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Some Environmental Impacts of Acid Rain Around a Tropical Landfill : A Case Study of Avu Landfill and Environs, Owerri, Southeastern Nigeria.

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Abstract

The concentrations of the hydrogen ion (pH) of groundwater, surface and rain water samples obtained around Avu landfill and environs as well as the ambient air quality around the landfill are discussed. The result of the pH analysis indicates that except for Oforola with a mean pH value of 5.60, the pH values of rain water obtained from other locations around the landfill and environs were below 5.60 thus indicating acid rain deposition. The pH values of groundwater and surface water samples obtained around the landfill and environs variy from 4.8 to 6.20 and thus do not conform with World Health Organization WHO, (2006) drinking water standard. .The ambient air quality investigation at the Avu landfill shows that the overall mean monthly concentrations of NO_2 and SO_2 are 0.53ppm and 95.17 ppm respectively ; these values do not conform with Unites States Environmental Protection Agency (USEPA) 2008 ambient air quality standard and thus contributes significantly to the acid rain deposition in the studied area.

Key words: Acid rain, landfill, pH, ambient air quality

1.0 Introduction

The Avu landfill (See Figure 1) is a large waste disposal site in Owerri west, Imo State, Nigeria. The waste dump which receives varieties of waste (non-degradable and bio-degradable) from Owerri metropolis and environs is not a sanitary landfill but rather an ordinary landfill. The landfill which covers an area of about 7.5 Km^2 was first used by the local Communities from 1983 to 1987 (before it became one of the Imo State Environmental Protection Agency waste dump). The quantity of waste disposed at the landfill has been on the increase due to rise in the population of Owerri and environs. The population which was 400,000 and 1,197,000 in 1982 and 1991 respectively has been estimated to rise to over 3,000,000 in 2011 (World Gazetteer, 2010).

The Avu landfill constitute a threat to the immediate environment ; apart from the production of leachate due to infiltration of water into the waste, obnoxious gases (SO_2 , NO_2, CH_4, CO, NH_3, and H_2S) are released following biochemical decomposition of organic materials at the landfill. Gaseous migration from landfills can modify the environment by causing air, soil and water pollution. Case histories of gas migration from landfills have been presented by Mohsen (1975) while the interaction of the various factors that influence gaseous emissions at landfills were described by Farguhar and Rovers (1975).The reaction of some of these gases (such as NO_2 and SO_2) with water to form acid rain has been discussed by Sharon (1988). Postel (1984) defined acid rain as all types of precipitation (rain, snow, hail and fog) with pH value of less than 5.60.

Uma (1984) carried out a chemical analysis of some groundwater and surface water resources of Owerri and its environs and observed that all the measured parameters conformed with the World Health Organization (WHO) 1984 drinking water standard with the exception of the pH values. The pH of the water resources studied (which were located around Avu landfill and environs) varied from 4.90 to 5.85. Ibe and Onu (1999) also carried out a chemical analysis of the same water resources earlier investigated by Uma (1984) and obtained a pH range of 4.36 to 6.20 thus confirming the acidic nature of water resources around Avu landfill and environs. Ibe and Onu (1999) further observed that the top soil at the Avu landfill has an average pH of 4.0.

The problems associated with acid rain call for adequate protection of our air, water and soil resources. The starting point is constant pH

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monitoring which can be achieved through chemical analyses and constant ambient air quality investigation. The present studies therefore examine the pH of the groundwater, surface water and rain water around Avu landfill and environs as well as the ambient air quality at the landfill. The pH would give a clue to the consistent acidic nature of water resources around the landfill since it came in use in 1983. Since there are no reported sulphur- bearing minerals in the area, the ambient air quality remains a major investigation that would unravel the cause of acid rain in the area.

2.0 Climatic Conditions

The Avu landfill is located within the equatorial belt of Nigeria. The mean monthly temperature of the area ranges from 25 to 28.5 °C while the mean annual rainfall is about 2.500 mm most of which fall between the months of May and October (National Root Crop Research Institute, 2008). The rainy period (May-October) is characterized by moderate temperature and high relative humidity. The months of November to April have scanty rainfall, higher temperatures and low relative humidity (Uma, 1984). The wind direction in Owerri area and environs (of which the studied area is a part) is mainly South-West, North-West and West. However, the South-West wind direction is the strongest (Anyanwu and Ogueke, 2003).

3.0 Geology and Hydrology

The study area is underlain by the Benin Formation (a major stratigraphic unit in the Niger Delta basin (See Figure 2). The Benin Formation consists of friable sands with intercalations of shale/clay lenses of Pliocene to Miocene age. The formation contains some isolated gravels, conglomerates and very coarse sands. The average thickness of the formation in the studied area is about 800 m while the average depth to water table is about 18 m (Avbovbo, 1978).The elevation of the study area is about 65 m above sea level. The study area is drained by Rivers Otamiri and Oramiriukwa (See Figure 1). The rivers serve both as domestic and commercial water supply sources; they are also used for fishing, recreation , sand extraction activities, tourism and research..

4.0 Materials and Methods

The pH of the groundwater, surface and rain water were determined using digital pH meter; the elevation of the study area was determined using the Global Positioning System (GPS). Water samples (from rain, surface and subsurface sources) were obtained at the various sampling locations (Figure 1) on monthly basis commencing from April, 2008 and ending in September, 2008.

The ambient air quality at the landfill was investigated using Growcon gas analyzers with digital read out. The gas analyzers were used to measure the concentrations of the gaseous emissions {NO_2, SO_2 CH_4, CO, NH_3 and H_2S) at landfill in parts per million (ppm) on monthly basis. The sensitivity of the equipment is about 0.01 ppm. The air quality analyses was carried out between the months of April, 2008 and September, 2008. The wind direction in the studied area provided a useful guide in measuring the gaseous emissions at points of maximum concentrations.

5.0 Results and Discussion

The results of the hydrogen ion (pH) concentrations of rain water obtained around Avu landfill is shown in Table 1 while those of groundwater and surface water samples are shown in Table 2. The result of the ambient air quality at the landfill is shown in Table 3.

5.1 Hydrogen Ion (pH) Concentrations of Water Resources

The mean pH of the rain water (See Table 1) obtained at various locations (Figure1) around the landfill and environs ranged from 5.20 to 5.60 with an overall mean of 5.16. Except for Oforola (with mean pH of 5.60), all the mean pH values obtained from other locations were less than 5.60 thus signifying acid rain deposition. The impact of the acid rain on the water resources (hand dug wells, borehole and surface water) of the study area is indicated by their mean pH values which ranged 4.80 to 6.20 with an overall mean of 5.50 (Table 2). Uma (1984) and Ibe and Onu (1999) had earlier observed the acidic nature of water resources around Avu landfill. Ibe and Onu (1999) also found that the pH of the top soil at Avu landfill is about 4.0. The pH of the rain water in the

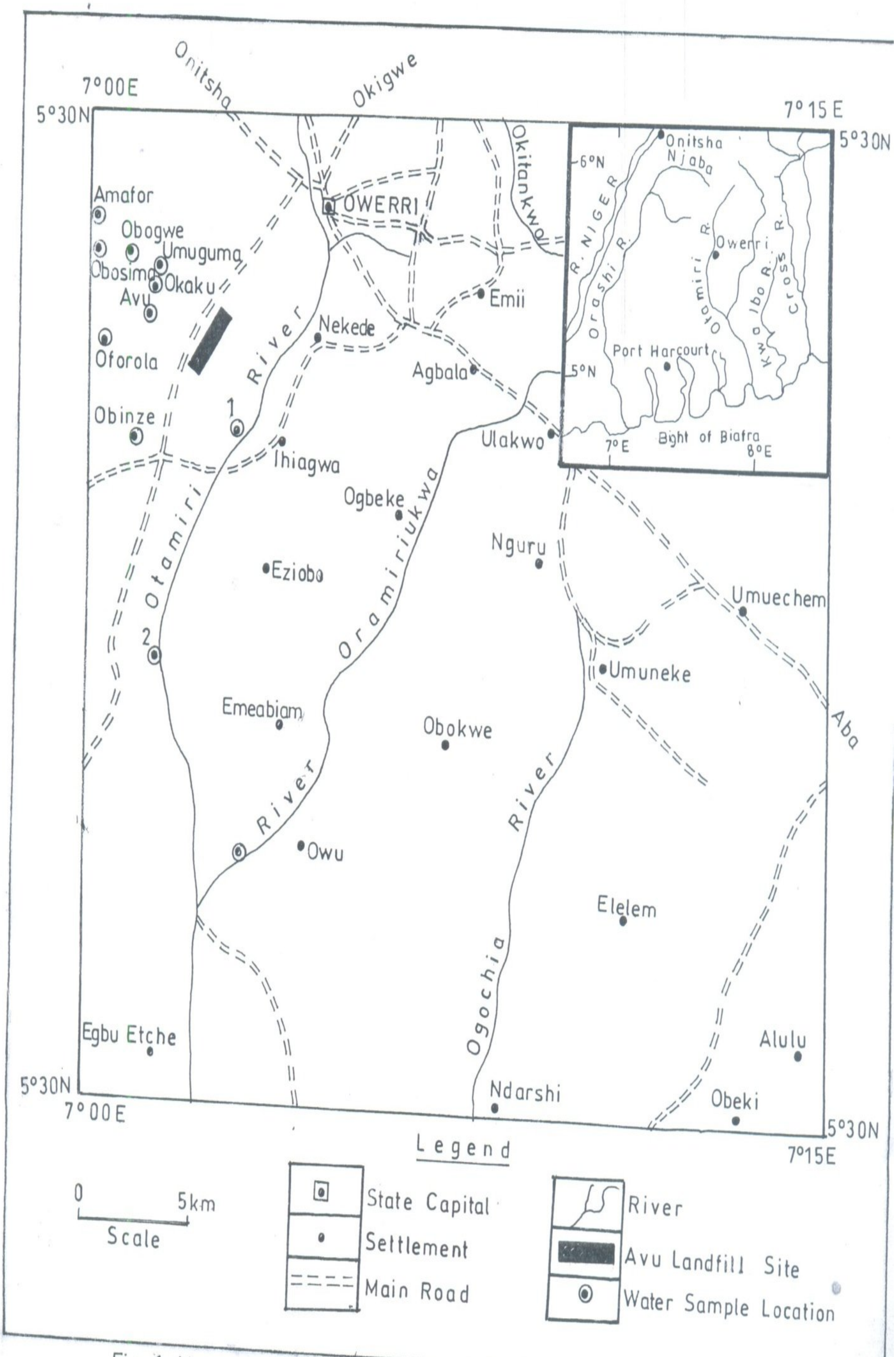

Fig. 1: Map of the study area showing sample locations

Table 1, Result of pH analysis of rain water around Avu landfill and environs

SAMPLE LOCATIONS	MEAN pH VALUES (April, 2008- Sept. 2008)	REMARKS
Avu	5.30	Acid rain
Okuku	5.40	Acid rain
Amafor	5.45	Acid rain
Umuokanne	5.50	Acid rain
Obinze	5.55	Acid rain
Obosima	5.20	Acid rain
Obogwe	5.30	Acid rain
Oforola	5.60	Acidic
Umuguma	5.46	Acid rain
Overall mean	5.16	Acid rain
pH of acid rain (Postel, 1984)	< 5.60	

studied area is a major contributor to the acidic nature of the water resources of the area.

Acid rain constitutes a variety of threat to the environment which includes damage to forests, fish and other living things, materials and human health. Acid rain can also reduce how far and how clearly one can see through the air, an effect known as visibility reduction. Certain crops like vegetables, legumes and some varieties of fruits do not thrive under highly acidic soil. Aquatic plants such as water hyacinth grow best between pH of 7.0 and 9.20 (Bourodemos, 1974). As acidity increases, submerged aquatic plants decreases and deprives water fowls of their basic food source. At pH of 6.0 , freshwater shrimp cannot survive; at pH of about 5.50, bottom-dwelling bacteria decomposer begins to die leaving un-decomposed leaf litter and other organic debris to collect at the bottom. This deprives planktons their food resulting in their death. As un-decomposed organic leave litter increases due to the loss of bottom- dwelling bacteria, toxic metals such as aluminums, mercury and lead within the litter are released. These toxic metals are inimical to the human health (Bourodemos, 1974). For instance, excessive concentration of Aluminum (> 0.2mg/l) in water causes potential neuro-degenerative disorders while lead (when in excess of 0.01mg/l) causes cancer and interference with vitamine D metabolism; it also affects mental development in infants and it is toxic to the central and peripheral nervous systems. People who ingest mercury in tainted fish suffer serious health problems; the concentration of mercury in excess of 0.001mg/l affects the kidney and central nervous system (Bourodemos, 1974). Below pH value of about 4.50, all fish will die (Bourodemos, 1974). Acidic water attacks metals and destroys the paints of vehicles and civil structures (buildings and over head bridge) as well as statues, sculptures and monuments that constitute part our cultural heritage.

On the basis of the pH values of the surface and subsurface water resources of the studied area, pre-use treatment with sodium bicarbonate is recommended; for the acid rain, the practice and usage of direct precipitation catchment should be discontinued. Since 80% of the groundwater in the study area is from hand dug wells (due the shallow water table of the area), water abstraction from deeper wells should be encouraged. Climate change, poor land use and gaseous emissions (from landfills, flow stations, refineries, volcanoes and industrial areas) are major sources of acid rain. However,in the studied area, gaseous emissions from Avu landfill are the two main sources of the acid rain deposition

Table 2: Results of pH analysis of some hand-dug wells, boreholes and surface water samples around Avu Landfill and environs

SAMPLING LOCATIONS	pH (after, Uma, 1984)	pH (after, Ibe and Onu, 1999)	pH (Ahiarakwem, 2008)
Avu hand-dug well	5.50	5.32	5.29
Okuku hand-dug well	5.80	5.30	5.20
Amafor hand-dug well	5.85	5.70	5.50
Umuokanne borehole	4.90	5.20	5.10
Obinze borehole	5.30	6.20	6.00
Otamiri River !& & 2)	5.30	5.40	5.35
Oramiriukwa River			5.50
Obosima hand-dug well		4.36	4.80
Obogwe hand-dug well		4.90	5.20
Oforola hand-dug well		6.10	5.80
Umuguma hand-dug well			6.10
Mean	5.44	5.39	5.44
WHO (2006)	6.50-9.00	6.5-9.0	6.5-9.00

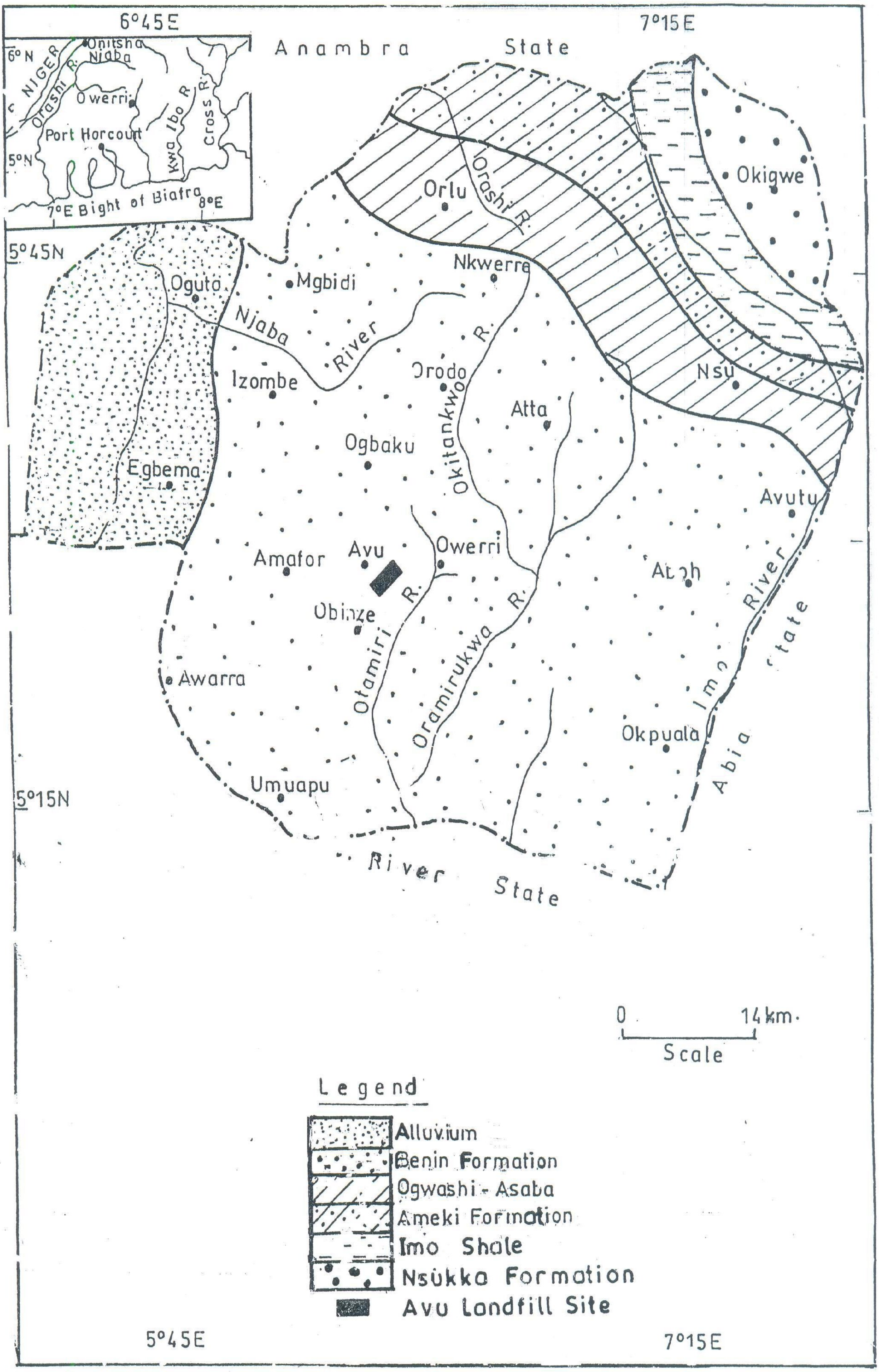

Fig. 2 : Geologic map of Imo State Showing the study area

Table 3: Gaseous emissions at Avu landfill

	Concentrations (ppm)					
Monthly mean values (2008)	**CO**	**NO_2**	**SO_2**	**H_2S**	**NH_3**	**CH_4**
April	3.00	2.00	99.00	3.20	2.00	4.00
May	8.00	0.40	39.00	1.30	4.00	5.50
June	6.00	0.30	93.00	1.50	3.00	6.00
July	4.00	0.20	120.00	2.00	1.00	6.80
August	6.00	0.25	100.00	1.90	1.00	10.00
September	14.00	0.20	120.00	0.60	0.40	8.00
Overall mean	6.83	0.56	95.17	1.75	1.90	5.04
USEPA limit 2008	<35.5 ppm	0.155 ppm	0.145 ppm	-	-	-
Averaging period	1hr	24hr	24hr	24hr	1hr	24hr

in the area.

5.2 Ambient Air Quality

The mean monthly concentrations of Nitrogen dioxide (NO_2) ranges from 0.25 to 2.00 ppm while that of Sulphur dioxide (SO_2) varies from 39.00 to 120.00 ppm. The mean monthly concentration of Carbon monoxide (CO) varies from 3.00 to 14.00 pm while Ammonia (NH_3) varies from 0.40 to 4.00ppm. The mean monthly concentrations of Hydrogen sulphide (H_2S) ranges from 0.60 to 3.20ppm while that of methane (CH_4) ranges from 4.00 to 10.00ppm. Except for NO_2 and SO_2, the concentrations of other measured gaseous constituents (CO, H_2S, NH_3 and CH_4) were in conformity with United States Environmental Protection Agency (USEPA) 2008 ambient air quality standard (See Table 3).

NO_2 reacts with water to form two strong acids (Nitrous and Nitric acids) thus contributing to acid rain formation. Apart from acid rain formation, NO_2 also produces ground level ozone or photochemical smog by reacting with volatile organic compounds (VOCs) in the presence of heat. The mean monthly concentration of NO_2 at the Avu landfill is in excess of USEPA (2008) air quality limit of 0.155ppm and thus contributes significantly to acid rain formation in the area.

The concentrations of SO_2 is also in excess of USEPA (2008) air quality limit of 0.145 ppm (Table 3) and thus is a major contributor to the acid rain problem in the studied area. SO_2 also reacts with water forming two strong acids (Sulphrous and Sulphuric acid).

It should be noted that SO_2 and acid rain accelerates the decay of building materials and paints including irreplaceable monuments, statues and sculptures that are part of cultural heritage.

CO also contributes indirectly to the formation of acid rain. CO is first oxidized to form Carbon dioxide (CO_2) which then reacts with water forming Carbonic acid(H_2CO_3).

Apart from contribution to acid rain formation, prolonged low level exposure to CO also diminishes visual perception, manual dexterity and ability to perform intellectual tasks (Lee, 1985). The simultaneous formations of the above mentioned acids can have great impact on the water and soil resources of an area.

6.0 Conclusion

The acid rain around Avu landfill and environs has resulted in the increase in the acidity level of the surface and subsurface water resources of the studied area. The pH of the surface and subsurface water samples obtained around the landfill and environs were not in conformity with WHO (2006) drinking water standard and thus constitute a threat to both humans and animals. The pH of the surface resources (which varies from 5.35 to 5.50) in the study area can result in an increase in organic debris at their bottom and this can result in the release of toxic metals (Aluminum, Mercury and Lead) into the water. The acid rain also has serious impact on the soil around the landfill. It should be noted that the mean pH of the soil is about 4.0 (Ibe and Onu, 1999). The acid rain also constitutes a threat to paints of vehicles, buildings, statues, sculptures and irreplaceable monuments that are part of cultural heritage. NO_2 and SO_2 are the major contributors of acid rain in the study area; there are however, minor contributions from CO and other sources such as forests and vehicles.

Rain water (direct precipitation) catchment and usage should be discontinued in the studied area. Pre-use treatment of the surface and groundwater in the area using sodium bicarbonate is recommended so as to raise the pH to acceptable level. The Avu landfill (which is simply an ordinary landfill) should be replaced by a sanitary landfill which would be equipped with scrubbers that would absorb the gases released at the landfill.

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