dispersion patterns discussed in this text. The location of the victims showed that the dispersion at Jos was either linear or polynomial dispersion. The dispersions are influenced by atmospheric ventilation, stagnation and recirculation. The last chlorine gas explosion follows the linear or polynomial dispersion because of the current state of aerosol loadings in Jos. The aftermath effect of this kind of dispersion may be more threatening than the initial danger due to the chemical formation of more dangerous compounds. The atmospheric conditions for the formation of toxic compound were investigated using twelve years MERRA satellite observation. The degree of freedom of methane, carbon oxide and ozone was nearly uniform for the past five years. This means the next five years or more may be threatening for life forms within the region. The installation of gas tracers within major locations in Jos was suggested to monitor the formation of dioxins in the atmosphere.

Keywords: Dispersion patterns; chlorine gas explosion; mathematical model

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INTRODUCTION

Chlorine may be frequent (even in developed countries) because of its verse use to both domestic and industrial applications. Aside natural disasters, chlorine gas are used as a weapon of mass destruction. Few of the Asian countries e.g. Syria, Iraq, Indonesia, have experienced chlorine explosion as a weapon used to terrorize victims (Akinyemi *et al*., 2015). The danger of chlorine environmental pollution is enormous because of its chemical and physical properties. For example, exposure of chlorine gas pollution in the environment may react with other elements and compounds to form a host of dangerous toxins. The toxic chlorine initiated products possess a verse biological mechanism to life forms. The biological mechanism of its threats may begin with coughing and choking of its victims as the lining of the throat and lungs are inflamed. Victims close to the pollution source may experience different degrees of burning in main parts of the body. The extensive effects of chlorine environmental pollution is the development of health challenges like cancer (testicular cancer and breast cancer), endocrine disorders and low sperm count. Some of its products e.g. chlorofluorocarbon leads to gradual damage of the atmosphere via ozone layer depletion-leading to global warming and acid rain; dioxins can be borne to locations far from the source to cause health concerns. Chlorine reacts with most organic compounds and supports the combustion of the newly formed hydrocarbon. We propose that should hydrocarbon gas (e.g. methane which is a primary constituent of natural gas) be present in the air at the time of chlorine explosion, it may enhance the magnitude of atmospheric warming over a region.

The odour thresholds are always exceeded in a chlorine gas explosion. Ironically, even before the main gas explosion in Jos Nigeria, there had been reports of loose gas contents (Otubor & Olorunfemi, 2015). New Jersey department of health and senior services (NJDHSS) gave the odour threshold as 0.1ppm. Recently (25th July, 2015) the water treatment plant in Jos, north-central, Nigeria experienced chlorine explosion which claimed 5 lives and affected over 100 persons aside other life forms (Akinyemi et al., 2015). One month after the explosion, there are still reports of chlorine gas leakages (Akinyemi *et al*., 2015). We seek to know the pollution transport pattern to seek out ways of proffering solutions to save lives.

THEORETICAL BACKGROUND

Emetere et al. (2015a,b) had propounded the advection dispersion flow equations stated below

$$\frac{\partial C}{\partial t} + V_x\frac{\partial C}{\partial x} - V_z\frac{\partial C}{\partial z} - V_y\frac{\partial C}{\partial y} = \frac{\partial}{\partial z}\left(K_z\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_y\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{z2}\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_{y2}\frac{\partial C}{\partial y}\right) - P + S \quad (1)$$

$$-V_z\frac{\partial C}{\partial z} = -\frac{\partial}{\partial z}\left(K_z\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial y}\left(K_y\frac{\partial C}{\partial y}\right) \quad (2)$$

$$V_x\frac{\partial C}{\partial x} = \frac{\partial}{\partial y}\left(K_{y2}\frac{\partial C}{\partial y}\right) - \frac{\partial}{\partial z}\left(K_{z2}\frac{\partial C}{\partial z}\right) \quad (3)$$

Here, C(x,y,z) is the pollutants diffusion mean concentration at a point (x,y,z) [kg/m^3], K_y, K_x is the eddy diffusivities in the direction of the y- and z- axes [m^2/s]. The different constants in the above section Equation (3) is the ascending particulate-mild dispersion equation. The solution to equation (3) was done via separation of variable i.e. C=X(x)Y(y) with the initial boundary conditions as X(0)=a; X$^{|}$(0)=0; Y(0)=a; Y$^{|}$(0)=0; ; Z(0)=b. Z=1. The solution is given as

$$C(x,y,z) = a^2\mathrm{bcos}\left(\frac{\mathrm{n}\pi}{\mathrm{k_y}}\right)\cos\left(\frac{\mathrm{n}\pi}{\mathrm{k_z}}\right)\exp(-\frac{n\pi}{V_z}) \quad (4)$$

a, b, n, α, and β are tuning constants that can be determined via remotely sensed data set. The practical application of equation (4) is explained in the next session. Equation (4) represents three occurrences i.e. sinusoidal flux of the aerosol content ($\mathrm{bcos}(\left(\frac{\mathrm{n}\pi}{\mathrm{k_y}}\right))$, vertical profile of aerosol content ($a\cos(\frac{\mathrm{n}\pi}{\mathrm{k_z}})$) and dynamics of the aerosol content ($a[\exp\left(-\frac{n\pi}{V_z}\right)]$). The sinusoidal pattern of the gas dispersion via satellite imagery enables the assumption that the term for aerosol content is equal to unity i.e. $a\exp\left(-\frac{n\pi}{V_z}\right)\sim 1$. Therefore, equation (4) transforms to

$$C(x,y,z) = a\mathrm{bcos}(\frac{\mathrm{n}}{\mathrm{k_y}})\cos(\frac{\mathrm{n}}{\mathrm{k_z}}) \quad (5)$$

RESEARCH SITE/METHODOLOGY

Jos is located in Plateau State. Its topographical underlay is high plains of about 1,300 m above sea level. Jos is located at latitude 9°52'N, Longitude: 8°54'E. Its topography is an elevation of about 1285 m (Emetere et al., 2015). The chlorine explosion occurred at the water treatment plant in Dogo Karfi, Jos (see the red dot on **Fig. 1**).
Since the dynamics of the aerosol content has been defined via equation (4) as

$$\gamma = a[\exp\left(-\frac{n\pi}{V_z}\right)] \quad (6)$$

The main objective of this section is to expand equation (6) such that the mean free path and thermal conductivity is defined in equation 7 & 8 respectively

$$\lambda = \frac{m}{\pi\rho\sigma^2\sqrt{2}} \quad (7)$$

λ is the mean free path, m mass of molecule, ρ is the density of the gas, σ is the molecular diameter $\kappa = \frac{nv\lambda C_v}{3N_A}$, where κ is the thermal conductivity, n is the particles per unit volume, v is the mean particle speed, C_v is the molar heat capacity, N_A is the Avogadro's number. Hence, equation (6) can be transformed to

$$\gamma = a[\exp\left(-\frac{n^2 m C_v}{3\sqrt{2}N_A\rho\sigma^2\kappa}\right)] \quad (8)$$

Equation (8) is solved using **Table 1** below. From the various solutions obtained from our preliminary calculations, we can deduce eight kinds of dispersions expected at the last chlorine gas explosion i.e. normal dispersion, exponential dispersion, logarithmic dispersion, linear dispersion and polynomial dispersion.

Table 1. Basic properties of chlorine

Atomic Number	17
Atomic Wt.	35.457
Density at 32°F and 1 atm	0.2006 lb/ft^3
Thermal Conductivity at 32°F	0.0042 Btu/lb./ft^2/°F/ft
Critical Temperature	291.2°F (144°C)
Critical Pressure	1118.36 psia
Specific Heat	0.226 Btu/lb/°F

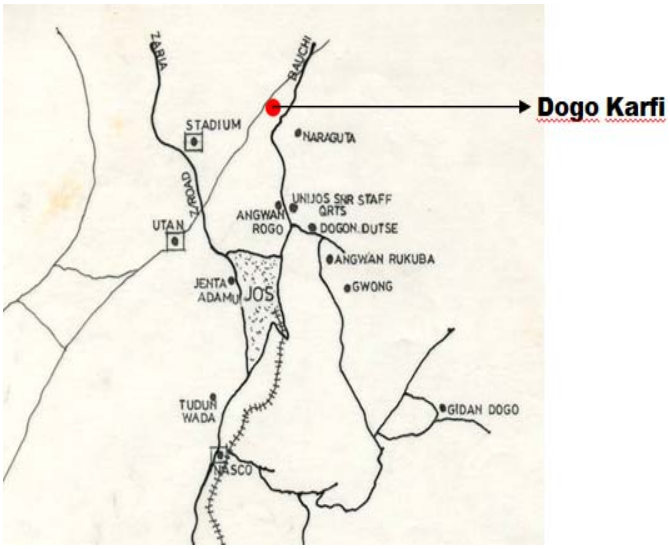


Fig. 1 Location of Dogo Karfi in Jos metropolis

RESULTS AND DISCUSSION

The properties of chlorine gas were used to model the kinds of dispersion around Dogo Karfi (**Figs. 2-9**). The normal dispersion is illustrated via equation (5) and the expected diffusion of the released chlorine gas is shown in **Fig. 2** below. The normal dispersion is only possible in a non-perturbed lower atmosphere. Theoretically, this assumption is impossible because of the dynamism of the friction layer (planetary boundary layer) of the atmosphere (Emetere and Akinyemi, 2013; Spada et al., 2015). The atmospheric coefficient signifies points of highest impact. For example, life forms at the source would be affected the most i.e. b = 0.6 while sources away from the explosion would be least affected i.e. b=0.1. Within the planetary boundary layer, other forms of dispersions may occur (Emetere et al., 2015). In **Fig. 3**, the physics of the exponential dispersion is illustrated. The possibility of more than two diffusion patterns is shown at higher atmospheric coefficient. More importantly, there exists the possibility of non-diffusion region. This is may be largely due to the wind dynamics. The wind pattern over an area is essential in determine pollution transport. For example, same concentration and volume of air pollution that lead to episodic occurrence over an area may barely get noticed over another region depending on the rate of dispersion and diffusion (Erbrink and Scholten, 1995).

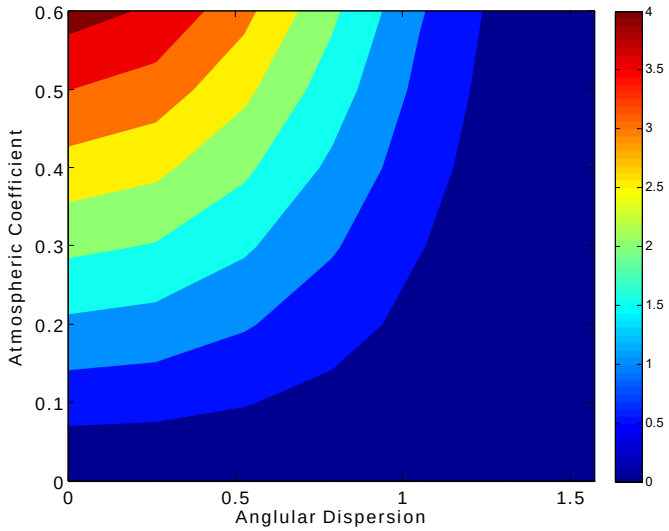


Fig. 2 The normal dispersion from source

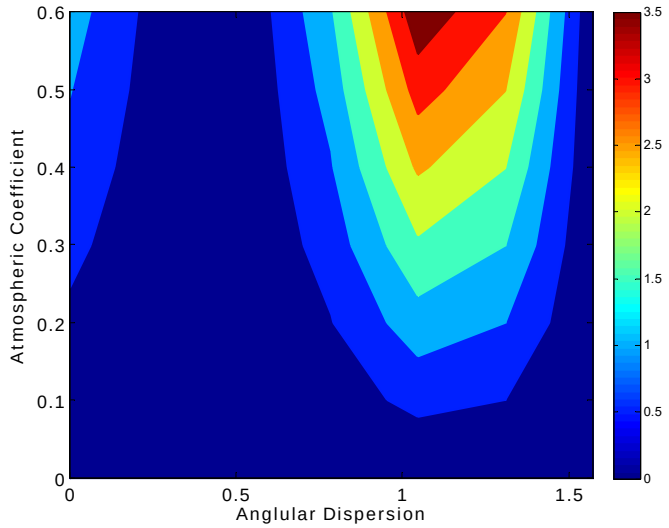


Fig. 3 The exponential dispersion from source

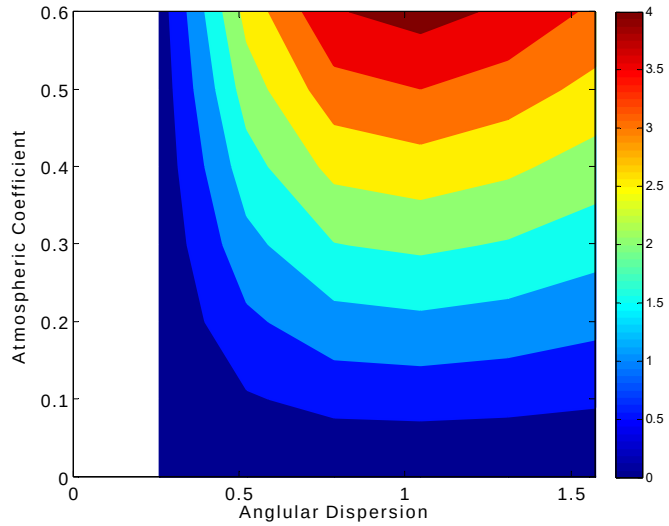


Fig. 4 The logarithmic dispersion from source

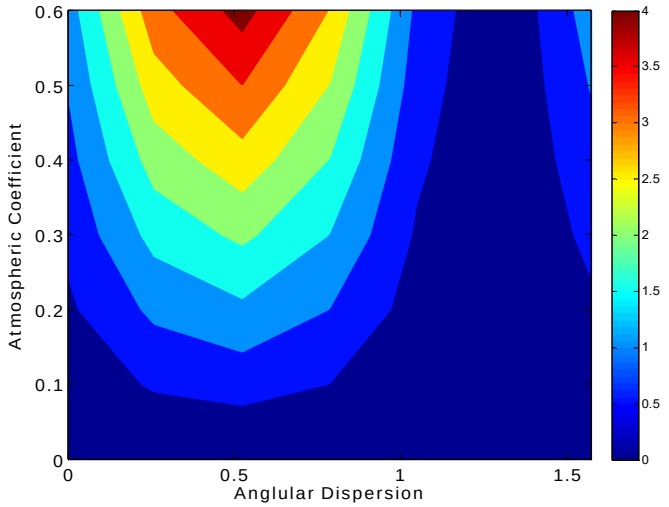


Fig. 5 The Linear (1) dispersion from source

The logarithmic dispersion is domant when the angular dispersion is less than $\frac{\pi}{9}$ (**Fig. 4**). This kind dispersion occurs when the atmospheric ventilation, stagnation and recirculation is low (Kumar et al, 2013).

There is the possibility of higher diffusion rate. The linear and polynomial dispersions are similar to the exponential dispersion i.e. in its multi directional diffusion (**Figs. 4–9**). The second order polynomial dispersion has the non-diffusion region. **Figs. 6** and **8** shows that the diffusion rates can be homogenous and has a greater tendency of defying the wind dynamics. The location where victims were found in the Jos gas explosion suggests that the dispersion kind is either a linear or polynomial (Akinyemi *et al*., 2015). This kind of dispersion is prominent because of the role of aerosols in the lower atmosphere (Adah *et al*., 2010; Emetere, 2014).

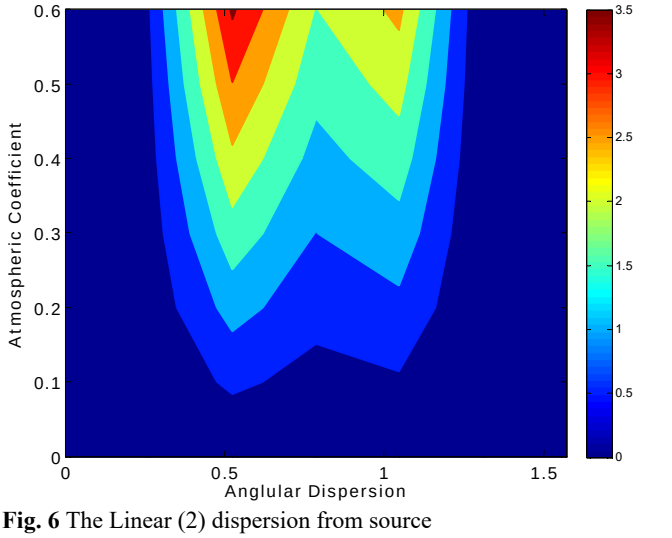


Fig. 6 The Linear (2) dispersion from source

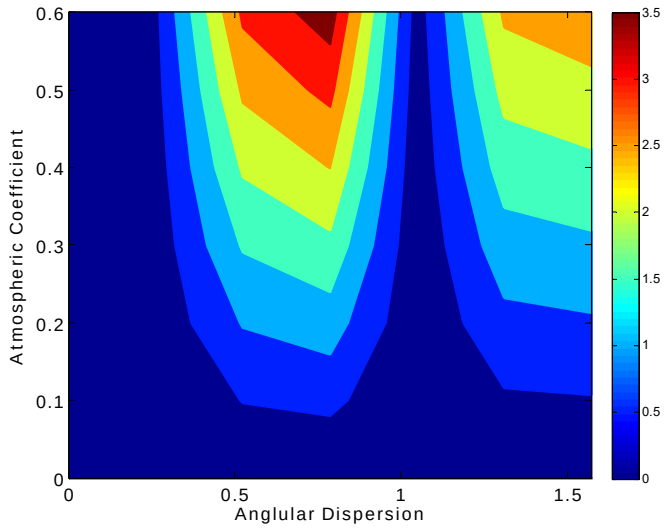


Fig. 7 The 2nd Polynomial dispersion from source

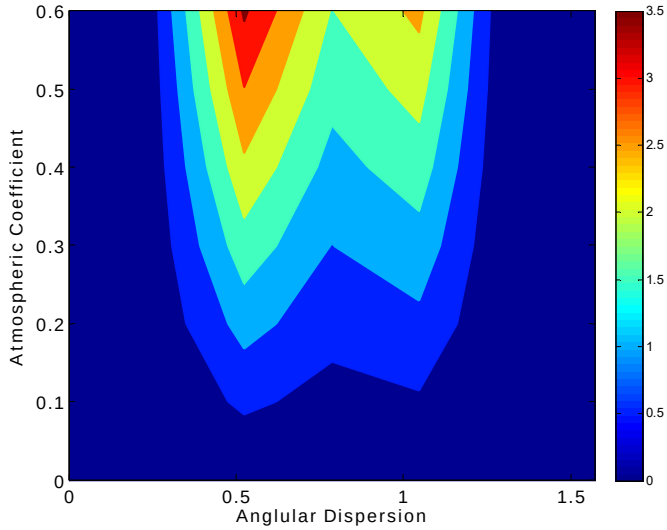


Fig. 8 The 3rd Polynomial dispersion from source

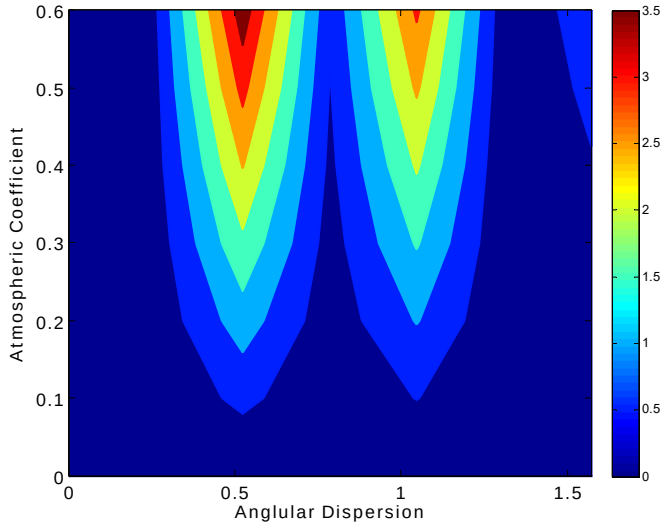


Fig. 9 The 4th Polynomial dispersion from source

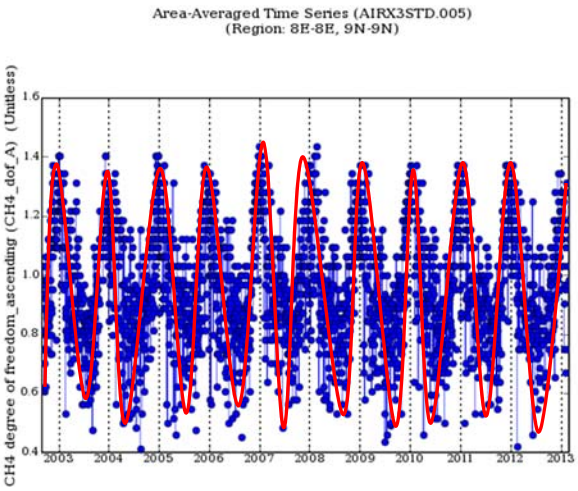
What kind dispersion occurred in Dogo Karfi? Since the mode of pollution dispersion was via explosion. Then the possible dispersion expected from an explosion of such magnitude is the polynomial dispersion. The main characteristics of the polynomial dispersion is its multi sources of dispersions i.e. a primary source and as many secondary sources. The nature of the planetary boundary layer of Jos is characterized with updrafts of particulates. Hence, the long term effect of the chlorine explosion may be the formation of dioxins.

Under standard atmospheric conditions, all dioxins are stable at low vapour pressure and have limited solubility in water. There are over 230 types of dioxins and cam be distinguished by the position and number of chlorine atoms attached to the two benzene rings. Their toxicity depends on the location and the number of additional chlorine atoms attached to the benzene rings (Bellward *et al*., 1990). Since chlorine reacts with methane, carbon monoxide and ozone, we studied a twelve years atmospheric content of methane, carbon monoxide and ozone per year from the MERRA satellite observation as shown in **Fig. 10**.

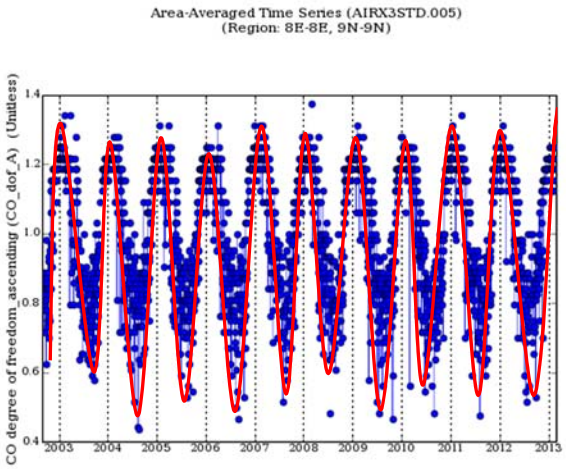
The satellite observation shows that the degree of freedom of methane, carbon monoxide and ozone had been uniform for the last five years. This means that the next five years or more may be threatning as dioxin formation or ozone depletion is certain.

CONCLUSION

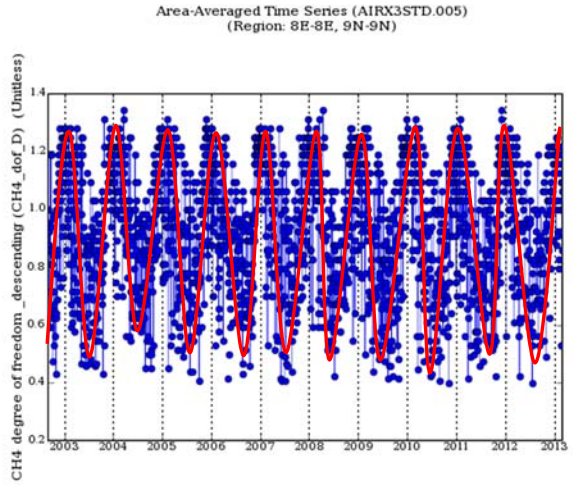
The systemic dispersion analysis of chlorine gas explosion in Jos Nigeria was carried out via some basic properties chlorine gas. This lead to the formulation of eight possible dispersion patterns. The dispersions are influenced by atmospheric ventilation, stagnation and recirculation. The last chlorine gas explosion follows the linear or polynomial dispersion because the current state of aerosol loadings in Jos. The aftermath effect of this kind of dispersion may threatening due to the chemical formation of more dangerous compounds like dioxin. Hence, we recommend the urgent intervention of government, research institute or agency to install gas tracers at strategic locations in Jos to monitor the volume of dioxin formation in the future.



A



B



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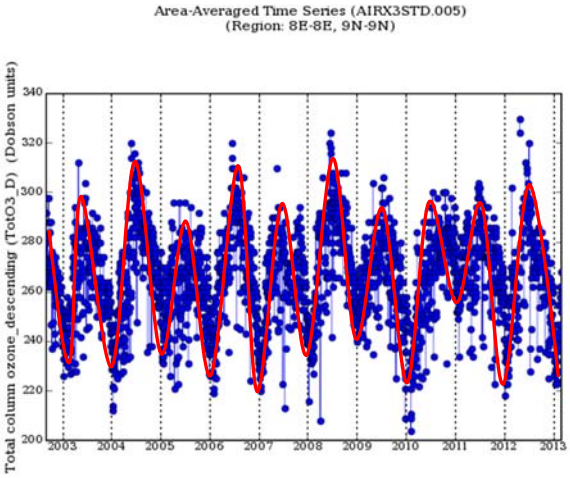
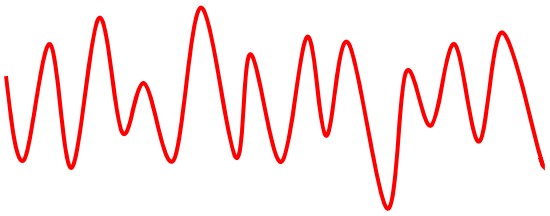


D



E

Fig. 10 (a) degree of ascending methane; (b) degree of ascending carbon monoxide; (c) degree of descending methane; (d) degree of descending monoxide; (e) ascending ozone layer

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