ANALYSIS OF GAS FLARING EFFECT ON SOIL HEAVY METAL CONCENTRATION IN NIGER DELTA OIL PRODUCING COMMUNITY OF OLOGBO, EDO STATE, NIGERIA

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ABSTRACT

Soil heavy metal concentration is being altered by the outcome of flaring activities. Therefore, this study was carried out to investigate the effect of gas flaring on soil heavy metal concentration in Niger Delta oil producing community of Ologbo, Edo State, Nigeria**.** Specifically, it examined the effect of gas flaring on soil heavy metal concentration at 0-15 cm and 15-30 cm depths. Field-based survey was adopted to obtain six soil samples (depth: 0-15cm and 15-30cm) from three stations (500m, 2,000m and 4,000m) away from the Gas Flare Sites (GFS) and two from control point (CP) (30,000m away) for comparison. The Soil Quality Parameters (SQPs) investigated include: iron (Fe), manganese (Mn), zinc (Zn), chromium (Cr), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni), vanadium (V) and hydrocarbon content (THC) while descriptive statistics and the Student's t-test were used in data analysis and hypotheses testing. Results showed that at 0-15cm depth, Fe, Mn, Zn Cu Cr and Cd were highest at station 3 with the lowest values at station 2. Regarding 15-30cm depth, results showed that Fe, Mn, Zn Cu Cr and Cd were also highest at station 3. Generally, Fe, Mn, Zn Cu Cr and Cd were significantly enriched at all sample stations when compared with the control station with Fe, Zn and Mn being the highest heavy metal contaminants. Statistical tests showed no significant difference in SQPs spatially and vertically portraying no possible effect of gas flaring on soil heavy metal concentration. Periodic monitoring of SQPs is recommended with the view to detecting possible changes arising from unabated gas flaring.

Key words: Control station, Gas flaring, Heavy metal concentration, Oil producing communities

INTRODUCTION

The world is blessed with profuse reserves of crude oil and natural gas for human utilization and societal development. Available statistics showed that global natural gas deposits at the end of 2018 stood at 6.95 quadrillion cubic feet with majority of reserves found in the Russian Federation and the Middle East (Wang, 2020). The United States of America (USA) emerged world highest producer of natural gas amounting to about 831.8 billion cubic feet, followed by Russia (669.5 billion cubic feet) while Nigeria emerged as the 17th with about 49.2 billion cubic feet (Garside, 2019) out of the 3937 billion cubic meters (bcm) produced worldwide in 2018 (International Energy Agency, 2020). Out of these figures, about 145bcm was flared with Nigeria flaring about 7435 million cubic meters from about 178 flaring stations as a result of technological, governance as well as financial limitations (Bamji, 2019). Therefore, gas flaring is environmentally unfriendly and unsustainable combustion of surplus natural gas and crude oil during upstream and downstream exploration, exploitation and processing of natural gas and petroleum hydrocarbons (Atuma and Ojeh, 2013).

Soil heavy metal concentration which is the capacity of a soil to function for specific land uses or within ecosystem boundaries (United States Department of Agriculture [USDA], 1995) is being altered by the outcome of flaring activities. There is increased predilection of crude oil over natural gas due to the high profit margin between the two naturally occurring resources which is why Multinationals keep flaring gas as a comparative advantage in order to achieve their exploitative goals and profitable ambitions from crude petroleum business (Nyong, 2016). Notwithstanding the socio-economic benefits accruing from crude oil and natural gas business the world over (Mandel, 2016; American Petroleum Institute-API, 2017) and, the negative consequences are better imagined than experienced. As gas flares, the atmospheric nitrogen and carbon dioxide are forced to combine with elemental oxygen forming acidic oxides which dissolve in rain water to give diluted carbonic and other deadly compounds (Hewitt, Sturges, and Noa, 1995; Botkin and Keller, 1998).

Continued gas flaring particularly in the Niger Delta region of Nigeria where majority of the oil and gas business is taking place has led to a number of agro-ecological effects and socio-economic as well as health-related crises in host communities; decline in farm output, elevated soil temperature along with acidic rainfall water have also been reported (CSL Stockbrokers, 2020). Depletion of soil moisture (SM) (Botkin and Keller, 1998), changes in soil alkalinity and adverse ecological and bacterial spectrum modifications by the gas flaring (Nwaugo et al., 2005) has also been reported.

Odjugo (2007) reported significant modification of the local micro-climate and soil physico-chemical properties by gas flaring. Sand content of the soil, pH, bulk density, air and soil temperatures have also increased toward the flare site, while the reverse was the case with silt, clay, chemical properties of the soil and relative humidity (Odjugo and Osemwenkhae, 2009). The alteration of distribution fungi, as well as variation in soil physical and chemical characteristics, have also been linked to the impact of gas flaring (Ukoima et al., 2016). Fungi play vital role in the disintegration of soil organic matter as well as make available soil nutrients crops and plants utilization (Frąc, Hannula, Bełka, and Jędryczka, 2018). The available moisture content in the soil for plant uptake have also been impacted by continuous flaring of gas in oil producing communities of Nigeria Niger Delta region (Elenwo et al., 2019).

Therefore, although crude oil and natural gas are of high economic value to Nigeria, the adverse gas flaring effect accompanying it particularly on soil; bacteria, temperature, pH and moisture are unquantifiable. Ologbo, as an oil producing community in Edo State, hosts a Flow Station with a flare stack and Gas flaring is ongoing; poisonous gaseous compounds are being released into the atmosphere with devastating consequences on humanity and the environment. With these copious empirical reports on gas flaring induced soil pollution elsewhere and the fact that it could lead to reduced access to productive farmlands, conflicts, loss of livelihoods and attendant food security challenges, this study was carried out to investigate the effect of gas flaring on soil heavy metal concentration in Niger Delta oil producing community of Ologbo, Edo State, Nigeria**.** With the specific objectives of examining the effect of gas flaring on soil heavy metal concentration at 0-15 cm and 15-30 cm depths respectively.

THE STUDY AREA

This study was carried out in Ologbo community in Ikpoba-Okha Local Government Area (LGA), Edo State in the Niger Delta region of Nigeria. Ologbo is the host community for the Nigeria Petroleum Development Company (NPDC) Flow Station situated between Latitudes 6° 3"31.68" – 6° 3' 57.6"North of Equator and Longitudes 5° 34'52.74" – 5° 35' 26.88"East of Greenwich (Goselle and Ibanga, 2019). Ologbo community is bounded in the north by

Igbobaye and Imasabor communities, in the east and south by Ossiomo River and in the west by Obamahan community all in Ikpoba-Okha LGA. Ologbo community can simply be accessed through Benin – Sapele Road (Figure 1).

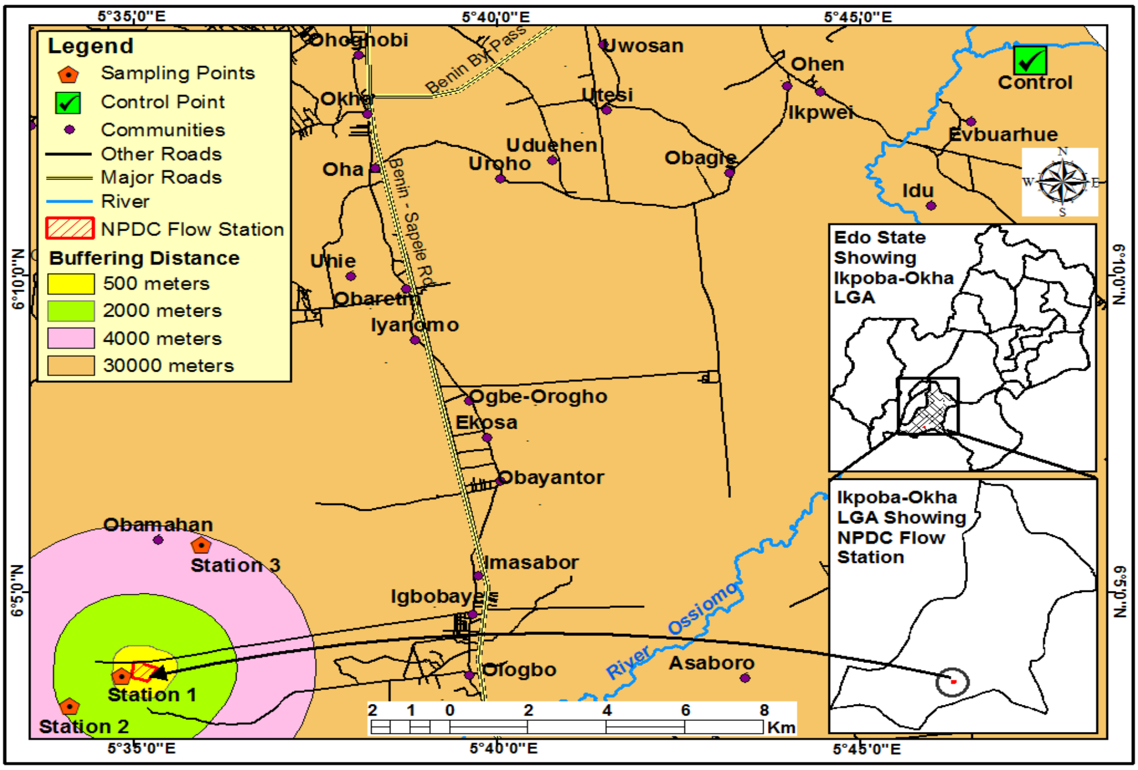

Figure 1: NPDC Flow Station at Ologbo Showing Sampling Locations

The climate of Ologbo community falls within the humid tropical equatorial with regular pressure from the tropical continental and maritime air masses from the nearby Atlantic Ocean. The mean annual temperature is as low as 22.3°C in January and as high as 31.4°C in February. Annual rainfall exhibits bimodal pattern with the first peak around June and the second peak in September with short dry season in August (Goselle and Ibanga, 2019). Geologically, Ologbo community is predominantly underlain by the coastal plain sand formation of sedimentary origin (Nigeria Geological Survey Agency, 2006).

MATERIALS AND METHODS

This study adopted a field-based experimental approach with soil samples constituting the principal dataset. The soil samples were retrieved with the aid of soil auger at specified ranges from the gas flaring stacks in the NPDC Flow Station based on the position taken by Argo (2002) and Ovuakporaye (2012) who reported that the space range of 200 meters from the flare stack to about 35,000 meters can be regarded as falling within the zone of influence by gas flaring. Subsequent to this framework by Argo and Ovuakporaye, three soil sampling stations were created. Soil samples were collected at a distance of 500meters, 2,000 meters and 4,000 meters from the gas flare facility, while the Control Station was located at Evbuarhue community which is 30,000 meters away from the third sampling station as seen in Figure 1. The choice of the control station was so determined because Onuorah (2000) and Odjugo (2007) noted that the impact of gas flaring on the environmental quality is statistically insignificant beyond 15,000 meters and 20,000 meters radius of the flare site. Soil samples were taken at two depths namely, 0 - 1 5 and 15 - 30cm beginning from near the fence of the flare facility (500m). The choice of these depths was based on the fact that research has shown that, 0-15cm and 15-30cm is the root zone and most soil nutrients are concentrated within the top half meter of the soil (Lekwot et al., 2014).

During the field-based experimental survey, a total of eight soil samples were collected that is, six from the flare vicinity and two from the control point. The geographical coordinates of the soil sampling stations are presented in Table 1. A stainless steel, hand-held Dutch type Soil Auger was used to collect representative soil samples at each soil sampling station in each grid. Soil samples for physical and nutrient elements analyses were sub-sampled into polyethylene bags that had been appropriately labelled using masking tape and indelible ink. The soil samples were immediately taken to the laboratory for analysis after collection in order to sustain the soil microorganisms. Laboratory analysis was done at Martlet Environmental Research Laboratory Limited, Benin City, Edo State.

Table 1: Geographical Coordinates of Soil Sampling Stations

Stations	Sampling Locations	Latitude	Longitude	Elevation
1	500 meters	6° 3' 41.033"N	5° 34' 50.291"E	29 meters
2	2,000 meters	6° 3' 13.166"N	5° 34' 6.088"E	16 meters
3	4,000 meters	6° 5' 46.915"N	5° 35' 55.634"E	25 meters
Control	30,000 meters	6° 13' 28.162"N	5° 47' 19.817'E	66 meters

Laboratory and statistical analyses

In conducting the soil analysis, importance was placed on those soil properties directly affecting soil fertility status. Parameters analyzed include: iron (Fe), manganese (Mn), zinc (Zn), chromium (Cr), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni), vanadium (V) and hydrocarbon content (THC). The soil samples were subjected to laboratory analysis in order to determine the concentration of the selected elements in the gas flaring impacted soils. Detailed description of the analytical procedures on the determination of the amount of Fe, Mn, Zn, Cr, Cu, Cd, Pb, NI, V and THC in typical crude oil and flare-impacted soils have been provided by Atuma and Ojeh (2013), Aigberua et al (2017) and Akpokodje et al (2019).

The laboratory results were further analysed using descriptive statistics and presented using tables and charts. Also, the Student t-test in Statistical Package for Social Sciences (SPSS) Version 22 was deployed to assess the possible differences in soil parameters (heavy metal concentration) between two stations as well as between each station and the control point

RESULTS AND DISCUSSION

Effect of Gas Flaring on Soil Parameters (heavy metal concentration) at 0-15cm depth

The values of heavy metal concentration of soil within flare vicinity at 0-15cm were generally observed to be higher in Station 1 (500m from the fence of the flow station) than values obtained at the Control Station (Table 2). The highest effect of gas flaring on soil heavy metal concentration at 0-15cm depth was noticed in Fe which recorded a value of 970mg/kg, followed by the effect on Zn concentration which was 137mg/kg. The volume of Mn was 53.1mg/kg when compared to 15mg/kg noticed in the Control Station vicinity while V recorded a value of 1.31mg/kg and was still higher than the control value of 0.2mg/kg.

Table 2: Concentration of Soil Heavy Metal Concentration (0-15cm) at different Locations away from Flow Station

Heavy Metals	Control	Station 1	Station 2	Station 3
Fe	290	970	823	1023
Mn	15	53.1	39.8	60.4
Zn	14.1	137	53.3	147.9
Cu	7.81	37.3	27	46.3
Cr	0.63	3.08	1.7	5.38
Cd	0.5	2.47	2.55	4.09
Pb	0.16	3.32	2.08	1.74
Ni	0.28	1.91	0.53	1.23
V	0.2	1.31	0.62	0.83
THC	0.86	3.5	2.47	3.3

*Observed values in mg/kg

Similar to the pattern observed at Station 1, values of heavy metal concentration of soil at Station 2 were generally observed to be higher than the value obtained at Control Station (Table 2). The highest effect of gas flaring on soil parameters (0-15cm) was evidenced on Fe concentration which recorded a value of 823mg/kg against 290mg/kg recorded at the Control Station, followed by the effect on Zn concentration which recorded a value of 53.3mg/kg against 14.1mg/kg observed at the Control Station. The concentration of Mn also follows with 39.8mg/kg against 15mg/kg found in the Control Station while a value of 0.53mg/kg at the station was recorded for Ni against 0.29mg/kg found at the Control Station.

The concentration of heavy metals in the soil at Station 3 was also generally observed to be higher than values obtained at Control Station. The highest effect of gas flaring on soils with heavy metal concentration was on Fe which reached the value of 1023mg/kg against 290mg/kg found at the Control Station, followed by the effect on Zn concentration which recorded a value of 60.4mg/kg against 14.1mg/kg recorded for Control Station. These were also followed by Mn, with the value of 147.9mg/kg recorded against 15mg/kg seen at the Control Station. Heavy metal concentration of 0.83mg/kg at Station 3 was recorded for V, a value that was higher than 0.02mg/kg recorded at the Control Station.

From the foregoing, it could be inferred that Fe, Mn, Zn, Cu, Cr and Cd were highest at Station 3, followed by values determined for Station 1 while the lowest Fe, Mn, Zn, Cu, Cr and Cd values were recorded at Station 2. This pattern was similar to observed distributions within the flow vicinity. Values of Ni and V were observed to be generally low in all the sample locations. Lowest values were obtained at Station 2 while the highest values were recorded at Station 1. Similarly, highest values for Pb and THC were recorded in Station 1 while lowest values were recorded in Stations 3 and 2 respectively. The high values of Ni, V, Pb and THC at Station 1 implied a strong influence of gas flaring at the Flow Station on the immediate environs.

The overall results revealed that the highest average metal pollution on soil noticed on Fe, Zn, Mn and Cu were significantly enriched at sampled stations when compared with the Control Station (Table 3). When compared with other studies, the mean concentration of Fe was lower than 46261±2124mg/kg reported by Nowrouzi and Pourkhabbaz (2014) in the Persian Gulf, Hara Biosphere Reserve and higher than 62 - 264 mg/kg found in drilling holes within the Ologbo oil catchment as reported by Imarhiagbe et al. (2015). Also, the average volume of Pb, Cd and Ni found in this study was comparatively lower than Pb (36.65±7.32mg/kg), Cd

(3.54±0.51mg/kg) and Ni (79.86±17.11 mg/kg) reported by Nowrouzi and Pourkhabbaz (2014). The mean value of 42.07mg/kg for Mn obtained in this study is also lower than 105.13mg/kg in selected locations examined by Uyigue and Enujekwu (2017). Aigberua et al. (2017) also reported the mean dry season volume of 4.52 ± 1.71mg/kg and wet season value of 2.67± 2.07mg/kg for Cr at oil spillage impacted areas in Rumuolukwu community, Rivers State, Nigeria which was also close to the 2.69mg/kg determined in this study.

Table 3: Descriptive Statistics of Soil Heavy Metal Concentration in Ologbo Flow Station (0-15cm)

Heavy Metals	Mean	SE	SD	Sample Variance	Range	Min.	Max.	Sum	CoV
Fe	776.5	167.6	335.2	112350	733	290	1023	3106	43.17
Mn	42.07	9.98	19.9	398.6	45.5	15	60.4	168.3	47.30
Zn	88.07	32.5	64.9	421.81	133.8	14.1	147.9	352.3	73.69
Cu	29.61	8.26	16.5	273.2	38.5	7.8	46.3	118.4	55.72
Cr	2.69	1.02	2.05	2.2	4.75	0.63	5.38	10.79	76.21
Cd	2.4	0.75	1.47	4.2	3.59	0.5	4.09	9.61	61.3
Pb	1.83	0.65	1.3	1.67	3.16	0.16	3.32	7.3	71.04
Ni	0.98	0.367	0.73	0.53	1.63	0.28	1.91	3.95	74.5
V	0.74	0.23	0.46	0.21	1.11	0.2	1.31	2.96	62.16
THC	2.5	0.6	1.2	1.44	2.64	0.86	3.5	10.13	48.0

The statistical comparisons between soil heavy metal concentrations at Stations 1, 2 and 3, and the Control Station using t-test statistics at 0.05 level of confidence is presented in Tables 4. It was hypothesized that there is no significant difference between the heavy metal concentrations in the soil at different sampling points at 0-15cm. At 0.05 level of confidence, this hypothesis was sustained suggesting that the heavy metal concentration parameters did not differ significantly for the different points at 0-15cm depth.

Table 4: Summary of Student t-test for differences in Soil Heavy Metal Concentration at 0-15cm Depth

Stations	t Critical	P-Value	Significant difference
Stations 1 and 2	2.262157	0.131893	No significant difference
Stations 1 and 3	2.262157	0.151463	No significant difference
Stations 2 and 3	2.262157	0.131829	No significant difference
Station 1 and control	2.262157	0.21872	No significant difference
Station 2 and control	2.262157	0.265088	No significant difference
Station 3 and control	2.262157	0.212792	No significant difference
Stations 1,2,3 and control	2.262157	0.227866	No significant difference

Effect of Gas Flaring on Soil Parameters (Heavy Metal Concentration) at 15-30cm Depth

The values of heavy metal pollution on soils within the flare vicinity at 15-30cm were generally observed to be higher in Station 1 (500m from the fence of the Flow Station) than values obtained at the Control Station (Table 5). The highest effect of gas flaring on soil heavy metal concentration at 15-30cm was noticed in Fe which recorded a value of 896mg/kg, followed by Zn concentration which was 129.1mg/kg. The volume of Mn was 48.5mg/kg when compared to 12.1mg/kg noticed in the Control Station. The least heavy metal concentration of 0.67mg/kg was recorded for V, a value slightly higher than 0.6mg/kg established at the Control Station.

Table 5: Soil Heavy Metal Concentration (15-30cm) at different Locations away from Flow Station

Heavy Metals	Control	Station 1	Station 2	Station 3
Fe	232	896	570	956
Mn	12.1	48.5	27.9	45
Zn	9.5	129.1	38.6	141
Cu	5.33	36.1	16.5	40.1
Cr	0.22	2.99	1.49	4.49
Cd	0.39	2.15	2.23	3.62
Pb	0.1	3.1	1.63	1.62
Ni	0.16	0.71	0.49	0.99
V	0.6	0.69	0.38	0.7
THC	0.43	3.1	2.1	3.15

*Observed values in mg/kg

Similarly, when the soil heavy metal concentration parameters at Station 2 were compared to that of the Control Station, the values were generally observed to be higher in Station 2 than that of the Control Station (Table 5). The highest effect of gas flaring on heavy metal concentration was evidenced on Fe which recorded a value of 570mg/kg, followed by the effect on Zn concentration which recorded a value of 38.6mg/kg. The volume of Mn was 27.9mg/kg, which is higher than the Control Station value of 12.1mg/kg. Vanadium (V) recorded was 0.38mg/kg, which was less than 0.6mg/kg value at the Control Station.

The soil heavy metal concentration parameters were generally observed to be higher in Station 3 than values obtained at the Control Station. The highest effect of gas flaring on the soil heavy metal concentration was on Fe which was 956mg/kg against 232mg/kg recorded at the Control, Zn concentration was recorded as 141mg/kg. The volume of Mn was 45mg/kg when compared to 12.1mg/kg noticed at the Control Station. Cu recorded a value of 40.1mg/kg. V recorded a value of 0.7mg/kg which was slightly higher than 0.6mg/kg recorded at the Control Station.

From the foregoing, it was observed that the overall effect of gas flaring on soil heavy metal concentration at 15-30cm depth showed that Fe, Mn, Zn, Cu, Cr and Cd were highest at Station 3, followed by values determined at Station 1. The lowest observed Fe, Mn, Zn, Cu, Cr and Cd values were recorded at Station 2. Meanwhile, the value of Ni and V were observed to be generally low in all the sampled locations.

Considering the descriptive statistics of heavy metal concentration in soil at Ologbo Flow Station at 15-30cm depth (Table 6), the value recorded for Fe within the vicinity of the Flow Station was an average value of 663.5mg/kg. Also, the mean concentration of Mn was 33.37mg/kg, Zn (2.29mg/kg), Cu (79.6mg/kg), Cr (24.51mg/kg), Cd (2.09mg/kg), Pb (1.61mg/kg), Ni (0.58mg/kg), V (0.59mg/kg) and THC (2.19mg/kg). Standard deviation varied from 333.9 for Fe, 16.7 for Mn, 65.4 for Zn, 16.42 for Cu, 1.8 for Cr, 1.32 for Cd, 1.22 for Pb, 0.35 for Ni, 0.14 for V to 1.27 for THC. Range values of observed soil heavy metal concentration parameters were lowest for V (0.32mg/kg) and highest for Fe (724mg/kg).

Table 6: Descriptive Statistics of Soil Heavy Metal Concentrations in Ologbo Flow Station (15-30cm)

Heavy Metals	Mean	SE	SD	Sample Variance	Range	Min.	Max.	Sum	CV
Fe	663.5	166.7	333.9	11151	724	232	956	2654	50.32
Mn	33.37	8.39	16.7	282.16	36.4	12.1	48.5	133.5	50.07
Zn	79.6	32.6	65.4	4271.7	131.5	9.5	141	318.2	82.16
Cu	24.51	8.21	16.42	269.8	34.7	5.33	40.1	98.03	66.99
Cr	2.29	0.92	1.8	3.4	4.27	0.22	44.9	9.19	78.6
Cd	2.09	0.66	1.32	1.75	3.23	0.39	3.62	8.39	63.16
Pb	1.61	0.61	1.22	1.5	3	0.1	3.1	6.45	105.2
Ni	0.58	0.17	0.35	0.12	0.83	0.16	0.99	2.35	60.34
V	0.59	0.07	0.14	0.02	0.32	0.38	0.7	2.37	23.73
THC	2.19	0.63	1.27	1.62	2.72	0.43	3.15	8.78	57.99

The statistical comparisons between soil heavy metal concentration at Stations 1, 2 and 3 and the Control Station using t-test statistics at 0.05 level of confidence is presented in Table 7. The hypothesis that there is no significant difference between soil heavy metal concentrations at different sampling points at 15-30cm was accepted. This suggests that the soil heavy metal concentration did not differ significantly for the different points at 15-30cm depth.

Table 7: Summary of Student T-test of Differences in the Soil Heavy Metal Concentrations at 15-30cm depth

Stations	t Critical	P-Value	Significant difference
Stations 1 and 2	2.262157	0.187424	No significant difference
Stations 1 and 3	2.262157	0.246352	No significant difference
Stations 2 and 3	2.262157	0.195154	No significant difference
Station 1 and Control	2.262157	0.219313	No significant difference
Station 2 and Control	2.262157	0.258978	No significant difference
Station 3 and Control	2.262157	0.221212	No significant difference
Station 1,2,3 and Control	2.262157	0.227159	No significant difference

The overall assessment showed that there is heavy metal pollution of the soil with different depths (0-15cm and 15-30cm) in all the sampled stations. Soil heavy metal concentrations also decreased in concentration in relation to the distance away from Flow Station especially between Stations 1 and 2. Atmospheric effects, input/out rate and the already existing natural concentration in the soil in addition to gas flaring may be responsible for the minute differences in heavy metal pollution on soil from one point to another (Uno et al., 2013).

CONCLUSION

The prime motivation for this study was to scientifically investigate the status of soil heavy metal concentration with the view to statistically establish whether it has been altered by protracted gas flaring in Ologbo community. The overall effect of gas flaring on soil heavy metal concentration at 0-15cm depth showed that Fe, Mn, Zn, Cu, Cr and Cd were highest at Station 3, followed by values determined for Station 1. The lowest values of Fe, Mn, Zn, Cu, Cr and Cd were also established at Station 2. Regarding15-30cm depth, the overall effect of gas flaring on soil heavy metal concentration showed that Fe, Mn, Zn, Cu, Cr and Cd were highest at Station 3, followed by values determined at Station 1. In general, Fe, Mn, Zn, and Cu were significantly enriched at all sample locations since their concentration values are greater than 10. The highest average heavy metal contamination discovered was Fe, Zn and Mn. The difference in heavy metal contamination from one point to another may be due to the difference in the magnitude and input for each metal in the atmosphere and/or the difference in the removal rate of each metal from the air basin.

At 95% confidence level, the study concluded that heavy metal concentrations at different sampling locations and depths were not significantly different from one another portraying no possible effect of gas flaring on soil heavy metal concentration. This allusion is nevertheless, not a justification for gas flaring to be continued unabated in Ologbo. With continuous gas flaring, the study area will over time undergo further alterations in its environmental system. Efforts should be made to discontinue gas flaring by converting the flared quantities to wealth for local consumption and commercial purposes will in turn reduce the stress on forest resources as primary energy demand for cooking, thereby facilitating a green environment and mitigation of global warming and climate change. The study also recommended periodic monitoring of soil heavy metal concentration parameters to detect possible changes arising from unabated gas flaring.

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