Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.15, 2014

www.iiste.org

Meteorological Conditions in the Vicinity of Landfill and its Implications for Atmospheric Pollutant Stagnation in Rumuolumeni, Port Harcourt, Nigeria

Vincent Ezikornwor Weli[1] and Obisesan Adekunle[2]

1. Centre for Disaster Risk Management, University of Port Harcourt P. O. box 246, Choba, Port Harcourt, Nigeria.
2. Department Of Geography And Environmental Management, University Of Port Harcourt, P.M.B. 5323, Port Harcourt

*E-mail of the corresponding author: welivinezi@yahoo.com

Abstract

The paper examined the meteorological conditions in the vicinity of landfill and its implications for atmospheric pollutant stagnation in Rumuolumeni. Air quality parameters such as; Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Methane (CH_4), Hydrogen sulphide (H_2S), Ammonia (NH_3) and Volatile Organic Compounds (VOCs) were measured using an industrial scientific ITX multigas monitor. The weather parameters (wind speed and direction, temperature, and relative humidity) were collected using Kestel 400 version 3.00 handheld weather trackers. Result indicates that the mean temperature around the dumpsite was lower than that of the neighbouring community and decreases with increase in distance from the dumpsite. This implies that pollutants stagnation is expected at the vicinity of the landfill. The total mean of relative humidity at the landfill site was higher than the relative humidity at the residential area and there was no pattern derived between distance from the center of the dumpsite and relative humidity. The total mean wind speed at the landfill site was lower than that of the residential area, thus greater proportion of air pollutants from the dumpsite were deposited around the landfill. In this study, the concentrations of SO_2, CH_4, VOC, H_2S, and NH_3 were all higher at the landfill site and thus, this suggests that the landfill site at Rumuolumeni was a good source of these pollutants. Mean temporal value of temperature, relative humidity and wind speed was 29.7°C, 65.3% and 0.24m/s respectively. It was also discovered that relative humidity correlated inversely with temperature. Furthermore, both temperature and relative humidity were significantly correlated with NO_2, NH_3 and H_2S. Wind speed had significant influence on the concentration of both VOC and SO_2. The study also showed that distance from the centre of the landfill site influences the concentrations of the air pollutants. Distance significantly influenced the concentrations of NO_2 and SO_2. Periodic assessment of the air quality arising from the landfill site in the residential area is advocated in the area.

Keywords: air quality, landfill, meteorological parameters, pollutants concentration, residential areas.

1. Introduction

Landfills are currently the most widely used method for disposing of solid waste. In the United States, approximately 55 percent of waste generated is disposed of in landfills, while 28 percent is recycled and 17 percent is incinerated (Air and Waste Management Association, 2008 cited in Blauvelt, 2009). According to the EPA, the methane produced by the rotting organic matter in unmanaged landfills is 20 times more effective than carbon dioxide at trapping heat from the sun. Not only does methane get produced by the various forms of rotting organic matter that find their way into landfills, but household cleaning chemicals often make their way here as well. The mixture of chemicals like bleach and ammonia in landfills can produce toxic gases that can significantly impact the quality of air in the vicinity of the landfill. Aside from the various types of gases that can be created by these landfills, dust and other forms of non-chemical contaminants can make their way into the atmosphere. This contributes further to the air quality issue that plagues modern landfills. Air pollution in Nigeria is not new and several scholars have attempted to examine the concentration of pollutants and their effect on our environment. Some of the studies are those of Ede (1999), Ossai *et al;*(1999), Okecha (2000), Efe (2005, 2006 and 2008),

Awofolu (2004), Akeredolu *et al*. (1994), Akani (2007) and Weli, (2014). From the available literature, it is obvious that there is dearth of empirical analysis of the implications of meteorological conditions in the stagnation of LFG emissions. A closer examination at the Rumuolumeni landfill indicates that potentially hazardous foul odors are commonly experienced by passersby and inhabitants of the community especially those around the landfill. The goal of this paper therefore is to unravel the role of meteorological parameters in stagnating LFG emission at Rumuolumeni landfill in Port Harcourt with a view to providing support to the regulatory community in developing mitigation plans

2. Methodology

Air quality parameters such as; Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Methane (CH_4), Hydrogen sulphide (H_2S), Ammonia (NH_3) and Volatile Organic Compounds (VOCs) were measured using an industrial scientific ITX multigas monitor. The weather parameters (wind speed and direction, temperature, and relative humidity) were collected using Kestel 400 version 3.00 handheld weather trackers. The composite sampling technique was used. The Rumuolumeni dumpsite was the reference point at which weather parameters and air quality parameters were taken. Air quality parameters and weather parameters were collected with respect to varying distance of 5m from the center of the dumpsite into the residential area at different locations for seven days in the month of December, 2012. The sampled locations within the dumpsite were labeled as D1, D2, D3 and D4 in which D1 was the point at the center of the dumpsite while the sampled locations within the residential area were labelled as RA1, RA2, RA3, RA4, RA5, RA6, and RA7. Descriptive statistics was used to explain the mean values of the air quality parameters and weather variables. Pearson Correlation Statistics was used to examine the influence of distance from the dumpsite to the concentrations of Land Fill Gas (LFG). The relationship between meteorological parameters and LFG were graphically presented using scatter diagram.

$$r = \frac{\sum_{i=1}^{n}(X_i - X)(Y_i - Y)}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \qquad (1)$$

Where r – correlation coefficient
X- Independent variable
Y-Dependent variable
X- Mean of X
$\bar{Y}$- Mean of Y

$$T = r\sqrt{\frac{n-2}{1-r^2}} \qquad (2)$$

The relationship between meteorological parameters and LFG emissions at the sampled points were examined using the multiple linear Regression analysis.The pollutant concentration (dependent variable) and the other meteorological parameters represent the independent variables. This enabled us to identify the degree and nature of relationship which exist between the meteorological parameters and LFG in the vicinity of the dump site. The multiple regression techniques is of the form;

$Y = a+\beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots + \beta iji + e$
(3)

Where,
Y = Pollutant concentration,
a = Constant term

$\beta_1 \beta_2 \beta_3 \ldots \beta_j$ = Regression coefficients
$x_1 x_2 x_3 \ldots x_j$ = Independent variables (air temperature, wind speed and relative humidity).

3. Result and Discussion of Findings

3.1 Spatial variations in the level of meteorological parameters around the dumpsite

Fig1 and table 1 describe the spatial variability and aerial extent of mean temperature in the study area and it is observed that temperature increased from the dumpsite to the residential area, though there was a slight variation. However, the aerial coverage of the mean temperature between 28.05°C and 28.35°C was 0.004 sq km while the mean temperature between 30.50°C and 30.79% covered 0.098 sq km.

Table 1: Spatial Coverage of Mean Temperature

S/N	Mean Temperature (^oC)	Spatial Area Extent (sq km)
1	28.05-28.35	0.004
2	28.36-28.66	0.023
3	28.67-28.96	0.048
4	28.97-29.27	0.073
5	29.28-29.57	0.104
6	29.58-29.88	0.241
7	29.89-30.18	0.186
8	30.19-30.49	0.351
9	30.50-30.79	0.098
Total		**1.128**

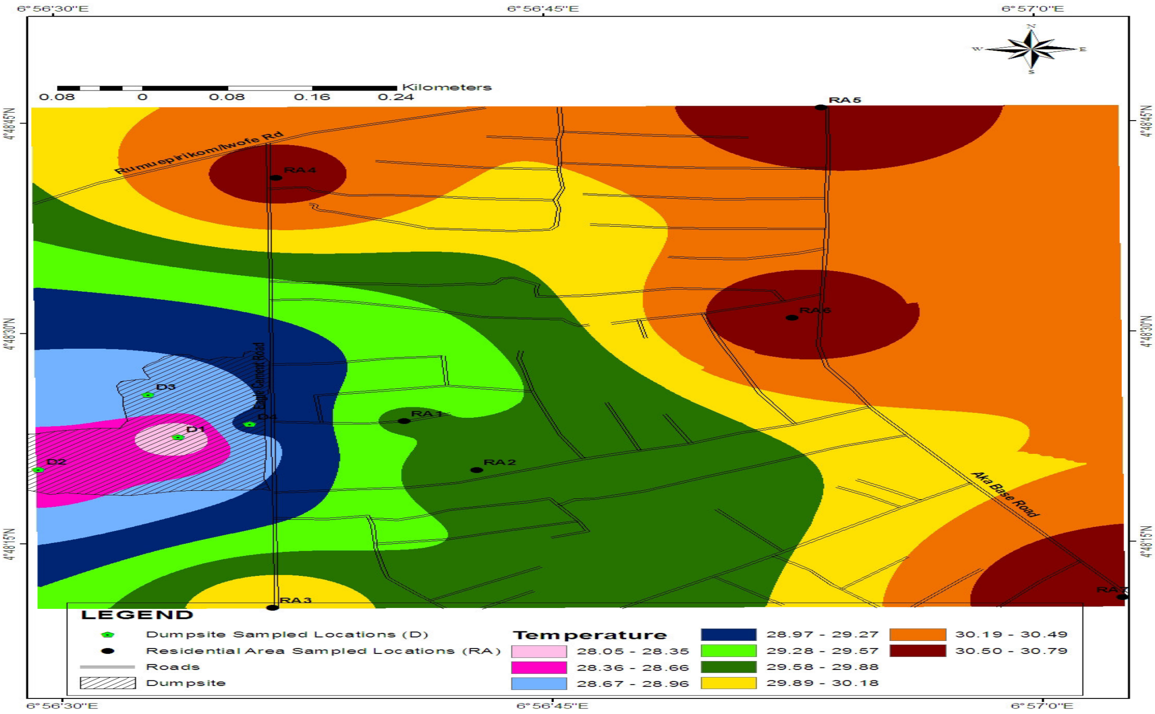

Fig. 1: Spatial Variation of Temperature

Figure 2 and table 2 present the spatial variation in the wind speed and its spatial coverage. There were some areas in both dumpsite and residential areas that experienced higher wind speed but generally the residential area had lower rate of wind speed. However, the wind speed ranging from 0.07 and 0.12 m/s covered an area of 0.009 sq km in the study area while the wind speed between 0.51 m/s and 0.55m/s covered 0.021 sq km. The wind speed between 0.13m/s and 0.17 m/s covered 0.432 sq km while the wind speed between 0.18m/s and 0.23m/s covered 0.246 sq km. The analysis therefore reveals that the study area could be said to be experiencing a low wind speed as the wind speed between 0.07m/s and 0.28 m/s covered 0.868 sq km which represent 77.05% of the entire study area.

Table 2: Spatial Coverage of Wind speed.

S/N	Wind speed (m/s)	Spatial Area Extent (sq km)
1	0.07-0.12	0.009
2	0.13-0.17	0.432
3	0.18-0.23	0.246
4	0.24-0.28	0.181
5	0.29-0.34	0.124
6	0.35-0.39	0.045
7	0.40-0.45	0.038
8	0.46-0.50	0.031
9	0.51-0.55	0.021
Total		**1.128**

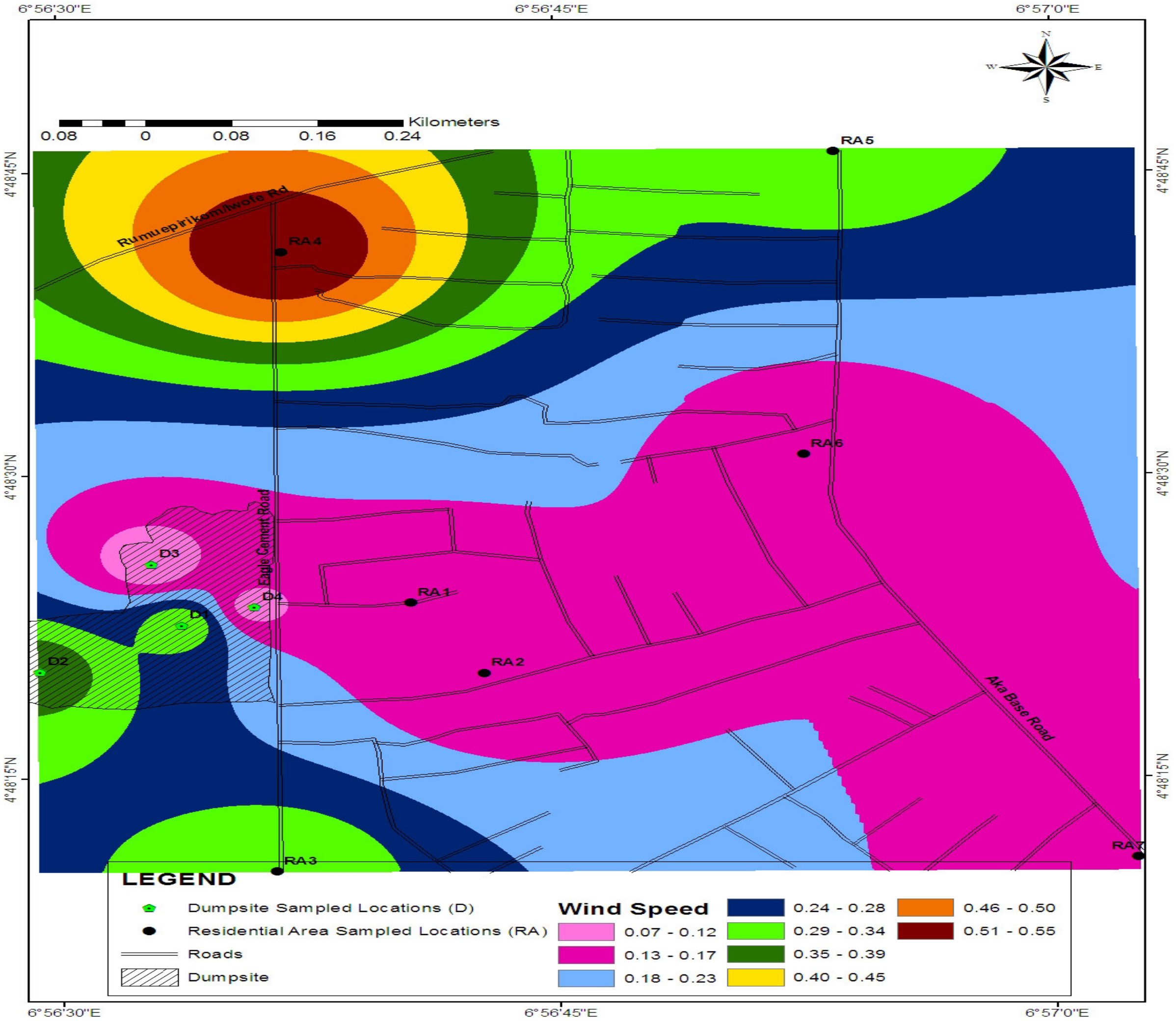

Fig. 2: Spatial Variation of Wind speed

Figure 3 and table 3 represent the spatial variation and aerial coverage of relative humidity in the study area respectively. The analysis reveals that generally, the relative humidity was higher in the dumpsite than the residential area and to be specific, the greater part of the residential area was having low relative humidity. Nevertheless, the relative humidity ranging between 62.80% and 63.42% covered 0.069 sq km in the study area while wind speed between 64.05% and 64.66% covered 0.301 sq km and the wind speed between 67.78% and 68.39% covered 0.021 sq km. Expect the wind speed between 62.80% 63.42% and 64.044%, there was a general pattern of the higher the range in the relative humidity, the lower the area coverage. This Pattern opposed the pattern observed in the spatial variability of temperature in relation to the area extent.

Table 3: Spatial Coverage of Relative Humidity

S/N	Relative Humidity (%)	Spatial Area Extent (sq km)
1	62.80-63.42	0.069
2	63.43-64.04	0.168
3	64.05-64.66	0.301
4	64.67-65.28	0.219
5	65.29-65.91	0.198
6	65.92-66.53	0.059
7	66.54-67.15	0.051
8	67.16-67.77	0.044
9	67.78-68.39	0.021
Total		**1.128**

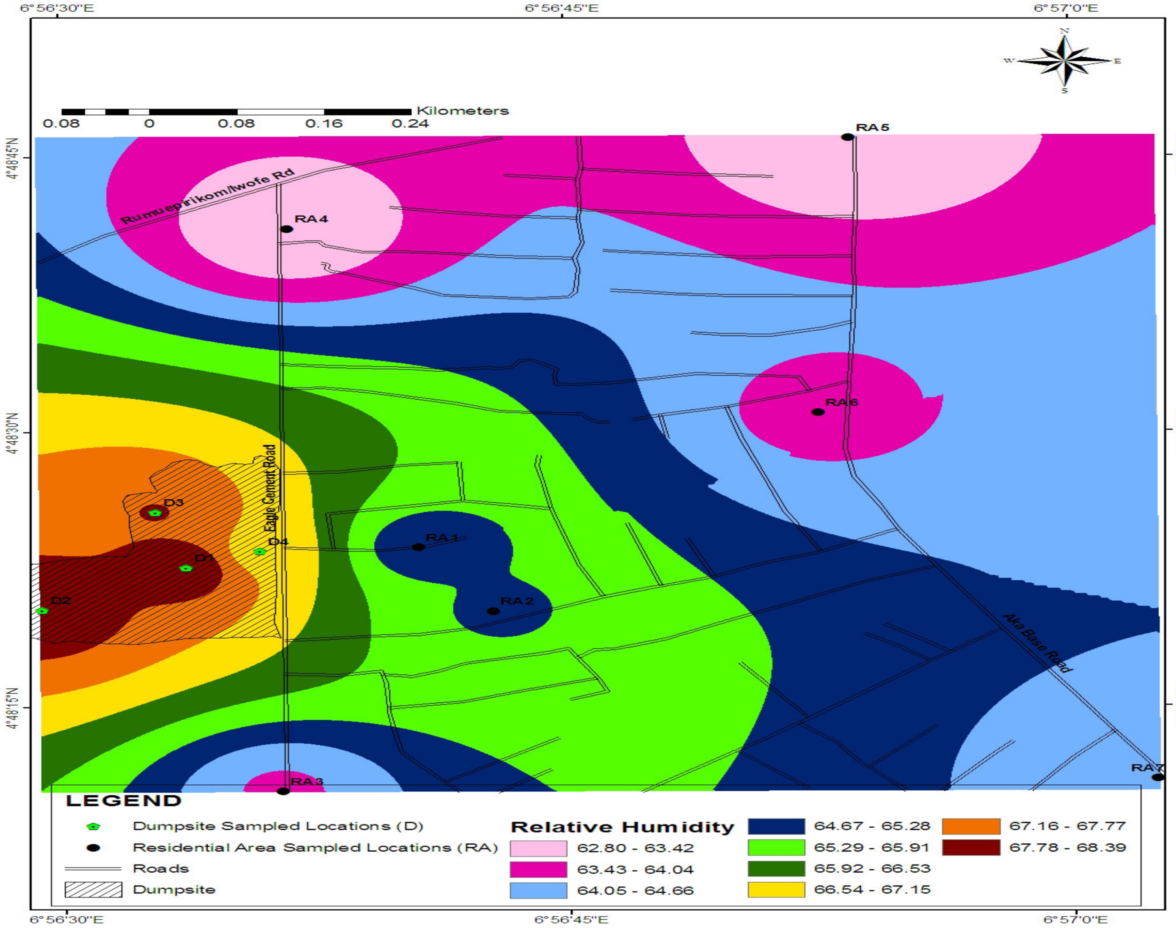

Fig. 3: Spatial Variation of Relative Humidity

3.1 Relationship Between Meteorological Parameters and LFG Concentrations

Table 5 presents the correlation matrix between weather parameters and air quality parameters which was derived from Table 4. Temperature was significantly correlated with Nitrogen dioxide with correlation coefficient (r) =0.740 at p=0.05 (2-tailed). The relationship was directly proportional (Fig 4). In addition, temperature correlated significantly with $NH_3$and H_2S at 5% level of confidence but the relationship was inversely proportional (Fig 4.14; Fig 5). The least influence of relationship can be observed in the CH_4 with r=0.072 and yet, directly proportional relationship. The relative humidity was significantly correlated with NO_2, NH_3 and H_2S with r=0.653 (p=0.05), 0.727 (p=0.05) and 0.646 (p=0.05) respectively. The relationship between NO_2 and relative humidity was inversely proportional while the relationship between NH_3 and H_2S was directly proportional. The regression analysis between relative humidity and NO_2, NH_3, H_2S can be found in Fig 7, Fig 8 and Fig 9 respectively.

Table 4: LFG concentration and meteorological parameters

Sampled Locations	Temp (^oC)	Relative Humidity (%)	Wind speed (m/s)	NO_2 (mg/m^3)	SO_2 (mg/m^3)	CH_4 (mg/m^3)	VOC (mg/m^3)	NH_3 (mg/m^3)	H_2S (mg/m^3)
D1	28.0	68.4	0.34	0	0.681	0.105	2.971	0.300	0.404
D2	28.4	68.4	0.39	0	1.677	0.138	2.971	0.098	0.223
D3	28.9	67.8	0.07	0.019	0.288	0.007	1.310	0.098	0.084
D4	29	66.8	0.1	0	0.026	0.007	1.885	0	0.084
RA1	29.6	64.8	0.13	0	0	0	0.863	0	0.014
RA2	29.8	65.2	0.13	0	0	0	0.543	0	0.098
RA3	30.1	63.9	0.34	0.056	0.079	0	1.789	0	0
RA4	30.6	62.8	0.56	0.056	0.550	0.026	2.460	0	0.056
RA5	30.7	62.8	0.31	0.019	0.629	0.203	1.917	0	0.125
RA6	30.7	63.8	0.13	0.075	0.026	0.105	1.406	0	0.084
RA7	30.8	64.1	0.14	0.056	0.288	0.072	0.735	0	0.014

Table 5: Correlation matrix between LFG concentration and meteorological parameters

	Temperature	Rel Humidity	Wind speed (mg/m^3)	NO_2 (mg/m^3)	SO_2 (mg/m^3)	CH_4 (mg/m^3)	VOC (mg/m^3)	NH_3 (mg/m^3)	H_2S (mg/m^3)
Temperature	1								
Rel. Humidity	-0.956*	1							
Wind speed	0.030	-0.186	1						
NO_2	0.740*	-0.653*	0.171	1					
SO_2	-0.411	0.412	0.591*	-0.257	1				
CH_4	0.072	-0.046	0.303	0.020	0.616*	1			
VOC	-0.486	0.373	0.739*	-0.144	0.736*	0.446	1		
NH_3	-0.766*	0.727*	0.193	-0.396	0.440	0.243	0.587*	1	
H_2S	-0.699*	0.646*	0.284	-0.474	0.574*	0.490	0.684*	0.903*	1

Significant at 95% confidence level.

In terms of wind speed, it is observed that VOC had a significant relationship with wind speed as r=0.739 at 5% significant level while the correlation coefficient between SO_2 and wind speed was 0.591 and significant at 5% significant level. The regression analysis between wind speed and SO_2; and between wind speed and VOC is observed in Fig 10 and Fig 11 respectively. Additionally, SO_2 was significantly correlated with CH_4, VOC and H_2S and the relationship was directly proportional. The correlation coefficient between SO_2 and CH_4, VOC, H_2S was 0.616 (p=0.05), 0.736 (p=0.05) and 0.574 (p=0.05) respectively. In a similar situation, VOC was significantly correlated with NH_3 and H_2S with a relationship that was directly proportional. Finally, the correlation between NH_3 and H_2S was very high as r=0.903 (p=0.05)..

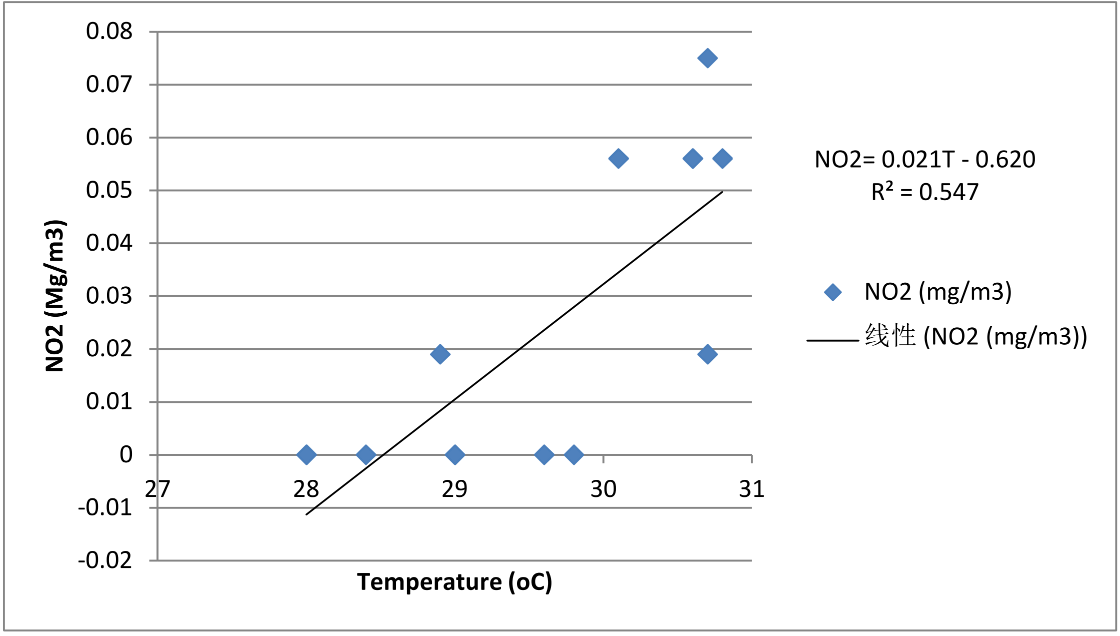

Fig. 4: Scatter diagram between NO_2 and temperature

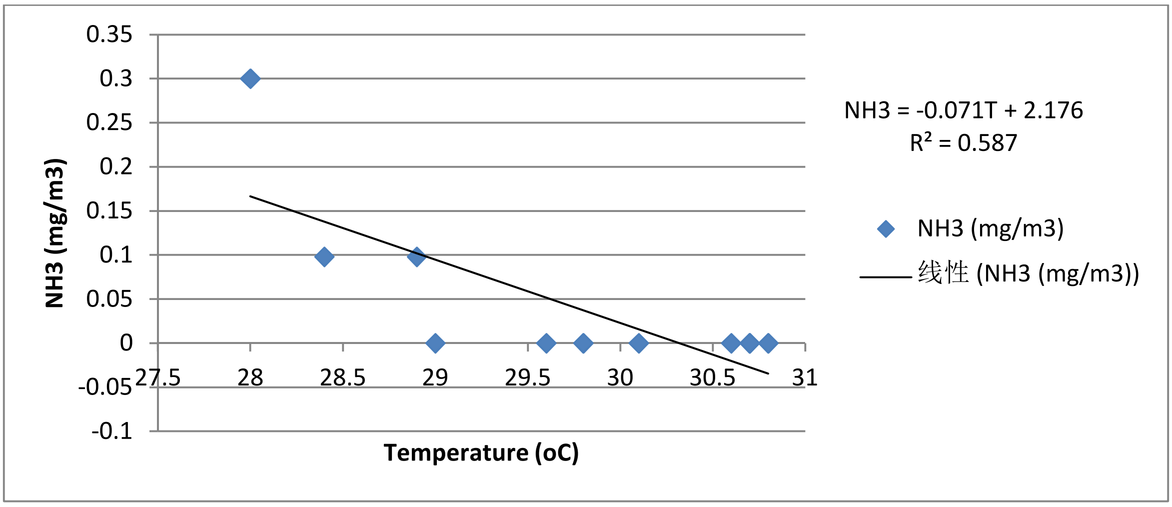

Fig. 5: Scatter diagram between NH_3 and temperature

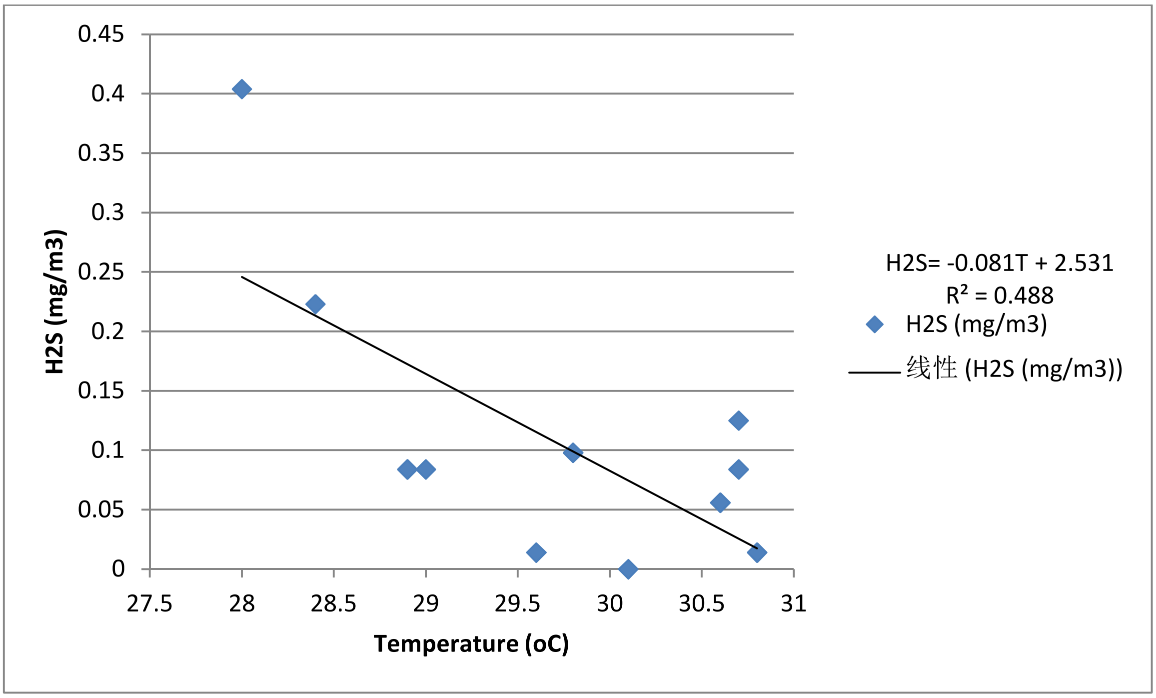

Fig. 6: Scatter diagram between H_2S and temperature

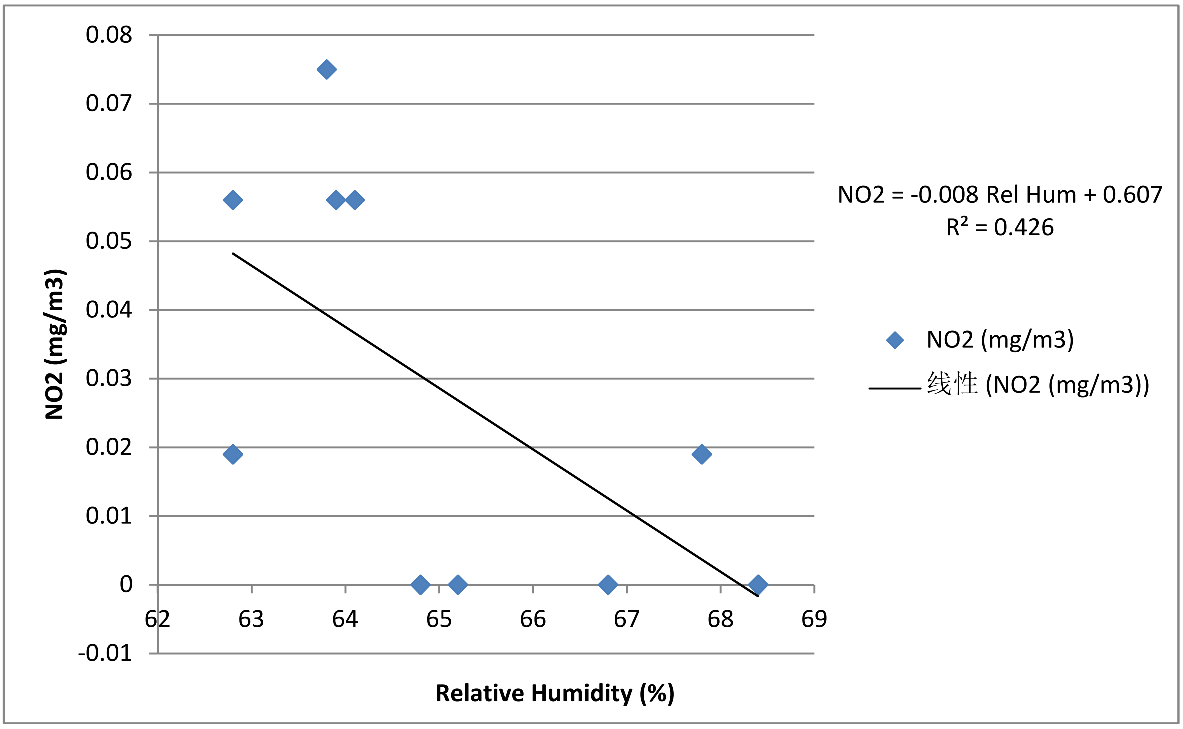

Fig. 7: Scatter diagram between NO_2 and relative humidity

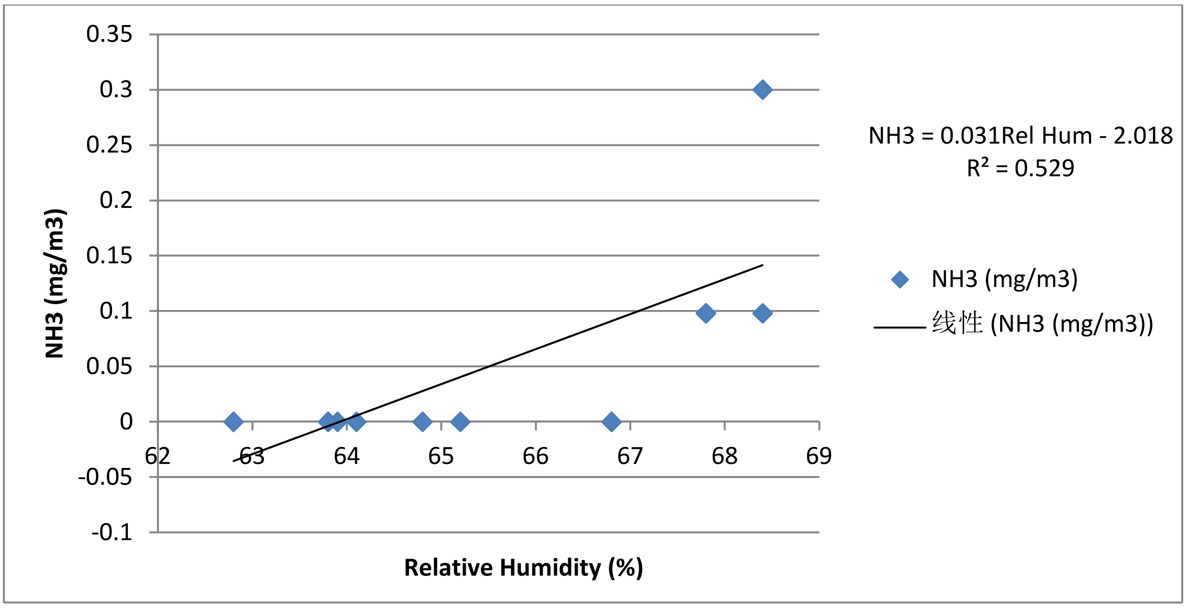

Fig. 8: Scatter diagram between NH_3 and relative humidity

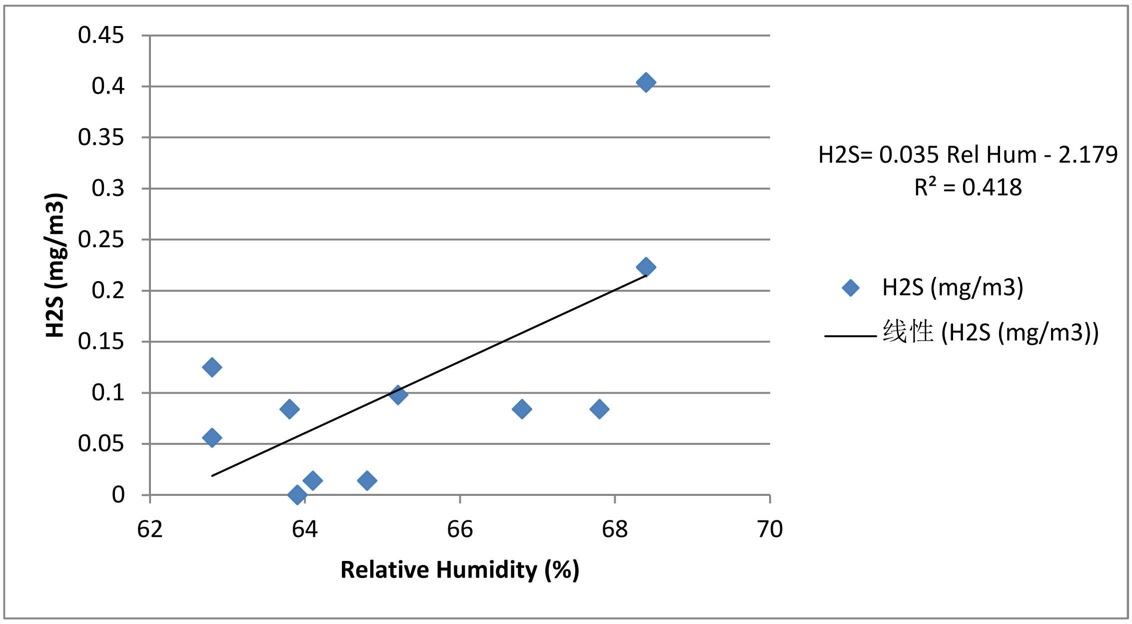

Fig. 9: Scatter diagram between H_2S and relative humidity

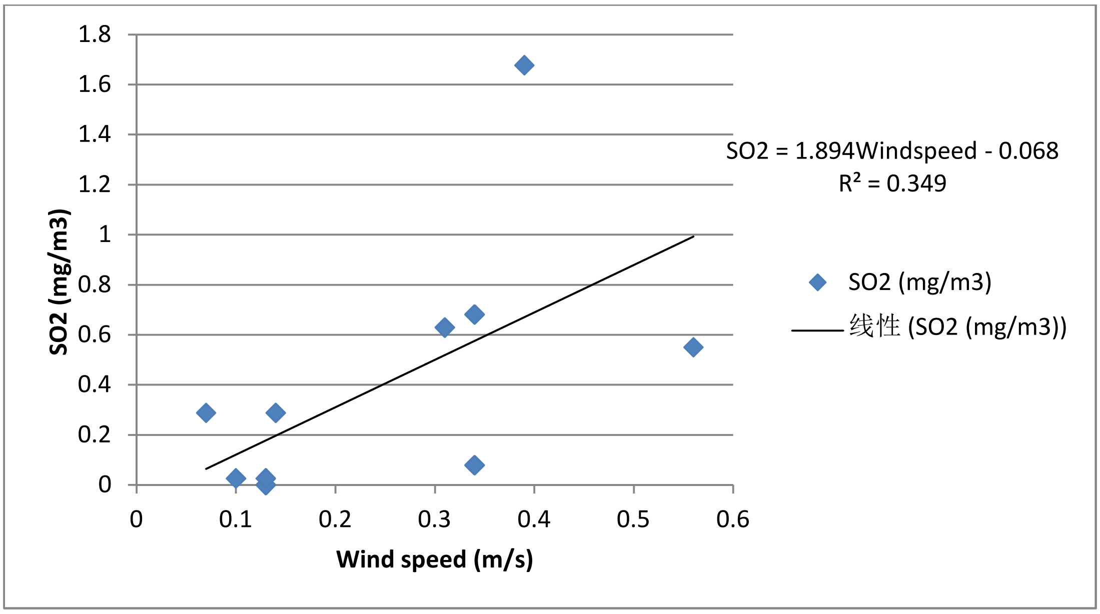

Fig.10: Scatter diagram between SO_2 and wind speed

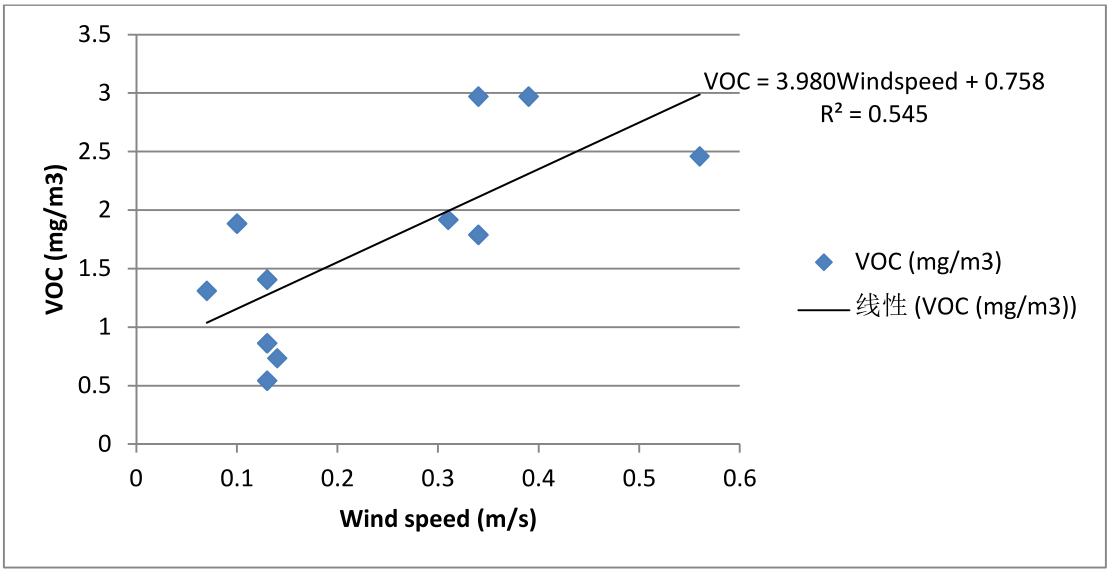

Fig. 11: Scatter diagram between VOC and wind speed

3.2 Implications for Atmospheric Pollutant Stagnation

The analysis reveals that the relative humidity at the dumpsite was higher than the residential, although without any regular pattern with distance from the dumpsite. Cossu and Reiter (1996) confirmed that landfill gas is characterized by high relative humidity, near that of the saturation point. The temperature was generally lower at the dumpsite than the residential area. The increase in the temperature in the residential area could be attributed to the problem of urban heat island and insufficient of vegetation in the area. The wind speed was generally low with a mean value of 0.24m/s and this indicated that the wind speed was calm though calmer in the dumpsite. According to Pillay et al (2011), wind speed ranging between 0.51m/s and 1.8m/s was regarded as calm. The calmness could be attributed to the dry season when the data was collected. Ogba and Utang (2009), Weli, (2014) argued that the percentage of calmness of wind is higher during the dry season than the rainy season. The reason is that the prevailing winds in the Niger Delta change with time and location. The wind direction throughout the time of study was north easterly. This could be attributed also with the dry season but Ogba and Utang (2009) affirmed that north easterly wind is one of the predominant winds during the year in the study area. Pillay et al (2011) concluded that wind speed and direction will affect the noise, dust and odour impacts from the site. The low speed of the wind favours the accumulation of pollutants in the study area especially the dumpsite and the direction of wind brought about the spread of these pollutants to the residential areas. Ogba and Utang (2009), Weli, (2014) agreed that the relatively low wind speed favours pollutant accumulation and stagnation in most part of the Niger Delta and Port Harcourt city respectively. In addition, the calmness during the dry seasons may lead to high concentration of pollutants in the study area. Wind speed is correlated significantly with SO_2 and VOC with a percentage contribution of 34.9% and 54.6% respectively. This analysis is similar to the result derived in the study of Turner (1961) whereby wind speed was able to explain 50% of the variation in SO_2 in Stockholm.

The level of concentrations of SO_2, CH_4, VOC, NH_3 and H_2S were higher in the dumpsite than the residential area while the case was opposite for NO_2.The higher concentration of the air qualities parameters (SO_2, CH_4, VOC, NH_3 and H_2S) at dumpsite signals that the dumpsite is a major source of the air pollutants which can affect other environmental resources. For instance, IPCC (1996) cited in Kumar et al (2004) affirmed and confirmed that methane (CH_4) gas emitting from landfill is estimated to account for 3-19% of the sources in the world and the higher concentrations of CH_4 in the dumpsite with 38.8% of the total concentration could be attributed to the deposition of sludge in the area. The increase in the H_2S may be caused by the microbial decay of organic matter and reduction in the sulphate ion (Ideriah and Stanley, 2008). In the same vein, Ideriah and Stanley (2008) noted that the concentrations of SO_2 and NO_2 at the dumpsite could be attributed to the industrial solid wastes which make up the waste composition in the landfill site. The concentrations of SO_2 and NO_2 may in effect lead to the formation of acid rain when released into the atmosphere as they become incorporated in clouds and be deposited as rainfall in the form of dilute sulphuric and nitric acid. The acid rain may affect the livelihood of the neigbourhood by destroying the plants and properties. Generally, the higher concentrations of air quality pollutants in the residential areas of the study area may be likened to the general low wind speed and the north-easterly direction of the wind. Ogba and Utang (2009) commented that studies have proven that wind speed and direction influence air pollution dispersion and concentration and according to Garcia et al (2007), upwind location have less pollutant concentration than downwind. It was noted that there was no significant variation in the concentrations of pollutants between the dumpsite and the residential areas. Cases of wind speed below 2ms^{-1}, the concentration of pollutants increase and becomes uniformly distributed around areas within the source zones (Tsai et al, 2004; Hung et al, 2005) while stagnant weather conditions with low wind speed contributes to accumulation of pollutants at ground level (Chiu et al, 2005). Furthermore, the predominantly built-up area in Port Harcourt comprising of high building to land ratio and high floor area ratio can result to high aerodynamic surface roughness which can in effect results to a weak wind speed which can equally result to low pollutants diffusion. Generally, according to Ogba and Utang (2009) and Weli, (2014) the wind speed in Port Harcourt is less than 3.1 ms^{-1} which also suggest low pollutant diffusion and stagnation.

The higher temperature in the dumpsite might have led to the increase in the concentrations of the pollutants in the dumpsite. Temperature had significant correlations with NO_2, NH_3 and H_2S. Pillay et al (2011) submitted that increased temperature accelerates microbiological activity up to an optimum temperature level. There was an inverse relationship between temperature and relative humidity. Thus, as temperature decreases, the relative humidity will increase, and likewise, as temperature increases, the relative humidity will decrease. Valsson and Bharat (2011) also submitted that the air temperature variation brings about a change in water evaporation and air saturation. leading to the change in air humidity. Schenker (2003) viewed that atmospheric chemistry is activated by the strong solar radiation, producing elevated levels of secondary pollutants. Similarly, Bardouki et al (2003) cited in Mkoma et al (2010) affirmed that the temporal and spatial variability of the atmospheric particles and its components are influenced by meteorological parameters such as rainfall, temperature, relative humidity and air flow patterns. The H_2S was higher in the landfill than the residential. The H_2S shows that the dumpsite was odourful which may affect the neighbouring communities. Connecticut Department of Public Health (CDPH) (1997) made it known that locations near the landfill will perceive this odour more than the far places especially in the morning time because this is when winds tend to be most gentle, providing the least dilution of the gas. The increase in the H_2S at the landfill may be attributed to the deposition of sludge from cattle feed lots, poultry farms and sewage treatments. It may also be attributed to the large quantities of organic materials from household and commercial wastes being received in this landfill (CDPH, 1997). According to Pillay et al (2011), landfill gas contains odorous compounds, which lead to odour impacts in the communities located downwind from the landfill. Pillay et al (2011) further stated that one of the significant odorous compounds is hydrogen sulphide (H_2S) despite only being emitted in trace quantities. Increase in the moisture contents can also bring about increase in the H_2S because of the enabling environment being provided for bacteria to act on the organic materials at a faster rate. The odour generated due to the increase in H_2S causes unpleasant environment. CDPH (1997) therefore concluded that landfill odours represent more of a public nuisance than a community health hazard; nevertheless unpleasant odour creates an adverse physiological response such as nausea, headache, nasal blockage, lung irritation, chest pain and aggravation of asthma. There was a significant correlation between H_2S and NH_3 and this must have increase the level of odour in the landfill site. The VOC was higher in the landfill site, proving that the landfill was a good source of the VOCs. This increase may be attributed to the dumping of municipal solid wastes (residential and industrial wastes) which include paints, personal care items, oils and greases, carpets, adhesives and automotive care products (CDPH, 1997; Benson and Cornelly, 2005). VOCs are very dangerous to human health because they are carcinogenic, mutagenic and/or teragenic (Benson and Cornelly, 2005). CDPH (1997) added that the amount of VOCs in landfills depend upon whether the chemical reactions are occurring which either remove or create them. Methane (CH_4) concentration(0.064mg/m^3) was also higher in the landfill site than the residential area which shows that CH_4 is also an air quality pollutant generated from the landfill that can be dispersed to the surrounding community. The presence of CH_4 could be linked to the microbial degradation of the organic components in municipal waste under anaerobic conditions (Scheutz, 2002). USEPA (1991) and Environmental Risk Limited (ERL) (1995) justified that the level of methane at the landfill site is always high. Bogner et al (1997) affirmed that landfills are estimated to release to the atmosphere between 9 and 70Tg of CH_4 per year, out of an estimated annual global emission of 600Tg.Methane is lighter than air and that is the reason why it disperses easily into the neighbouring community. ATSDR (2001) submitted that landfill gases are lighter than air, so that is why methane naturally moves upwards through the landfill sites, although the migration rate depends strongly on weather condition. The higher level in the concentration of methane in the landfill site could be attributed to pressure around the landfill. ATSDR (2001) concluded that when gas accumulates in landfill, it creates areas of high pressure where gas movements are restricted by compacted soil covers and areas of low pressure where the gas can move freely, and thus this variation in pressure causes the gas to move around the landfill in a process known as convection.

4. Recommendation

Weather parameters such as temperature, relative humidity and wind speed have been revealed to have effects on the stagnation of air quality parameters in the vicinity of the landfill in Rumuolumeni thereby raising serious health and environmental concerns to the inhabitants of the community. In view of this, the following recommendations are put forward.

1. Periodic assessment of the LFG emission in the residential area is necessary.
2. Assessment of air quality in relation to the landfill sites in the surrounding landuse areas is required.
3. The landfill should be closed to forestall further environmental and health damage.

REFERENCES

Akani, C.O (2008) Analysis of street level air temperature and quality along the Traffic corridors of Lagos metropolis. An Unpublished Ph.D thesis. University of Ibadan

Akeredolu, F.A; Oluwole, A.F; Beliku E.A; Ogunsola, O.J. (1994) 'Modelling of carbon monoxide concentration for motor vehicles travelling near roadway intersections in Lagos, Nigeria' *the 2nd int'l conference on air pollution*. Part 2 (of 2), Barcelonia

Air and Waste Management Association. *Landfills*, http://www.awma.org/enviro_edu/fact_ sheets1/index.html (accessed in October 2012).

ATSDR (2001): *Landfill Gas Primer* Department of Health and Human Services Agency for Toxic Substances and Disease Registry Division of Health Assessment and Consultation

Awofolu, O.R. (2004) ' Impact of automobile Exhaust on levels of lead in a Commercial Food from Bus Terminals'. *Journal of Applied Science and Environmental Management*. Vol. 8 No 1. Pp. 23-27.

Barrett, A., Lawlor, J. (1995) The economics of waste management in Ireland. Economic and Social Research Institute, Dublin. 129pp.

Bogner, J. E., Spokas, K.A., Burton, E.A., Sweeney, R. and Corona, V. (1997): Landfills as atmospheric methane sources and sinks. *Chemosphere* 31:4119-4130

Cossu R. and Reiter M. (1996): Landfill gas condensate production and disposal, In T.H. Christensen, R. Stegmann, R. Cossu, (editors) Landfilling of Waste. Published by Taylor and Francis Books Ltd., p485.

CTDPH (1996): Health Consultation: Hartford Landfill, Review of Air Emissions Data.

Chiu T.T., Lam T.H., and Hedley A.J. (2005): A randomized controlled trial on the efficacy of exercise for patients with chronic neck pain. 30(1): 1-7.

Efe S.I. (2008) Spatial distribution of particulate air pollution in Nigerian cities: Implications for human health. *The Environmentalist*. Vol. 7. Issue 2.

Efe S I (2005). Urban Effects on Precipitation Amount, Distribution and Rainwater Quality in Warri Metropolis, Ph.D Thesis, Dept. of Geography and Regional Planning Delta State University Abraka, Delta State, Nigeria , pp 2-47.

Efe S I (2006). Particulate Pollution and its Health Implications in Warri Metropolis, Delta State Nigeria. *Env. Anal.* 11, 1339-1351.

Douglas, T. 1992 Patterns of land, water and air pollution by waste. In: Newson, M. (Ed.) Managing the Human Impact on the Natural Environment John Wiley & Sons, 150- 171

EEA (European Environment Agency) 2003 Europe's environment: the third assessment. Environmental Assessment Rept. No. 10 EEA, Copeenhagen, Ch 7, 151-164.

Hung, I., Deshpande, C. G., Tai, C. and Huang, S. (2005): Spatial and temporal distribution of volatile organic compounds around industrial park of Taiwan. Aerosol and Air Quality Research, 5 (2): 141-253.

Ideriah T.J.K. and Stanley H.O. (2008): Air Quality around Some Cement Industries In Port Harcourt, Nigeria. Scientia Africana, Vol. 7 (No.2), pp 27-34.

IPCC (1996): Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, International Panel on Climate Change, Task Force on National Greenhouse Gas Inventories, Hayama, Japan, http://www.ipcc - nggip.iges. or.jp / public /gl/invs6.html.

Kumar, J.P., Jamal, T., Doetsch, A., Turner, F.R., Duffy, J.B. (2004): CREB binding protein functions during successive stages of eye development in Drosophila. Genetics 168(2): 877--893. (Export to RIS)

Obinna, V.C., Owei, O.B; Davis, B., and Okwakpam, I.O. (2009): Sanitizing Port-Harcourt: The phenomenon of urban street hawking and policy implications. *Journal of Nigerian Environmental Society,* Vol.5, No. 2. pp118-135

Ogba C.O. and Utang P.B. (2009): Air Pollution Climatology in Spatial Planning for Sustainable Development in the Niger Delta, Nigeria. FIG Working Week 2009 Surveyor's Key Role in Accelerated Development, Eilat, Israel, 3-8 May, 2009

Schenker U. (2003): Influence of Meteorological Parameters on Air Quality Simulations in Mexico City. Diploma Thesis Submitted to Ecole Polytechnique Federale de Lausanne (EPFL), Swiss Federal Institute of Technology, Lausanne.59p

Schwartz J. (2002): Air pollution and daily mortality in Birmingham, Alabam. American Journal of Epidemiology 137,1136-1147.

Tsai, C., Aggarwal, S. G., Chang, C. and Hung, I. (2004): Concentration profiles of acidic and basic air pollutants around an industrialpart of Taiwan. Water, Air and Soil Pollution, 151 (1-4): 287-304

Turner D.B. (1961): Relationship between 24-hour mean air quality measurement and meteorological factors in Nashville, Tennessee. Journal of Air Pollution Control Association 11, 483-488

USEPA (1991): Air Emissions from Municipal Solid Waste Landfills – Background Information for Proposed Standards and Guidelines. EPA-450/3-90-011a.

Valsson, S. and Bharat, A. (2011): Impact of Air Temperature on Relative Humidity - A study. Architecture-Time Space and People. pp1-4.

Weli, V.E. (2014) Spatial and seasonal variation of atmospheric pollutants concentration in Port Harcourt metropolis. An Unpublished Ph.D thesis. University of Ibadan. Nigeria