IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 16, Issue 7 Ser. II (July 2022), PP 01-11
www.iosrjournals.org

Effect of Gas Flare on the Physicochemical and Heavy Metals Levels in Mangrove Sediment and Vegetation around Awoba Flow Station in Rivers State Nigeria

[1]Simbi-Wellington W. S., [2]Ideriah T. J. K. and [3]Ojadi V.
1,3Department of Forestry and Environment, Rivers State University Nkpolu Oroworukwo, Port Harcourt
2Institute of Pollution Studies, Rivers State University Nkpolu Oroworukwo, Port Harcourt

Abstract
This research was conducted to assess physicochemical parameters and heavy metals in mangrove sediment and vegetation (leaves) around Awoba Flow Station in Bille, Rivers State. Samples were collected from four sampling transects laid on the North, South, West and East axes of the flow station and a control location about 200km away from the flow station in the wet and dry season months. Heavy metals were determined using Atomic Absorption Spectrophotometer. Data were analysed using the multivariate analysis of SPSS statistical package.The results showed Mn in leaves ranged from 55.6388mg/kg to 26.9675mg/kg, Mg in leaves recorded around the flow station were WT (404.3238mg/kg), NT (374.6192mg/kg), ET (341.3100mg/kg) and ST (341.0467mg/kg) were significantly higher than the concentrations in the control location CT (220.9250mg/kg). The concentrations of Pb in sediments were significantly higher in two locations around the flow station NT and ET (8.1425mg/kg and 7.7075mg/kg respectively) and lowest around the control station CT (5.4531mg/kg). pH values in sediment were generally low ranging from 3.2 to 4.1. Percentage Total organic carbon (TOC)measured ranged from NT (3.0745%) to WT (2.2458%). The concentrations of Cr in vegetation and Cu in sediments were above the standard limits recommended by the Rivers State Ministry of Environment and therefore pose serious threat to aquatic life around the ecosystem and communities that are dependent on the forest. The mangrove sediment within the study area is very acidic with maximum pH of 3.2. Regular monitoring of pollutants and adequate sensitization was recommended.

Keywords: Gas Flare, Mangrove, Sediment, Vegetation, Flow Station, Rivers State

---

Date of Submission: 08-07-2022 Date of Acceptance: 22-07-2022

I. Introduction

Gas venting and flaring is the controlled combustion and release of gas during the process of oil production. It is the burning of natural gas in flare stacks during oil operations and is associated with the rapid oxidation with simultaneous release of heat and light. Gas flaring is considered the major source of global warming and main emitter of nitrogen (II)oxide, carbon monoxide, and methane which have the capacity to cause environmental pollution and ecological disturbances or destruction (Ubani and Onyejekwe, 2013).

Large quantities of gas containing about 90% methane which are difficult to liquefy and transport are produced in the Nigeria oil fields. Gas produced are therefore, burnt off at flow stations above oil wells, using stacks of about 7-9m high. The Flare process is comprised of a flare stack and pipes that delivers gas to the stack. Flares generate heat and noise; large flares are very noisy as a result of the velocity and volume of gas flowing through them (EPA, 2012).

In the year 2009 Nigeria was ranked the ninth largest gas producer in the world and a major gas supplier by the BP Statistical during a review of World Energy. National Oceanic and Atmospheric Administration (NOAA) reported that Nigeria flares a large proportion of its natural gas due to the non-availability of facilities to produce and market the associated natural gas. Nigeria flared 593 billion cubic feet (Bcf) of natural gas in 2007 and 532 Bcf of natural gas in 2008 due to lack of infrastructure to produce and market (Nigeria Oil, Gas Exploration Laws and Regulations Handbook, 2010).

In Africa, Nigeria is the highest emitter of greenhouse gas, classified as the sixth producer of crude oil in the world, and is ranked as one of the top 10 countries releasing 75% of the flaring emissions in the world (UNDP, 2012) with about 123 flaring sites and over 250 oil fields. Many flaring sites burn 24hours daily and have been flaring for over 50 years. Over the years, this practice has endangered the health of human and has adversely affected the environment, particularly coastal communities (Bassey, 2008). According to Osuntokun, (2002) gas flaring is a major contributor to environmental hazards such as acid rain which has impacted heavily on the Niger Delta environment causing damage to vegetation, increased mortality of aquatic lives and corrosion

of roofing sheets. Agho and Etiosa (2007) reported that emissions from gas flaring increases atmospheric greenhouse concentration and contributes to global warming. Gas flaring emissions (NOx, SOx, H_2S) are the main sources of lung irritants and carcinogenic benzene (Tawari and Abowei, 2012). Simbi-Wellington and Ideriah (2022) reported the detection of fourteen Polycyclic Aromatic Hydrocarbons listed as carcinogenic and mutagenic by the United States Environmental Protection Agency (USEPA, 2013) in mangrove soil and vegetation around a gas flare station in Rivers State. According to the report,TPAHs concentration in soil and vegetation recorded in all the study locations were above the Canadian maximum recommended limit of 0.02mg/kg and therefore poses serious threat to human and other life forms in the mangrove forest ecosystem around the gas flaring Station. Carcinogenic and mutagenic PAHs such pyrene, Benz (a) anthracene and Benz (a) pyrene were observed to have concentrations higher than USEPA, 2013 recommended limits (2.0×10^{-1}, 1.0×10^{-4} and 2.0×10^{-4} respectively) in the mangrove soil.

Gas flaring also gives rise to other environmental problems such as high temperature, noise pollution and visibility reduction caused by soot arising from the flares. Reports from local communities in the Niger-Delta region of Nigeria reveals that the unpleasant odour, loud noise and high temperature caused by flaring and venting have resulted in several health issues such as cancer, skin diseases, hearing problems, respiratory and eye infections (Efel, 2003; Nkwocha and Pat Mbano, 2010).

A major proportion of natural gas produced in Nigeria is associated gas (associated with crude oil). Nigeria flares 17.2 billion m^3 of natural gas annually in the Niger Delta region (Ajugwo, 2013; Ayoola, 2011). Above 75 % of associated natural gas are flared in Nigeria despite the ban of unauthorized flaring, this is equivalent to a daily pollution level of 45 million tons of carbon dioxide. Nigeria currently owns over 123 gas flaring locations in the Niger Delta region and has been ranked among the top emitters of greenhouse gases in Africa (Uyigue and Agho 2007). According to Agbola and Olurin, (2003) about 45.8 billion kw of heat is released into the Niger Delta atmosphere daily from flaring of 1.8 billion cubic feet of gas. Gas flaring has several environmental consequences; it leads to both direct and indirect effects on air quality, vegetation, soil, water quality and impacts on wildlife (WAF, 2018).

Fatemeh *et al.* (2013), reported that the preeminence of metal contaminants in the environment due to population growth, urbanization and industrial activities has become a problem of increasing concern, since the emission of heavy metals increases the metal concentrations in biota. Clemens *et al.* (2002) reported that heavy metal accumulation in plants is a multi-step process which includes mobilization into the soil solution, absorption by the roots and xylem and further transport to the shoots. According to Weng *et al.* (2004) the multi-step process of metal accumulation by plants is largely determined by soil pH. The report further stated that acidity is an important soil parameter which determines the availability of heavy metals as it affects the chemical speciation of metals in soil and the ability to bind on active sites. Heavy metal accumulation in plant tissues (roots and leaf) is influenced by the metabolic requirements for essential micro-nutrients such as Zn and Cu required for protein synthesis, chloroplast processes, enzyme activities, carbohydrate metabolisms and growth hormones (Philips, 1977). Generally, heavy metals concentrations are very low in leaf tissues, most absorbed heavy metals are accumulated in stems and roots (Hansen *et al.*, 1978).Nwawuike (2018) reported that the trace and major element concentrations in *R. racemosa* leaves, stems and roots sampled in Isaka mangroves indicated variations in concentration of Nickel (Ni), Niobium (Nb) and Arsenic (As). Nb had the highest concentrations in the roots and lowest in the leaves. While the concentrations of Cu and Pb were higher in stems and lowest in the leaves.

Review of literature have shown that the environmental impacts of oil exploitation and exploration on host communities in Nigeria have not been fully considered, this study therefore aims at providing information Heavy Metals concentrations in Mangrove Sediment and Vegetation around a Gas Flare Station in Rivers State Nigeria.

II. Materials And Methods

Study Location

The study station situated around Awoba flow station, Bille lies along 4^0 31' 51.486"N, 6^0 49' 11.962" E while the control station lies along 4^0 46'39.908" N, 6^0 46' 25.980"E. Both stations are in Degema Local Government Area of Rivers State.

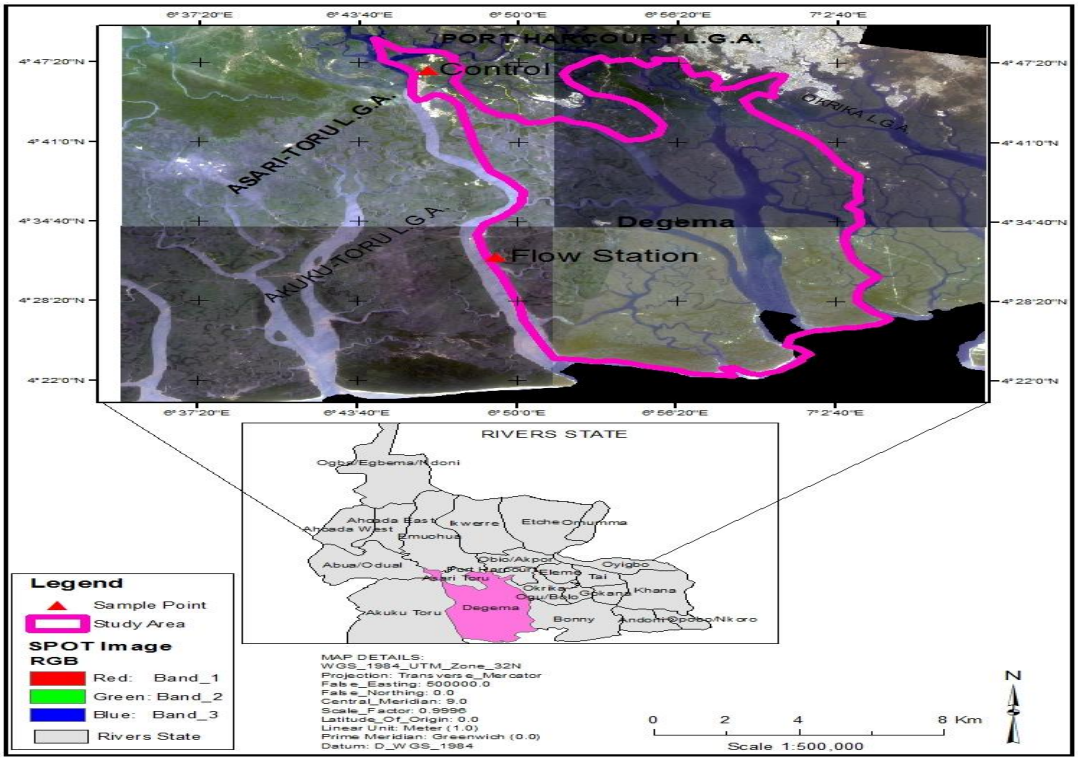

Fig 1 Map of Rivers State showing Degema Local Government area and study area

Sampling Techniques and Experimental Design

The systematic sampling method was used in this research. Sampling locations were taken 20 meters away from the flow station (Central Point), four transects measuring 10m x 90m were laid, each on the North (NT), South (ST), West (WT) and East (ET) of the Flow Station and were sub-divided into three sampling units measuring 10m x 30m. A total of 12 sampling units were laid for the study. Samples were randomly collected in triplicates within each sampling unit. The wind direction was noted and considered as a factor. Samples were also collected at the control (CT) station which is a mangrove forest in Degema town, over 200km away from the study station. Samples were collected in four different months; two dry season months (March 2017/March 2018) and two wet season months (June 2017/September 2017).

Data were analyzed using the General Linear Model (GLM): Multivariate of SPSS statistical package (IBM SPSS, 2011). Means were considered significant at $P \leq 0.05$ and were separated using Duncan Multiple Range Test.

Table 1 Geographical Coordinates of Study Locations

LOCATION	N (Latitude)	E (Longitude)
CENTRAL POINT	4^0 31' 52.90"	6^0 49' 10.45"
WEST 1	4^0 31' 52.88"	6^0 49' 09.38"
WEST 2	4^0 31' 52.61"	6^0 49' 08.49"
WEST 3	4^0 31' 52.57"	6^0 49' 07.42"
SOUTH 1	4^0 31' 50.90"	6^0 49' 11.20"
SOUTH 2	4^0 31' 48.74"	6^0 49' 12.43"
SOUTH 3	4^0 31' 46.97"	6^0 49' 13.64"
EAST 1	4^0 31' 53.59"	6^0 49' 13.13"
EAST 2	4^0 31' 55.54"	6^0 49' 18.16"
NORTH 1	4^0 32' 00.85"	6^0 49' 08.79"
NORTH 2	4^0 30' 00.37"	6^0 49' 02.16"
NORTH3	4^0 31' 56.50"	6^0 49' 02.30"
CONTROL CENTRAL	4^0 46' 43.91"	6^0 49' 25.98"
CONTROL 1	4^0 46' 44.70"	6^0 49' 27.93"
CONTROL 2	4^0 46' 45.50"	6^0 49' 29.55"
CONTROL 3	4^0 46' 42.59"	6^0 49' 28.40"
CONTROL 4	4^0 46' 46.27"	6^0 49' 27.54"

Determination of Metals in Sediment and Plants

Heavy metals in soil were analyzed using the Aqua-Regia Digestion Procedure by the American Public Health Association (APHA) 1995 standard method. 5g of air dried, 2mm mesh size sieved soil samples were weighed and transferred into 100ml glass beakers. A mixture of 2ml nitric acid, 6ml hydrochloric acid and 20ml distilled water was added to the soil samples. Digested samples were filtered and aspirated into the Atomic Absorption Spectrophotometer immediately after calibration with standard solutions. Concentration values for each metal was expressed in units of mg/kg.

Trace and heavy metals in plants were analyzed using the Dry Ash Method. Plant samples were finely grinded and oven dried at a temperature of 60^{o}C. 0.5g of oven dried samples were placed in 30ml porcelain crucible. Samples were ignited in a muffle furnace for 6 hours at a temperature of 450^{o}C. 5ml of HNO_3 solution was added to the cooled samples. Samples were allowed to evaporate to dryness, returned to the furnace and reheated at 400^{o}C for 15mins. 10ml of HCl was added to cooled samples and filtered into 50ml volumetric flask. Filtrates were used for the determination of metals using the Atomic Absorption Spectrophotometer.

Determination of Physicochemical Parameters in Sediment

Soil augers were used to collect soil samples randomly in the sampling units. Samples were collected in four different months (March 2017, June 2017, September 2017 and March 2018) at the study locations (NT, ST, WT, ET & CT) for laboratory analyses of physicochemical parameters such as soil pH, Cation Exchange Capacity (CEC), Total Organic Nitrogen (TON) & Total Organic Carbon (TOC).

Soil pH Determination

Soil pH was determined in a 1:1 soil to water ratio using a Glass Electrode pH Meter. Samples were air dried and passed through a 2mm sieve. 20ml of distilled water was added to 20g of sieved samples in a 50ml beaker, stirred and allowed to stand for 30minutes. The pH meter was inserted into the suspension and measurement taken.

Effective Cation Exchange Capacity Determination

Effective CEC was calculated by adding the sum of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity and was expressed in meg/100g. Exchangeable bases were determined using standard methods involving EDTA titration (Loganathan, 1984) while the exchangeable acidity was determined by using 5 drops of phenolphthalein indicator titrated with 0.05m NaOH solution.

Total Organic Nitrogen Determination

Total Organic Nitrogen was determined using the regular Macro-Kjeldahl digestion method. Samples were air dried and grinded to pass through a 0.5mm sieve. 20ml of distilled water was added to 10g of samples in a Macro-Kjeldahl Flask. The flask was swirl for few minutes and allowed to stand for 30mins. 1 tablet of mercury catalyst, 10g of K_2SO_4 and 30ml of conc. H_2SO_4 was added. The flask was heated at low temperature on the digestion stand, the temperature was increased steadily until the digest was clear and the H_2SO_4 condenses. Cooled digest was carefully transferred into another Macro-Kjeldahl flask. Distillation apparatus was attached to the Macro-Kjeldahl flask to commence distillation. Total Organic Nitrogen content was then calculated in percentage.

Total Organic Carbon Determination

Total Organic Carbon was determined using the Walkley & Black method. Grinded samples were passed through a 0.5mm sieve. Sieved samples were weighed in duplicates into 250ml Erlenmeyer flask. 10ml of $K_2Cr_2O_7$ solution were accurately added into each flask and swirl gently. 20ml of conc. H_2SO_4 was added to the solution and allowed to stand on sheets of asbestos for 30mins. 100ml of distilled water was added thereafter. 3-4 drops of indicator were added and titrated with 0.5N ferrous sulphate solution. Total Organic Carbon was then calculated in percentage.

III. Results

Metals in Mangrove Leaves

Table2 shows no significant differences in the mean concentration of copper recorded in the mangrove leaves at the different locations, however the highest mean concentration was recorded at location CT (14.1975mg/kg) while the lowest was recorded in location ET (2.7930mg/kg).The mean concentration of manganese recorded in location WT (55.6388mg/kg) and location NT (53.2667mg/kg) were significantly higher ($P \leq 0.05$) than the mean concentration observed in the other locations, the lowest was observed in location CT. Statistical analysis ($P \leq 0.05$) showed no significant differences in the mean concentration of chromium, nickel and lead recorded in the study locations. However, the highest means were observed in location WT (Cr:

6.1613mg/kg; Ni 2.88201mg/kg) and location CT (Pb: 0.9988mg/kg). The lowest means were observed in location ST (Cr: 3.3476mg/kg), ET (Ni: 1.8038mg/kg) and ET & NT (Pb: 0.0001mg/kg).
The mean concentration of magnesium recorded in location WT (404.3238mg/kg), NT (374.6192mg/kg), ET (341.3100mg/kg) and ST (341.0467mg/kg) were significantly higher at P≤0.05 than the mean concentration recorded in location CT (220.9250mg/kg).

Table 2 Mean Concentrations (mg/kg) of Metals in Leaves at the study Locations

LOCATION	Cu	Mn	Cr	Ni	Mg	Pb
WT	4.6363[a]	55.6388[a]	6.1613[a]	2.8201[a]	404.3238[a]	0.0463[a]
ST	5.2452[a]	33.2833[b]	3.3476[a]	2.3019[a]	341.0467[a]	0.0343[a]
ET	2.7930[a]	28.4700[b]	5.2266[a]	1.8038[a]	341.3100[a]	0.0001[a]
NT	3.0087[a]	53.2667[a]	4.7692[a]	1.9026[a]	374.6192[a]	0.0001[a]
CT	14.1975[a]	26.9675[b]	3.9701[a]	2.6494[a]	220.9250[b]	0.9988[a]

Mean with different superscripts within columns are significantly different at p≤0.05 using DMRT

Statistical analysis (P≤0.05) revealed that the highest concentration of manganese (56.7600mg/kg), chromium (17.4371mg/kg) and nickel (8.8122mg/kg) were recorded in the month of June 2017 and the lowest in the month of September 2017 (Mn: 24.7129mg/kg; Cr: 0.0001mg/kg, Ni: 0.0167mg/kg). Though no statistical differences were observed in the concentration of copper and lead, the highest means were however recorded in the month of June 2017 (Cu: 16.5844mg/kg; Pb: 1.0544mg/kg) and the lowest in the month of September 2017 (Cu: 0.1655mg/kg; Pb: 0.0001mg/kg). The mean concentration of magnesium recorded was significantly different in all the months. The highest was recorded in the month of March 2017 (525.3293mg/kg) and the lowest in the month of September 2017 (169.0586mg/kg) as shown in Fig 2- 7.

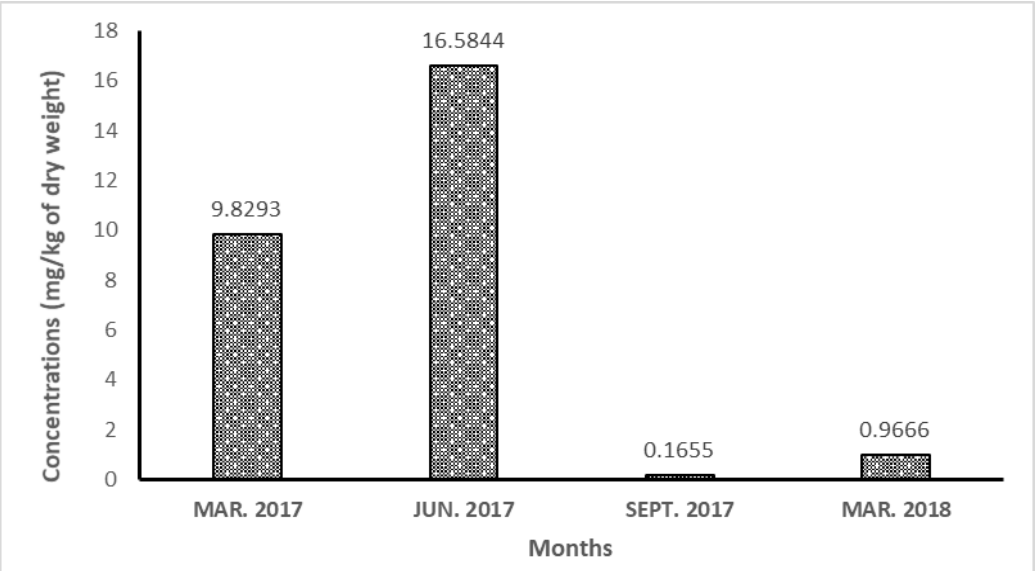

Fig 2: Variationsin the concentrations of Cu in Vegetation leaves.

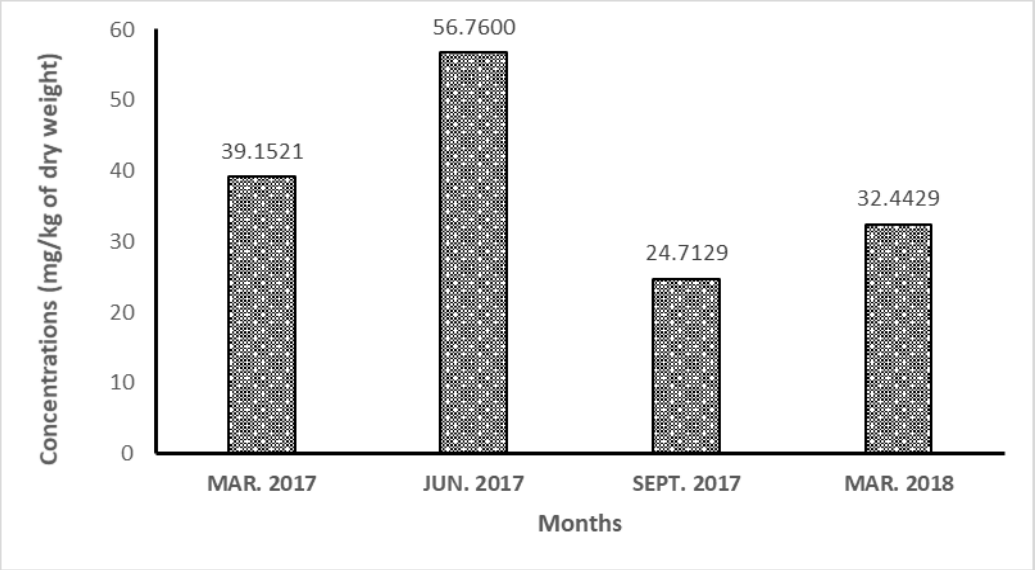

Fig. 3: Variationsin the concentrations of Mn in Vegetation leaves.

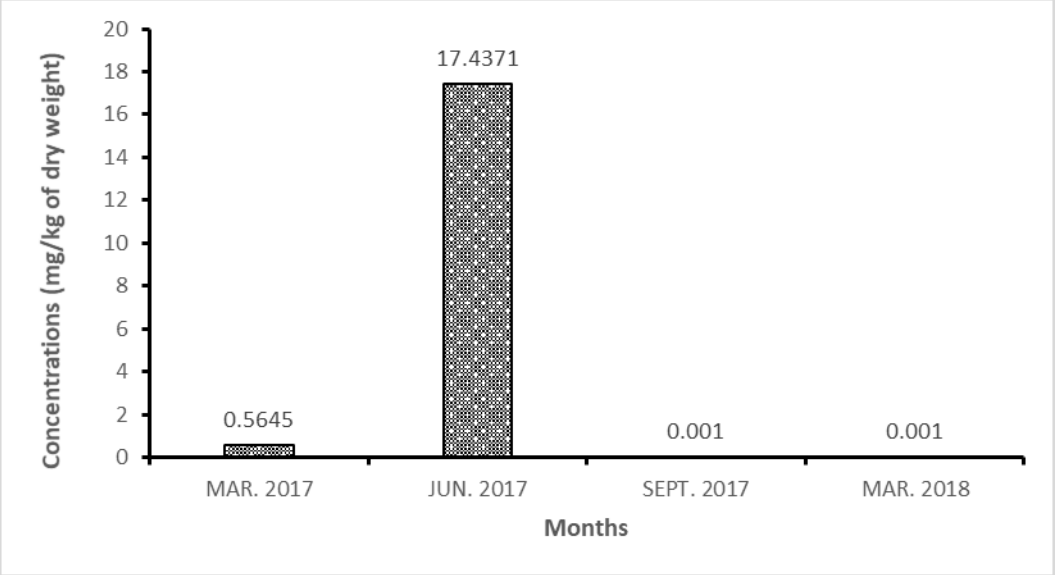

Fig. 4: Variationsin the concentrations of Cr in Sediment leaves

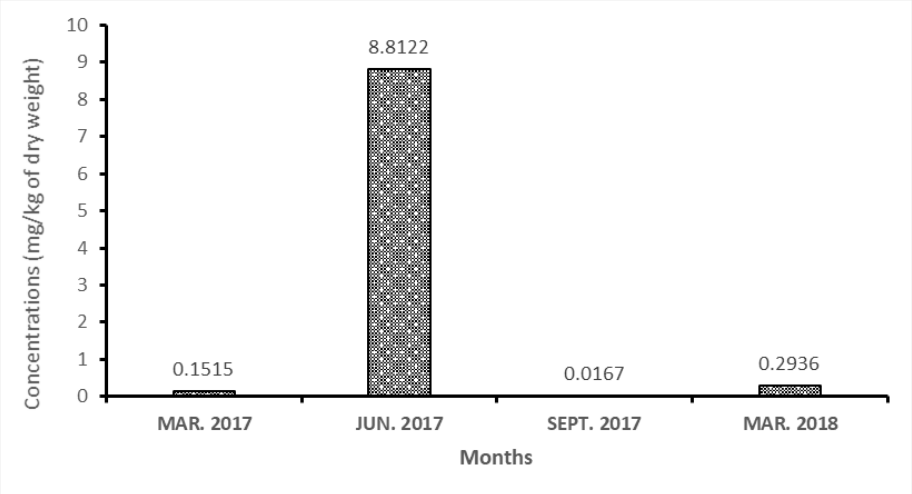

Fig. 5: Variationsin the concentrations of Ni in Vegetation leaves

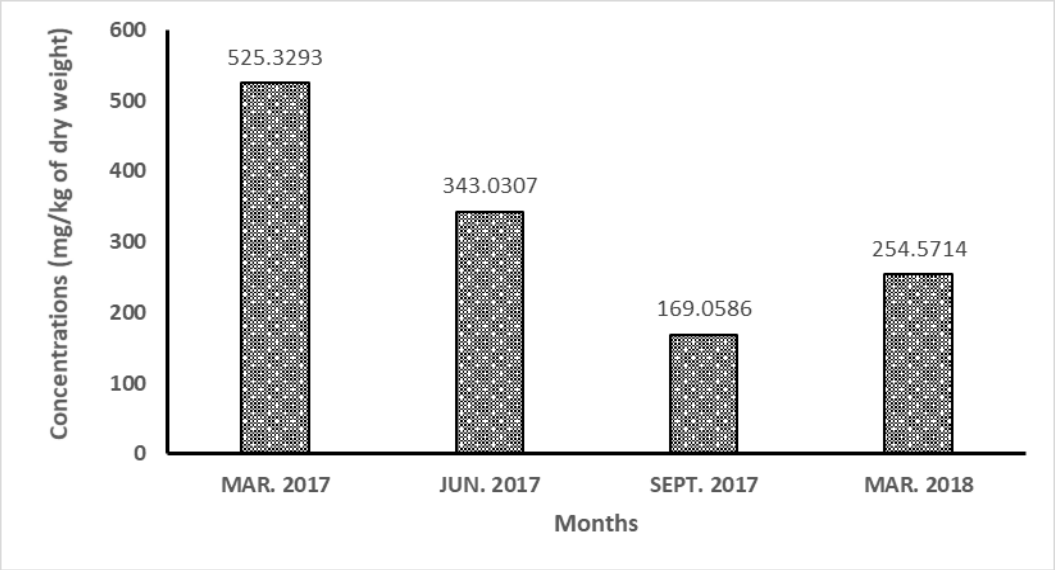

Fig. 6: Variationsin the concentrations of Mg in Vegetation leaves.

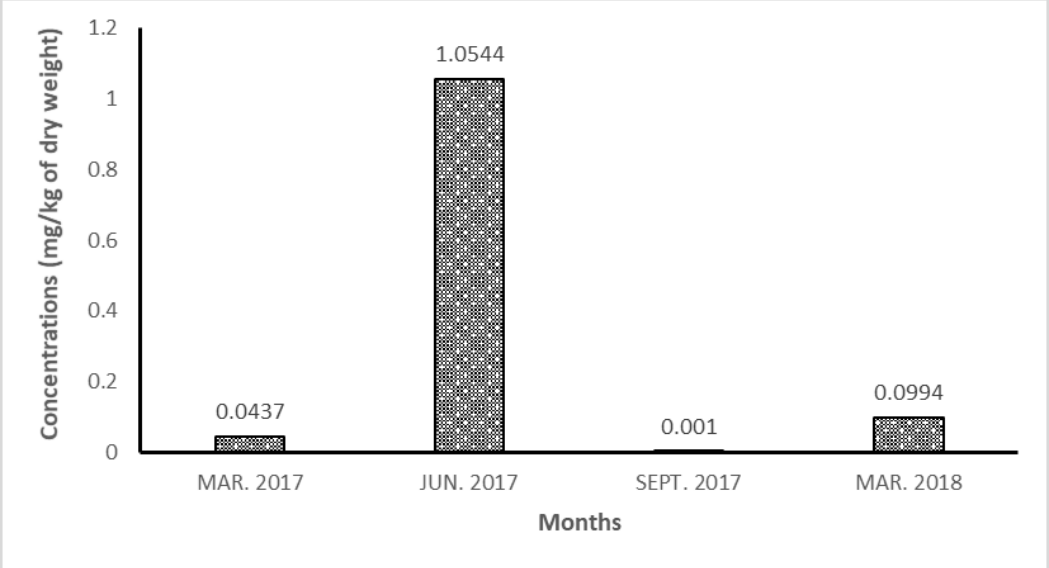

Fig. 7: Variationsin the concentrations of Pb in Vegetation leaves

Physicochemical Parameters in Mangrove Sediments

Soil pH observed at location CT (3.2) was significantly lower than the pH recorded at locations NT (4.1) and location ET (3.9) Table 3. The soil pH recorded for the month of March 2018 (4.1063) and March 2017 (4.0125) were significantly higher than the pH observed in the month of June 2017 (3.2125) and September 2017 (3.3375) Fig 9. Mean CEC levels were significantly higher in locations NT (25.4908meq/100g) and ET (24.8913meq/100g) and lowest in location CT (9.4340 meq/100g) Table 3. The mean CEC concentration was significantly higher in the month of march 2017 (20.2844meq/100g) and significantly lower in the month of September 2017 (14.8849meq/100g). The concentration observed for the month of June 2017 (18.0533 meq/100g) and March 2018 (17.6974 meq/100g) were not statistically different from the highest and lowest concentrations (Fig 9).

Highest mean percentage of Total Organic Carbon (TOC) were observed in locations NT (3.0745%) and ST (2.8925%). The lowest were observed in locations WT (2.2458%) and ET (2.4473%). The mean percentage observed in location CT (2.5652%) was not significantly different from the percentage observed in other locations at $P \leq 0.05$ using the Duncan Multiply Range Test as shown in table 3. No significant difference was observed in the percentage of TOC recorded in all the months of data collection, Fig 9. The mean percentage of Total Organic Nitrogen observed was significantly higher in location NT (0.2564%) and ST (0.2502%) at $P \leq 0.05$ and lowest in location WT (0.19141%) while the percentage observed in location CT

(0.2184%) was not significantly different from the highest and lowest (Tab 3). No significant difference was observed in the percentage concentration of TON recorded in the different months of data collection.

Heavy Metals in the Mangrove Sediments

No significant differences were observed in the mean concentrations of Cu, Cr, Ni and Cd in all the study locations.The mean concentrations of lead were statistically higher in locations NT and ET (8.1425mg/kg and 7.7075mg/kg respectively). Concentration at location CT (5.4531mg/kg) was significantly lower at P≤0.05 using the Duncan Multiply Range Test (Table 4.3).No significant differences were observed in the mean concentration of Pb, Ni and Cu observed in all the months of study. The mean concentration of Cr observed in the month of March 2018 (3.0150mg/kg) was significantly lower than the concentration observed in the month of June 2017 (5.6844mg/kg), March 2017 (5.7044mg/kg) and September 2017 (5.8513mg/kg). Mean concentration of Cd was significantly higher in the month of March 2017 (0.4063mg/kg) and lowest in the month of March 2018 and September 2017 (0.0607mg/kg and 0.0907mg/kg respectively).

Table 3 Mean Physicochemical parameters and Heavy metals in Mangrove Sediments at the Study Locations

Location	pH	Cu	CEC (Meq/100g)	TON (%)	TOC (%)	Ni (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
WT	$3.7000^{a,b}$	1.9358^{a}	14.2058^{b}	0.1941^{b}	2.2458^{c}	2.7750^{a}	5.4908^{a}	$5.9717^{a,b}$	0.2875^{a}
ST	$3.5333^{a,b}$	2.0250^{a}	17.3934^{b}	0.2502^{a}	$2.8925^{a,b}$	45.074^{a}	6.2633^{a}	$6.1942^{a,b}$	0.0926^{a}
ET	3.9333^{a}	1.1117^{a}	24.8913^{a}	$0.2115^{a,b}$	$2.4473^{b,c}$	1.6276^{a}	5.7325^{a}	7.7075^{a}	0.1517^{a}
NT	4.0667^{a}	1.5842^{a}	25.4908^{a}	0.2564^{a}	3.0745^{a}	1.7009^{a}	4.9958^{a}	8.1425^{a}	0.2342^{a}
CT	3.2438^{b}	2.6357^{a}	9.4340^{c}	$0.2184^{a,b}$	$2.5652^{a,b,c}$	3.0707^{a}	3.3932^{a}	5.4531^{b}	0.2425^{a}

Mean with different superscripts within columns are significantly different at p≤0.05 using DMRT

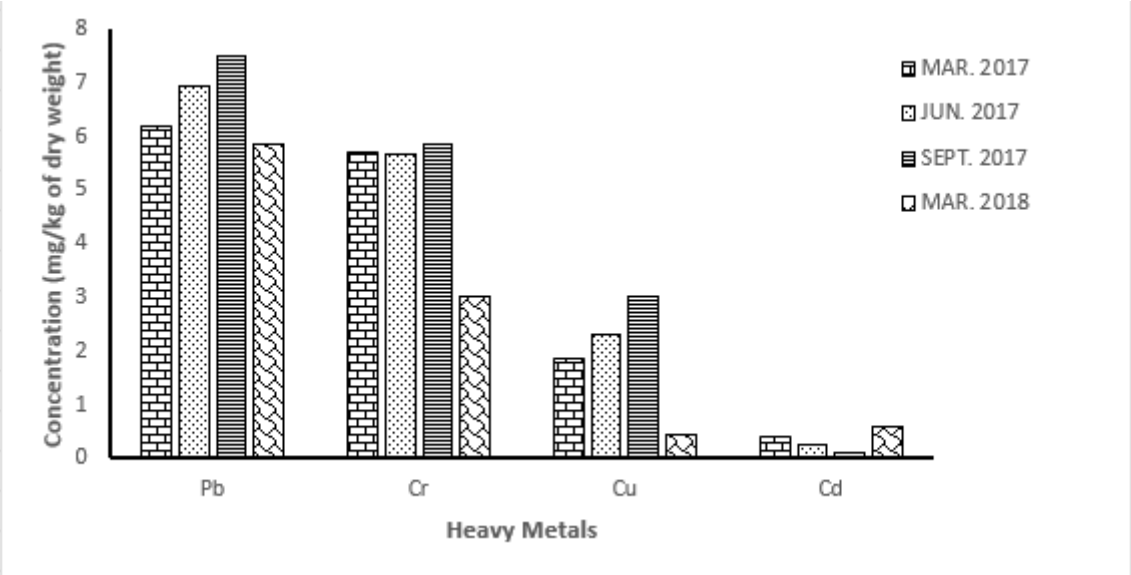

Fig 8: Variations in the concentrations of Heavy Metal in sediments.

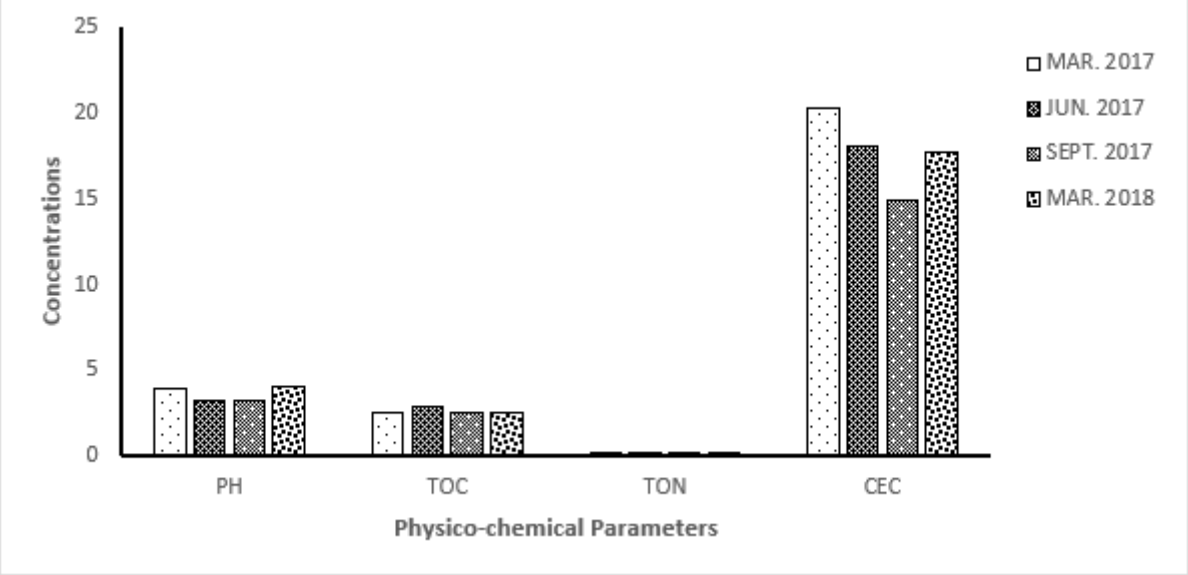

Fig 9: Variationsin the physicochemical parameters in sediments.

IV. Discussion

Heavy metals in mangrove vegetation

Cu, Mn, Cr, Ni, Mg, and Pb were all detected in the mangrove leaves at the study locations. Concentrations of Cd recorded in all the locations and months of study were below 0.001. No significant differences were observed in the mean concentrations of Cu, Cr, Ni and Pb recorded in the mangroves leaves at both the control and study locations. All observed concentrations of Cu were below the DPR Target (36mg/kg) and intervention (190mg/kg) limits. Concentrations of metals in the mangrove leaves were all within the naturally occurring levels stated by the Rivers State Ministry of Environment (RSMEnv., 2002) with the exception of Cr. The concentration of Cr observed were all above the naturally occurring level (RSMEnv., 2002) of 0.05 – 0.5ppm.

This report agrees with Hansen et al. (1997) which states that very small amounts of heavy metals are found in leaf tissues as most absorbed heavy metals are accumulated in the stem and roots. Nwawuike (2018) observed concentrations of Cu were higher in the stems and lowest in the leaves of *Rhizophora racemosa* a true mangrove species.

The mean concentration of manganese in mangrove leaves were significantly higher in stations WT (55.6388mg/kg) and station NT (53.2667mg/kg). The high concentration observed in location WT can be attributed to wind dispersal, as the recorded wind direction was South/West. The mean concentrations observed at the other locations were not significantly different however the mean value observed at the control location (26.9675mg/kg) was lower. Fatemeh et al. (2013) reported that the release of heavy metals into the environment increases the metal concentrations in biota, therefore the concentration at distances away from the major source varies from the concentration at distances close to the source of pollution.

Mean concentrations of chromium, nickel and lead in mangrove leaves at the study stations were not significantly different. However, the highest mean values were observed in station WT (Cr: 6.1613mg/kg; Ni 2.88201mg/kg) reflecting the wind direction (South/West).

The mean concentration of magnesium in mangrove leaves at station WT (404.3238mg/kg), NT (374.6192mg/kg), ET (341.3100mg/kg) and ST (341.0467mg/kg) were significantly higher than the mean concentration recorded in station CT (220.9250mg/kg). this is likely an indication that persistent flaring is the major source of Magnesium in mangrove leaves around Awoba Flow Station.

Generally, it was observed that the mean concentrations of Mn and Mg in leaves were significantly lower at the control location which is about 200km from the flow station. This finding agrees with report by Okezie and Okeke (1987) which stated that the destruction level of agricultural crops reduces as distance increases from flare stations, an indication that the pollutant level decreases with increasing distance from gas flares.

The mean concentration of Mn (56.7600mg/kg), Cr (17.4371mg/kg) and Ni (8.8122mg/kg) in mangrove leaves were significantly higher in the month of June 2017 and the lowest in the month of September 2017 (Mn: 24.7129mg/kg; Cr: 0.0001mg/kg, Ni: 0.0167mg/kg). The mean concentration of Mg in mangrove leaves were significantly different in all the months of data collection. The highest was recorded in the month of March 2017 (525.3293mg/kg) and the lowest in the month of September 2017 (169.0586mg/kg). This observation can be attributed to the fact that September is a rainy month and the pollutant emissions and

concentrations are higher during the dry seasons owing to meteorological factors such as high temperature. Efel *et al*. (2005) reported that during the wet season, a combination of heavy rainfall and in some cases, high wind speed off the oceans, significantly improve pollutant concentrations in the environment. Simbi-Wellington and Ideriah (2020) reported higher pollutant emissions and concentrations in the dry season months around a gas flaring station in Rivers State.

Heavy Metals in Mangrove Sediments

Mean concentration of Cu, Cr, Ni and Cd in mangrove sediments were not significantly different in the study locations. However, the mean concentration of Cu ranges from 1.1117mg/kg observed in location ET to 2.6357mg/kg observed in location CT. RSMEnv. (2002) states that concentrations of Cu in soil solutions above 0.1ppm adversely affects crop growth and is especially toxic to aquatic life.

Though no significant differences were observed in the mean concentration of Cr and Ni at the study locations, the mean concentrations were higher in location ST (45.074mg/kg and 6.2633mg/kg respectively). The lowest mean concentration of Cr was recorded in location CT (3.3932mg/kg), while the lowest for Ni was recorded in location ET (1.6276mg/kg). The concentrations of Cr and Ni observed were the naturally occurring levels stated by The RSMEnv., (2002).

The mean concentrations of lead in the mangrove sediments were statistically higher in locations NT and ET (8.1425mg/kg and 7.7075mg/kg respectively). Concentration at location CT (5.4531mg/kg) was significantly lower at $P \leq 0.05$ (Table 4.2). Generally, the mean concentrations of Cu, Cr and Pd in the mangrove sediments were lower at the control location, an indication that the gas flared is the major source of these pollutants in soil. Uyigue and Enujekwu (2017) revealed that the soil parameters at study stations were generally affected by gas flaring emissions.

No significant differences were observed in the mean concentration of Pb, Ni and Cu observed in all the months of study. However, the highest mean of Pb and Cu was observed in the month of September 2017 (7.4956mg/kg and 3.0300mg/kg respectively) while the highest for Ni (33.4657mg/kg) was observed in the month of June 2017. The mean concentration of Cr observed in the month of March 2018 (3.0150mg/kg) was significantly lower than the concentration observed in the month of June 2017 (5.6844mg/kg), March (5.7044mg/kg) and September 2017 (5.8513mg/kg). Mean concentration of Cd was significantly higher in the month of March 2017 (0.4063mg/kg) and lowest in the month of March 2018 and September 2017 (0.0607mh/kg and 0.0907mg/kg respectively).

Physicochemical Parameters in the Mangrove Sediment

The pH values of sediments in all the study locations (CT 3.2; NT 4.1; ET 3.9; WT 3.7; ST 3.5) are strongly acidic according to the guidelines by RSMEnv. (2002) which states soil pH of 5.0 and below is strongly acidic.The acidic nature of the soil can be attributed to the effects of acid rain caused by the emissions of NO_2 and SO_2 from flares and vehicles. According to Scheren *et al* (2002) acid deposition results in soil acidification and greatly decreases the soil pH of surface soil. Uyigue and Enujekwu (2017) observed that pH was generally acidic even at distances away from flare points at three locations within Ogba/Egbema/Ndoni LGA of Rivers State.

The highest mean CEC in the mangrove soil was observed in location NT (25.4908meg/100g) where the soil pH was less acidic when compared to other locations. Lowest CEC was observed in location CT (9.4340 meg/100g). According to RSMEnv. (2002), CEC value of 2meg/100g is considered good for Ca while CEC value of 0.2meg/100g and above is considered good for K. Highest mean percentage of Total Organic Carbon (TOC) and Total Organic Nitrogen observed were significantly higher in locations NT (TOC 3.0745%; TON 0.2564%). Lowest TOC and TON were observed in WT (TOC 2.2458%; TON 0.19141%) and ET (TOC 2.4473%; TON 0.2115%). RSMEnv. (2002) stated that TOC value of <1% is considered low while TON value of <0.1% is considered low. Hence the TOC and TON values at the study locations can be considered good since the observed values are all higher than the required standard.

V. Conclusion

This research has provided evidence on the distribution of heavy metals in vegetation and sediments of the mangrove forest around Awoba flow station. Heavy metal such as chromium exceeds the permissible limits in plant materials. This high concentration of toxic pollutants in the sediment and vegetation can constitute hazard to the plants and other life forms that depends on it. Pollutants such as Pb, Mn, Ni and Cu had concentrations within recommended limits and therefore do not presently pose serious concern in the area. The mangrove sediment within the study area is very acidic with maximum pH of 3.2. Copper was observed to be above recommended limits in the sediment and can be toxic to both plants and wildlife of the mangrove forest. Regular monitoring of pollutants arising from gas flaring should be encouraged, particularly around major sources of livelihood.

References

[1]. Agbola, T., & Olurin, T., (2003) "Landuse and Landcover Change in the Niger Delta," Excerpts from a Research Report presented to the Centre for Democracy and Development.
[2]. Agho M & Etiosa, U. (2007). Coping with Climate Change and Environmental Degradation in the Niger Delta of Southern Nigeria. Bulletin of Community Research and Development Centre (CREDC) Nigeria, 20-21.
[3]. Ajugwo, O.A. (2013). Negative effects of gas flaring: the Nigerian experience. Journal of Environmental Pollution and Human Health 1(1): 6-8.
[4]. APHA (1985). Standard Methods for the examination of wastewater 15th Edition. American Public Health Association, Washington, DC.
[5]. Ayoola, T.J. (2011). Gas flaring and its implication for environmental accounting in Nigeria. Journal of Sustainable Development 4(5) 244-250.
[6]. Bassey, N. (2008). The Oil Industry and Human Rights in the Niger-Delta. Paper Presented at National Environmental Summit, Abuja Nigeria, 2-5.
[7]. Clemens, S., Palmgren, M.G. & Kramer, U. A. (2002) Long Way Ahead: Understanding and Engineering Plant Metal Accumulation. Trends in Plant Sciences.; 7:309-315.
[8]. Efel, S.I. (2003). Effect of Gas Flaring on Temperature and Adjacent Vegetation in Niger Delta Environment. International Journal of Environment 1(1), 91-101.
[9]. Efel, S.I.; Ogban, F.E, Horsfall, M.J. & Akporhonor, E.E (2005). Seasonal Variations of Physicochemical Characteristics in Water Resources Quality in Western Niger Delta Region, Nigeria. Journal of Applied Scientific Environmental Management (3).
[10]. EPA (Environmental Protection Agency) (2012). Understanding the Basics of Gas Flaring. Accessed at www.epa.ohio.gov.
[11]. Fatemeh, E., Sanaz K. & Ali, S. (2013), ''A Study on Heavy Metal Concentration in Sediment and Mangrove (Avicenia marina) Tissues in Qeshm Island. Journal of Applied Scence. 2(10) 498-504.
[12]. Hansen, M.H., Ingvorsen. K.& Jorgensen, B.B. (1978), ''Mechanisms of hydrogen Sulphide release from coastal marine sediments to the atmosphere'', Limnol. Oceanogr, (23) 68-76.
[13]. IBM SPSS (Statistical Package for Social Sciences) (2011) Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.
[14]. Nigeria Oil, Gas Exploration Laws and Regulations Hand. (2010). Strategic Information and Regulations. International Business Publications USA 1(1) 330-7884-8
[15]. Nkwocha E.E & Pat-Mbano, E.C. (2010). Effect of gas flaring on buildings in the oil producing rural communities of Rivers State, Nigeria. African Research Reviews 4(2), 90-102.
[16]. Nwawuike N. & Ishiga H. (2018) Heavy Metal Concentrations in Mangrove Sediments and R. racemose in Niger Delta, Nigeria. Journal of Geography, Environment and Earth Science 17(4).
[17]. Okezie, D W & Okeke, A. O.(1987). Flaring of associated gas in oil industry: impact on growth, productivity, and yield of selected farm crops – Izombe flow station experience. Paper presented at the Nigerian National Petroleum Corporation (NNPC) Workshop, Port Harcourt.
[18]. Osuntokun A. (2002). Dimension of Environmental Problems in Nigeria. Davidson Press, University of Ibadan, Nigeria, 32-33.
[19]. Philips, D.J.H. (1977), "The common mussel mytelus edulis and indicator of trace metal in Scandinavian water", Zinc and Cadmium. 2nd edition: 55.
[20]. RSMEnv. (Rivers State Ministry of Environment)(2002). Interim Guidelines and Standards on Environmental Pollution Control and Management in Rivers State. Rivers State Ministry of Environment and Natural Resources. 39-45
[21]. Scheren, P. A., Ibe, A. C. Janssen, F. J. & Lemmens, A. M. (2002) "Environmental pollution in the Gulf of Guinea-a regional approach." Marine Pollution Bulletin, 44 (7). 633-641.
[22]. Tawari C.C. & Abowei, J.F.N. (2012). Air Pollution in the Niger Delta Area of Nigeria. International Journal of Fisheries and Aquatic Sciences 1(2), 94-117
[23]. Simbi-Wellington, W. S. & Ideriah, T. J. K (2020) Assessment of Air Quality in Mangrove Forest around Gas Flare in Awoba Flow Station in Rivers State Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 13(2)1. 38-47
[24]. Simbi-Wellington, W. S. & Ideriah, T. J. K (2022) Evaluation of Polycyclic Aromatic Hydrocarbons Levels in Mangrove Forest and Sediment around Gas Flare in Awoba Flow Station Rivers State Nigeria. Quest Journals Journal of Research in Environmental and Earth Sciences 8(3) 25-34
[25]. Ubani E.C & Oyejekwe I.M. (2013). Environmental impact analysis of gas flaring in the Niger Delta region of Nigeria. American Journal of Science and Industrial Research 4(2) 246-252.
[26]. United State Environmental Protection Agency (USEPA, 2013) Polycyclic Aromatic Hydrocarbons (PAHs) What are the standards and regulations for PAHs exposure? USEPA 1-4.
[27]. UNDP; United Nations Development Programme (2012). Niger Delta Biodiversity Project. Accesses at https://info.undp.org/docs/pdc/Documents/NGA/Niger%20Delta%20Biodiversity_Prodoc.pdf
[28]. Uyigue, E. & Agho, M. (2007). "Coping with climate change and environmental degradation in the Niger Delta of southern Nigeria." Community Research and Development, Centre Benin City
[29]. Uyigue L. & Enujekwu F.M. (2017). Physicochemical Analysis of Gas Flaring Impact on the Environment of Host Communities in the Niger Delta. Journal of Environmental Pollution and Human Health. 5(1).
[30]. WAF (World Animal Foundation) (2018). Oil and Gas: A threat to world wildlife.
[31]. Weng, L.P., Lexmond, T.M., Temminghoff, E.J.M.& Riemsdijk, W.H.V. (2004) Understanding the effects of soil characteristics on phytotoxicity and bioavailability of nickel using speciation models. Environmental Science Technology. 38:156-162.

Simbi-Wellington W. S, et. al. Effect of Gas Flare on the Physicochemical and Heavy Metals Levels in Mangrove Sediment and Vegetation around Awoba Flow Station in Rivers State Nigeria." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 16(7), (2022): pp 01-11.