

Changes in Fungal Population and Soil Physico-Chemical Properties Following Gas Flare in Oloma Community, Bonny Local Government Area

Ukoima, H.N; Chukunda, F.A; Ngerebara, D.O and Halliday, S
Department Of Forestry And Environment, Faculty Of Agriculture,
Rivers State University Of Science And Technology,
Nkpolu-Oroworukwo, Port Harcourt
Email: rijmanconsult@yahoo.com, Ukoima.hudson2@ust.edu.ng

ABSTRACT

*This study was designed to investigate changes in fungal and soil properties following gas flare in Oloma community, Bonny Local Government Area of Rivers State, Nigeria. Standard procedures were used for soil analysis. Fungal population was ascertained using conventional method such as wet- blotter paper and compound microscope. All experiments were in three replicates. Soil samples were collected at 50m, 100m, 150m and 1km away from the flared site. The result on fungal population showed that Counts of heterotrophic fungi were highest (0.41×10^5 cfu/ml) at 150 meters and lowest (0.03×10^5 cfu/ml) at 50 meters. The most prevalent fungi which occurred at the vicinity of flare were; *Fusarium moniliforme* (2), *Rhizopus stolonifer* (7), *Penicillium sp* (6), *Aspergillus niger* (3) and *Candida sp* (1). *Rhizopus stolonifer* was the most prevalent fungus. *R. stolonifer* had the highest percentage occurrence (36.8%) followed by *A. niger* (33.3%). The result on the soil physical properties showed that soil type was sandy in all distances from the flared point. Clay (9.4%) was highest at 1km and lowest at 50m away from the flared. pH was 4.0 at 50m from the flared point While at 1km pH was 5.90. Sand and clay were significant at $P < 0.05$. The findings on soil chemical properties indicated that total nitrogen (0.001%) was the least nutrient that occurred at 50m and the highest was phosphorous (6.44mg/g). At 100m the least nutrient was total nitrogen (0.006%) and the highest sodium (5.22cmol/kg). Phosphorus was highest (2.76 mg/kg) at 150m and 1km respectively. Similarly, total N was lowest (0.006%) at 150m and 1km respectively. Potassium, Sodium and Total carbon were all significant ($P < 0.05$) in all distances. This study has shown that gas flare has effect on fungal population and soil physico- chemical properties at the flared site.*

Keywords: Gas flare, Soil physico- chemical properties, fungal population, percentage occurrence

Introduction

Flaring and venting of natural gas in most developed countries occur as a safety measure to dispose of gas during emergencies or during the breakdown of machineries (Gerner *et al*, 2004; World Bank, 2002). In developing countries, flaring and venting is practiced because it is cheap and there is lack of the technology needed to harvest or re-inject gas (Edino *et al*, 2010; Worila, 2002). A total estimated amount of 160 Billion Cubic Meters (BCM) of gas was flared in 2004, of which Nigeria flared over 14%, ranking second only to Russia among the top twenty gas flaring countries (Elvidge, *et al*, 2009; World Bank, 2007). Globally, lack of efficient regulatory framework, inaccessibility to domestic and international markets and huge finances to undertake gas flaring reduction projects are the main reasons for the continuous flaring of gas (World Bank, 2002). However, in Nigeria, all these reasons seem to be true in addition to inadequate capabilities and overlapping responsibilities of government institutions, unclear operational procedures and political instability and corruption (Gerner *et al*, 2004; International Conservation Fund (ICF), 2006; Omakaro, 2009 and Ishione, 2004). Gas flaring has been ongoing since the discovery of crude oil in the late 1950s in Nigeria. Studies have shown that it has grave economic, social and health implications for Nigeria and the world in general, because of its negative environmental impacts and its contribution to climate change (Abdulkareem, 2005; Leahey *et al*, 2001; Oseji, 2007; Ishione, 2004 and World Bank, 2007). Besides, it has been said to affect the physiochemical properties of soil, fungal, bacterial and plant population in flaring vicinity (Abere and Ukoima, 2014; Abdulkareem, 2005 and Atuma and Ojeh, 2013) and decrease chlorophyll content in plants near flare sites (Abdulkareem, 2005; Isichei and Sanford, 1976). Therefore, government needs to help reduce this practice in developing countries by having an appropriate legal, regulatory and financial environment that promotes the utilization of gas (World Bank, 2002; Gerner, *et al*, 2004). Bonny is an area of global importance because of the establishment of the Nigerian liquefied natural gas project (NLNG). Biodiversity conservation is under threat due to the rapid rate of environmental degradation occasioned by oil and gas exploration activities. Furthermore, since the inception of gas flaring in Nigeria, there have

been insufficient empirical studies on its impacts over time on the mangrove. This limited study in addition to low level of environmental awareness of gas flaring impacts in the country, is one of the major reasons the Nigerian Government lacks an efficient gas flaring regulatory policy (Ishione, 2004). It is therefore, necessary to determine the impact of gas flaring on the fungal population and physico-chemical properties of soil in Oloma community in Bonny Local Government Area of Rivers State, Nigeria. This will help to protect the livelihood of the inhabitants of the Bonny people. Beside, this research will provide evidence based information to aid Nigerian government policy and implementation mechanism to tackle gas flaring.

Materials and Methods

Location of Study:

The study was carried out in Oloma, Bonny Local Government Area of Rivers State, Nigeria located at latitude $4^{\circ}26'N$ and longitude $7^{\circ}10'E$ with a total area of 249.27sqm. Bonny has population of 214,983. The area is characterized by heavy rain fall, high temperature and relative humidity. The vegetation is dominated by the red mangrove *Rhizophora racemosa* and *Rhizophora mangle* as well as microbial populations (Ukoima et al, 2014; Ukoima and Umechuruba, 2009a, 2009b; Ukoima and Amakiri, 2009c, 2009d and Ukoima and Wemedo, 2002). In some areas the white mangrove *Avicennia africana* is interspread with *Nypa* palm, hence dominated by mangrove forest system. The area has open coast, sand beaches, intertidal flats and creeks. The low intertidal zone is usually bare of vegetation, with clay, peat and sand deposit (NASRDA, 2005). The area is predominantly salt water, extensive mangrove swamps, tidal flats, influenced by semi-diurnal tidal regime, National Space research and Development Agency, Nigeria (NASRDA, 2005).

Isolation and Identification of Fungi soil samples.

Twenty soil samples were collected within the distance of 50m, 100m, 150m and 1km from the flare point. Pure cultures of fungi were obtained by aseptically transferring representative colonies of different morphological types which developed onto freshly prepared potato dextrose agar plates and incubated at $25^{\circ}C$ for 7 days. The experiment was in three replicates. The fungi which grew out of the tissues were later identified with the help of a stereo-binocular and compound microscopes. Slide preparations of spores were observed on compound microscope. The fungi were identified on the basis of morphological characteristics such as colony form and color, type of mycelium, fruiting bodies and spores (Barnett and Hunter, 1972). The identification of these fungi was done as described by (Barnett and Hunter, 1972; Common Wealth Mycological Institute, 1974).

Determination of Soil Physico-Chemical Properties of the Area

Soil sampling for physico-chemical analysis

Twenty soil samples were collected randomly using soil auger at the depth of 0-15cm. Soil samples were collected at intervals of 50m(A1), 100m(A2), 150m(A3) and 1km(A4) (control) away from the flare point. Composite soil samples were taken to the Soil Science laboratory of the Rivers State University of Science and Technology, Port Harcourt, Nigeria.

Physical Parameters

Soil texture

Soil bulk density was determined by the core method (9). Soil texture was done using the hydrometer method (Day, 1965).

Soil pH

Soil pH was determined in H_2O and INKCl by pH meter method of dipping pH meter glass electrode into 1:2.5 soil/water (Maclean, 1965).

3.4.2. Soil Chemical Properties

Exchangeable cations (Na^{+} , K^{+} , Ca^{++} and Mg^{++})

This was determined by 1 normal ammonium acetate (IN NH_4OAC) extraction method. Na^{+} and K^{+} were measured using the flame photometer while Ca^{++} and Mg^{++} were determined by complexometric titration method as modified by (Day, 1965). Ethylenediaminetetracetic acid and (EDTA) titration of Ca^{++} and Mg^{++} in the presence of Erichrome Block T (EBT) indicator was carried out at pH10. Mg^{++} was obtained as the difference between Ca^{++} and Mg^{++} . All units were expressed in $Cmol/Kg^1$.

Total exchangeable acidity (TEA)

Total exchangeable acidity was ascertained by INKCL extraction method and titrating with 0.1N, NaOH using phenolphthalein as indicator to a pink end point as modified by (Day, 1965). The unit was expressed in $Cmol/Kg^1$.

Available phosphorous

Determination of available phosphorous ($\mu\text{g/g}$) was done as described by (%) (Bray and Kurz, 1945). It was determined by plotting standard curve of absorbance against concentration of phosphorous in the extract.

Total nitrogen

Micro Kjeldah digestion and distillation method of (Bray and Kurz, 1945; Breamer, 1965) was used to determine total nitrogen (%). The distillate was titrated with standard H_2SO_4 to an end point of green to pink.

Organic carbon

Wet method and titration with ferrous ion was used to determine organic carbon (%) (Sanchez, 1976). It was carried out by reducing dichromate ion using organic carbon and un-reacted dichromate ion measured by titration.

Total Hydrocarbon (THC)

This was determined by Toluene extraction method. The absorbance of the extract at $42\mu\text{m}$ in spectrophotometer 20D were determined with the aid of standard curves of oil extractant. THC was expressed in $\mu\text{g/g}$.

Organic matter (OM)

The organic matter content was determined using the wet oxidation method described by (Sanchez, 1976; Worila, 2002) and multiplying the value by factor of 1.724.

RESULTS

Determination of fungal population at flared site

Counts of heterotrophic fungi were highest (0.41×10^5 cfu/ml) at 150 meters and lowest (0.03×10^5 cfu/ml) at 50 meters. Fungal population reduced (3.0×10^5 cfu/ml) (Table 1 and figure 1). The most prevalent fungi which occurred at the vicinity of flare were; *Fusarium moniliforme* (2), *Rhizopus stolonifer* (7), *Penicillium sp* (6), *Aspergillus niger* (3) and *Candida sp* (1). *Rhizopus stolonifer* was the most prevalent fungus. *R. stolonifer* had the highest percentage occurrence (36.8%) followed by *A. niger* (33.3%) (Table 2).

Table 1: counts of heterotrophic Fungi isolated from the flared site

S/N.	Distance from the flared site	Total heterotrophic fungi (X 10CFU/ML)
1.	50m	0.03×10^5 cfu/ml
2.	100m	0.35×10^5 cfu/ml
3.	150m	0.41×10^5 cfu/ml
4.	1 Km	0.15×10^5 cfu/ml

Kilometers (Km) and Meters (m)

Table 2: Frequency of occurrence of fungi isolate from the flared soil site

S/N	Organism	No. of Occurrence	Percentage (%) Occurrence
1.	<i>Aspergillus niger</i>	3	33.3
2.	<i>Candida sp.</i>	1	5.26
3.	<i>Fusarium moniliforme</i>	2	10.53
4.	<i>Penicillium sp.</i>	6	31.6
5.	<i>Rhizopus stolonifer</i>	7	36.8

Determination of the soil physical properties at the flared site

The result on the soil physical properties showed that clay (9.4%) and silt (16%) were highest at 1km. However, clay was lowest (1.4%) at 50m and silt lowest (1.7%) at 100m. Soil type was sandy in all distances (Table 3 and Figure 1). pH was 4.0 at 50m from the flared While at 1km pH was 5.9. Sand and clay were significant at P<0.05.

Table 3: Physical properties at the flared site

S/No.	pH	Soil depth (cm)	Distance (m)	% sand	% clay	% silt	Texture
1.	4.10	0-15	50	96.6	1.4	2	Sand
2.	4.40	0-15	100	94.6	3.7	1.7	Sand
3.	5.00	0.15	150	94.6	3.7	1.7	Sand
4.	5.90	0.15	1Km	74.6	9.4	16	Sand

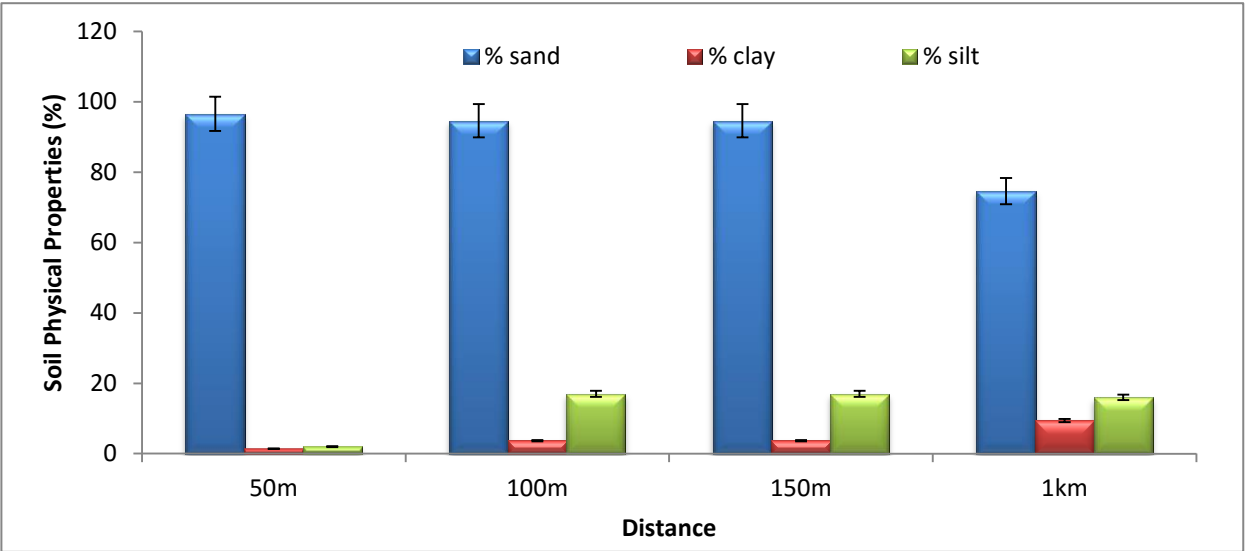


Figure 1: Physical properties of soil at various distances apart.

Determination of the soil chemical properties at the flared site

The findings on soil chemical properties indicated that total nitrogen (0.001%) was the least nutrient that occurred at 50m and the highest was phosphorous (6.44mg/g). At 100m the least nutrient was total N (0.006%) and the highest Na (5.22 cmol/kg). P was highest (2.76 mg/kg) (2.76 mg/kg) at 150m and 1km respectively. Similarly, Total Nitrogen was lowest (0.006%) (0.006%) at 150m and 1km respectively. (Tables 4, 5, 6 and Figures 2-7). Potassium, Sodium and Total carbon were all significant ($P < 0.05$) in all distances.

Table 4: Soil chemical properties at the flared site

S/No.	Soil	Flared	Available	%	% organic	Mg	Ca	K
	Depth (cm)	Point (M)	P (Mg/Kg)	organic C	matter	(cmol//kg)	(cmol//kg)	(cmol//kg)
1.	0-15	50	6.44	1.00	1.72	0.80	0.60	0.07
2.	0-15	100	3.68	1.83	3.16	0.60	1.00	0.31
3.	0.15	150	2.76	1.07	1.85	1.60	0.80	0.17
4.	0.15	1km	2.76	4.27	7.36	2.00	0.60	3.64

Table 5: Soil chemical properties at the flared site

S/No.	Soil	Flared point	Na	THC	TN	TEA	Exch. Al
	Depth (cm)	(Metres)	(Cmol//kg)	(Mg//kg)	(%)	(Cmol/kg)	(Cmol/kg)
1.	0-15	50	0.20	600.00	0.001	1.56	1.00
2.	0-15	100	5.22	150.00	0.006	2.12	0.80
3.	0.15	150	1.48	100.00	0.006	1.28	0.60
4.	0.15	1km	40.87	160.00	0.006	1.80	0.40

Table 6: Correlation of soil depth on some physico-chemical properties

	Soil depth
Avail.P	P>0.05 ^{NS}
<i>P-value</i>	0.484
%OC	P<0.05*
<i>P-value</i>	0.033
Mg	P>0.05 ^{NS}
<i>P-value</i>	0.202
Ca	P>0.05 ^{NS}
<i>P-value</i>	0.518
K	P<0.05*
<i>P-value</i>	0.004
Na	P<0.05*
<i>P-value</i>	0.008
TN	P>0.05 ^{NS}
<i>P-value</i>	0.594
TEA	P>0.05 ^{NS}
<i>P-value</i>	0.824
Exch.Al	P>0.05 ^{NS}
<i>P-value</i>	0.171
THC	P>0.05 ^{NS}
<i>P-value</i>	0.840
%Sand	P<0.05*
<i>P-value</i>	0.001
%Clay	P<0.05*
<i>P-value</i>	0.031
%Silt	P>0.05 ^{NS}
<i>P-value</i>	0.654

*Significant Difference at Probability level of 0.05. NS-Not significant difference (P>0.05).
P-value-probability values

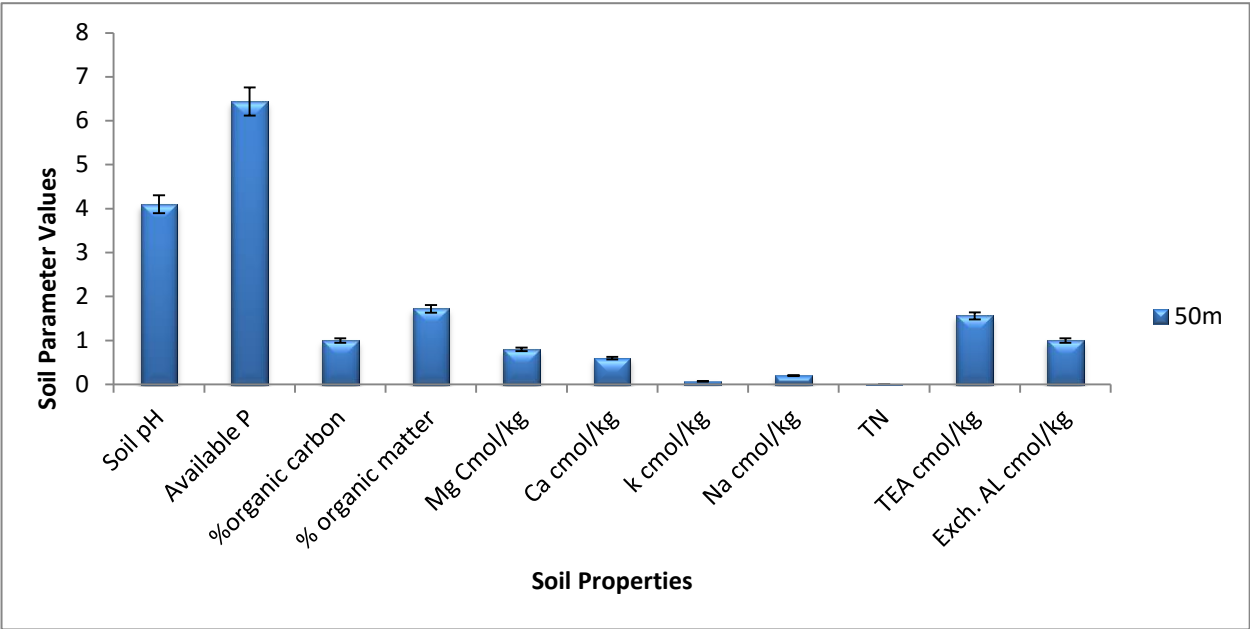


Figure 2: Chemical properties of soil at 50m apart.

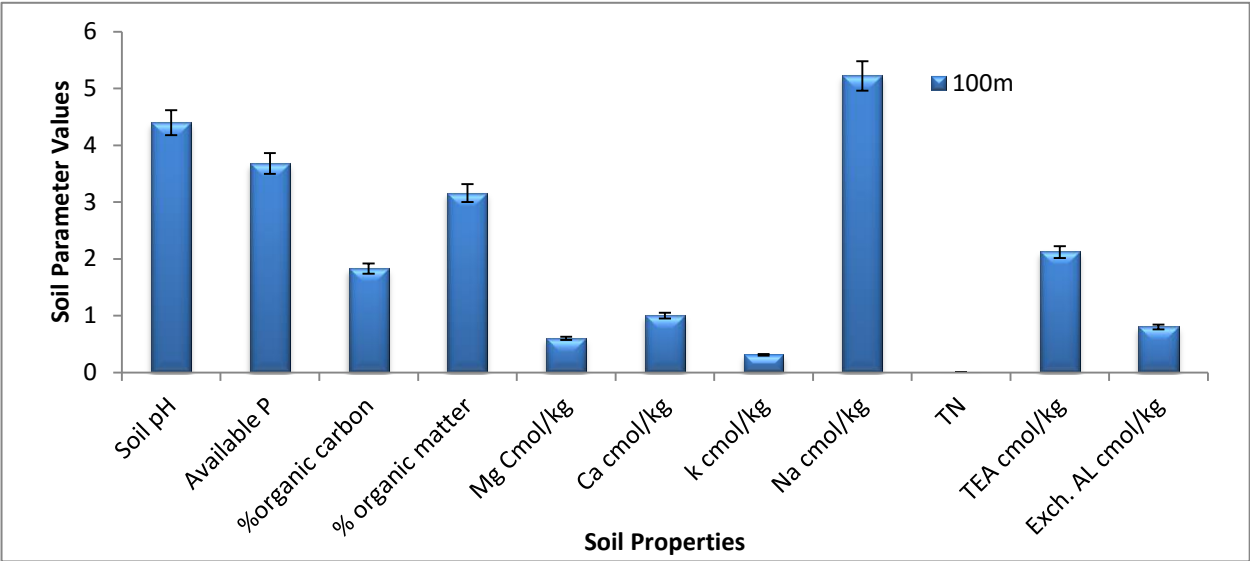


Figure 3: Chemical properties of soil at 100m apart

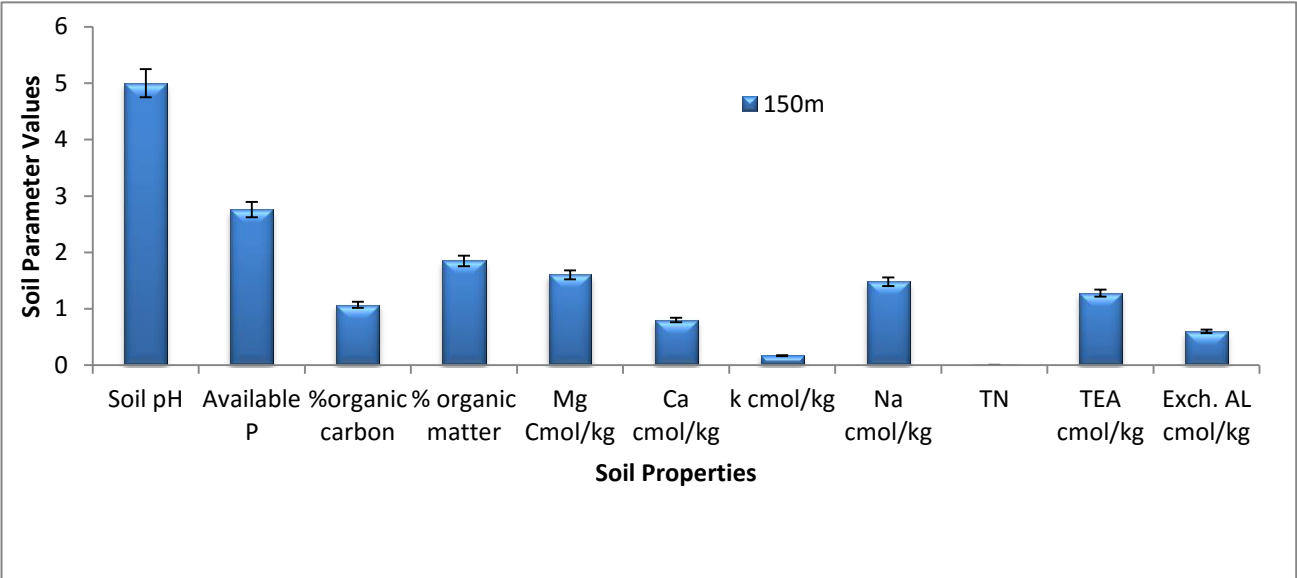


Figure 4: Chemical properties of soil at 150m apart.

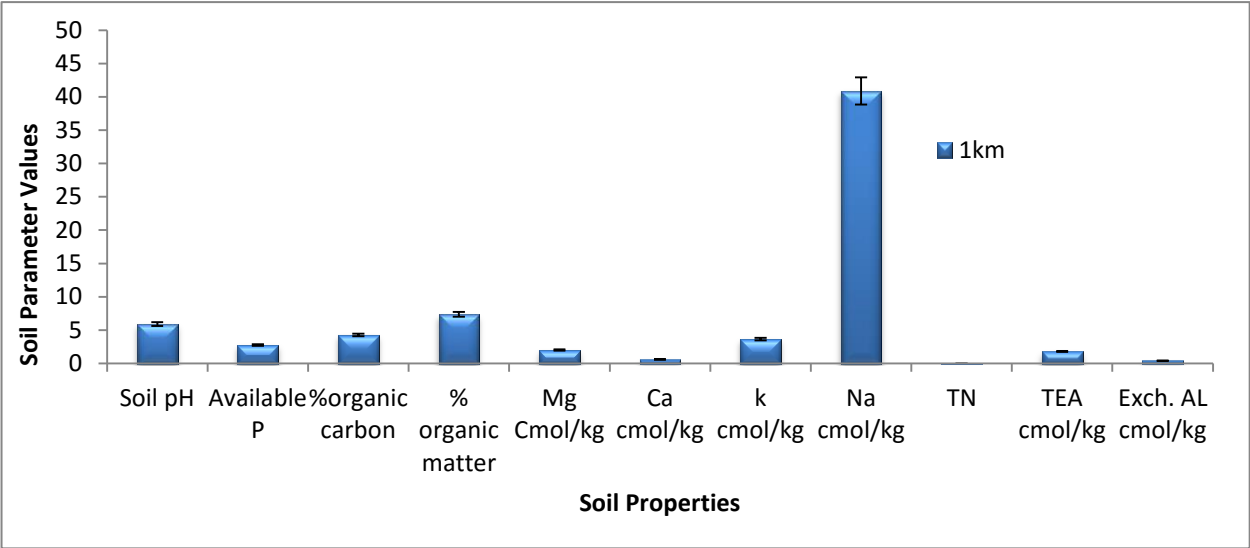


Figure 5: Chemical properties of soil at 1km apart.

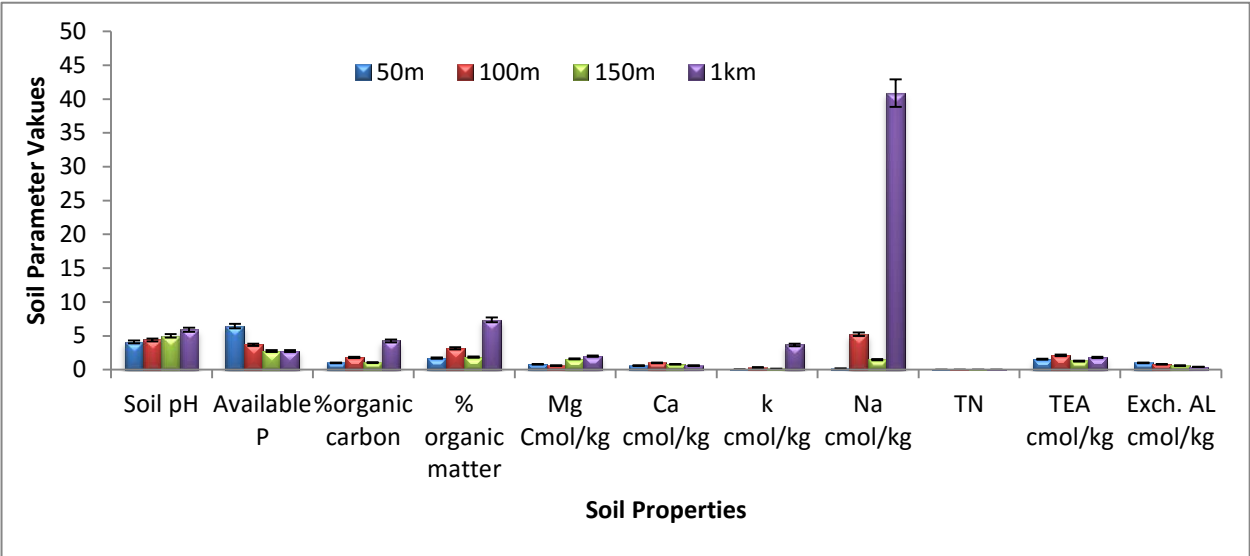


Figure 6: Chemical properties of soil at various distances apart.

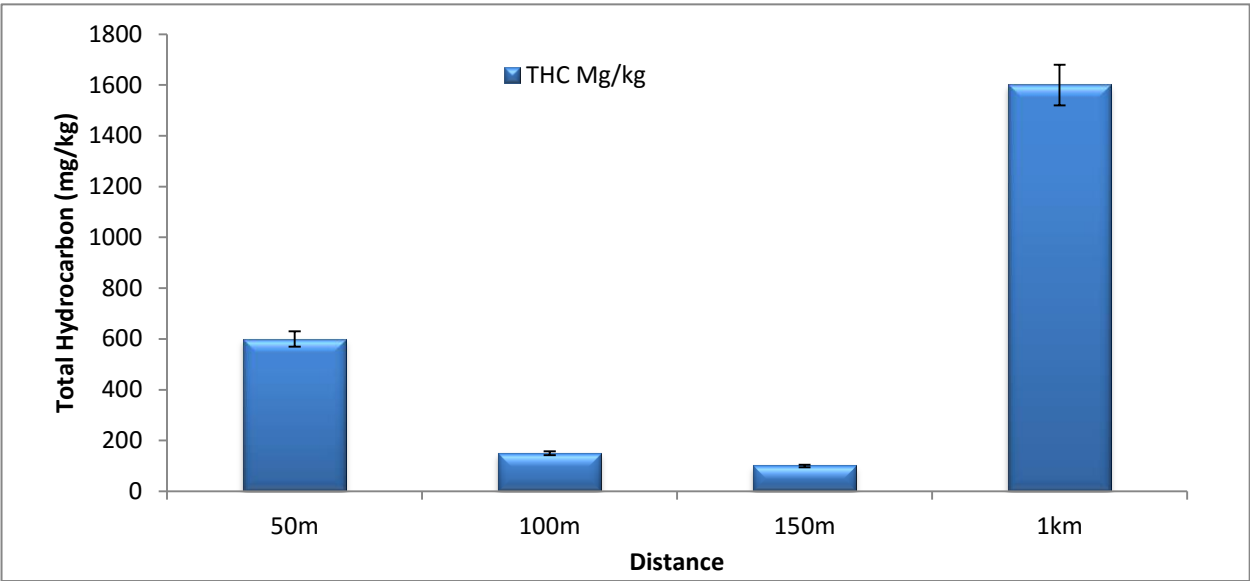


Figure 7: Total hydrocarbon of soil at various distances apart.

DISCUSSION

Determination of fungal population at flared site

Counts of heterotrophic fungi were highest (0.41×10^5 cfu/ml) at 150 meters and lowest (0.03×10^5 cfu/ml) at 50 meters from the flare. Fungal population was generally low. This is understandable as most fungi thrive at room temperature. This experiment is an indication that gas flare hinders the growth of fungi. It is in consonance with the works of (Stavishenko,2002), showed that fungi population is low in oil and gas region in Siberia.

Determination of the soil physical properties at the flared site

The result on the soil physical properties showed that clay (9.4%) and silt (16%) were highest at 1km. However, clay was lowest (1.4%) at 50m and silt lowest (1.7%) at 100m. Soil type was sandy. The abundance of sandy soil is an indication of poor soil type. Nutrients are easily leached from such soils and plant growth is hindered. The fact that clay and silt occurred further from the flared site is an indication that gas flare has effect on soil type. More so, pH values ranged from 4.0-5.0 at the distance of 50m – 150m respectively. This is another indication of a poor soil type caused by gas flare. The works of Atuma and Ojeh (2013), Nwaguo et al, (2005) and Odjugo and Osemiwenkhae (2009) clearly supports this research. These authors showed that pH changed from acidic range of 4.0-4.2 to 6.4-6.6 away from the flare point.

Determination of the soil chemical properties at the flared site

The findings on soil chemical properties indicated that the least nutrients occurred at 50m in the following order; Total nitrogen (0.001%), Potassium (0.07 cmol/Kg), Sodium (0.20 cmol/Kg), Magnesium (0.80 cmol/Kg), Organic carbon (1%), Total exchangeable acidity (1.56%) and Organic matter (1.72%). The highest nutrients occurred at 1 km from the flared sites in the following sequence; Total nitrogen (0.006%), Total exchangeable acidity (1.80 cmol/Kg), Magnesium (2.00 cmol/Kg), Potassium (3.64 cmol/Kg), Organic carbon (4.27%), Organic matter (7.36%) and Sodium (40.87 cmol/Kg) .

This research agrees with the works carried out by Alakpodia (2000) and Ogidiolu (2003). Both authors opined that exchangeable cation or base (Ca, Mg, K and Na) in soils under gas flare is low. According to their research the mean exchangeable cation/base value of the soils under gas flaring is below the values of 20 milliequivalent/100g of soils required for high soil fertility. In the same vein the mean value is lower than 4.0 milliequivalent/100g of soils necessary for retaining most nutrient cations in the soil. Ogidiolu (2003) and Ishmael and Umukoro (2012) confirmed that soils within the 100 meters radius of the site of gas flaring are mostly affected because their nutrients are very low. These authors also suggested that low mean value of exchangeable base indicates that gas flaring is detrimental to the accumulation of these basic nutrients in soils and thereby promoting soil fertility loss. This research showed that total nitrogen was low at 50 m away from the flared site. This is in consonance with the works of Ogidiolu (2003) who observed that organic matter and total nitrogen decline in gas flaring sites.

REFERENCES

- Abere, S.A and Ukoima, H.N. Impacts of expansion project of the Nigeria Liquified Natural gas on the wildlife status of Bonny Island. *Journal of Biology, Agriculture and Healthcare*. 4(13):2224-2208
- Abdulkareem, A.S. Evaluation of Ground level concentration of pollutant due to Gas. Flaring by computer simulation: A case study of Niger-Delta Area of Nigeria. *Leonardo Electronic journal of Practices and Technologies*. 2005. 6(1). 29-42
- Atuma, M.I and Ojeh, V.N . Effect of gas flaring on soil and cassava productivity in Evedei, Ukwani Local Government area, Delta State, Nigeria. *Journal of Environmental Protection*. 2013. Vol4:1054 – 1066
- Alakpodia, I.J. Soil characteristics under Gas flare in Niger Delta, Southern Nigeria. *Geo-studies forum, An international Journal of Environmental and Policy Studies*. 2000. 1 (2): 1 – 10
- Barnett, H.L and Hunter B.B. *Illustrated Genera of Imperfect Fungi*. Burgess Publishing Company. Minneapolis, Minnesota. 1972.
- Bray, R.H and Kurz, L.T (1945). Determination of P and available forms phosphorous. *Soil Science*. 1945. 59: 39-48.
- Breamer, J.M. (1965). *Total Nitrogen. In methods of soil analysis, part 2*. American Society Agronomy Inc. Madison, Academic Press. London.
- Day, P.R .Particle fractionalization and particle size analysis. In C.A. Black (ed) .Experimental confirmation by hydrometer theory. *Soil Science*. 1965.75:181-186.
- Commonwealth Mycological Institute (1974). Descriptions of Pathogenic Fungi and Bacteria. *Commonwealth Mycological Institute*, Kew ,Surrey, England. 1974. Vols;44,549,572-575,630 and 675.
- Edino, M.O., Nsofor, G.N and Bombom, S.L. Perceptions and attitudes towards gas flaring in the Niger Delta, Nigeria. *Environmentalist*. 2010. 30:67-75

- Elvidge, D.C., Ziskin, D., Baugh, K.E., Tuttle, T.B, Ghosh, T., Pack, W.D., Erwin, H.E and Zhizhin, M.A. Fifteen year record of global natural gas flaring derived from satellite data. *Energies*. 2009.2: 595-622.
- Gerner, F., Svensson, B and Djumena, S. Gas flaring and venting: A regulatory framework and incentive for gas utilization. *Public policy for the private sector*. 2004. P. 279.
- International conservation Fund (ICF) . Nigeria: Guide for Carbon Credit Development for Flare Reduction Projects International. June 2006.
- Ishisone, M. Gas flaring in the Niger Delta. The potential Benefit of its Reduction on the Local Economy and Environment. *Nature.berkeley.Edu/classes*. 2004.
- Ishmael, O.S and Umukoro, G.E . Global impact of Gas flaring. *Energy and Power Engineering*. 2012. 4, 290-302
- Isichei, O.A and Sanford, W.W . The effects of waste gas flares on the surrounding vegetation in south east Nigeria. *Journal of Applied Ecology*. 1976. 13(1):177-187
- Ismail, O.S and Umukoro, G.E. Global impact of Gas flaring. *Energy and Power Engineering*. 2012.12(4): 290-302
- Kershaw, K. A. *Quantitative and Dynamic Plant Ecology* 2nd Edition, Edward Arnold, London. 1975.P.305
- Leahey, D.M., Preston, K and Stroscher, M. Theoretical and Observational assessments of flare efficiencies. *Journal of Air Waste Management Association*. 2001.51 (12):1610-1616
- Maclean, E.O . Aluminium. In methods in soil analysis. *Agronomy*. 1965.9: 978-997.
- National Space research and Development Agency, Nigeria. (NASRDA). (2005).
- Nduka, J.K.C., orisakwe, O.E., Ezenweke, L.O., Ezenwa, T.E., Chendo, and Ezeabosili, M.N. Acid rain phenomenon in Niger Delta region of Nigeria: Economic, biodiversity and public health concern. *The scientific world Journal*. 2008. 8: 811-818
- Nwaugo, V.O; Onyeagba, R.A and Nwachukwu, N.C. Effect of Gas Flaring on Soil Microbial Spectrum in Parts of Niger-Delta Area of Southern Nigeria. *African journal of Biotechnology*. 2005. 5 (19). 1684-5315
- Odjugo, P. A and Osemiwenkhae, E.J. Natural Gas Flaring affects microclimate and reduces Maize (Zeamays) yield. *Internation Journal of Agriculture and Biology*. 2009. 11 (4): 408-412
- Omokaro, O. Oil and gas extraction I the Niger Delta Region of Nigeria: The social and environmental challenges. *Freiberg Online Geology*. 2009. 24: 13-20
- Oseji, J.O. Near surface aquifer characteristics and Ground water potential in Onicha-Ukwuani, Delta State, Nigeria. *The Pacific Journal of Science of Technology*. 2009. 10(2): 633-642.
- Ogidiolu, A. Effects of Gas Flaring on soil and vegetation characteristics in oil producing Region of Niger Delta Nigeria. *International Journal of Ecology and Dynamics*. 2003. .1(1): 47-53.
- Stavishenko, I.V; Zalesvo, S.V; Lugaskii, N.A; Kryazhevskikh, N.A and Morozov, A.E .Communities of wood attacking fungi in the region of oil and gas production. *Russian Journal of Ecology*. 2002.33 (3): 161-169.
- Sanchez, P.A . Properties and management of soils in the tropics. Wiley and Sons. New York. 1976.P.543.
- Singh, G.B and Yadav, D.V . Integrated Plant Nutrient System in Sugarcane. *Fertilizer News*. 1992.37:15-12.
- Ukoima, H.N ; Abere, S.A and Omokhua, G.E .Andoni marine ecology: Emphasis on the biology and Importance of some useful plants. *Journal of Environment and Earth Science*. 2014.4(18):22243216
- Ukoima, H.N and Umechuruba, C.I. Enumeration of fungi on some mangrove plants in Port Harcourt. *International Journal of Agriculture*. 2009a. 1(2):126-129
- Ukoima, H.N and Umechuruba, C.I. Effect of relative humidity and temperature on fungi Isolated from marine habitat in Port Harcourt. *International Journal of Bioscience*. 2009b. 4(2):104-107
- Ukoima, H.N and Amakiri, M.A. Diversity and abundance of mycoflora in the mangrove Soil in Port Harcourt, Rivers State. *Journal of Science and Technology Research Policies*. 2009c. 8(3):30-33
- Ukoima, H.N and Amakiri, M.A. Fungi associated with the roots of some mangrove forest Trees in Port Harcourt. 2009d. *Environment and Conservation*. 13(1):39-42
- Ukoima, H.N; Wemedo, S.A and Morpho, F. Survey of some bacterial pathogens on Leaves and seeds of white mangrove plants. *Indian Forester*. 2007. 133(1):637-641
- Walkey, A and Black, I.A . Determination of organic carbon. *Soil Science*. 1934. 37: 29-39.
- Worila, I.L .Environmental law and policy of petroleum development: Strategies and mechanisms for sustainable management in Africa. *Aripez Centre for Environment and Development*, Port Harcourt; Nigeria. 2002.
- World Bank .*Report on consultations with stakeholders*. World Bank – GGFR Report on global gas flaring reduction public – private partnership. Washington, D.C. 2002.
- World bank .*Kyoto mechanism for Flaring Reduction*. World Bank Group Report 2.2003.
- World Bank. *A Twelve Year Record of National and Global Flaring Volumes Estimated Using Satellite Data Final Report*. www.siteresources.worldbank.org. 2007.