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Assessment of Physicochemical Properties and Heavy Metal Load in Soils of Ebocha Gas Flaring Site in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author OIA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OON and MON managed the analyses of the study. Authors OIA and MON managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The negative impact of gas flaring on the environment cannot be overemphasised. This study assessed the effect of gas flaring on the physicochemical properties and heavy metal contents in soils of Ebocha gas flaring site in Rivers State. It involved the assessment of various distances from gas flaring point to 200 meters away (50 m, 100 m, 150 m, and 200 m) which represents the extent of gas flared pollution on soils to determine the physicochemical properties and heavy metal load. The gas flaring significantly decreased soil organic carbon and calcium content when compared with non-gas flaring polluted soils. Soil acidity increased, soil exchangeable ions decreased. N, P and K were altered in gas flared soils when compared to the controls. There were detrimental effects on soils physicochemical properties. Heavy metals observed were Cd (Cadmium), Ni (Nickel), As (Arsenic), Cr (Chromium), while Pb (Lead) was not detected. The concentration of heavy metals in gas flared soils decreases down soil depth from 0-15 cm to 45-60 cm respectively. The gas flaring extremely caused the acidic nature of gas flared soils. Coefficient of variation (CV) in percentage shows significant increase in acidic nature of the gas flared soils when compared with the control soils.

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Keywords: Gas flaring; Ebocha soils; physicochemical; heavy metals; pollution.

1. INTRODUCTION

Environmental contamination is a global challenge. Air, water and soil are continuously being polluted on daily basis as a result of human activities thereby altering ecological integrity. Soil being a universal sink and the basis for plant productivity bears the greatest brunt of environmental pollution [1]. It is getting polluted in a number of ways. There is urgency in controlling the soil pollution in order to preserve the soil fertility and increase the productivity [2]. Generally most pollutants are introduced in the environment by sewage, waste, accidental discharge or else they are by-products or residues from the production of something useful. Due to this precious natural resources like air, water and soil are getting polluted far beyond human control [3]. Great deals of these pollutants have been identified in view of their negative effects on the ecosystem and public. There have been reports of carcinogenic, mutagenic, physiological alterations, and other grades of medical conditions, including cancer, neurological, reproductive and developmental effects [4]. Deformities in children, lung damage and skin problems have also been reported [5]. Issues of bioaccumulation associated with the ingestion and uptake of these pollutants within vital cellular organs of humans and animals have been equally identified [6].

Globally, the economy of both developed and developing countries is run by technological exploits, natural resources and mineral wealth for which the nation is known. In 81 countries of the world, the extractive industry is the main economic driver and globally they account for a quarter of GDP [7]. Gas flaring entails burning of natural gas that is associated with crude oil when it is pumped up from the ground. Waste gases are subjected to such a process either because the gases are waste or it is difficult to store and transport them [8]. Non-waste gases are burnt off to protect the processing equipment when unexpected high pressure develops within them. Gas flaring in oil rigs and wells has been attributed to greenhouse gases in our atmosphere [9]. Nigeria flare significant amount of natural gas into the environment leading to loss of substantial amount of money per annum. For instance, World Bank reported that 150 to 170 billion m^3 of gases are flared annually, worth up to about $ 30.6 billion, the price equivalent of one-quarter of the United States' gas consumption or 30% of the European Union's yearly gas consumption [10]. Lower amount of gas equivalent have been reported to loss due to gas flaring to the tone of $2.0 billion per annum (Christopher, 2008). Despite the incentives to capture the associated gas and bring it to market, the volume of gas flared is still high. About 70 million /m^3 of natural gas are flared per day. On yearly basis, [11] reported that Nigeria flare about 17.2 billion m^3 of natural gas in the Niger Delta. Between 2006 to 2014 several oil wells were explored in Nigeria. Within the period the production, utilization and quantity flared varies. Also, the amount targeted could not be met. This is typically attributed to several reasons including delays in upgrade of facilities to flood terrain, inadequate line, limited facilities, obsolete equipment, community disturbance, activities of militia etc [12]. The demand for gas increase as a result of new opportunities for gas micro power, combined cycle turbines, independent power plant, and gas to liquids and expansion in liquefied natural gas trade also contributed to the utilization.

In Niger Delta, one of the threatening environmental problems prevalent in the area is environmental pollution caused by oil exploration and related activities atmosphere [13]. Other effects of gas flare on vegetation include: Chlorosis: SO_2 destroys plant tissues and produces gradual yellowing of leaves as chlorophyll production is impeded [13] Necrosis: Bhatia, [14] observed that plant organs are impacted by air pollutants leading to necrosis (dead areas on leaves) Epinasty: (downward curvature of leaves and abscission (dropping of leaves), reduction in growth rate and eventual death of plant [11]. Reductions in soil moisture content, in extension reduce fertility and crop yield. Petroleum exploitation and production in the Niger Delta over the years have resulted in a number of environmental, socio-economic and political problems in the region [15,16]. Oil spillage and gas flaring have caused severe environmental damages, loss of plants, animals and human lives [17], and loss of revenue to both the oil producing companies and the government [18]. Vegetation is removed to make way for seismic lines and sites. Storage, distribution and transportation of oil and gas using Tankers and pipeline network result in some quantities of petroleum products being released into the environment [19,20].

This has been the issue with regards to oil and gas production, and Niger Delta is no exception [21]. Consequently, the underlining effects of gas flaring on these locations and its inhabitants are numerous [22,23]. Notable ones are poor soil fertility (due to soil pH, heavy metals and toxics pollution), health hazards (such as skin problems, cancer, reproductive health problems, respiratory disorders etc.), climate change (bringing about flooding) and economic loss (due to impediment of their traditional occupation, farming) [24,25,26]. This research examined the impact of gas flaring on the soils of Ebocha in Rivers State to know how it has affected soil properties.

1.1 Study Area

The study was carried out in Ebocha in Ogba-Egbema-Ndomi Local Government Area of Rivers State. Rivers State in Nigeria is one of the States in Niger Delta Area. Home to 20 million people and 40 different ethnic groups, this floodplain makes up 7.5% of Nigeria's total land mass (Fig. 1). It is the largest wetland and maintains the third-largest drainage basin in Africa, [27]. Screen house investigations were carried out at the Department of Biology, Federal University of Technology Owerri, Imo state located at latitude 5.3866° N, and longitude 6.9916°E.

2. METHODS OF SOIL SAMPLE COLLECTION

Soil samples were collected from a depth of 0-60cm using soil auger specifically at a distance of 50 m, 100 m, 150 m, 200 m and control (non gas flare site), and transported to the laboratory for physicochemical and heavy metals tests [28,29,30].

2.1 Soil Sample Test

All the soil samples collected were air dried at room temperature, passed through a 2 mm sieve and analysed for: Particle size composition by hydrometer method [30] Organic carbon by chromic acid digestion method of Walkley and Black [29] Total nitrogen by regular micro-kjedhl digestion method and available phosphorus by Brays PI solution of Bray and Kurtz [12]. and determined in accordance with Essien [29] procedure; Soil pH determined were determined potentiometrically in distilled water using soil to water ratio of 1:1 [30]; Cation exchange capacity

Fig. 1. Map of Rivers State showing Ebocha in Ogba Egbema Ndoni

Plate 1. A gas flaring site

value was determined by using ammonium acetate (NH_4OAC) leachate method; And concentration of selected metals [lead, cadmium, nickel, arsenic and chromium] in the soil were determined by Atomic Absorption spectrophotometer (AAS).

2.2 Heavy Metal Determination

Heavy metals like lead, cadmium, nickel, arsenic and chromium were determined using double acid method of extraction and extraction acid read out with AAS.

The samples were mixed gently and homogenized and sieved through 2 mm mesh - sieve. The samples were first dried, and then placed in electric oven at a temperature of 40°C approximately for 30 minutes. The resulting fine powder was kept at a room temperature for digestion.

2.3 Digestion of Soil Samples

1 g of the oven dried sample was weighed using a top loading balance and placed in 250 ml beakers separately to which 15 ml of aqueous solutions (35% HC1, and 70% high purity HNOs in 3:1 ratio) was added. The mixture was then digested at 70% till the solution became transparent The resulting solution was filtered through whatman filter paper no 42 and into a 50 ml dilute 50 ml volumetric flask and diluted to mark volume using deionized water and the sample solution was analysed for concentration of lead, cadmium, nickel, arsenic and chromium using an atomic absorption spectrophotometer (Perkin-Elmer A Analyst 400).

2.4 Analysis of Soil Samples for Heavy Metals

AAS A Analyst 400 model was used in determining the content of metals in the previously digested soil samples. The nitrous oxide, acetylene gas and compressor were fixed and compressor turned on and the liquids trap blown to rid of any liquid trapped. The extractor and AAS control were turned on. The slender tube and nebulizer piece were cleaned with purifying wire and opening of the burner was cleaned with an arrangement card. The worksheet of AAS programming on the joined PC was opened and the empty cathode light embedded in the light holder. The light was turned on, beam from cathode adjusted to hit target zone of the arrangement card for ideal light throughput, at that point the machine was touched off. The fine was set in a 10 ml graduated chamber containing deionizer water and yearning rate was estimated. The analytical blank was prepared and a series of calibration solutions of known amounts of analyte element (standard) were made. The blank and standards were atomized in turn and their responses were measured. A calibrator graph was plotted for each of the solutions after which the sample solutions were atomized and measured. The various metals concentration from the solution were determined from the calibration based on the absorbance obtained for the unknown samples.

2.5 Statistical Analysis

Data were analyzed using mean and coefficient of variation (C.V) in percentages in a Microsoft excel package 2010.

3. RESULTS

3.1 Physicochemical Analysis

The result gotten from the physicochemical analysis of the soils showed that gas flaring altered the physical and chemical properties of were adversely affected (Table 1). The organic carbon, total nitrogen, available phosphorous, calcium, texture class, potassium, magnesium and sandy loam were affected. High risk of pollution was observed at 50 meter distance, 100 meter, 150 meter, and 200 meter distance respectively (Table 1). Heavy metals such as lead, cadmium, nickel, arsenic, and chromium decreased down the depth from 0 -15 cm to 45 – 60 cm. (Fig. 2). While Ni was only heavy metal detected in control environment (non-gas flare site) Table 3.

4. DISCUSSION

The results on the gas flared soils showed that the gas flaring altered the physical and chemical properties of the soils, and influenced the growth of pepper at various distances as 50 m, 100 m, 150 m and 200 m. In Niger Delta, one of the threatening environmental problems prevalent in the area is environmental pollution caused by oil exploration and related activities. As an oil producing region, oil spillage is one of the most outstanding causes of water and land or soil pollution including gas flaring and industrial effluents [31]. Experimental results are in accord with the findings of [30] and Thus information regarding the use of organic manure to improve physical, chemical and biological properties of soils contaminated with petroleum products, with a view of making them available for crop production is very important [31]. Gas flaring is becoming an acute environmental problem in Nigeria, particularly when large areas of agricultural land are contaminated. In most cases, the soil may remain unsuitable for crop growth for months or years, until oil is degraded to a tolerable level [31]. Depletion in nutrient status (Nitrogen and Phosphorus), inhibition of microbial activities and seed germination has been reported in gas flaring contaminated soils [17]. The formation of waxy texture in soils contributes to reduction of oxygen content in such soils [31]. The formation of oily scum, which impedes oxygen and availability of water to biota as well as formation of hydrophobic micro-aggregates with clay surfaces, are associated with oil contaminated soils [18].

Table 1. Physicochemical properties of gas and non gas flared soils

Treatments	pH	OC	TN	AP	Ca	K	Mg	TC	Sand	Silt	Clay
T_0(Control)	4.69	3.72	0.010	26.69	0.42	0.13	0.22	SL	87.15	5.05	5.03
T_1(50 Meters)	4.32	2.68	0.021	18.16	0.42	0.12	0.22	SL	84.96	5.00	5.02
T_2(100 Meters)	5.02	2.25	0.022	16.79	0.37	0.13	0.22	SL	82.62	5.01	5.02
T_3(150 Meters)	5.84	0.63	0.048	13.77	0.40	0.12	0.22	SL	81.81	5.01	5.01
T_4(200 Meters)	5.76	0.53	0.051	6.47	0.36	0.12	0.21	SL	81.59	5.00	5.02
Mean	5.34	2.07	0.035	11.56	0.33	0.12	0.22		83.78	5.01	5.02
CV (%)	1.2	0.75	0.001	3.21	0.02	0.01	0.01		2.65	0.09	0.01

OC = Organic Carbon, TN = Total Nitrogen, AP = Available Phosphorus, Ca = Calcium, TC = Texture class, K = Potassium, Mg = Magnesium, SL = Sandy loam

Nwachukwu MO, et al. [31] on contaminated soils. The soil pH at all levels of gas flared contamination distances tends to be acidic and the soil acidity was due to the effect of gas flaring on soil samples. However, gas flare-contaminated soil significantly decreased soil acidity as in Table 1, this observation accords with [29] that crude oil-contamination increases soil acidity in the Niger Delta.

OC contents of soil increased due to gas flaring, which is as the result of the carbon supplement from the hydrocarbons in the gas flaring site. OC observation in this study agrees with [5] who observed a similar trend of OC in a soil sample contaminated with 3% by weight weathered crude oil. N and P are usually limiting in oil-contaminated soil [19] made similar observations in their study. Similar trends were observed in K.

Plate 2. Soil samples collected from the study area

Table 2. Heavy metal contents in Ebocha gas flared soils

Soil Depth (cm)	Heavy Metals in mg/kg (WHO/FAO Limit)				
	Pb(10-15)	Cd (<1-2)	Ni (2-21)	As (<5-20)	Cr(150)
0 – 15	3.5	1.9	20.4	6.8	7.7
15 – 30	3.3	1.4	19.4	5.1	7.2
30 – 45	2.6	1.2	17.8	5.0	6.3
45 - 60	2.5	1.0	15.1	4.7	6.2
Mean	3.0	1.4	18.2	5.4	6.9
C.V %	1.2	1.1	2.6	1.3	1.2

Pb = Lead, Cd = Cadmium, Ni = Nickel, As = Arsenic, Cr = Chromium, C.V = Coefficient of variation

Table 3. Heavy metal contents in non- gas flared soils

Soil Depth (cm)	Heavy Metals in mg/kg (WHO/FAO Limit)				
	Pb(10-15)	Cd (<1-2)	Ni (2-21)	As (<5-20)	Cr(150)
0 – 15	ND	ND	3.5	ND	ND
15 – 30	ND	ND	2.4	ND	ND
30 – 45	ND	ND	1.2	ND	ND
45 - 60	ND	ND	ND	ND	ND
Mean	ND	ND	2.3	ND	ND
C.V %			1..6		

Pb = Lead, Cd = Cadmium, Ni = Nickel, As = Arsenic, Cr = Chromium, C.V = Coefficient of variation, ND = Not detected

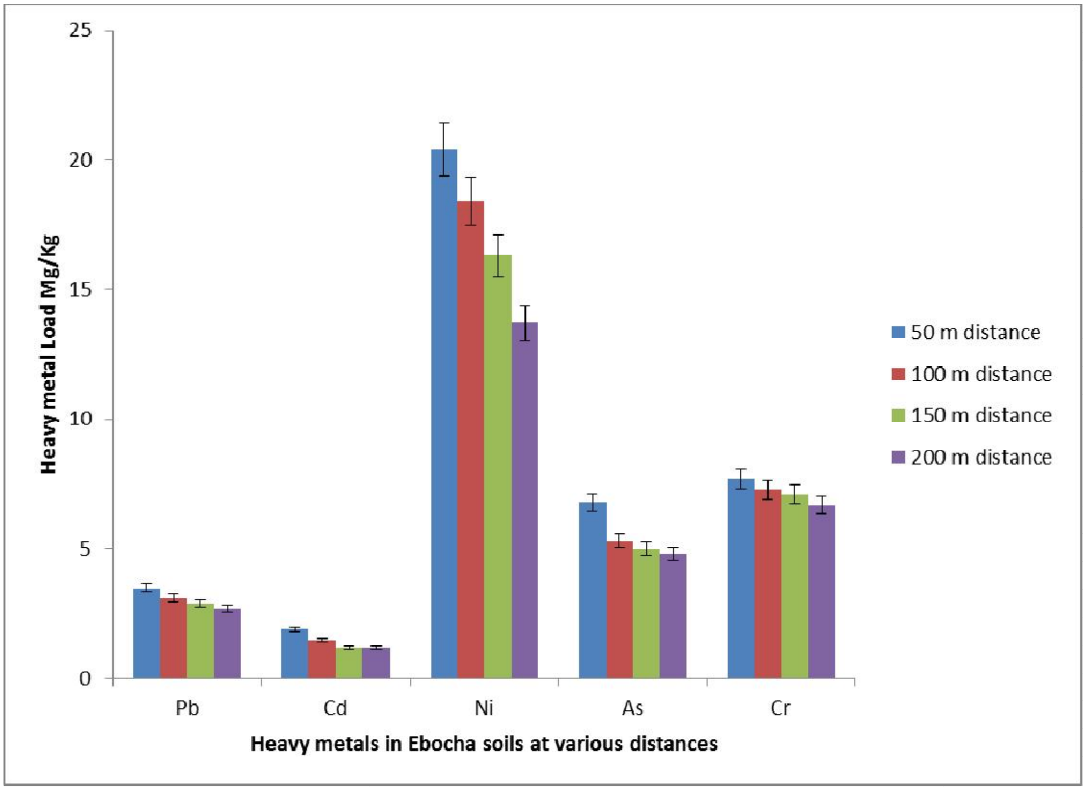

Fig. 2. Heavy metal contents in Ebocha gas flared soils

However, heavy metals observed were Cd (Cadmium), Ni (Nickel), As (Arsenic), Cr (Chromium), and Pb (Lead). The concentration of heavy metals in gas flare soils decreases down soil depht respectively.

5. CONCLUSION

Gas flaring affects the physicochemical properties of the soil. The effects in this study enumerated from gas flaring effluents are known to be detrimental and not environmentally-friendly.

6. RECOMMENDATIONS

Industries especially mining industry should avoid constant discharge of flaring gas to the environment; suitable means such as regeneration of the flared gas should be employed. Awareness should be created on the hazards accompanied by gas flaring.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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