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Spatial Analysis of Atmospheric Pollutants from Rumuolemeni Landfill, Port Harcourt using GIS

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Abstract
The study identified spatial variation of air quality status in the vicinity of the landfill site in Rumuolumeni. Air quality parameters of nitrogen oxide (NO_2), sulphur dioxide (SO_2), methane (CH_4), volatile organic compounds (VOC), ammonia (NH_3), hydrogen sulphide (H_2S) and weather parameters of temperature, relative humidity, wind speed, wind direction, were collected with respect to distance from the center of the dumpsite into the residential area at various locations for seven days using composite sampling technique. Global Positioning System (GPS) was used to determine the longitude (y-coordinate) and latitude (x-coordinate) of each location which was used with the air quality and weather parameters to determine the areas of equal concentration of air quality through the method of interpolation in ArcGIS 9.3 environment. The spatial coverage of levels of concentration of each air quality parameters was calculated in hectares (ha) in ArcGIS 9.3 environment. The GIS analysis showed that the spatial coverage of the entire study area was 1.128 sq km. Result indicates that concentrations of NO_2 in the study area varied spatially; values ranging between 0.034mg/m^3 and 0.042mg/m^3 covered 0.217sq km while the range between 0.026mg/m^3 and 0.033mg/m^3 covered 0.194sq km and much of this spatial coverage was within the built up area of the study area. However, the concentration of VOC between 0.543 and 0.813 mg/m^3 had a spatial coverage of 0.019 sq km while the higher levels of concentration between 2.432 and 0.2.971 covered 0.027 sq km. The concentration levels of VOC between 1.353 and 1.622 mg/m^3 covered 0.267 sq km, 1.893 and 2.162 covered 0.150 sq km and 1.623 and 1.892 mg/m^3 covered 0.280 sq km. There was no general pattern between the level of concentration of VOC and the spatial coverage. The spatial coverage of the concentration of SO_2 range of values of 0.187 and 0.373 mg/m^3 was 0.413 sq km. The mean value of wind speed at the dumpsite was 0.22m/s while it was 0.25m/s in the residential area. This indicates that the pollutants have the tendency to stagnate over time in the vicinity of the landfill. It is recommended that the landfill be closed given the rate of urban sprawl to avoid the unhealthy consequences of inhaling these toxic gases.
Keywords: Pollutant concentration, GIS, ArcGIS 9.2, interpolation, meteorological parameters.

1. Introduction

Landfills have led to some of the most heated, acrimonious battles over pollution in the public commons that have ever been seen. While there are a number of reasons for the vehement arguments that often surround landfills, one of the largest is the juxtaposition of both the understood need for landfills and the lack of will to live near one. Despite the arguments over landfills in general, there are no arguments over the assertion that there are many things that contribute to the environmental problem of landfills. Solid wastes are mainly disposed of to landfill, because landfill is the simplest, cheapest and most cost-effective method of disposing of waste (Barrett and Lawler, 1995). In most low- to medium-income developing nations, almost 100 per cent of generated waste goes to landfill. Even in many developed countries, most solid waste is landfilled. For instance, within the European Union, although policies of reduction, reuse, and diversion from landfill are strongly promoted, more than half of the member states still send in excess of 75 per cent of their waste to landfill (e.g. Ireland 92 per cent), and in 1999 landfill was still by far the main waste disposal option for Western Europe (EEA, 2003). Furthermore, although the proportion of waste to landfill may in future decrease, the total volumes of municipal solid waste (MSW) being produced is still increasing significantly, in excess of 3 per cent per annum for many developed nations (Douglas, 1992). Solid waste composition, rate of generation and methods of treatment and disposal vary considerably throughout the world and largely determine the potential of waste to impair air quality. In Port Harcourt, the case is not different as landfill is the only available option for waste disposal. Landfill is therefore likely to remain a relevant source of atmospheric toxics for the foreseeable future in the city.
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 spatial extent of LFG emissions especially landfills close to high density residential areas. 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 explore a GIS-based technique to identify the spatial coverage of air toxic pollutants emitted at Rumuolumeni landfill in Port Harcourt with a view to identifying the contribution of landfill emissions to ambient hazardous air pollutant (HAP) concentrations and providing support to the regulatory community in developing mitigation plans.

2. The study area

The study area is Rumuolumeni Landfill Site in Port-Harcourt City Local Government Area of Rivers State. Port Harcourt is situated between latitudes 4^o 42’ and 4^o 55’N and between longitudes 6^{o}53’ and 7^o 08’E (Fig 1). Port-Harcourt metropolis is the capital of Rivers State of Nigeria and lies in the Southern part of Nigeria, 40 kilometers up the North of the Bonny Rivers. Rumuolumeni is a suburb of the city of Port Harcourt. It houses the Ignatius Ajuru University of Education. The area 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.

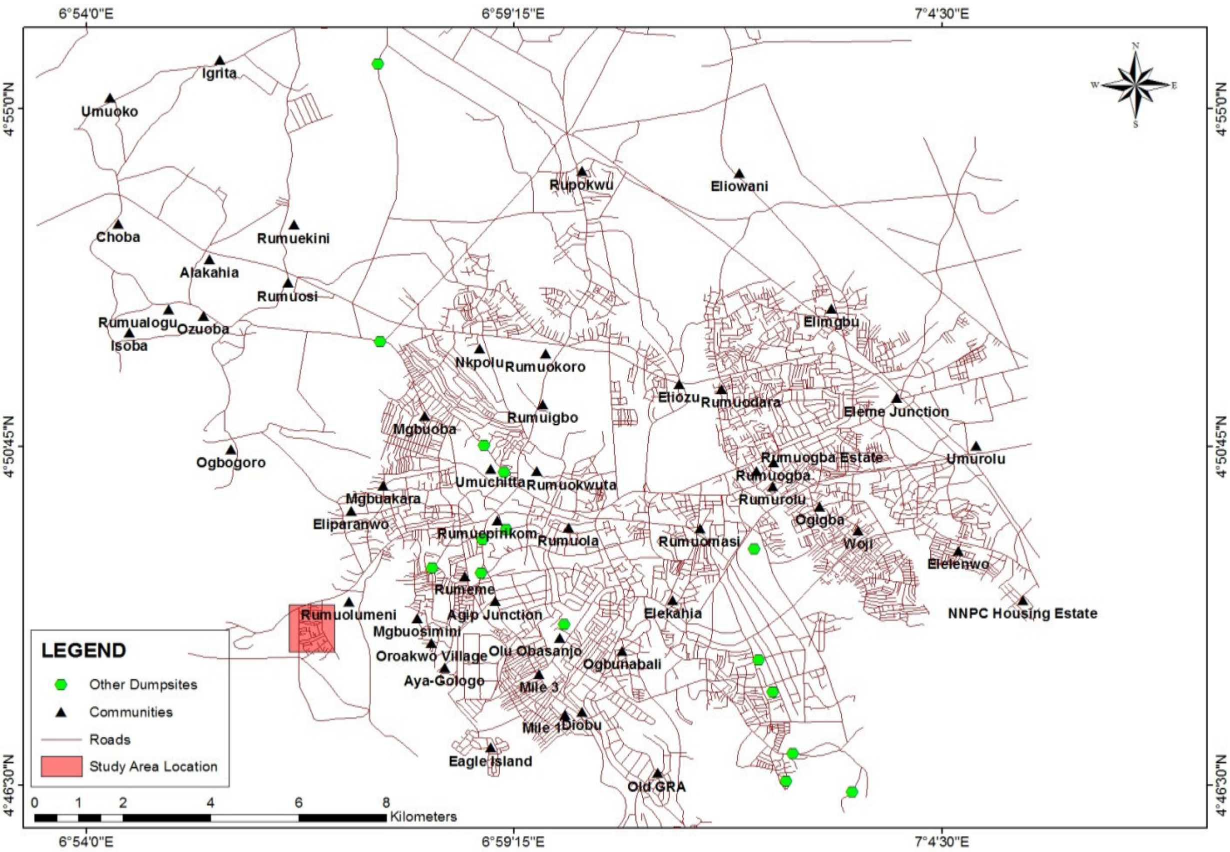

Fig 1: Map of Port Harcourt Metropolis showing Rumuolemeni and other landfills

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 in this study.

3.1 GIS Analysis for Generation of Maps

Global Positioning System (GPS) was used to determine the longitude (y-coordinate) and latitude (x-coordinate) of the locations where readings of air pollutants and weather parameters were taken. These readings were used to map the areas of equal concentration of air quality or areas experiencing equal weather parameter within the study area using inverse distance weighted (IDW) type of interpolation method in ArcGIS 9.3 environment. The maps were gotten in raster form. The IDW maps were converted to vector format in order to calculate the spatial coverage of concentration of each air quality parameters and weather parameters in square kilometers (sq km) in ArcGIS 9.3 environment using the calculate geometry module.

3.2 Generation of Landuse map

Landuse map of the area was acquired from the imagery of the area sourced from google earth 2012 version. The imagery was georeferenced in ArcGIS 9.3 to world coordinate system. From the groundtruthing of the land use types in the area through reconnaissance survey, four landuse types were identified namely built up area, farmland, forest and dumpsite. The landuse types were digitized in vector format from the geo-referenced imagery by capturing and classifying similar spectral reflectance in the imagery as same landuse. The spatial coverage of each landuse type was determined in square kilometers using the calculate geometry module of ArcGIS 9.3.The landuse map gave an insight of the size of the dumpsite in the midst of the surrounding landuse types. 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. The land identified includes derived forest, farmland, landfill site and residential area. Through the use of GIS analysis, it was discovered that the residential area covered 1.32 sq km, landfill site covered 0.06 sq km, farmland covered 0.03 sq km while derived forest covered 0.32 sq km. The residential area was mostly found on the Eastern, North Eastern and South Eastern parts of the landfill site

4. Results and Discussion of Findings

4.1 Spatial Variations of Air Pollutants Influenced by Landfill and Weather Parameters.

Findings indicate that the mean value of temperature was 28.0^oC at the centre of the dumpsite while the general mean value of temperature at the dumpsite was 28.6^oC (table 1). Moving away from the dumpsite into the residential area, it was discovered 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^oC while the farthest location which was 956.90m in the residential area had a mean value of temperature of 30.8^oC.

The general mean value of temperature in the residential area was 30.3^oC. 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. Furthermore, the windspeed 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 windspeed in the residential area was 0.25m/s and with this, the wind speed was higher at the residential area than the dumpsite. 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 nitrogen oxide (NO_2) in the study area varied very slightly among the sampled locations, though there was no concentration of NO_2 at the center of the dumpsite.

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Table 1: Spatial variations of air quality and weather parameters influenced by landfill.

Sampled Locations	Distance (m) from Dumpsite Center	Temp (°C)	Relative Humidity (%)	Wind speed (m/s)	NO_2 (mg/m³)	SO_2 (mg/ m³)	CH_4 (mg/m³)	VOC (mg/m³)	NH_3 (mg/m³)	H_2S (mg/m³)	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

The concentration of NO_2 was higher in the residential area and there was no pattern in relation with the distance from the center of the dumpsite. The highest mean value of NO_2 at the residential area was recorded at RA6 which was 0.075mg/m^3 while the least which was 0.019mg/m^3 recorded at RA5. 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 the residential area with its attendant health implications.

4.2 Spatial Variation in the Concentration of Atmospheric Pollutants in the Vicinity of the Landfill

Result show that the concentration of NO_2 increases from the dumpsite to the residential area. Higher concentrations of NO_2 were observed in residential areas especially in RA4, RA6 and RA7 and their environs. However, the concentrations of NO_2 in the study area varied in terms of spatial coverage and areas; it is thus observed in table 2 that the concentration ranging between 0.034mg/m^3 and 0.042mg/m^3 covered 0.217sq km while the range between 0.026mg/m^3 and 0.033mg/m^3 covered 0.194sq km and much of this spatial coverage was within the built up area of the study area (see fig 2). The higher ranges NO_2 (0.059 and 0.075mg/m^3) had a very small spatial coverage and still existed in the built up area. SO_2 from the concentration was highest at the residential area. The interpolation analysis showed that 0.326sq km of the total study area experienced concentrations of SO_2 between 0.000 and 0.186 mg/m^3 while the concentration between 0.187mg/m^3 and 0.373

mg/m^3 covered 0.413 sq km. The spatial coverage of the concentrations of SO_2 continued to decrease with increase in the range of concentration of SO_2 in the study are (see fig 3). The analysis therefore suggests that the more the spatial area extent, the lower concentrations of SO_2. Similarly concentrations of NH_3 due to the influence of dumpsite indicate that NH_3 decreased from the dumpsite towards the entire surrounding areas and the least concentrations was observed in the residential areas. It was also discovered that NH_3 concentration was highest at the centre of the dumpsite. Fig 4 explains the total area covered by each level of the concentrations of ammonia in the study area and it revealed that the concentrations between 0.000 and 0.033 mg/m^3 had 0.835 sq km ha which was highest and as shown also in Figure 4. In a similar situation, the concentration levels between 0.034 and 0.067 mg/m^3 covered an area of 0.160 sq km. The spatial coverage of NH_3 continued to decrease with increasing distance. Volatile organic compounds (VOCs) concentration was observed mainly in the dumpsite while the least was observed in some pockets of residential areas. Generally, the concentration of VOC reduces from the dumpsite towards other land use type around the dumpsite. Though there are few places within the dumpsite that experienced lower concentration of VOC. However, the concentration of VOC between 0.543 and 0.813 mg/m^3 had a spatial coverage of 0.019 sq km while the higher levels of concentration between 2.432 and 0.2.971 covered 0.027 sq km. The concentration levels between 1.353 and 1.622 mg/m^3 covered 0.267 sq km, 1.893 and 2.162 covered 0.150 sq km and 1.623 and 1.892 mg/m^3 covered 0.280 sq km. There was no general pattern between the level of concentration of VOC and the spatial coverage. The area coverage of higher concentrations of VOC was 1.014 sq km which ranged between 1.084 and 2.431mg/m^3. This gives an indication that VOC concentrations in the area were high. Hydrogen sulphide (H_2S) concentration was highest at the dumpsite and the concentration reduced from the dumpsite towards other surrounding areas around the dumpsite. The level of concentration of H_2S ranging between 0.000 and 0.045mg/m^3 covered an area of 0.045 sq km while the highest range (0.361-0.404 mg/m^3) covered only 0.001sq km. The concentrations between 0.046 and 0.090 mg/m^3 had coverage of 0.430 sq km while the highest spatial coverage (0.571 sq km) was observed in the concentration level ranging between 0.091 and 0.135 mg/m^3. Generally, the area covered in the study area with higher concentration of H_2S (0.136-0.404 mg/m^3) was just 0.082 sq km and most of the spatial coverage was observed in the dumpsite and area close to it. Unlike other air pollutants investigated in this study, CH_4 concentration was higher in the residential area than the dumpsite though the concentration in the dumpsite was moderately high. Thus, the most of areas with the highest and least concentrations of CH_4 could be observed in the residential area. The spatial coverage of the highest level of CH_4 concentration (0.181-0.203 mg/m^3) was 0.015 sq km while the least concentration (0.000-0.045 mg/m^3) had a spatial coverage of 0.521sq km. The levels of concentrations were generally high in both the dumpsite and residential areas but the highest concentration was observed at the residential area (see table 2 and fig 6).

Table 2: Spatial Coverage of CH_4 Concentration

S/N	CH_4 Concentrations (mg/m^3)	Spatial Area Extent (sq km)
1	0.000-0.022	0.137
2	0.023-0.045	0.384
3	0.046-0.068	0.224
4	0.069-0.090	0.150
5	0.091-0.113	0.122
6	0.114-0.135	0.044
7	0.136-0.158	0.031
8	0.159-0.180	0.021
9	0.181-0.203	0.015
Total		**1.128**

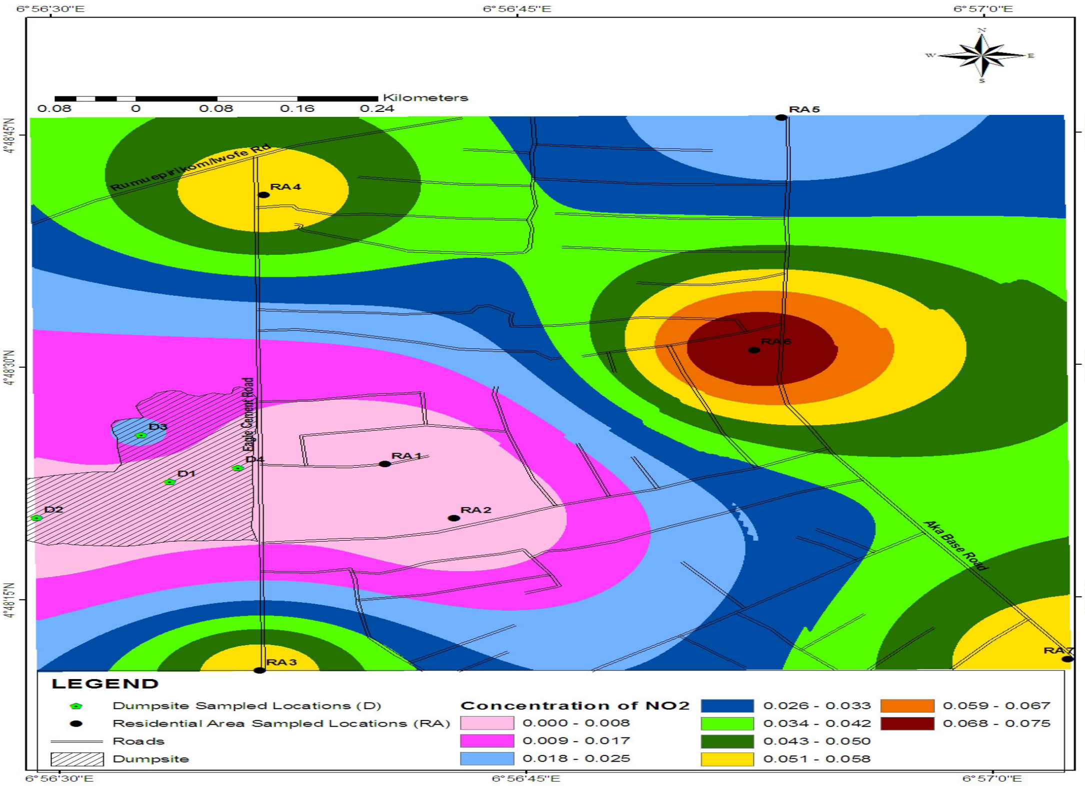

Figure 2: Nitrogen oxide variation around the dumpsite

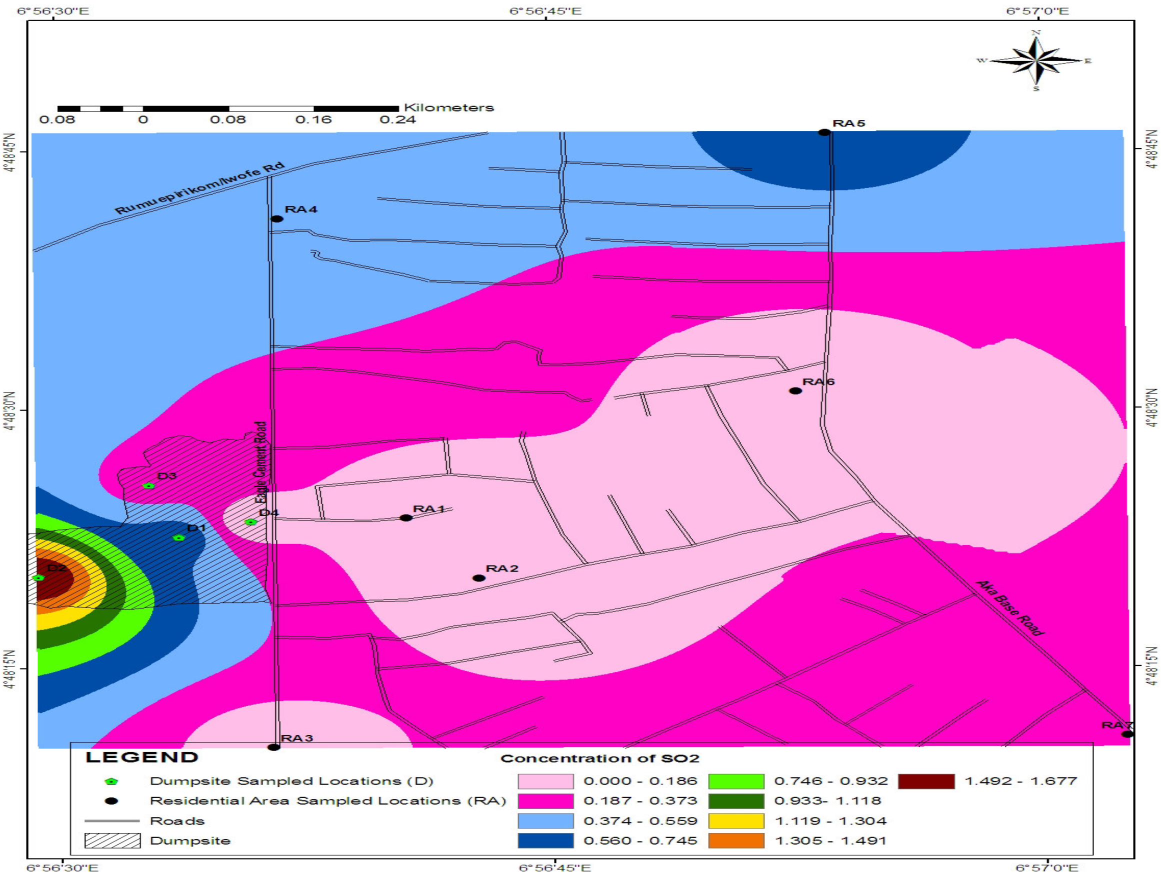

Fig. 3: Sulphur dioxide variation around the landfill.

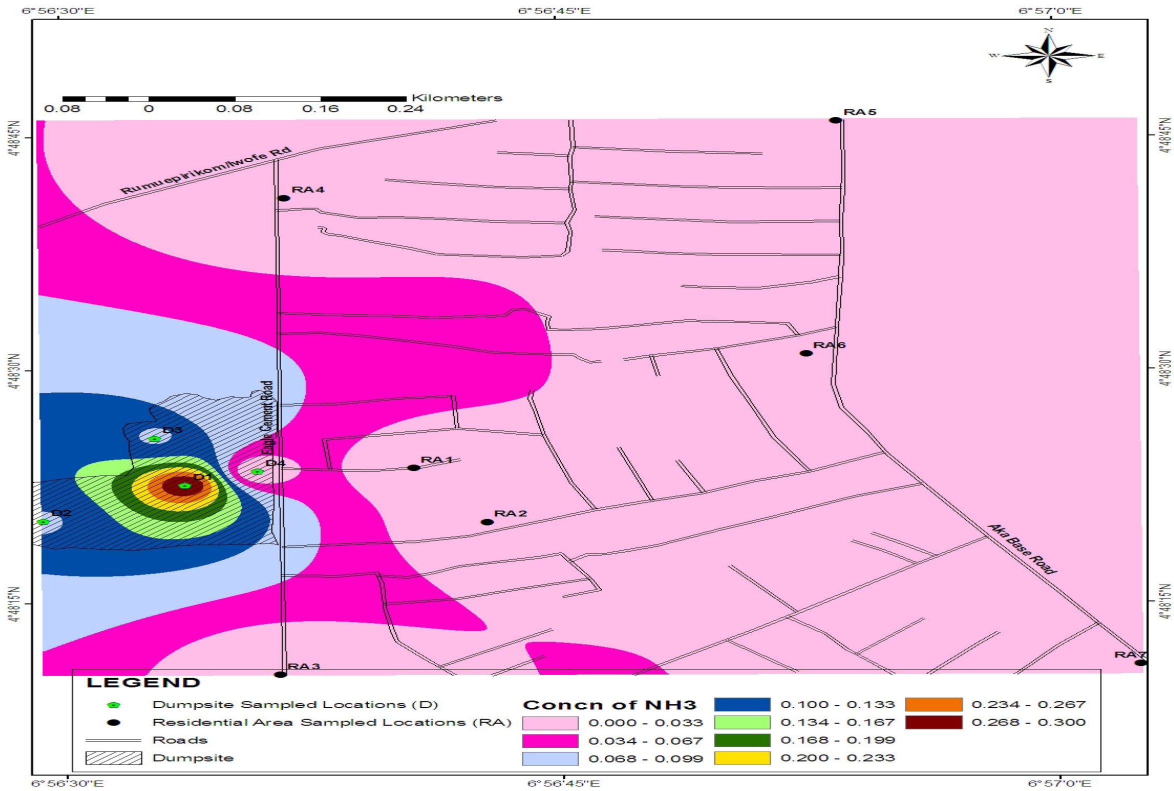

Fig. 4: Spatial Variation of NH_3 from the dumpsite

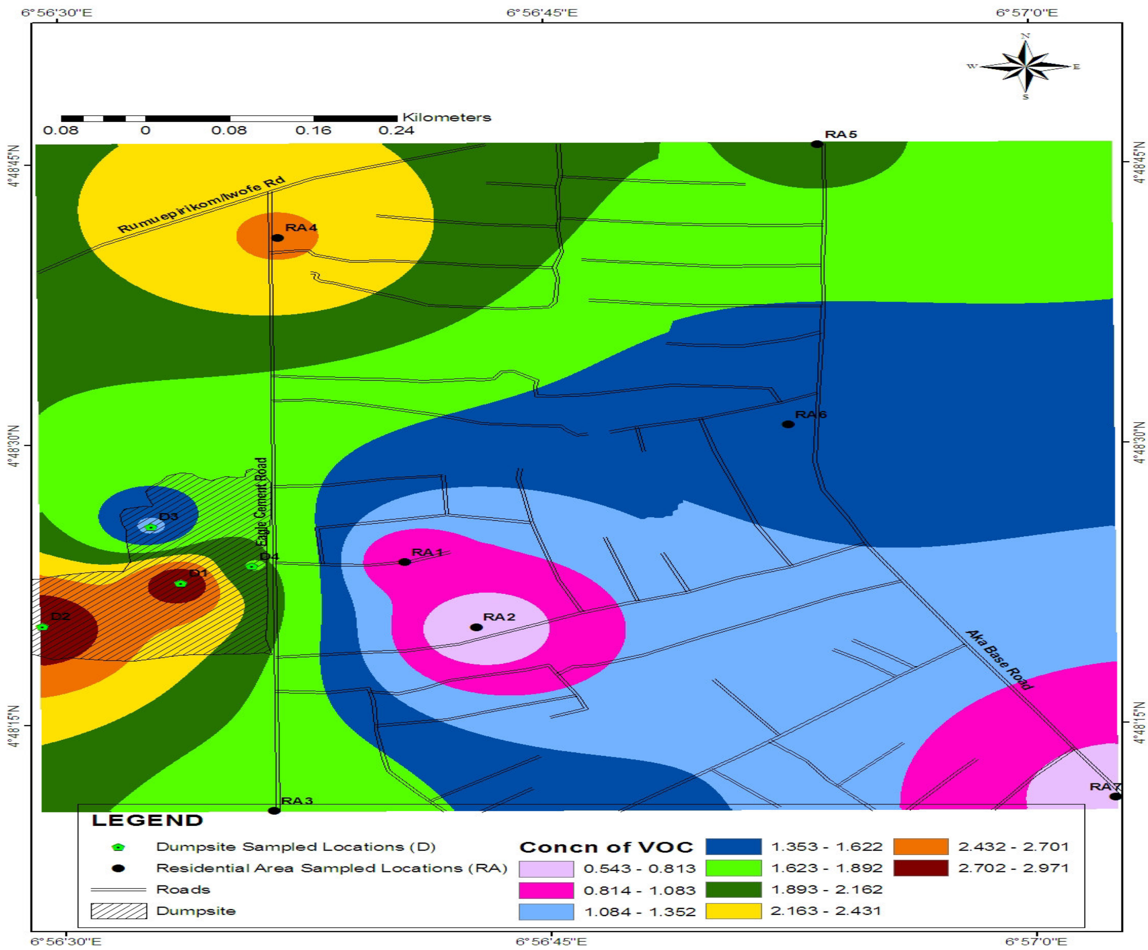

Fig. 5: Spatial Variation of VOCs from the landfill.

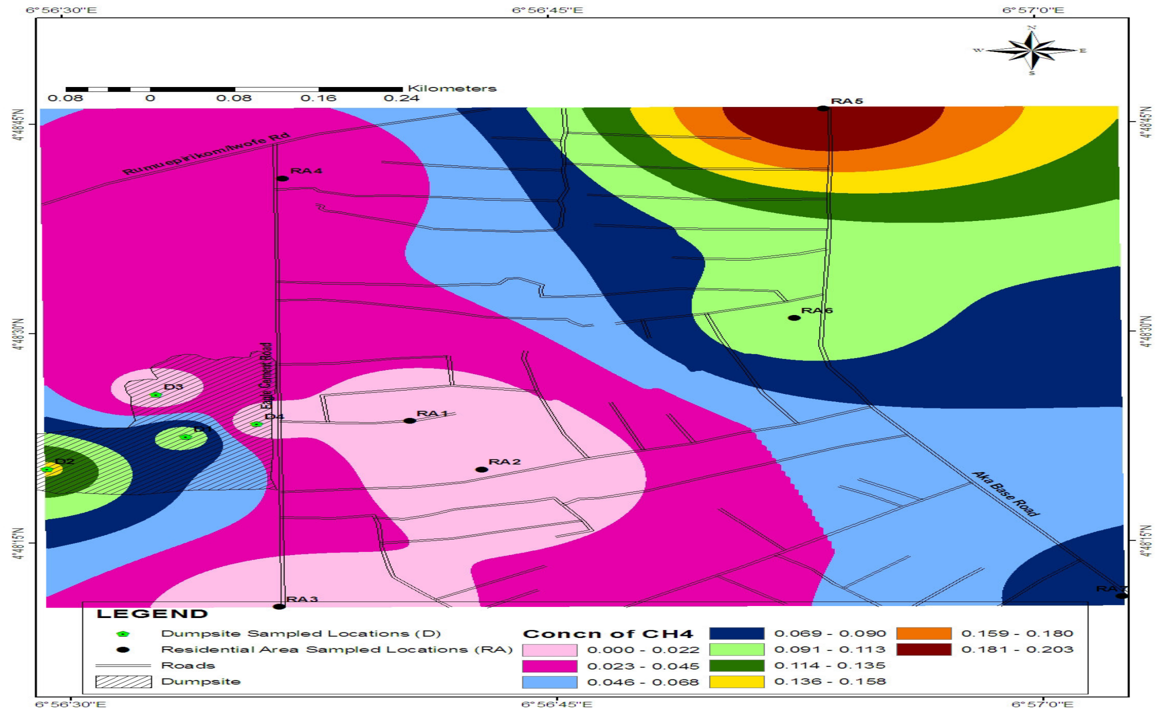

Fig. 6: Spatial Variation of CH_4 from the landfill.

5. Recommendation

The landfill site in Rumuolumeni is discovered to have been a source of LFG emission which has migrated into the high density residential areas posing serious health challenge in the study area, it is therefore recommended that:

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.

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