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Alteration of Organic Matter by Gas Flaring Activity: A Case Study of Utorogu Community in Niger-Delta, Nigeria

Ejelonu Benjamin Chibuzo
Department of Chemical Sciences, Adekunle Ajasin University, P. M. B. 001, Akungba-Akoko, Ondo State, Nigeria

Abstract
The Niger-Delta area of Nigeria is endowed with petroleum resources. However, her environment has been degraded through oil exploration activities. The soil has been exposed to serious varying degrees of heat effects due to the flaring of residual gases at the different gas plants/flow stations situated within the various oil producing communities. Several literatures have revealed that heat impacts negatively on soil properties, such as organic matter, total available pools of organic carbon, nitrogen, etc. Although some studies exist on the pollution status of the region, the situation of a number of communities has not been investigated. This study therefore, examined a three year (1998-2000) profile of organic matter, organic carbon, total soil nitrogen and carbon-to-nitrogen ratio as a function of distance from flaring epicenter and depth from soil surface within the Utorogu community using standard analytical techniques. Soil samples were collected during the dry and wet seasons at variable distance away from the flaring epicenter (downwind)- 20 m, 200 m, 1000 m and 5000 m respectively; and at 0-15 cm and 15-30 cm depths from the soil surface. The results of the study show variations with depth, season and distance. Across the various years, distance and depths, the mean values of the determined soil properties range as follows; soil organic matter: {Below detection limit-3.63% and 0.66-2.13%; Below detection limit-3.68 and 0.27-2.31; Below detection limit-7.20% and 0.10-2.18%}; organic carbon: {Below detection limit-2.11% and 0.13-1.22%; Below detection limit-2.17% and 0.07-1.30%; Below detection limit-2.20% and 0.11-1.28%}; total nitrogen: {Below detection limit-0.43% and 0.02-0.24%; Below detection limit-0.48% and 0.11-0.36%; Below detection limit-0.51% and 0.09-0.31%}; and carbon-to-nitrogen ratio: {Below detection limit-5.00 and 4.50-6.50; Below detection limit-6.58 and 3.50-6.49; Below detection limit-5.38 and 2.75-5.80}, for both the dry and wet seasons, and for the years 1998, 1999 and 2000 respectively. This study reflects potential environmental impacts of gas flaring within a typical oil producing community.
Keywords: Niger delta area, Petroleum resources, Oil producing communities, Downwind, Below detection limit

1. Introduction

Anywhere, the petroleum industry is a power generating entity. When significant deposits of oil were discovered in the 19th century, this fossil fuel appeared to offer limitless source of energy to drive development. While the oil and the gas it supplies provide multiple benefits to human society, every stage in the life cycle from exploration to use can have harmful impacts on our health and environment (UNEP, 1997). During the process of preparing crude oil for export or local consumption, effluents and gas are removed from the oil. Residual gases are generally flared at the plant site. Nigeria flares more gas than any other country in the world (UNEP 1997). Seventy six percent (76%) of the natural gas that is a by-product of oil extraction is being flared in Nigeria, Saudi Arabia 20%; Iran 19%; Mexico 5%; Britain 4.3%; Algeria 4%; Former Soviet Union 1.5%; U. S 0.6%; Netherlands 0% (Moffat and Liden, 1995). Giwa et al., (2014), stated that enormous heat is part of the products of gas flaring, which causes health problems among others. This was in agreement with the report of Egbuna, (1989), who had observed that harmful environment heat related effects are obvious as the surrounding soil gets scorched, vegetation and farmlands look parched, villagers complain of an illness colloquially referred to as “internal heat” which may not be unrelated to the cumulative effect of long exposure to radiant heat from gas flared. Also, Orimogunje et al., (2010), showed that effects of heat from gas flaring on crops include stunted growth, defoliation of leaves, wrinkling of leaves, withered leaves and premature ripening of fruits. Also, gas flaring is reported to destroy vegetation, wild life and cause ecological destabilization (Ologunorisa, 2001; Abdulkareem, 2005; Odjugo and Osemwenkhae, 2009). Soil quality (SQ) is rapidly joining air and water quality as a major goal of natural resource management. Soil quality describes the capacity of a soil to partition water, cycle nutrients, sequester carbon, protect groundwater, support vegetation, and assimilate waste. Human management that results in either soil degradation or enhancement can tremendously alter SQ through changes in biological, chemical and physical soil properties.

This study examined the alteration of soil properties (organic matter, total available pools of organic carbon, nitrogen, and carbon-nitrogen ratio) by gas flaring activity using Utorogu Community in Niger-Delta, Nigeria as a case study.

2.0 Materials and Methods

2.1 Site Description

The Niger-Delta area of Nigeria is endowed with petroleum resources. Daily a lot of oil prospecting and processing activities are carried out with concomitant release of effluent, gaseous wastes (resulting from the flaring of residual gases) into the environment, and the improperly handling of these wastes with time can result into pollution of the environment in the vicinity of the oil installations and beyond. The inhabitants of the Niger Delta are farmers and fishermen. They live off of the land and are dependent upon the productivity of that land for survival. Destruction of farmland by oil/gas prospecting and processing activities has pushed tens of thousands of people to the brink of starvation and prevented income generation from that land. Fisheries, farms, mangrove swamps, rain forests and water have all suffered severe damage from the impacts of petroleum exploration and energy consumption on these communities, threatening the survival of the people of the Niger Delta.

The Utorogu community belongs to the Ughelli-North Local Government Area of Delta State, Nigeria. It houses the Gas Plant- a natural gas processing plant, which processes natural gas and associated crude oil. Ughelli-North falls within latitude 5 $^{o}30^{1}$N and longitude 5 $^{o}59^{1}$E.

2.2 Analytical Procedures

Soil samples were collected four times over dry and wet seasons. The dry season samples consisted of samples collected in February and March (composite sample), while composite samples of August and September gave the wet season samples. Samples were collected downwind at distances 20 meters, 200 meters, 1000 meters and 5000 meters respectively away from the flare site to determine the impact of the heat generated by gas flaring on soil qualities with distance. Soil samples were collected at Utorogu gas Plant Station using soil auger. The soil sampling was done at 0-15cm and 0-30 cm depth respectively. Organic carbon and matter were determined by the Method of Walkley and Black (Walkley and Black, 1934 and Anderson and Ingram, 1993), while total nitrogen was determined using the Micro-Kjedahl Method (Jackson, 1964).

3.0 Results and Discussion

3.1 Results

The results obtained on the analysis of the soil samples for the soil quality parameters, namely, organic matter, organic carbon, soil total nitrogen and carbon-nitrogen ratio are presented in Figures 1-4. The results obtained for the determined soil quality parameters showed variations with depth, season and distance.

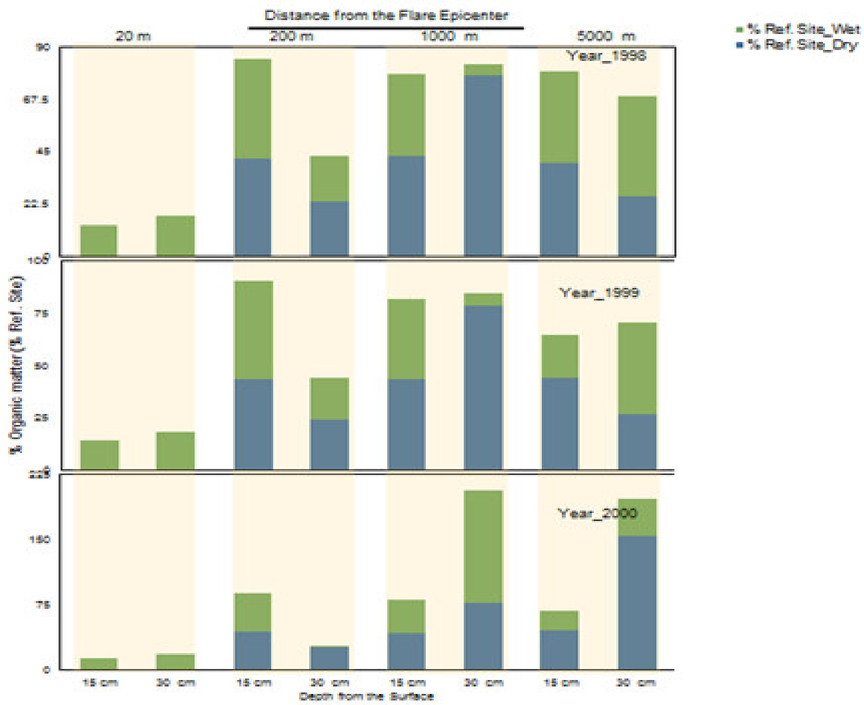
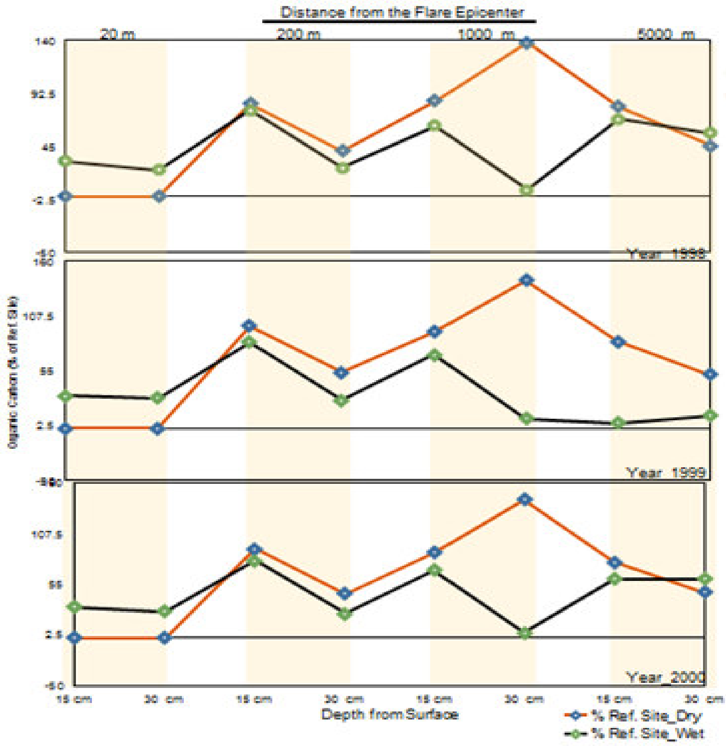


Figure 1: The Organic Matter Composition of Soil Samples as a Function of Distance from Flaring Epicenter and Depth from Soil Surface



Figur 2: Three-year Profile of Organic Carbon as a Function of Distance from Flaring Epicenter and Depth from Soil Surface

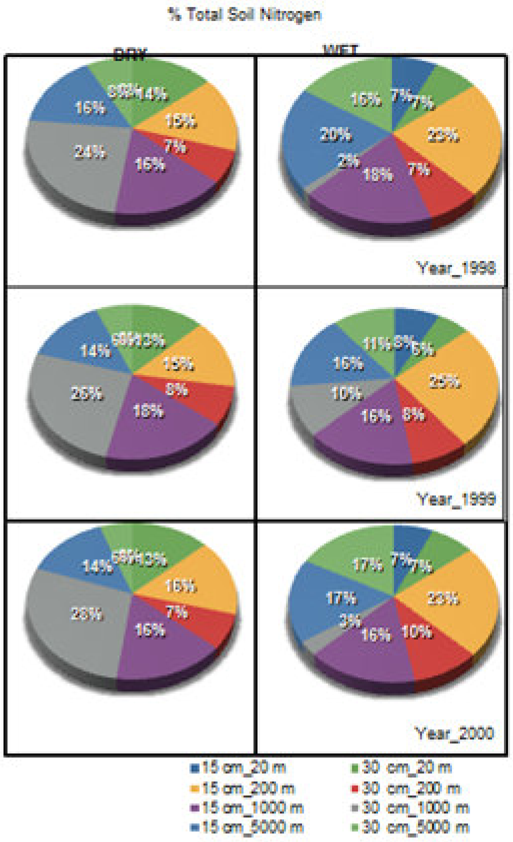


Figure 3: Three-year Distribution of Soil Total Nitrogen as a Function of Distance from Flaring Epicenter and Depth from Soil Surface

Table 1.0 Carbon-to-Nitrogen ratio of soil samples

Depth (cm)	DRY_C/N ratio (normalized with Ref. Site)	WET_C/N ratio (normalized with Ref. Site)	Distance from Flare Epicenter_Year 1998
15 cm	BDL	1.84	
30 cm	BDL	0.97	20 m
15 cm	1.93	1.89	
30 cm	1.92	1.06	200 m
15 cm	1.92	1.95	
30 cm	1.79	1.4	1000 m
15 cm	1.86	1.95	
30 cm	1.83	1.08	5000 m

Depth (cm)	DRY_C/N ratio (normalized with Ref. Site)	WET_C/N ratio (normalized with Ref. Site)	Distance from Flare Epicenter_Year 1999
15 cm	BDL	1.73	
30 cm	BDL	1.17	20 m
15 cm	2.26	1.4	
30 cm	2	0.75	200 m
15 cm	1.72	1.96	
30 cm	1.66	1.39	1000 m
15 cm	2	1.89	
30 cm	2.41	1.26	5000 m

Depth (cm)	DRY_C/N ratio (normalized with Ref. Site)	WET_C/N ratio (normalized with Ref. Site)	Distance from Flare Epicenter_Year 2000
15 cm	BDL	1.07	
30 cm	BDL	0.58	20 m
15 cm	2.05	2.08	
30 cm	1.97	0.97	200 m
15 cm	1.96	4.51	
30 cm	1.57	2.8	1000 m
15 cm	1.99	2.19	
30 cm	1.9	1.67	5000 m

BDL = Below Detection Level

Figure 4: Carbon-to-Nitrogen Distribution of Soil Samples as a Function of Distance from Flaring Epicenter and Depth from Soil Surface

3.2 Discussion

Fire-induced quantitative and qualitative changes of soil organic matter (SOM) have been comprehensively reviewed by Gonzàlez-Pérez et al., (2004) and Knicker, (2007). They posited that high temperatures could possibly remove some organics from the upper few centimetres of the mineral soil. SOM generally contains approximately 56% Organic Carbon. It is the soil organic matter that provides nutrients to the soil life and plants, increased water retention and reduced draft requirements for tillage. SOM helps stabilize soil particles, thus decreasing erosion. It also improves soil structure and workability, enhances aeration and water penetration, and increases water-holding capacity, and stores and supplies nutrients for growth of both plants and soil micro-organisms. Too little SOM results into poor soil structure, poor aggregate stability, inefficient cycling of nutrients; while too much of it (as result of excessive manure applications), results into nitrate leaching, phosphorus runoff. SOM could also affect the mobility of metals from soil to plants. Typical amounts of SOM in soil vary from<1% in ordinary soil to 90% in bogpeat soil and between1% to 20% in mineral soils (Radojevic and Bashkin, 1999). SOM values obtained in the soil samples are within the range of ordinary soil to mineral soil (Figure 1). The organic matter mean results showed that gas flaring has significant negative impacts on the organic matter composition of the soil samples collected from within the studied community; the distance most adversely affected being the distance, 0-20 m from the flaring epicenter. This finding is in good agreement with the works of Okeke and Okpala, (2014); Kumar et al., (2013); Ogidiolu, (2003); and Alakpodia, (2000) respectively, who in their respective studies confirmed the negative impacts of gas flaring/heat on soil nutrients. According to Alakpodia, (2000) and Ogidiolu, (2003), the decline in the mean value of organic matter is brought about by intense heat, which affects the process of its formation. They also observed an increasing pattern in their results with increasing distance from the flaring epicenter. For both the dry and wet seasons, the mean organic matter values of soil samples collected from the Utorogu Gas Plant vicinity are less than those of the of the Reference Locations (4.63-5.22%-dry season and 4.86-4.96%-wet season), suggesting that the soil samples from the studied communities are not as rich in plant nutrients as the soils from the Reference Locations.

The mean organic carbon % of the soil samples analyzed range from high, moderate, low to very low (Oklebo *et al.*, 1993). Soils containing less than 1% organic carbon are low in organic matter (Odu *et al.*, 1994). Soil organic carbon content is said to reduce the heat capacity and thermal conductivity of soil, which suggests that soil samples with low organic carbon will not possess great ability to reduce soil heat capacity and thermal conductivity (Kalita et al., 2012). The mean values of percentage organic carbon at the distance of 0-20 m from the flaring epicenter were found mostly to be at below detection limit level; after which it steadily increases with distance away from the flaring epicenter (Figure 2). The observed results from this study was supported by the findings obtained by Kalita et al., (2012), in their study on the effect of natural gas flaring (light pollution) on soil health/environment of paddy field of Assam near the vicinity of oil wells under Oil India Limited**.** They found that as the distance increases away from the flaring epicenter the value of soil organic carbon contents increase.

The determination of total nitrogen is of interest because it gives an indication of the reserves of organic nitrogen capable of undergoing mineralization under suitable condition to give mineral nitrogen (NH_4^+, NO_3^-), which are the available forms of nitrogen in soil and typically constitute only about 2% or less of the total nitrogen. The mean total nitrogen % of the soil samples analyzed range from high, moderate to low (Oklebo *et al.*, 1993). Nitrogen is required by plants to make amino acid, proteins, enzymes and the light capturing molecules, chlorophyll (Follet et al., 1985). The results of the soil samples showed the mean values of total nitrogen to range between below detection limit (within 0-20 m distance)-0.51% (from beyond 0.20 m distance). The values were found to increase with distance from the flaring epicenter (Figure 3). These findings confirm the reports of Kalita et al., (2012) and Okeke and Okpala, (2014), who in separate studies reported that the mean values of nitrogen in soil samples collected from the vicinity of flaring pits were significantly different from those of the control samples. They concluded that the percentage mean total nitrogen values increased with distance from the flaring epicenter, which might be due to increase in soil temperature within the flaring epicenter which lowers down the availability of nitrogen. The mean total nitrogen % of soil samples from the Reference Locations is found to be relatively above those of the studied soil samples.

The C/N ratio values obtained for the soil samples are generally low (Figure 4). Most agricultural soils have a C/N ratio of about 10 -12 and the higher the C/N ratio is above this value the greater are the chances of nutrients being immobilized by micro-organism and rendered unavailable to plants (Odu et al, 1994), suggesting that nutrient immobilization by micro-organisms will be less important a factor within these communities. Uzoho et al., (2007), reported that C/N ratio relates to soil organic matter decomposition and nitrogen mineralization, and a C/ N ratio of 20, where C and N are the available quantities, has been widely accepted as the upper limit at which the danger of robbing the soil of nitrogen (nitrogen mineralization) may not exist.

4. Conclusion

This study has revealed that gas flaring activities have significant negative impacts on the soil properties analyzed for, especially those within the immediate vicinity of the flaring epicenter. Also, the mean values of the analyzed soil quality parameters increased with increasing distance away from the flaring epicenter, suggesting that a stoppage to gas flaring can bring about a general improvement to the overall quality of soil samples within the oil producing community, and as well as in other oil producing communities where gas flaring activities are still going on to-date. Again, the information thus generated from this study could serve as a baseline data to assess how environmentally friendly the activities of the oil producing company has remained over the years within the Utorogu oil producing community in the Niger-Delta area of Nigeria.

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