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Effects of Gas Flaring on the Physicochemical and Microbiological Quality of Water Sources in Egbema, Imo State, Nigeria

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Abstract. This study evaluated the effects of gas flaring on the physico-chemical and microbiological characteristics of water sources at Egbema, Imo State, Nigeria. Surface and ground water samples from the area were compared with samples from Ihiagwa Autonomous Community in Owerri West, a non-gas flared community. Both water sources were then compared with WHO standards for drinking water. The results revealed that water sources from the gas flared area have high levels of temperature, total chlorine, nitrate, nitrites, sulphates, calcium, and zinc, chromium with a very acidic pH when compared with water from non-gas flared sources. Also, microbial load increased the farther the distance from the flare site. The human health imparts of the presence of heavy metals and microorganisms in drinking water had been reported. In conclusion, gas flaring can pollute water sources within oil and gas facilities, thereby making them unsuitable for human consumption. Oil and gas industries should therefore treat water within their areas of operations before discharged into water bodies in addition to other remediation measures as part of their social responsibility.

Introduction

The continuity of life on earth hinges on the availability of water. Water, though relatively distributed worldwide, suffers portability owing to anthropogenic and other biogenic activities. In short, Water remains one of the environmental resources that suffers exploitation by life activities [1]. In a general point of view, water related challenges are either as a result of too much water with poor portability or scarcity of water [2].

Nigeria is the 6th largest producer of oil in the world and it is endowed with more gas reserves than oil. In spite of the massive endowment of this natural gas, much of it is flared. The Nigerian case attracts more attention because of the volume of the gas flared since the beginning of commercial oil production in the country and it was reported that Nigeria flares the highest of 17.7% [3] compared to other oil producing countries. The Niger Delta region, where Nigeria current large oil and gas resources are located, has been regarded to have the unifying features and has remained a source of global interest. Considering its openness to the Atlantic Ocean and watercourses, access to the sea and rivers such as the Benue and Niger Rivers, the Niger Delta embodies some of the major coastal upwelling sub-ecosystems of the world and is an important centre of marine biodiversity and marine food production ranked among the most productive coastal and offshore waters in the world [4]. Despite all these, the risk of the impact of oil producers have rendered the environment uninhabitable due to limitless sources of pollution.

Gas flaring, an inevitable activity of petroleum producers, is the burning of natural gas that is associated with crude oil when it is pumped up from the ground [5]. In petroleum-producing areas where insufficient investment was made in infrastructure to utilize natural gas, flaring is employed to dispose of this associated gas [6]. It is a common practice in the oil and gas industry as a means of burning off unwanted, flammable gases via combustion in an open atmosphere [7]. As gas is flared, Acid precipitates from the emission of gases SO_2, NO_2 and CO_2. These atmospheric pollutants results in acid rain [8]. Walk and Godfrey [9] discussed that acid rain has a negative impact on surface water and groundwater as a result of the effects of atmospheric deposition and

trace elements during gas flaring. The study reports on the effect of gas flaring on the physico-chemical and microbiological quality of ground and surface water.

Material and Methods

Study areas

Imo State is one of the nine states in the Niger Delta region of Nigeria endowed with natural resources. Egbema, an oil and gas producing community in Imo State with active gas flaring by Shell Petroleum Development Company (SPDC) in partnership with Nigerian Petroleum Development Company (NPDC), constitute the study community. Egbema lies on longitude 64928.24 East and latitude 5248.53 North. It is located in the South/Western part of Imo state and shares common boundaries with Owerri in the East, Oguta in the North and Ogba/Egbema/Ndoni in Rivers state in the South West .The study area is characterized by two seasons, the wet (or rainy) and dry seasons. The rainy season starts in March and ends in October, with a peak in June and July. This community is also located in between many other active oil and gas flaring sites such as Ossu, Oguta and Izombe oil and gas fields operated by Addax and Akri and Ebocha oil and gas fields run by Nigeria Agip Oil Company. Ihiagwa autonomous community in Owerri West, a non-oil and gas producing area, constitute the control community. The residents of both communities were mainly hunters, fishermen, farmers, traders and civil servants and share many common characteristics.

Collection of water samples

Two important seasons in Nigeria were considered during sampling. The Rainy (wet) season which is between March and July and the Harmattan (Dry Season) which was within November, 2015 to February, 2016. Water samples were collected from twenty drinking water sources from each of the communities in triplicates. These include twenty underground water sources from commercial bore holes water sources and twenty surface water sources from streams within and around Egbema community. Control samples were collected from boreholes and Otamiri stream at Ihiagwa, a non-oil producing community in Owerri West Local Government Area of Imo State, Nigeria. The samples were collected aseptically into clean plastics and bijou bottles previously sterilized with absolute alcohol and rinsed thrice with the sample before collection; then labeled for identification and carried to the laboratory in an ice box for immediate analysis. Samples were collected and analysed for wet and dry seasons.

Sample analyses

Colour was determined by visual observation after matching the samples against white background, while the odour and taste was determined by organoleptic method. The pH, TDS and conductivity of the samples were evaluated with a HANNA EC probe/meter, which was first standardized (HANNA EC 215). Total Chlorine, nitrates, sulphates, calcium, zinc, iron, chromium, phosphates, were determined by using HANNA EC (HI 83099) multi COD photometer. Microbiological analysis was done using standard microbiological techniques. Identities of bacteria and fungi isolated were confirmed using standard manual [10].

Results

Table 1 and Table 2 represents the Physicochemical parameters of the water for dry season and wet season respectively. The bacterial and Fungal counts for the dry and wet season are also shown in table 3 and 4. The distribution of bacteria and fungi isolated from the water sample for the wet and dry seasons is shown in Table 5 and Table 6 respectively.

Table 1: Physico-chemical analysis of water sample for Dry season

Parameters	Borehole	Stream pt1	Stream pt2	Stream pt3	Control	WHO STD
Temp (^{0}C)	30.7	30.6	30.5	30.2	27.6	25-27
pH	5.4	4.9	5.5	5.2	3.8	6.5-8.5
Conductivity (mg/ml)	30	20	10	20	70	-
TDS (mg/ml)	20	10	10	10	10	1000
Ca (mg/ml)	160	20	10	20	10	500
Zn (mg/ml)	0.12	0.02	0.02	0.02	0.08	5
Fe (mg/ml)	0.0	0.51	0.24	0.08	0.08	0.3
Cr^{6+} (µg/ml)	4	0	0	0	22	50
CrO_4^{2-} (µg/ml)	9	0	0	0	49	50
$Cr_2O_7^{2-}$ (µg/ml)	8	0	0	0	46	50
NO_3 – N (mg/ml)	2.8	0.9	0.3	2.2	2.4	50
NO_3^- (mg/ml)	12.3	4	1.5	9.7	10.5	50
P (mg/ml)	0.57	0.18	0.04	0.04	0.07	-
P_2O_5 (mg/ml)	1.30	0.41	0.10	0.10	0.16	-
PO_4^{3-} (mg/ml)	1.74	0.55	0.13	0.14	0.22	-
Total chlorine (mg/ml)	018	0.16	0.22	0.48	0.12	250
Sulfate (mg/ml)	0	0	0	0	10	100

Table 2: Physico-chemical analysis of water sample for Wet season

Parameters	Stream pt1	Stream pt2	Stream pt3	Borehole	Control	WHO STD
Temp (°C)	29.7	30.0	29.9	29.7	27.2	25-27
pH	4.2	5.0	5.3	5.3	4.6	6.5-8.5
TDS (mg/ml)	0	0	0	0	0	1000
Conductivity (mg/ml)	0	20	20	20	40	-
Zinc (mg/ml)	0.08	0.01	0.06	0.01	0	5
Calcium (mg/ml)	120	0	50	100	20	500
PO_4^{3-} (mg/ml)	1.13	0.38	0.71	0.2	0.13	-
P (mg/ml)	0.37	0.12	0.23	0.07	0.04	-
P_2O_5 (mg/ml)	0.84	0.29	0.53	0.15	0.10	-
NO_3 –N (mg/ml)	2.5	0.3	0.8	1.6	5.5	50
NO_3^- (mg/ml)	11.1	1.4	3.7	7.2	24.3	50
Iron (mg/ml)	0.06	0.26	0.14	0.0	0	0.3
Cr^{6+} (µg/ml)	4	10	0	7	2	50
CrO_4^{2-} (µg/ml)	9	21	0	16	6	50
$Cr_2O_7^{2-}$ (µg/ml)	8	20	0	15	5	50
Chlorine (mg/ml)	0.19	0.08	0.09	0.15	0.07	250
Sulfate (mg/ml)	0	0	0	0	0	100

Table 3: Mean Total Colony Counts of Microorganisms isolated from Water Samples for Dry Seasons

Sample code	TAC	TCC	THC	TFC	TSSC
A	8.0×10^{6}	0	1.0×10^{4}	1.3×10^{3}	0
B	2.8×10^{7}	1.0×10^{4}	0	2.4×10^{3}	2.6×10^{5}
C	2.3×10^{7}	1.2×10^{4}	5.0×10^{4}	3.4×10^{3}	5.3×10^{5}
D	1.5×10^{7}	2.0×10^{4}	7.0×10^{4}	2.1×10^{3}	8.5×10^{5}
E	7.2×10^{9}	3.0×10^{6}	8.0×10^{4}	0	0

TAC, Total aerobic count; TCC, Total coliform count; THC, Total hydrocarbon count; TFC, Total fungal count; TSSC; Total Salmonella-Shigella count

KEY:A=BOREHOLE,B=STREAM POINT1, C=STREAM PT2, D=STREAM PT3, E= STREAM CONTROL SAMPLE

Table 4: Mean Total Colony Counts of Microorganisms isolated from Water Samples for Wet Seasons

SAMPLE CODE	TAC	TCC	THC	TFC	TSSC
A	1.6×10^{3}	0	0	0	0
B	1.28×10^{8}	1.2×10^{4}	1.2×10^{5}	2.1×10^{5}	0
C	2.17×10^{8}	1.9×10^{4}	2.8×10^{5}	4.9×10^{5}	1.0×10^{3}
D	1.96×10^{8}	2.6×10 4	5.6×10^{5}	7.8×10^{5}	1.0×10^{3}
E	8.6×10^{8}	0	0	0	0

TAC, Total aerobic count; TCC, Total coliform count; THC, Total hydrocarbon count; TFC, Total fungal count; TSSC, Total Salmonella-Shigella count

Table 5: Distribution of Bacterial and Fungal isolates (wet season)

Sample code	Bacterial isolates	Fungal isolates
A	*Staphylococcus*	-
B	*Staph, bacillus, micrococcus luteus, Ent faecalis, E. coli, salm sp, shigella sp*	*Saccharomyces sp*
C	*Staph, M. luteus, Bacillus sp, Pseudomonas sp, E. coli, Klebsiela sp, Salmonella sp, Shigella sp*	*Penicillium notatum*
D	*Bacillus sp*	*Saccharomyces sp, Mucor sp, Penicillium notatum, Rhizopus sp*
E	-	-

KEY:A=BOREHOLE,B=STREAM POINT1, C=STREAM PT2, D=STREAM PT3, E= STREAM CONTROL SAMPLE

Table 6: Distribution of Bacterial and Fungal isolates (Dry season)

Sample code	Bacterial isolates	Fungal isolates
A	*Pseudomonas* sp, *Bacillus* sp, *Micrococcus luteus*, *Staphylococcus* sp, *Enterococcus faecalis*	*Saccharomyces sp*
B	*Micrococcus luteus, Staphylococcus* sp, *Enterococcus faecalis, Bacillus* sp, *Pseudomonas* sp, *Flavobacterium* sp, *Escherichia coli, Salmonella* sp, *Shigella* sp	-
C	*Micrococcus luteus*, *Staphylococcus* sp, *Bacillus* sp, *Flavobacterium* sp, *Pseudomonas sp*, *Escherichia coli*, *Salmonella* sp, *Shigella* sp	*Saccharomyces cerevisiae, Saccharomyces cerevisiae var ellipsoideus, Geotrichum candidum*
D	*Escherichia coli, Salmonella* sp, *Bacillus* sp, *Micrococcus luteus*	*Saccharomyces cerevisiae, Saccharomces cerevisiae var ellipsoideus*
E	-	*Rhizopus sp, Saccharomyces cerevisiae, Mucor sp, Aspergillis sp*

KEY:A=BOREHOLE,B=STREAM POINT1, C=STREAM PT2, D=STREAM PT3, E= STREAM CONTROL SAMPLE

Discussion

The pH for most of the locations monitored falls within the acidic ranged from 4.90 to 5.40 (Table 1). Some locations showed values as low as 4.20 (Table 2), which did not conform to the regulatory limits [11]. The low pH values observed at the various locations during the dry season may be attributed to the concentration of the water body by evaporation effect due to lack of rainfall. The WHO approved pH range for drinking water is 6.5 to 8.5. Low pH in the Niger Delta has also been observed by Amadi *et al*. [12], and was attributed to gas flaring in most parts of the Niger Delta as well as the presence of organic matter in the soil. The temperature at the various locations ranged from 29.7 to 30.7 ^{0} C (Tables 1, 2) with the dry season showing higher values than wet season. Temperatures recorded were above the regulatory limits for domestic water acceptability [11, 13]. The high values obtained for the dry season is important as it can affect the solubility and toxicity of metals in the water, which in turn results in corrosion of pipes and also affects cells of the mucous membranes [13]. The high temperature may be due to the heat emanating from the flares. The electrical conductivity of the water sample (Tables 1, 2) was within the Federal Ministry of Environment (FMENV) limit [14] for all locations sampled. There is a significant difference between the seasons with the dry season having higher values than wet season. According to Chikere and Okpokwasili [16] the high electrical conductivity values for the dry season may be attributed to evaporation resulting in the concentration of constituents in the water. Federal Ministry of Environment (FMENV) guideline value for electric conductivity in water for domestic and industrial use is 1000μS/cm [14]. Electrical conductivity is a measure of ionic strength, which is influenced by dissolved ionic substances. This greatly affects the taste and thus has a significant impact on the quality and acceptability of the water as being rated potable [15]. The values of zinc and iron were slightly higher than that of the control samples but within permissible limits. Also, the values of the other parameters were within WHO permissible limits. Coliform bacteria were present in most of the samples (Tables 3, 4), but below the WHO limit (10 CFU/100ml). Microbial load was higher in dry season than wet season (Tables 3, 4) and increased with distance from the flare site. Control samples had higher microbial population than the test samples (Tables 3, 4). The presence of some notable pathogenic organisms in the samples is worrisome as the host communities depends solely on the surface and groundwater for drinking without further treatment. The presence of coliform and other faecal coliforms suggest contamination from faecal materials. The health implications of coliforms such as *Escherichia coli* and *Enterococcus faecalis* in water bodies has been extensively discussed [14].

Emissions from gas flare pollute the water sources rendering them unfit for human use. Therefore, water sources within oil and gas facilities need to be treated by standard techniques to make them potable and drinkable by the residents of the host communities.

The distribution of bacteria and fungi isolated from the water sample for the wet and dry seasons is shown in Table 5 and Table 6 respectively. Some of the bacterial isolates are associated with soil and contaminated water. The presence of *Escherichia coli* and *Enterococcus faecalis* suggest faecal contamination. *Salmonella, Klebsiella* and *Shigella* species have been frequently isolated from water bodies contaminated with human and animal feaces. *Bacillus* and *Micrococcus* are soil borne bacteria and may contaminate water bodies from erosion and surface run off during rain.

Spores of *Penicillium*, *Mucor, Aspergillus, Geotrichum* and *Rhizopus* species may contaminate water bodies during surface run offs. Fungi from soil, air, crops, plant debris, organic matter, etc., may enter the water systems in various ways, although water is regarded as an unnatural environment [17]. Fungi can survive and persist after treatment, or enter during installation, repairs, replacement of pipes and during depressurization events, hence contaminating the water that reaches consumers [18, 19]. The inhalation of spores after aerosolisation of water may occur, when water passes through taps and showers, which is a concern for health care institutions such as hospitals [17, 18, 20]. Therefore, the presence of fungi in water should be considered as a primary threat as some of them are considered to produce mycotoxins and/or are opportunistic human pathogens.

Conclusion

The activity of gas flaring is not only having impact on air but also on water. This research demonstrates that the impact is evident by the physicochemical parameters reported. More so, seasonal variations also have varied results in the physicochemical and microbial load. There was a significant difference between the seasons with the dry season having higher values for the parameters than the wet season. Water must be protected. It is an inevitable natural resource. Therefore, Technologies to reduce the impact of flaring and/or Technologies that can reduce flaring should be adopted by oil producing countries.

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