Earthline Journal of Chemical Sciences
e-ISSN: 2581-9003; CODEN: EJCSB4
Volume 7, Number 1, 2022, Pages 35-52
https://doi.org/10.34198/ejcs.7122.3552

A Review of the Environmental Impact of Gas Flaring on the Physiochemical Properties of Water, Soil and Air Quality in the Niger Delta Region of Nigeria

Adeoye Ademola Elijah

Department of Chemistry, Federal University of Technology, Akure, Ondo State, Nigeria
e-mail: ademolaadeoye61@gmail.com

Abstract

The Niger Delta region of Nigeria is of great socio-economic importance due to its huge crude oil reserves. However, the process of exploration has been of great detrimental effect on the physiochemical properties of the soil, water and air quality in the region and has caused several public health issues. This review article is focused on readdressing the extent of the impact of one of the processes, gas flaring on the environment, using some physiochemical parameters of rain water, soil and air quality in some selected communities in the Niger Delta region based on series of previous researches. The results show that gas flaring has negatively impacted the physical and chemical properties soil, water and air components of the environment, most especially impacting areas very close to the flaring site. Also, recommendations were made as to how the flaring of gas can be reduced to a very minimal level as well as how these gases can be utilized making it more economical than the flaring process which is a very good case for further research.

1. Introduction

Gas flaring is one the hottest environmental issues in Nigeria [1] and the major source of sulfur dioxide, nitrous oxide, methane, carbon dioxide and particulate matter [2]. The effects cannot be over-emphasized most especially in the Niger Delta region of Nigeria. These emissions have had series of public health issues in the region coupled with occurrence of acid rain, greenhouse effect and corrosion of roofing sheets.

Gas flaring is the burning of natural gas and other petroleum hydrocarbons in flare

Received: October 26, 2021; Accepted: November 11, 2021

Keywords and phrases: gas; flaring; physiochemical; environment; soil; water; air.

stacks by upstream oil companies in oil fields during operation. It is the controlled combustion of associated gas generated during various processes including oil and gas recovery, petrochemical process and landfill extraction [3].

It is estimated that about 140 billion cubic meters of gas are flared annually across the oil-producing countries of the world [4]. Gas flaring has been illegal in Nigeria since 1984, yet the country still ranks among the top 10 gas-flare countries with about 7.4billion cubic meters of gas flared in 2018 and about 425.9billion standard cubic feet of gas flared in 2019 [5].

The health risks associated with gas flaring are glaring. In the oil-rich Niger Delta, 2 million people live within 4 kilometers (2.5 miles) of gas flare [6], which makes them more vulnerable to several health issues including cancer and lung damage, as well as deformities in children, asthma, bronchitis, pneumonia, neurological and reproductive problems [7]. Relatively, agricultural productivity (in the oil-producing areas) has been severely hampered by gas flaring. The combustion process raises the soil temperature, with a decline in crop yield and acid rains as its two major ripple effects. The smokes which emanate from the flares also lead to black rainfall and water bodies which affect aquatic and Wildlife.

The most flaring sight in gas production flow station is the ten-meter-high flame that burns continuously from vertical pipes at the many facilities owned by oil companies. One of such is located at Ebocha in Egbema in the Niger Delta. There, the vertical pipes are fed with gas given off during production [8]. Carbon dioxide and methane are the major greenhouse gases emitted in flaring and they make up to 80% of global warming.

The public health effects posed by gas flaring and the resultant air pollution cannot be over emphasized. Gas flare contains recognized toxins which are confirmed carcinogens like benzene, benzopyrene, toluene, mercury and arsenic. Ede in 1995 [9] monitored the air quality at Agbada, Bonny, Bomu, Tebidaba and Obagi in vicinity of gas flaring. Results showed high concentrations of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and suspended particulate matter above international standards and CO and suspended particulate matter were the greatest pollutants. This result supported by the increasing cases of respiratory and skin disorders in the region. Other cumulative impacts of these emissions include acid rain, reduction of soil fertility and global warming.

2. The Niger Delta and Gas Flaring

The Niger Delta region consist of 9 oil producing states namely Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ondo, Imo and Rivers. On 3rd August, 1956. Oil was discovered in commercial quantities in Oloibiri, Ogbia Local Government in the Bayelsa state [10]

The health risks associated with gas flaring are glaring. In the oil-rich Niger Delta, 2 million people live within 4 kilometres (2.5 miles) of gas flare [6] which makes them more vulnerable to several health issues including cancer and lung damage, as well as deformities in children, asthma, bronchitis, pneumonia, neurological and reproductive problems [7]. Relatively, agricultural productivity (in the oil-producing areas) has been severely hampered by gas flaring. The combustion process raises the soil temperature, with a decline in crop yield and acid rains as its two major ripple effects. The smokes which emanate from the flares also lead to black rainfall and water bodies which affect aquatic and Wildlife.

Figure 1. Gas Flaring site.

The economic costs of gas flaring are mind-boggling. Data obtained from the Nigerian Gas Flare Tracker showed that 25.9 billion Standard Cubic Feet of gas, valued at N460.5billion, were flared between January and November 2019. That amount would comfortably finance the capital expenditure of Ministries of Education, Power, Defence and Transport which stood at a combined total of N450billion. Also, the volume of gas flared is capable of generating 42,600 megawatts of electricity which would have helped solve the electricity problem of the country.

In fact, the environmental costs of gas flaring in Nigeria amount to N28.8 billion annually [11].

3. Impacts on the Environment

Carbon dioxide and methane are the major greenhouse gases emitted in flaring and they make up to 80% of global warming. According to [12], natural gas, propane, ethylene, propylene, butadiene and butane constitute 95% of the waste gases flared and CO_2 gas is produced when these gaseous hydrocarbons react with atmospheric oxygen. According to a World Bank sponsored study, gas flaring is one such anthropogenic activity defined as the wasteful emission of greenhouse gases (GHGs) that causes global warming, disequilibrium of the earth, unpredictable weather changes. It is a major natural disaster because it emits a cocktail of benzene and other toxic substances that are harmful to humans, animals, plants and the entire physical environment [13]. Some of the other impacts are listed below;

Acid rain: This unethical practice of gas flaring releases sulfur dioxide, carbon dioxide and nitrous oxide which are the major cause of acid rain. Not only that gas flaring degrades the air quality with the acid rain, but it also causes smoke, heat stress, soil bacteria reduction, destruction of forests and wildlife, deterioration of infrastructure and poor agricultural harvests [14].

During rainfall, these gaseous oxides react with water to form sulfuric, carbonic and nitric acids respectively which gets to the soil thereafter. The effect of this can be seen in plants succession where only acidic soil-adapted plants can grow in the area. The areas close to flare sites are now inhabited by grasses that can adapt the heat generated and acidic soil from the acid anhydrides, VOCs and hydrogen sulfide gas. This situation has shown biodiversity loss. The soil is no longer fertile for cultivation as the nutrients are depleted [15]. There is an additional economic consequence of acid rain as it causes corrosion to corrugated roofing sheets such as zinc plated sheets and consequently reduces their life span. The sheets usually last for over 20 years before but now last for 5 years. These sheets are commonly used in housing developments within the Niger Delta region. The house owners change the rusted and damaged sheets more often than expected and the aluminum roofing sheets which are highly resistant to acid rain are very expensive.

Thermal pollution: About 45.8 billion kilo watts of heat is discharged into the atmosphere from 1.8 billion cubic feet of gas every day in the Niger Delta region, leading to temperatures that render large areas inhabitable [16, 17]. Gas flaring causes elevated temperature in the vicinity of the flares, killing vegetation, reducing agricultural yield, suppressing growth and flowering of some plants and driving away nocturnal animals.

The warmth from the flares damages the soil, crops, cause discomfort to humans and animals and favors the metamorphosis of insects that destroy food crops [18].

3.1. Impact on climate change

Gas flaring contributes to climate change by emission of CO_2, the main greenhouse gas contributing 9 to 26% (~ 400 ppm) unlike CH4 which contributes 4 to 9% (~ 1.8 ppm) [19].

Since climate is the fundamental factor that determines organism life-stages such as plant germination and flowering, it can severely alter habitats and food sources for animals, and ultimately, could have significant impacts on biodiversity of species and ecosystems around the world. Global climate change affects our physical and biological environments, thus, it influences biodiversity both directly and indirectly through its interaction with other environmental factors [20].

3.2. Impact on agriculture

The flares associated with gas flaring give rise to atmospheric contaminants. These include oxides of Nitrogen, Carbon and Sulphur (NO_2, CO_2, CO, SO_2), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide (H_2S) [21]. These contaminants acidify the soil, hence depleting soil nutrient. In most cases, there is no vegetation in the areas surrounding the flare due partly to the tremendous heat that is produced and acidic nature of soil pH [21]. The effects of the changes in temperature on crops included stunted growth, scotched plants and such other effects as withered young crops [22]. He concluded that the soils of the study area are fast losing their fertility and capacity for sustainable agriculture due to the acidification of the soils by the various pollutants associated with gas flaring in the area.

3.3. Impact on human health

Gas flaring adversely affect human health by the inhalation of hazardous air pollutants emitted during incomplete combustion of gases flared. Adversely, these pollutants impair human health by causing cancer, neurological, reproductive and developmental defects [19]. Deformities in children, lung damage and skin problems have also been reported [23]. Incomplete combustion of hydrocarbons has also been identified to impair hematological parameters. These changes affect blood and blood-forming cells negatively leading to anaemia (aplastic), pancytopenia and leukemia [19].

4. Impact Assessment on Soil, Water and Air Quality based on Previous Research Works

Nwaogu and Onyeze in 2020 [24] carried out a research on the environmental impact of gas flaring on Ebocha-Egbema, Niger Delta, Nigeria. The results are as follows:

Table 1: Results for air quality assessment.

	Ebocha (Egbema)				
Parameters (mmol/L)	**500 (m)**	**1000 (m)**	**2000 (m)**	**5000 (m)**	**FEPA Standard (mmol/L)**
CO	20.00±0.010	15.00±0.012	12.00±0.012	10.00±0.018	10.0
NO_2	0.50±0.05	0.50±0.02	0.40±0.01	0.03±0.01	0.04 – 0.06
SO_2	0.40±0.005	0.40±0.012	0.30±0.009	0.20±0.009	0.01
CH_4	0.50±0.009	0.50±0.009	0.40±0.012	0.30±0.009	10.0
Particulates	1.60±0.015	1.50±0.012	1.30±0.012	1.50±0.012	0.1

4.1. Values obtained for all the parameters

(CO, NO_3, SO_4, CH_4 and particulates) from Ebocha were above the WHO and FEPA standard/permissible limit for normal environment, and were markedly higher when compared to values for communities very far from the flaring point. The mean values of all the air quality indices decreased as the distance from the flaring site increased indicating that gas diffusion increased with increasing distance. This result corroborates the work of Njoku et al [25].

Table 2: Values of water physicochemical parameters and WHO/FEPA Standard.

Physicochemical parameters (mg/l)	Water Samples		WHO/FEPA Standards
	Ebocha	Mbutu	
PH	5.2	6.58	6.5 – 8.5
Total hardness	192±1.20	40.0±1.40	-0.5
Calcium hardness	160±1.30	12.0±1.25	No limit
Total Solid	800±10.0	70.0±2.22	No limit
Chloride	56.74±2.50	1.28±0.03	250
Total Dissolved Solid	600±5.20	66.0±1.30	100 – 1000

Total Suspended Solid	200±2.50	4.0±0.25	No limit
Alkalinity	73.75±3.25	2.25±0.22	No limit
Sulphate	12.0±1.22	2.50±0.25	250 – 500
Phosphate	0.126±0.02	0.008±0.002	<5.0
Nitrate	8.0±0.02	2.00±0.01	10

Values are means ± S.D. of three determinations

From the above table, the mean values of pH of soil sample from both environments revealed that the sample from Ebocha was more acidic (pH 4.34) than that from Mbutu Mbaise (pH 5.21). High soil acidity creates chemical and biological conditions which may be harmful to plants and soil microorganisms. One of such conditions is the reduction in the capacity of plants to absorb cations [26]. The higher acidic nature of soil from Ebocha is attributable, at least in part, to the high concentrations of sulphur dioxide and particulates from the gas flared into the atmosphere which is washed back to the soil as acid rain. This observation agrees with the reports of [27] who noted that gas flaring increased soil acidity. This observation is also attributed to the high pollution level due to gas flaring in Ebocha, although the values for both NO_3 and SO_4, are below WHO in 1987 and FEPA in 1991 soil standards. The result of percentage carbon content from Ebocha soil was higher (1.16%) than that from Mbutu soil. This is due to high petroleum hydrocarbon pollution as a result of gas flaring in Ebocha when compared to Mbutu Mbaise.

5. Water Samples

Table 2 shows the values of the physicochemical parameters of the water samples from the two environments. The pH of the samples ranged from 5.42 for Ebocha to 6.58 for Mbutu. The Institute of Public Analysis of Nigeria (IPAN), reported that the pH of water is one the most important water parameters. An optimal pH range is very important for clarification of portable water, while a range outside the acceptable standard could lead to objectionable taste. Water samples from Ebocha (a polluted area) deviated from WHO and FEPA permissible pH range of 6.6-8.0. Thus, the water from Ebocha was found to be quite acidic (5.42), a value that could cause a shift in normal metabolism of living things within an ecosystem. The water sample from Ebocha had higher values for phosphate, sulphate and chloride when compared to that from Mbutu. This result agrees with the report of [28], who studied the physicochemical parameters and heavy metal contents of water from mangrove swamps. These compounds are essential for normal metabolism in plants and animals, as they serve as nutrients. When the plants eventually die, their debris undergoes aerobic biodegradation leading to anoxic conditions in water, which could have detrimental effects on aquatic organisms that require dissolved oxygen. The concentration of calcium and total hardness in water sample from Ebocha were high when compared to the values obtained for water from Mbutu. The difference is attributable to the detrimental effects gas flaring has on the portal water consumed in Ebocha and its environs. This corroborates the report of [28] who worked the physicochemical parameters and heavy metal contents of water from mangrove swamps of Lagos, Nigeria.

Based on the results from the study by Nwaogu and Onyeze [24], it was concluded that pollution due to gas flaring has negative impact on Ebocha environment (air, soil and water). This is obvious from the results of air quality indices and those of soil and water determined.

In another research work, Ahuchaogu et al. in 2019 [29] studied the effects of Gas flaring on surface water in Mkpanak Community of Akwa Ibom State, Nigeria

Analysis was carried out using the standard methods of the American Society for Testing and Materials, [30] and American Public Health Association, [31]. The laboratory analysis carried out on the collected samples (gas flaring point and non-gas flaring point) include the physical, chemical (including heavy metals analysis) and microbiological parameters. The physical parameters analyzed were Temperature, Color, Transparency, Turbidity, Odor. Chemical parameters checked were pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Salinity as in chloride ion level (Cl^-), BOD5, COD, Dissolved Oxygen (OD), Oxides of Nitrogen, Sulphur, Phosphorous, Potassium and Sodium ions adopting standard procedures. Digestion process was carried out using fume cupboard coupled with Atomic Absorption Spectrometer (AAS-model Unicam SOLAAR 969) appropriately to analyzed the possibility of heavy metals presence.

Comparison of the average water sample in the study area with the average of the water sample from the control area, World Health Standard 2008 and Nigerian Standard for Drinking Water Quality [32] for purpose of identifying and validating if the results of samples analyzed fall within the two standards above.

Table 3: Comparison of analyzed results from gas faring and non-gas faring samples WHO (2008) and (NSDWQ, 2007) Standards.

S/N	**Tested Parameters**	**Mean values ± Standard Deviation of gas flared samples**	**Mean values ± Standard Deviation of non-gas flared samples**	**WHO (2008) Acceptable Range**	**NSDWQ (2007) Acceptable Range**
A		**Physical Parameters**			
	Temperature (ºC)	25.30 ± 0.10	25.50 ± 0.10	27 - 28	Ambient
	Odour	Odourless	Odourless	Unobjectionable	Unobjectionable
	Colour (H/N)	Inoffensive	Inoffensive	5	15
	Transparency	Clear	Clear	-	-
	Turbidity (NTU)	11.72 ± 0.84	7.63 ± 3.03	5	5
B		**Chemical Parameters**			
	pH	6.46 ± 0.10	6.46 ± 0.05	6.5-8.5	6.5-8.5
	Electrical Conductivity (µS/cm)	9.07 ± 3.41	6.75 ± 0.75	1000	1000
	TDS (mg/l)	4.17 ± 1.61	3.40 ± 0.04	500	500
	TSS (mg/l)	0.14 ± 0.02	0.16 ± 0.02	-	-
	Total Hardness	20.17 ± 4.47	22.50 ± 0.10	-	150
	Salinity as Cl-	4.48 ± 0.23	4.64 ± 0.02	-	250
	DO (mg/l)	7.34 ± 0.56	7.80 ± 0.06	-	-
	COD (mg/l)	0.24 ± 0.09	0.18 ± 0.00	-	-
	NO3- (mg/l)	1.03 ± 0.45	0.79 ± 0.29	50	50
	SO42- (mg/l)	2.02 ± 0.03	0.99 ± 0.21	-	100
	PO43- (mg/l)	2.93 ± 0.26	1.71 ± 0.64	3.50	-
	BOD5 (mg/l)	0.10 ± 0.02	0.09 ± 0.00	-	-
	Potassium (K)	5.36 ± 0.98	4.73 ± 1.07	-	-
	Sodium (Na)	9.57 ± 0.61	10.44 ± 1.48	-	200
C		**Heavy Metals (mg/l)**			
	Lead (Pb)	0.00 ± 0.00	0.00 ± 0.00	0.01	0.01
	Copper (Cu)	0.00 ± 0.00	0.00 ± 0.00	2.00	1.00

	Zinc (Zn)	0.48 ± 0.11	0.35 ± 0.04	3.00	3.00
	Cadmium (Cd)	0.62 ± 0.36	0.48 ± 0.04	0.003	0.003
	Arsenic (Ar)	0.00 ± 0.00	0.00 ± 0.00	0.010	0.010
	Vanadium	0.00 ± 0.00	0.00 ± 0.00	-	-
	Nickel	1.23 ± 0.19	1.30 ± 0.29	0.070	0.020
	Iron	1.37 ± 0.13	1.25 ± 0.28	0.300	0.300
	Chromium	0.04 ± 0.01	0.03 ± 0.01	0.050	0.050
	Manganese	1.42 ± 0.46	1.43 ± 0.48	0.400	0.400

The mean temperature of the water samples collected from the study area was 25.30ºC which was slightly lower than that of the control area and was not within the acceptable range by the World Health Organization Standard 2008. The normal advisable level for temperature as stipulated by WHO is within the range of 27ºC-28ºC although it was close to the ambient temperature recommended by the NSDWQ, 2007 [32]. These could be due to the weather condition when the samples were taken from both the study and control area.

The Turbidity values for the surface water in the gas flaring area ranged from 10.95-12.62 NTU compared to 4.60-10.65NTU in the non-gas flaring area. The values are above the limits recommended by WHO and NSDWQ. This makes the water samples from both the study area and control area unsuitable for drinking because the high turbidity values indicate that the surface water has been polluted by the activities of man. In drinking water, the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases [33].

The water samples from the Gas flared Community and the Control Community was clear, inoffensive and odorless. This observation showed that the gas flares did not affect the Transparency, Colour and Odour of the surface waters in Mkpanak Community.

According to Fakayode [34], the pH is a very important factor for determining the quality of water because it controls the solubility and availability of mineral nutrients and heavy metals. The mean pH value for the surface water in both the study area and control area which was 6.46 was close to the acceptable range of 6.5 - 8.5 recommended. Although it lies slightly on the acidic side, the surface water may therefore be regarded as being neutral [34].

Electrical conductivity is a measure of the capacity of water to conduct electrical current. It is connected to the presence of ionic species in solution [35]. This study showed that the surface water from the gas flared area had electrical conductivity ranging from 7.0-13.0μS/cm compared to 6.0-7.5μS/cm for the non-gas flaring area although they were within the recommended limits of WHO and NSDWQ. The observed high conductivity of the surface waters in the study area indicated that the water was in contact with inorganic substances originating from the emissions of the flared gasses [36]).

Total Hardness is the total concentration of multivalent metallic cations in solution. Dissolved Calcium and Magnesium ions are the major sources of hardness in water whereas minor contribution is made by the ions of Aluminum, Barium, Manganese, Iron, Zinc, etc. The mean value of hardness gotten from the control area was 22.50mg/l compared with 20.17mg/l from the study area. This was well below the threshold limit of 150 mg/l as recommended by NSDWQ. Thus surface water from non-gas flaring areas is harder than surface waters from gas flaring areas because of the higher mean value for Total hardness in the study area. The increased hardness can reduce lather formation of soaps and increase the scale formation on hot water WHO.

Generally, the concentration of TDS is proportional to the degree of pollution. The TDS in the gas flaring area ranged from 3.0-6.0 mg/l while that from the non-gas flaring area ranged from 3.0-3.8mg/l and were far below the maximum limits recommended WHO and NSDWQ. The increase in TDS in the surface water of Mkpanak Community compared with the non-gas flared Community in this study could be due to increased pollution to the surface water from the activities of oil and gas companies operating there. Furthermore, high amount of TDS has been observed due to industrial pollution [37]. The values of Total Suspended Solids in the gas flaring areas ranged from 0.12 - 0.16mg/l. This was very low and almost the same with that of the non-gas flaring area which ranged from 0.14-0.18mg/l. These could be because the water samples from both the Gas flaring area and non-gas flaring area contained an appreciable amount of dissolved substances derived from surface runoff or overland flow. Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen required by aerobic biological organisms in a body of water to break down organic material present in a given water sample at a certain temperature over a specific period of time. It is widely used as an indication of the organic quality of water [37]. The amount of dissolved oxygen required to break down organic materials in the study area ranged from 0.08 - 0.12mg/l compared to an average 0.09mg/l in the control area.

According to [37], Dissolved Oxygen (DO) is very important for many chemical and biological processes taking place in water. A stream must have a minimum of about

2mg/l of DO to maintain higher life forms. The average concentration of DO which is a measure of how much the water samples is saturated with oxygen for the study area was 7.34 mg/L compared with 7.80mg/l in the control environment. The observed lower values of DO in study area compared with the control area may be due to high decomposition of organic matter, which can also indicate high pollution load in the water following many years of continuous gas flaring in the environment.

The surface water sources from the gas flared area had COD range of 0.16-0.34 mg/l compared with the constant 0.18mg/l from the non-gas flared area. The increased COD in the study area is an indication of pollution due to gas flaring. The flares associated with gas flaring gives rise to atmospheric contaminants which include the oxides of Nitrogen, Carbon and Sulphur. It was observed that the mean concentrations of phosphates (2.93mg/l), sulphates (2.02 mg/l) and nitrates (1.03 mg/l) which are the main constituents of the flared gasses was higher in the surface waters in the gas flaring area than the mean concentrations of phosphates (1.71 mg/l), sulphates (0.99mg/l) and nitrates (0.79mg/l) in the control area. These variations are an indication that gas flaring increases the concentrations of Nitrates, Sulphates and Phosphates in the surface waters of Mkpanak Community.

The two largest sources of Chromium emission in the atmosphere are from the chemical manufacturing industries and the combustion of natural gas, oil and coal. The mean concentrations of Chromium in the surface water of the study area (0.04mg/l) was slightly higher than that of the control area (0.03mg/l) and were both within the recommended limits by WHO and NSDWQ. Drinking water containing large concentrations of Chromium over a short period of time can lead to skin irritation or ulceration while ingestion over a long period of time can lead to liver or kidney damage [38]. The mean concentration of Potassium in the surface water of the area with gas flaring activities (5.36mg/l) was higher when compared with the area without gas flaring activities (4.73mg/l). The average amount of Sodium in the study area was below the average amounts found in the control area and both were below the threshold limits of the WHO, 2008 limits. This means that gas flaring activities did not affect the concentration of sodium in the surface waters of Mkpanak Community.

In another study by Ubani and Onyejekwe in 2013 [21], their research explores and presents a method of analyzing the environmental impact of gas flaring in the Niger Delta so to provide the data required for the complete analysis and evaluation of the various observed and noted health and environmental effects of gas flaring in Niger Delta. The major environmental impacts considered in the study are environmental pollution, and ecological disturbance or destruction. Several visitations to the neighboring communities adjacent to most gas flare locations were carried out to ascertain any existence of common environmental hazards. Data was gathered through a well-designed and articulating oral and written questionnaires, direct and first-hand observation of their environment, and comprehensive interview sessions with community heads (royal authorities where possible), patients and youth. Different samples at various proximities from the gas flare locations were taken and measurements and experimentations were meticulously carried out.

6. Results

Table 4: Temperature, pH and Moisture Content of the various soil samples.

Distance from flare point	A			B			E			G		
	pH	T (°C)	MC%	pH	T (°C)	MC%	pH	T (°C)	MC%	pH	T (°C)	MC%
10m	4.2	60	18	4	55	15	4.2	50	18	4.3	52	15
100m	5	46	26	5.1	4	21	5.2	41	25	5.2	40	20
200m	6.1	33	35	6.3	32	35	6.3	31	34	6.3	31	31
Control	6.6	45	45	6.7	29	41	6.6	30	40	6.6	29	35

The results obtained under environmental analysis showed that the pH of rainwater (<5.6) were not within regulation limits for most gas flare location. Rainwater samples collected during dry seasons were more acidic than those collected during rainy seasons. This can be explained by the fact that acids formed in the atmosphere with pollutants

$$(HO_X + H_2O \rightarrow HNO_3 \;\; \& \;\; SO_X + H_2O \rightarrow H_2SO_4)$$

are likely to be more diluted during the rainy season than dry season. In addition, the average of soil temperature (54°C and 42°C) as against 30°C, soil pH of (4.1- 5.1) as against 6.7 and the low soil moisture content of (17% - 23%) as against 40% for the (10m and 20m) and control. The results obtained shows that gas flaring is responsible for the contamination of water bodies which then affects the survival of fishes and other aquatic life. Almost no vegetation can grow in the area directly surrounding the flare due to the tremendous heat it produces and the acid nature of the soil Ph. This acid nature of the soil also has attendant effect on the soil usually used in agricultural purposes. Corrugated metal roofing sheets in the vicinity of flare corrode and deteriorate at a very faster rate as against their established life span.

From the results obtained in this study, it is concluded that most of the environmental hazard claims from different indigenes of communities adjacent to gas flare locations are true effects and reflections of the gas flaring activities in these regions.

7. Conclusion

Ending routine gas flaring in Nigeria will lead to an increase in revenue generation, infrastructural development, and power supply. It would also support thousands of jobs and businesses, improve health conditions in the oil-producing areas, and reduce the emission of CO_2 into the atmosphere. With these benefits in mind, tackling gas flaring in Nigeria should be a priority

Gas flaring are known to have impact on air quality, physical infrastructure, biodiversity composition including plants and animals especially insects, impacts on human health over a prolong period of time and water resources especially rainwater. Acid rain has been widely attributed to impact of gas flaring especially in the Niger Delta region of Nigeria. On water quality, gas flaring alters ions especially sulphate, carbonate, nitrate, pH, conductivity, lead and iron concentration especially in rainwater. On vegetation perspective, it could lead to loss of vegetation cover, reduced growth and productivity/yield probably due to changes in soil quality parameters.

8. Recommendation/Suggestions

Based on the review, the attendant impacts associated with gas flaring on vegetation and water quality could be reduced through the following six ways:

1. Utilization of the gas and generation of revenue from it.

2. Enforcement of laws aimed at minimizing the amount of gas flared into the atmosphere.

3. The Federal Government should pay attention to the development of critical infrastructure such as gas processing technologies and transportation pipelines to enhance the movement of gas from oil fields to end-users.

4. Greater investments in gas processing and utilization.

5. Investments in petrochemical industries should be encouraged. These industries

utilize gas to produce polymers, ammonia, hydrogen fuel for cars, etc. For example, in 2018, recycling of hydrocarbon byproducts of oil and gas extraction (about 22.3 billion cubic meters of gas) helped reduce greenhouse-gas emissions by 71 million metric tons [40].

6. Concrete efforts should be made to diversify the Nigerian economy to reduce dependence on crude oil for national revenue. Reduced dependence on petroleum would increase the government's tenacity in enforcing measures against gas flaring in the Country. Agriculture, tourism, and processing can provide alternative sources of revenue.

References

[1] Abdulkareem, A.S. (2005). Urban air pollution evaluation by computer simulation: a case study of petroleum refining company, Nigeria. *Leonardo Journal of Science Technical University of Cluj-Napoca Romania*, 6, 17-28.

[2] Ndubuisi, O.L., & Asia, I.O. (2007). Environmental pollution in oil producing areas of the Niger delta basin, Nigeria: empirical assessment of trends and people's perception. *Environmental Research Journal*, 1(1-4), 18-26.

[3] Generon.com (2019, September 24). What is Gas Flaring? — Why is It Done & Viable Alternatives. Retrieved from https://www.generon.com/what-is-gas-flaring-why-is-it-done-alternatives/

[4] McGreevey, C.M., & Whitaker, G. (2020). Zero Routine Flaring by 2030. Retrieved from https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030

[5] Eboh, M. (2019, December 31). Nigeria: Despite Paucity of Funds, Nigeria Flares N461bn Gas in 2019. Retrieved from https://allafrica.com/stories/201912310199.html

[6] Schick, L., Myles, P., & Okelum, O.E. (2018, November 14). Gas flaring continues scorching Niger Delta. Retrieved from https://www.dw.com/en/gas-flaring-continues-scorching-niger-delta/a-46088235

[7] Stockbrokers, C.S.L. (2020, February 18). Gas flaring: A never-ending dark tunnel. Retrieved from https://nairametrics.com/2020/02/18/gas-flaring-a-never-ending-dark-tunnel/

[8] Amanze, R.E. (2013). Gas flaring in Nigeria: cost and policy. *Energy and Environment*, 24(6), 77-78. https://doi.org/10.1260/0958-305X.24.6.983

[9] Ede, P.N. (1995). An analysis of the atmospheric impact of gas flaring in Rivers State. *Unpublished Master's Thesis, Department of Geography, University of Port Harcourt, Choba*.

[10] Tamuno, S., & Felix, J.M. (2006). Crude Oil Resource: A Blessing or Curse to Nigeria — The Case of the Niger Delta. *J. Res. Natl. Dev.*, 4, 53-58. https://doi.org/10.4314/jorind.v4i2.42332

[11] PWC (2019). Assessing the impacts of gas flaring on the Nigerian economy. Retrieved from https://www.pwc.com/ng/en/assets/pdf/gas-flaring-impact1.pdf

[12] Ismail, O.S., & Umukoro, G.E., (2012). Global impact of gas flaring. *Energy and Power Engineering*, 4(4), 290-302. https://doi.org/10.4236/epe.2012.44039

[13] Ayoola, T.J. (2011). Gas flaring and its implication for environmental accounting in Nigeria. *Journal of Sustainable Development*, 4(5), 244. https://doi.org/10.5539/jsd.v4n5p244

[14] Anejionu, O.C., Ahiarammunnah, P.A.N., & Nri-ezedi, C.J. (2015). Hydrocarbon pollution in the Niger Delta: Geographies of impacts and appraisal of lapses in extant legal framework. *Resources Policy*, 45, 65-77. https://doi.org/10.1016/j.resourpol.2015.03.012

[15] Frolovskiy, Dmitriy (2019, December). Gas flaring remains issue for Russia. Retrieved from https://asiatimes.com/2019/12/russias-gas-flare-up-but-less-than-before/

[16] Uyigue, E., & Agho, M. (2007). Coping with climate change and environmental degradation in the Niger Delta of southern Nigeria. *Community Research and Development Centre Nigeria (CREDC).*

[17] Kadafa, A.A. (2012). Oil exploration and spillage in the Niger Delta of Nigeria. *Civil and Environmental Research*, 2(3), 38-51.

[18] Osuji, L.C., & Adesiyan, S.O. (2005). Extractable hydrocarbons, nickel and vanadium contents of Ogbodo-Isiokpo oil spill polluted soils in Niger Delta, Nigeria. *Environmental Monitoring and Assessment*, 110(1-3), 129-139. https://doi.org/10.1007/s10661-005-6283-0

[19] Ajugwo, Anselm (2013). Negative effects of gas flaring: the Nigerian experience. *Journal of Environment Pollution and Human Health*, 1(1), 6-8.

[20] Ogawa-Onishi, Y., & Berry, P.M. (2013). Ecological impacts of climate change in Japan: The importance of integrating local and international publications. *Biol. Conserv.* 157, 361-371. https://doi.org/10.1016/j.biocon.2012.06.024

[21] Ubani, E.C., & Onyejekwe, I.M. (2013). Environmental impact analyses of gas flaring in the Niger delta region of Nigeria. *American Journal of Scientific and Industrial Research*, 4(2), 246-252. https://doi.org/10.5251/ajsir.2013.4.2.246.252

[22] Orimoogunje, O.I., Ayanlade, A., Akinkuolie, T.A., & Odiong, A.U. (2010). Perception on the effect of gas flaring on the environment. *Res. J. Environ. Earth Sci.* 2(4), 188-193.

[23] Ovuakporaye, S.I., Aloamaka, C.P., Ojieh, A.E., Ejebe, D.E., & Mordi, J.C. (2012). Effects of gas flaring on lung function among residents Gas flaring community in Delta State, Nigeria. *Res. J. Env. Earth Sci.,* 4(5), 525-528.

[24] Nwaogu, L.A., & Onyeze, G.O.C. (2020). Environmental impact of gas flaring on Ebocha-Egbema, Niger-Delta, Nigeria. *International Journal of Energy and Environmental Research*, 8(1), 1-11.

[25] Njoku-Tony, R.F., Ihejirika, C.E., Ebe, T.E., Nwachukwu, N., & Elimnitan, O.O. (2017). Effects of gas flare from Utorogu gas plant on biochemical variables of cassava leaves (*Manihot esculentum*) Niger Delta. *British Journal of Environmental Science*, 5(5), 27-38.

[26] Nagaraju, M., Narasimha, G., & Rangaswamy, V. (2007). Impact of effluents of sugar cane industry on soil physicochemical and biological properties. *Journal of Industrial Pollution Control*, 23(1), 73-76.

[27] Nwaugo, V.O., Onyeagba, R.A., & Nwachukwu, N.C. (2006). Effect of gas flaring on soil microbial spectrum in parts of Niger Delta Area of Sourthen Nigeria. *Annual Journal of Biotechnology,* 5(19), 1824-1826.

[28] Nwankwo, C.N., & Ogagarue, D.O. (2011). Effects of gas flaring on surface and ground waters in Delta State, Nigeria. *Journal of Geology and Mining Research*, 3(5), 131-136.

[29] Ahuchaogu, I. Israel, Ime, Etim, & Ofose, V. Etim (2019). Effects of gas flaring on surface water in Mkpanak community of Akwa-Ibom state*, Nigeria*. *International Journal of Engineering Research & Technology (IJERT)*, 8(9). https://doi.org/10.17577/IJERTV8IS090134

[30] ASTM, (1999). *Standard methods for examination of water and wastewater* (21st ed.). Washington, D.C.: American Society for Testing and Materials.

[31] APHA, (1998). *Standard methods for examination of water and wastewater* (20th ed.). Washington, D.C.: American Public Health Association.

[32] NSDWQ (2007). Standards Organization of Nigeria, Lagos, Nigeria: Nigerian Standards for Drinking Water Quality.

[33] Mann, A.G., Tam, C.C., Higgins C.D., & Lodrigues, L.C. (2007). The association between drinking water turbidity and gastrointestinal illness: a systematic review. *BMC Public Health*, 7(256), 1-7. https://doi.org/10.1186/1471-2458-7-256

[34] Fakayode, S. O. (2005). Impact assessment of industrial effluent on water quality of the receiving Alaro River in Ibadan, Nigeria. *Ajeam-Ragee*, 10, 1-13.

[35] Boukari, M. (1998). *Updating of hydrogeological knowledge about coastal sedimentary basin of Benin*. Cotonou, 134.

[36] Etu-Efeotor, J.O. (1998). Hydro chemical analysis of surface and ground waters of Gwagwalada area of Central Nigeria. *Global J. Pure Appl. Sci.*, 4(2), 153-162.

[37] Shivayogimath, C.B., Kalburgi, P.B., Deshannavar, U.B., & Virupakshaiah, D.B.M. (2012). Water quality evaluation of river Ghataprabha, India. *Int. Res. J. Environ. Sci.*, 1(1), 12-18.

[38] WHO, (2011). *International drinking water standard* (4th ed.). Geneva; World Health Organisation.

[39] WHO, (2008). *International drinking water standard* (3rd ed.). Geneva: World Health Organization.

[40] Frolovskiy, Dmitriy (2019). *Gas flaring remains an issue in Russia.* https://asiatimes.com/2019/12/russias-gas-flare-up-but-less-than-before/