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Air Quality in the Vicinity of a Landfill Site in Rumuolumeni, Port Harcourt, Nigeria

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Abstract
The study investigated the air quality status in the vicinity of Rumuolumeni landfill with a view to determining the possible influence of weather parameters on the concentration of air pollutants from the landfill. Air quality parameters determined include nitrogen oxide (NO_2), sulphur dioxide (SO_2), methane (CH_4), volatile organic compounds (VOC), ammonia (NH_3), and hydrogen sulphide (H_2S). Weather parameters examined include temperature, relative humidity, wind speed, wind direction. These data were collected with respect to distance from the center of the dumpsite into the residential area at 200m intervals for seven days using composite sampling technique. Pearson Correlation Statistics was used to test significant influence of distance from the dumpsite on the concentrations of pollutants. Results indicate that, pollutants considered except NO_2 were higher at the dumpsite than the residential area. The mean value of SO_2, CH_4, VOC, NH_3 and H_2S at the dumpsite was 0.67 mg/m^3, 0.06 mg/m^3, 2.28 mg/m^3, 0.12 mg/m^3, and 0.19 mg/m^3 respectively. Distance from the center of the dumpsite accounted for 41% (r^2 of 0.4096; r of 0.64) and 29% (r^2 of 0.2916; r -0.54) variation in the concentrations of NO_2 and NH_3 respectively at p=0.05. Results indicate that NO_2, NH_3 and H_2S had significant correlations with temperature at 5% significant level with correlation coefficients (r) of 0.740, -0.766, and -0.699 respectively. In addition, NO_2, NH_3 and H_2S were significantly correlated with relative humidity at 5% significant level with correlation coefficient (r) of -0.653, 0.727 and 0.646 respectively while SO_2 and VOC were significantly correlated with wind speed at 5% significant level with correlation coefficient (r) of 0.591 and 0.739 respectively. The study recommends that measures to capture landfill gases and prevent their migration to the community are necessary.
Keyword: air quality, landfill, meteorological parameter, atmospheric pollutants, Port Harcourt.

1. Introduction

Landfilling is the most common and environmentally safe method of disposal for the fraction of municipal solid waste (MSW) that cannot be reduced, recycled, composted, combusted or processed. Open dumping of MSW, which is practiced by about three-fourth of the countries and territories in the world are a primitive stage of landfill development (kumar, et al; 2004). 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).

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emission of obnoxious gases, groundwater contamination and leakage of methane gas. Despite increased regulations on municipal solid waste, many people who live near landfills continue to report health problems associated with foul odors, pests, polluted water and traffic. Globally, the most MSW is dumped in non-regulated landfills and generate landfill gas (LFG) as a by-product (see Johnson, 2010). LFG is generated when organic material decomposes anaerobically, consisting of 45% to 60% methane gas, 40% to 60% carbon dioxide, and 2% to 9% other gases which are mostly emitted to the atmosphere (Metz, et.al, 2007). For instance, the International Panel on Climate Change (IPCC) has estimated that methane emission from landfills account for 3-19% of the anthropogenic sources in the world and is considered as a large contributor to global warming after agricultural activity and losses from fossil fuel distribution (IPCC, 1996; Metz et al, 2007; Johnsson, 2010).
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 effects of meteorological parameters on the concentration 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. But unfortunately, the influence of meteorological parameters to the concentration levels of gaseous pollutants however has not been given due and sustained attention especially as it affects emissions from landfills in Port Harcourt. This study therefore is an attempt to provide the understanding of the governing effects of meteorological parameters on the concentration of LFG emissions.

2. Study Area.

The study area is Rumuolumeni, a suburb of the city of Port Harcourt. It houses the Ignatius Ajuru University of Education. The city has witnessed enormous growth in its population, since its inception. Over the years the city has grown in heaps and bounds from a population of about 7,000 person in 1914 (Obinna et al, 2009) to population of 440,399 according to the 1991 census (National Population Commission, 1992). Its present population is projected to be 987,998 applying an average annual growth rate of 5.8% (Greater Port-Harcourt Development Project, 2007). Port-Harcourt is not only a key administrative center but also an important commercial and educational center as well as railway terminus with a viable sea and airport. It is now the center of Nigeria oil and gas industry. The city therefore is a veritable magnet attracting immigrants not only from rural areas but also from other urban centers. This has serious implications for waste generation in the area.

3. 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 atmospheric pollutants. The relationship between weather parameters and air pollutants were graphically presented using scatter diagram.

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

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

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

Where;
t = Calculated value
n = Number of samples
r = Correlation coefficient

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

$$Y = a+\beta_1 x_1 + \beta_2x_2 + \beta_3x_3\ldots+\beta iji + e \quad (3)$$

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).

4. Results and Discussion of Findings

Table 4.1 presents the spatial variations of air quality influenced by landfill site in Rumuolumeni. Result indicates that the mean value of temperature was 28.0^{o}C at the centre of the dumpsite while the general mean value of temperature at the dumpsite was 28.6^{o}C. Away from the dumpsite into the residential area, findings showed that temperature values increases with the distance whereby sample location RA1 which was the nearest among other locations with the distance of 221.93m in residential area had a mean value of temperature of 29.6^{o}C while the farthest location which was 956.90m in the residential area had a mean value of temperature of 30.8^{o}C. The general mean value of temperature in the residential area was 30.3^{o}C. Generally, the relative humidity in the study area was relatively high but the relative humidity at the center of the dumpsite was 68.4% and total mean value of relative humidity at the dumpsite was 67.9%. The mean value of relative humidity at RA1 at a distance of 221.93m was 64.8%, RA2 was 65.2% while it was 62.8% at RA5 and RA7 which was the farthest into the residential area was 64.1%. The total mean value of relative humidity in the residential area was 63.9%. This shows that the relative humidity was higher at the dumpsite than the residential area and more so, the relative humidity did not have any pattern in relation with distance from the dumpsite. Result revealed the wind speed which is one of the major factors determining the dispersion of pollutants was measured and the results of the analysis show that the mean value of wind speed at the center of the dumpsite (D1) was 0.34m/s while at D2 with a distance of 154.65m from the
center of the dumpsite, the wind speed was 0.22m/s. On the other hand, the mean value of windspeed at RA1 having a distance of 221.93m from the center of the dumpsite (D1) was 0.13m/s. The point RA4 had the highest mean value of wind speed of 0.56m/s in the residential area while the farthest point (956.90m) in the residential area from the center of the dumpsite (RA7) was recorded a mean value of 0.14m/s. The total mean value of wind speed in the residential area was 0.25m/s and with this, the wind speed was higher at the residential area than the dumpsite. The analysis on wind speed can be observed in Fig 4.3. The higher wind speed in the residential area could be due to the decrease in the urban trees which would have reduced the wind speed. Tahir and Yousif (2013) admitted that the more compact is the foliage on the tree or a group of trees, the greater is the influence of these trees on wind speed.

The concentration of sulphur dioxide (SO_2) at the center of the dumpsite was 0.681 mg/m^3 while the highest concentration was recorded at D2 with a mean value of 1.677 mg/m^3. Nevertheless, the total mean value of the concentration of SO_2 was 0.668 mg/m^3. Meanwhile, the concentration of SO_2 in the residential area was highest at RA5 with a mean value of 0.629 mg/m^3 while there were no concentrations of SO_2 at RA1 and RA2. The total mean value of SO_2 at the residential area was 0.225mg/m^3. Methane (CH_4) varied both at the dumpsite and residential area. The concentration of CH_4 was 0.105mg/m^3 at the center of the dumpsite (D1) while the mean value of the concentration was 0.138mg/m^3 at D2. In the residential area, at RA5, the mean value of the concentration of CH_4 was 0.203mg/m^3. The range of the concentration of CH_4 was between 0.000mg/m^3 and 0.203mg/m^3 while the total mean value at the residential area was 0.058mg/m^3. Volatile organic compounds

(VOC) had the highest mean value among other air pollutants considered in the study area (both dumpsite and residential area). At the dumpsite, the mean value of the concentration of VOC was 2.971mg/m^3 at the center of the dumpsite (D1) while the concentration of VOC was 1.301mg/m^3 at D3. Generally, the total mean value of the concentration of VOC at the dumpsite was 2.284mg/m^3. The concentrations of VOC varied slightly at the residential area. Although the concentration was lower than that at the dumpsite but the concentration was high at RA3, RA4, RA5 and RA6 with 1.789mg/m^3, 2.460mg/m^3, 1.917mg/m^3 and 1.406mg/m^3 respectively. The concentration of ammonia (NH_3) was only observed at the dumpsite with the highest at the center of the dumpsite with a mean value of 0.300mg/m^3. At the residential area, there was no concentration of NH_3. In the same vein, the concentration of hydrogen sulphide (H_2S) was significantly higher at the dumpsite than the residential area. The total mean concentration of H_2S at the dumpsite was 0.199mg/m^3 but the highest concentration was observed at D1 with a mean value of 0.404mg/m^3. At the residential area, it was observed that the concentration was highest at RA5 with a mean value of 0.125 mg/m^3 while there was no concentration at RA3. However, the total mean concentration of H_2S in the residential area was 0.056mg/m^3. The wind direction during the study at all the sampled locations was North East. This suggests that much of the pollutant concentrations may be felt greatly towards this direction.

4.1 The Relationship between meteorological parameters and LFG emission in Rumuolumeni landfill site

Table 1 presents the correlation matrix between weather parameters and air quality parameters. 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 2). In addition, temperature correlated significantly with $NH_3$and H_2S at 5% level of

confidence but the relationship was inversely proportional (see Fig 3and Fig 4). 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 5, Fig 6 and Fig 7 respectively.

Table 1: Correlation matrix between weather and air quality parameters at the vicinity of the landfill

	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 p=0.005

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 shown in Fig 8 and Fig 9 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).

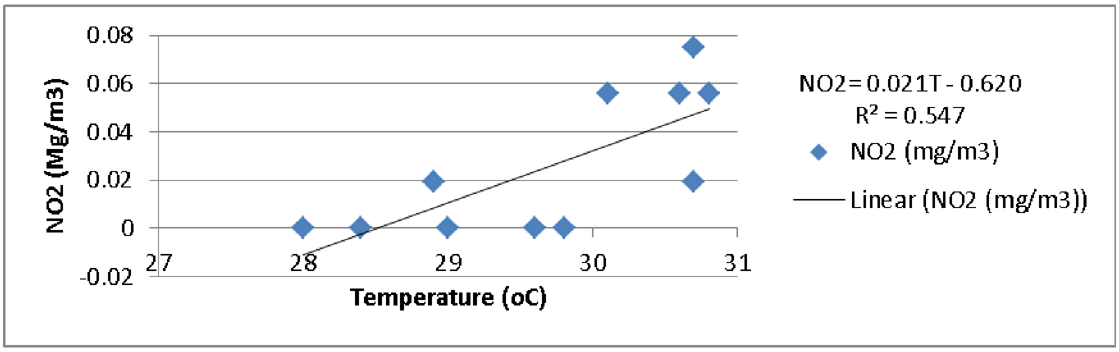

Fig. 2: Scatter diagram between NO_2 and temperature

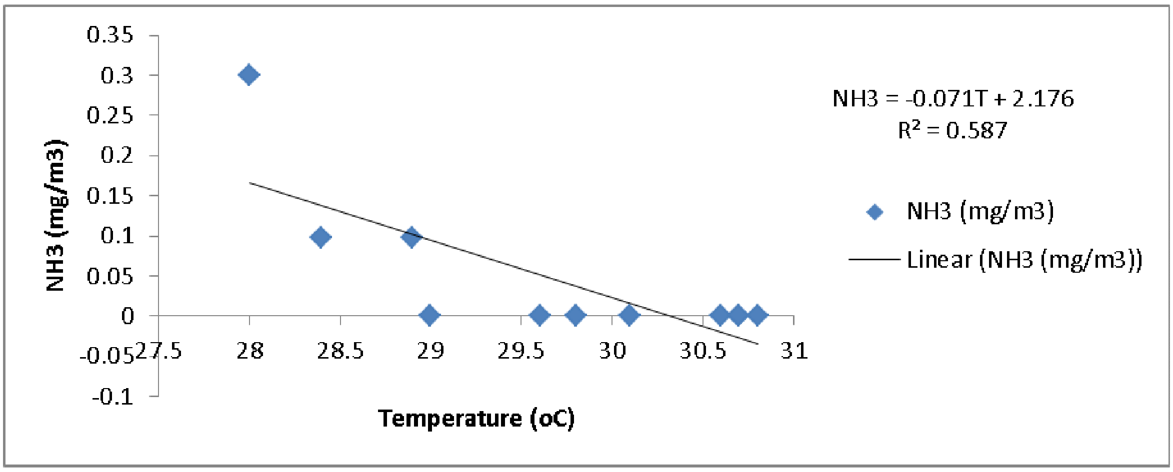

Fig. 3: Scatter diagram between NH_3 and temperature

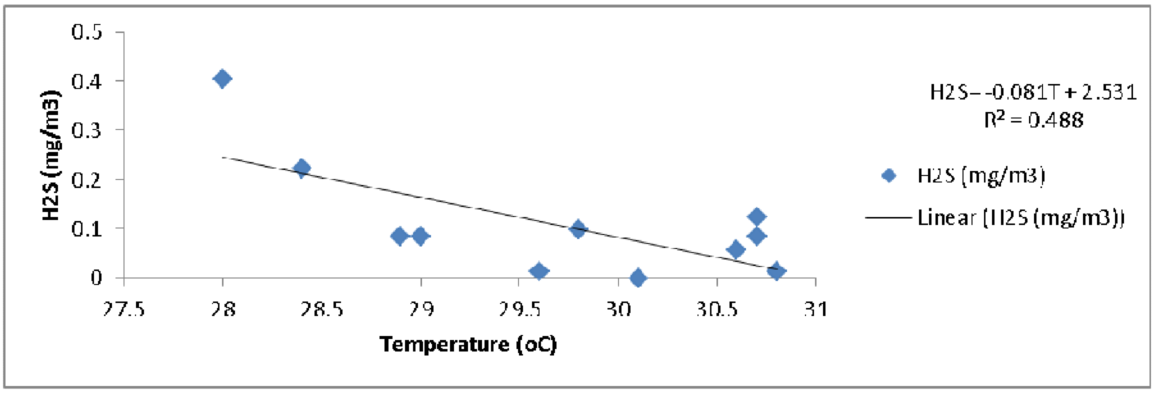

Fig. 4: Scatter diagram between H_2S and temperature

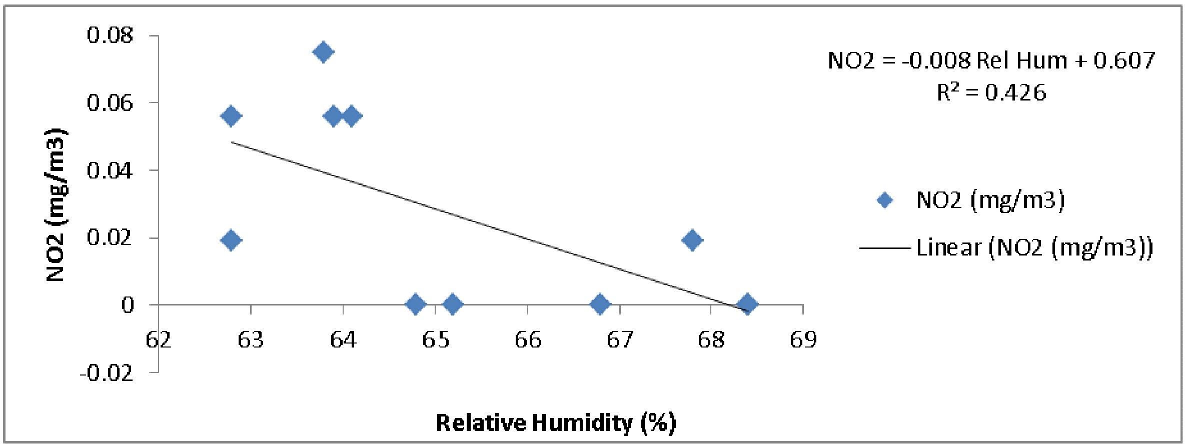

Fig. 5: Scatter diagram between NO_2 and relative humidity

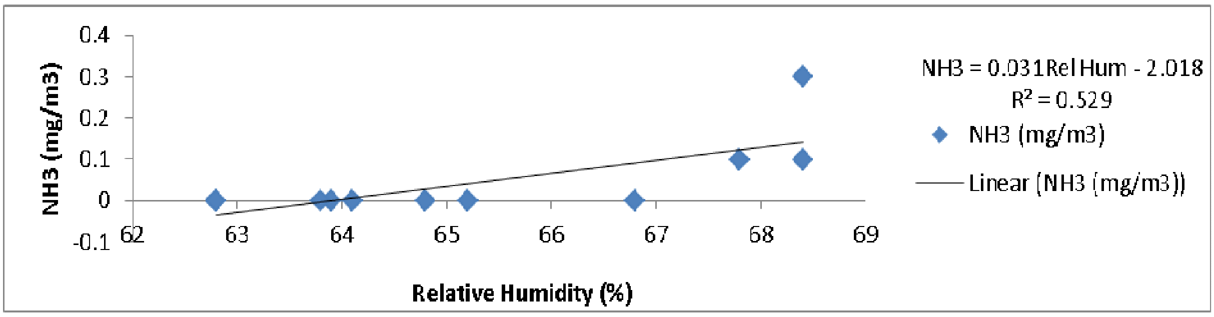

Fig. 6: Scatter diagram between NH_3 and relative humidity

Table 2: Distance and Air Quality Parameters

Sampled Locations	Distance (m) from Dumpsite Center (X)	NO_2 (mg/m^3) (Y)	SO_2 (mg/m^3) (Y)	CH_4 (mg/m^3) (Y)	VOC (mg/m^3) (Y)	NH_3 (mg/m^3) (Y)	H_2S (mg/m^3) (Y)
D1	0	0	0.681	0.105	2.971	0.300	0.404
D2	154.65	0	1.677	0.138	2.971	0.098	0.223
D3	74.0	0.019	0.288	0.007	1.310	0.098	0.084
D4	76.09	0	0.026	0.007	1.885	0	0.084
RA1	221.93	0	0	0	0.863	0	0.014
RA2	290.23	0	0	0	0.543	0	0.098
RA3	384.42	0.056	0.079	0	1.789	0	0
RA4	576.31	0.056	0.550	0.026	2.460	0	0.056
RA5	946.86	0.019	0.629	0.203	1.917	0	0.125
RA6	636.65	0.075	0.026	0.105	1.406	0	0.084
RA7	956.90	0.056	0.288	0.072	0.735	0	0.014

Table 3: Pearson's correlation statistics for distance and LFG pollutants with their level of significance.

	Correlation Coefficient (r)	r^2	Coefficient of Determination (%)	t-test for t- calculated value $\frac{r.\sqrt{N-2}}{\sqrt{1-r^2}}$	t-table value at 9 d.f. at p=0.05	Significance
NO_2	0.640	0.4096	40.96	2.48	1.83	S
SO_2	-0.087	0.0076	0.76	0.09	1.83	NS
CH_4	0.444	0.1971	19.71	1.49	1.83	NS
VOC	-0.288	0.0829	8.29	0.90	1.83	NS
NH_3	-0.540	0.2916	29.16	1.92	1.83	S
H_2S	-0.425	0.1806	18.06	1.41	1.83	NS

Note: S- Significant; NS- Not Significant

Pearson's correlation statistics was used to test this hypothesis and the analysis was done using the data in table 2. The dependent variable (Y) is each of the air quality parameter while the independent variable (X) is distance. Table 3 shows the correlation statistics, significance level and the correlation coefficient (r) of the relationship between distance and the respective pollutants-NO_2, SO_2, CH_4, VOC, NH_3 and H_2S. The value of r between distance and the pollutants- NO_2, SO_2, CH_4, VOC, NH_3 and H_2S are as follows: 0.640, -0.087, 0.444, -0.288, -0.540 and -0.425 respectively while the r^2 was 0.4096, 0.0076, 0.1971, 0.0829, 0.2916 and 0.1806 respectively suggesting a coefficient of determination 40.96%, 0.76%, 19.71%, 8.29%, 29.16% and 18.06% respectively. The coefficient of determination showed that distance can only explain 40.96% of the concentration of NO_2, 0.76% of SO_2, 19.71% of CH_4, 8.29% of VOC, 29.16% of NH_3 and 18.06% of H_2S. Table 3 further revealed that NO_2 and CH_4 increases with increasing distance away from the dump site while SO_2, VOC, NH_3 and H_2S decreases with increasing distance from the dump site. These results suggest that NO_2 and CH_4 known as green house gases will aggravate the increase in temperature around the residential areas of Rumuolumeni. T-test was used to test the level of significance of the relationship between distance and the air quality parameters. The calculated t-value for NO_2, SO_2, CH_4, VOC, NH_3 and H_2S is 2.48, 0.09, 1.49, 0.90, 1.92 and 1.41 respectively with a degree of freedom of 9. The table t-value at 0.05 probability level at degree of freedom of 9 is 1.83. It is discovered that t-calculated was higher than t-table in NO_2 and NH_3. This indicates that distance from the dumpsite influences the concentrations of NO_2 and NH_3 in the study area.

Result shows that temperature influences the concentrations of NO_2, NH_3 and H_2S. Similarly, relative humidity influences the concentrations of NO_2, NH_3 and H_2S. Cossu and Reiter (1996) confirmed that landfill gas is characterized by high relative humidity, near that of the saturation point.the study revealed that wind speed influences the level of concentrations of SO_2 and VOC. 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) and Weli, (2014) submitted that the percentage of calmness of wind is higher during the dry season than the rainy season. This means that SO_2 and VOC will stagnate around the Rumuolumeni with their attendant health implications (see ATDSR, 2001; Efe, 2008 and Weli, 2014).

Table 4: Spatial variations of air quality and weather parameters influenced by dumpsite

Sampled Locations	Distance(m) from Dumpsite Center	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)	WIND DIRECTION
D1	0	28.0	68.4	0.34	0	0.681	0.105	2.971	0.300	0.404	North East
D2	154.65	28.4	68.4	0.39	0	1.677	0.138	2.971	0.098	0.223	North East
D3	74.0	28.9	67.8	0.07	0.019	0.288	0.007	1.310	0.098	0.084	North East
D4	76.09	29	66.8	0.1	0	0.026	0.007	1.885	0	0.084	North East
Mean		**28.6**	**67.9**	**0.22**	**0.005**	**0.668**	**0.064**	**2.284**	**0.124**	**0.199**	
RA1	221.93	29.6	64.8	0.13	0	0	0	0.863	0	0.014	North East
RA2	290.23	29.8	65.2	0.13	0	0	0	0.543	0	0.098	North East
RA3	384.42	30.1	63.9	0.34	0.056	0.079	0	1.789	0	0	North East
RA4	576.31	30.6	62.8	0.56	0.056	0.550	0.026	2.460	0	0.056	North East
RA5	946.86	30.7	62.8	0.31	0.019	0.629	0.203	1.917	0	0.125	North East
RA6	636.65	30.7	63.8	0.13	0.075	0.026	0.105	1.406	0	0.084	North East
RA7	956.90	30.8	64.1	0.14	0.056	0.288	0.072	0.735	0	0.014	North East
Mean		**30.3**	**63.9**	**0.25**	**0.037**	**0.225**	**0.058**	**1.388**	**0.000**	**0.056**	

D- Dumpsite, RA- Residential Area

Table 5: Level of Significance between meteorological parameters and LFG pollutants

	Temperature			Relative Humidity			Wind speed		
	t-test for t-calculated value $\frac{r.\sqrt{N-2}}{\sqrt{1-r^2}}$	t-table value at 9 d.f. at p=0.05	Significance	t-test for t-calculated value $\frac{r.\sqrt{N-2}}{\sqrt{1-r^2}}$	t-table value at 9 d.f. at p=0.05	Significance	t-test for t-calculated value $\frac{r.\sqrt{N-2}}{\sqrt{1-r^2}}$	t-table value at 9 d.f. at p=0.05	Significance
NO_2	3.30	1.83	S	2.58	1.83	S	0.52	1.83	NS
SO_2	1.35	1.83	NS	1.34	1.83	NS	2.19	1.83	S
CH_4	0.22	1.83	NS	0.14	1.83	NS	0.95	1.83	NS
VOC	1.66	1.83	NS	1.21	1.83	NS	3.29	1.83	S
NH_3	3.57	1.83	S	3.17	1.83	S	0.59	1.83	NS
H_2S	2.93	1.83	S	2.53	1.83	S	0.88	1.83	NS

Note: S- Significant; NS- Not Significant

5. Recommendations

The landfill site in Rumuolumeni is discovered to have been a source of LFG emission and it is therefore recommended that:

1. Measures to capture landfill gases and prevent their migration to the community are warranted.
2. Environmental education about air LFG emissions is required so that residents can understand the effects of landfill sites in the neighbourhood empirically.
3. Studies on the air quality variations with seasons are required so as to understand the effects of seasons on LFG emission.
4. Periodic assessment of the LFG emission in the residential area is necessary.
5. Assessment of air quality in relation to the landfill sites in the surrounding landuse areas is required.
6. The landfill should be closed to forestall further environmental damage.

6. Acknowledgement

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