Environmental Impact Assessment of Gas Flaring on Groundwater Quality in Ughelli North of Delta State, Nigeria.

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Abstract

This study was carried out in Ughelli North of Delta State with a view to unveiling the environmental impact of gas flaring which is a product of oil exploration on groundwater. The study was experimental in nature from which data were generated. Gas flared data were measured through an open-air sampling process using sage thermal mass flow meter. The flared gases measured were carbon monoxide (CO), nitrous oxide and Sulphur oxide. Data on groundwater quality were obtained from two sources (well and borehole). The water samples were collected into sterilized cans and taken to the laboratory for analysis. One hypothesis was tested using multiple regression analysis. The study revealed that most chemical parameters of borehole and well water in Ughelli North communities are lower than the recommended limit by WHO. However, the mean concentration of iron, phosphate and BOD value were higher than the recommended limit value. The study further revealed that gas flaring has a significant effect on the physicochemical properties of the water in Ughelli North. At $P<0.05$, and r^2 value of 0.099 implying that 99% of the water quality in the area is attributed to the presence of SO_2. Similarly at $P<0.05$ and r^2 value of 0.98 implies that 98% of the groundwater quality in the study area is attributable to the presence of NO_2. It was therefore recommended that an impact prediction and proper assessment of oil companies operating within the area be carried out. This is with a view to touching essentially on the change brought about by gas flaring. All regulatory bodies such as federal environmental protection agency and other agencies responsible for impact assessment should carry out their functions to maximum expectation.

KEYWORDS: Gas flaring, Permissible Level, Water Quality, Well Water and Ughelli North,

Introduction

Many definitions exist in the literature that explains the concept of environment impact assessment. According to Ivbijaro (2012), environmental impact assessments are tools for assessing the impacts of a proposed development policy, plan, programme or project on the environment and people. Another definition by Munn (1979) refers to the need of man to identify and predict the impact to the environment on man's health, to identify and predict the impact of the project on man's health and well-being and of legislative proposals, policies, programmes, projects and operational procedures. It is also meant to interpret and communicate information about the impacts of environmental consequences of development actions.

Environmental impact assessment was established in the United States of America in 1969 and has since spread to other parts of the world. Environmental Impact Assessment was initially an adhoc procedure carried out by local planning authorities and developers, primarily for oil and gas related development, but the procedure started in Nigeria the 1990s. According to Olawapo (2003), if Environmental Impact Assessment had been developed earlier than the 1990s, the consequential effects and environmental degradation resulting from oil spillage in the Niger Delta region of Nigeria could have been minimized.

According to Glasson, Therivel and Chadwick (1999) the process of environmental impact assessment involve many steps which include project screening, consideration of alternatives, scooping, description of the project, description of the environmental baseline, identification of the main impacts, evaluation and presentation of findings.

Human beings are constantly in a state of interaction with the environment, and this could either be positive or negative in nature. One of such interaction involves such activities as the exploration and exploitation of oil resources which eventually ends up in gas flaring as is found in Nigeria. Audu (2013) defined gas flaring as the deliberate burning of large quantity of natural gas leading to the release of large amount of pollutant. According to Ismail and Umukoro (2012), gas flaring is one of the most challenging energy and environmental problems confronting mankind regionally and globally as at today. Nigeria is the world's biggest flare of gas (Nwaocha and Mbano, 2010). This is due to unsustainable exploration practices coupled with the lack of gas utilization infrastructure. Odiong, Orimwogunje, Ayanlade and Akinkwolie (2010), observed that gas flaring contributes maximally to climate change, food insecurity, low income, loss of vegetation and pollution of water bodies. Succinctly, gas flaring contaminates both surface and ground water resulting to economic loss and environmental degradation.

According to Efe, (2005) water resources either in the form of rain, river or groundwater, is one of the most essential components of the environment that is presently under threat from oil exploitation and pollution in the Niger Delta region of Nigeria. Oil companies operating in Nigeria has been a major contributor to environmental degradation and pollution of various magnitudes which has resulted in various ecological and human disasters over the last three decades (Avwiri and Ebeniro, 1995). When gases are flared and consequently stored in the atmosphere, it is washed down through rainfall. The emergent effect is acid rain with so much impact on water quality. This has been corroborated by Efe (2010) who observed that most of the residents within gas flare areas complain of high counts of particulate matter in their sources of water supply soon after every down pour.

Despite these consequences the problem of gas flaring in Ughelli North communities has been neglected. It is the realization of the implication of this gas flaring that has informed the need for this study. To achieve this, the following specific objectives were investigated;

- Evaluate the volume of flared gas in the study area
- Assess the effect of gas flaring on ground water quality in Ughelli North communities
- Examine adaptation/mitigation measures to gas flaring.

In line with the following objectives one hypothesis was posed as follows;
Ground water quality is not significantly affected by gas flaring in Ughelli North communities.

Materials and Methods

Description of Study Area

Ughelli North is one of the twenty five (25) local government area of Delta State. It is made up mainly of seven main settlements as: Ughelli, Ogor, Agbarha, Orogun, Uwheru, Evwreni and Ehwu. It is located between latitudes $5^{0}28^{1}$N and $5^{0}32^{1}$N of the equator and longitude $5^{0}58^{1}$E and $6^{0}03^{1}$E of the Greenwich meridian (See Fig. 1).

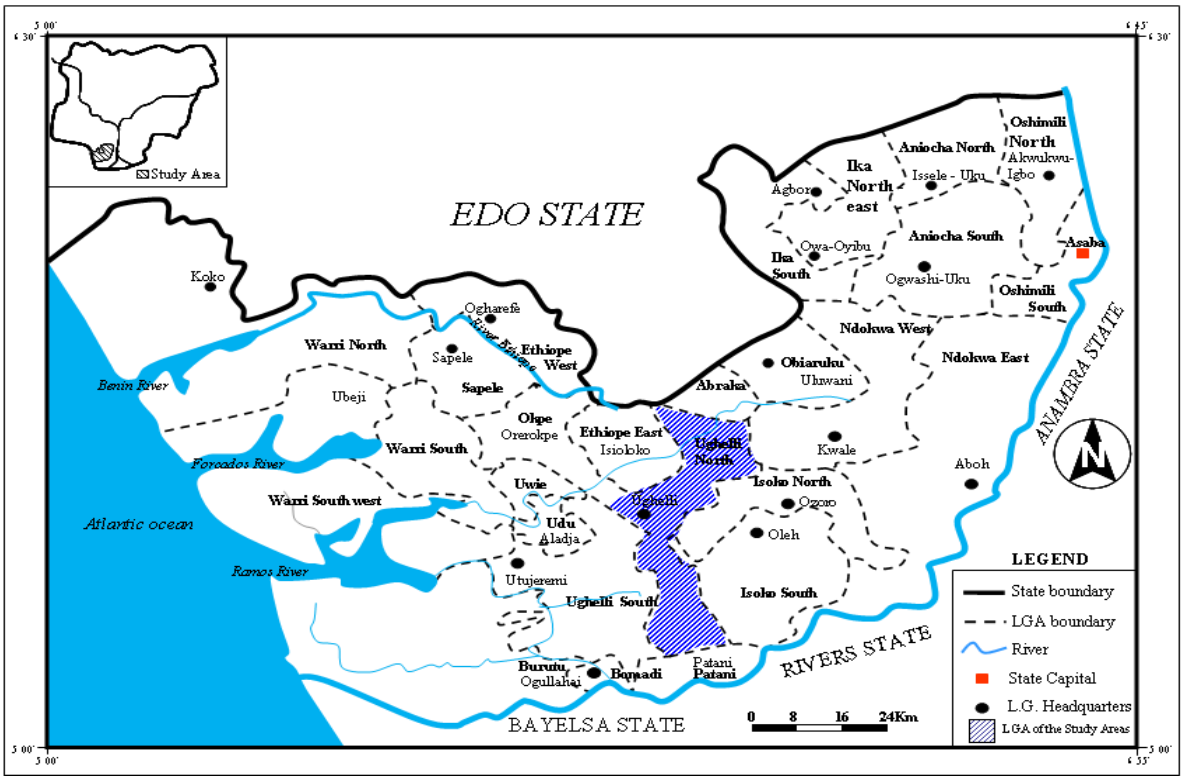

Fig. 1: Delta State Map showing study location

Source: Modified after Ministry of Lands, Survey and Urban Development, Asaba (2008)

The study area is a low-lying plain and constitute mainly of recent unconsolidated sediment. This sediment is partly of marine and of fluvial origin. The land elevation is about 5 metres above sea level and there is the absence of imposing hills that rise above the general land surface. The area is transverse by numerous flat – flowing rivers that drain into the Atlantic ocean. The climate of the area is characterized by high but uniform temperatures. The mean daily maximum temperature is about 30^{0}C and a minimum of about 28^{0}C all the year round (Efe, 2005). Rainfall distribution ranges between 3000mm^{3} to 3500mm^{3}. Within the period of the rainy season and the water table is usually very high especially in the valley region. The study area falls within the disturbed lowland rainforest. The ever green tropical rainforest occurs inland from the mangroves with a considerable number of tree species. The rainforest is characterized by trees that

occur at the three storeys namely the emergent upper, middle and lower storeys. The trees normally grow to a height of between 50 – 60metres.

Much of the typical lowland rainforest has been seriously disturbed by anthropogenic factor over the year, thereby resulting in the emergence of secondary forests.

Ughelli North Local Government Area has a total population of 166,029 according to the 1991 population census figure and 321,028 in the 2006 population census (National Population Census, 2006). However, the recent 2016 projected population stands at 441, 600 (National Bureau of Statistics, 2016). This increase in population is as a result of migration into Ughelli main town and other settlements in the study areas. And more also, with the presence of many oil companies situated in most of the settlement has aided in the upliftment of the economic status of the area.

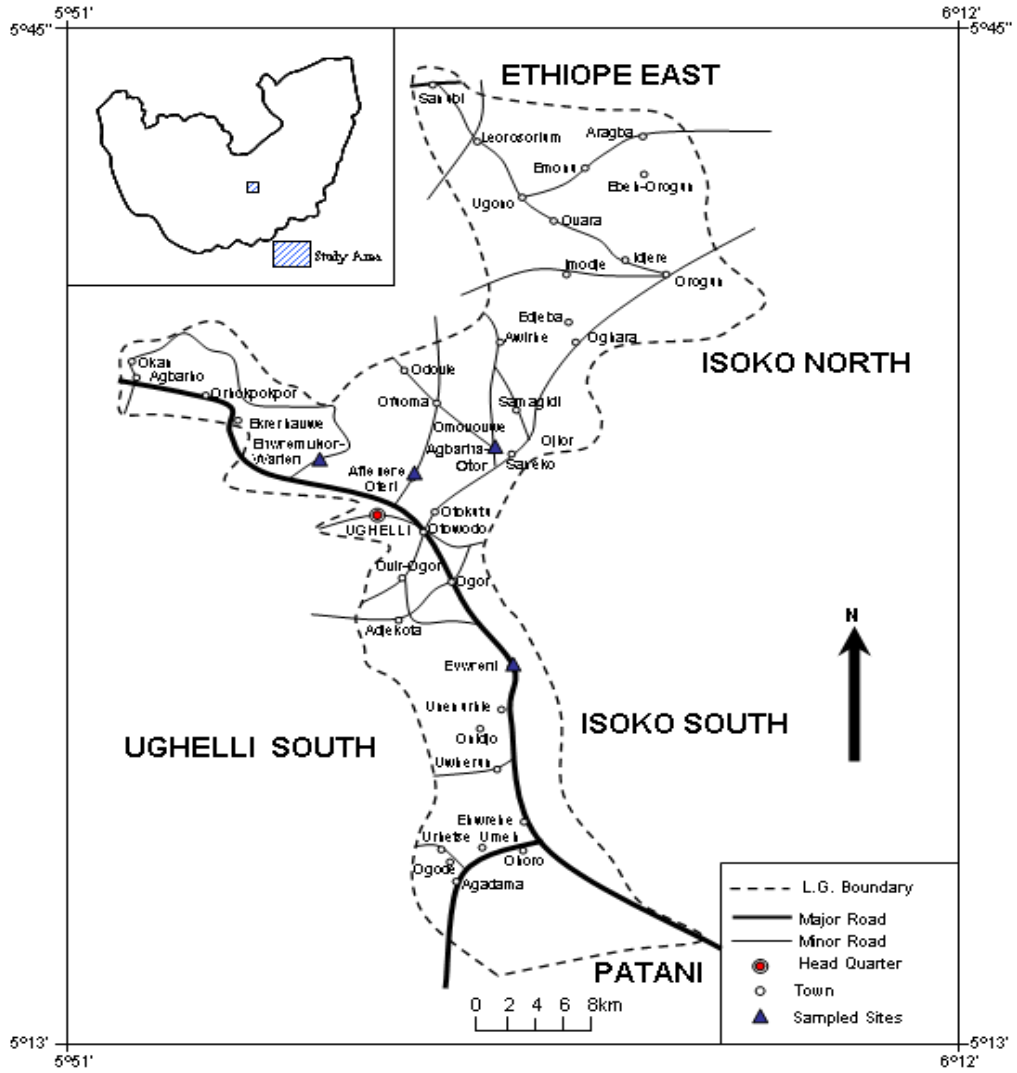

FIG 2: Study Area showing sampled sites
Source: Modified after Ministry of Lands, Survey and Urban Development, Asaba (2008)

The data for this study were derived mainly from primary source; the reason for the choice is to adequately capture flared gases and water pollutants. The choice of gas investigated was based

primarily on the predominance of such gases and the ability for trapping them. Such gases include (carbon monoxide, nitrous oxide and Sulphur oxide) while water quality data include anions (sulphate, phosphate and nitrate). These gases according to Efe (2005) are predominant in polluted water in any oil exploration area. The study adopted the systematic sampling technique and distances of over 50km from the flare stack in Ughelli. Most of the sampling sites were selected due to closeness to active oil and gas flaring sites. To achieve this, three experimental sites (Afiesere, Agbarha-Otor and Ehriemukowho-Warien) and one control site (Evwreni) were selected for sampling (see Fig. 2). Ughelli was purposely selected due to its gas flare stack. The control site Evwereni, which is over 40km south of the flare site was chosen Odjugo (2007), had earlier observed that the impact of gas flaring on the environment are statistically insignificant beyond 15km and 20km radius of the flare sites.

Gas flared data were measured through the use of safe thermal mass flow meter. This is instruments that possess an advanced sensor with software technology integrated with advanced mobile computers for superior environmental test. It performs an analysis of ambient air through the use of physical properties, with continuous output signal. Gas flare emission measurements were carried out in areas that were congested with high rise buildings where the effect of the wind will not pose a hindrance. A total of sixteen (16) air samples were recorded in the morning and evening for two consecutive times at each of the sample sites. Table 1 shows the Department of Petroleum Resources, Federal Ministry of Environment and World Health Organization (WHO) analytical method adopted in this study.

Table 1: Standards and Methods of Analysis

Test Parameter	**Units**	**Standard test method**	**Description of methods**
Ph	pH	ASTM D1293b	pH meter
Temperature	^0C		Thermometer
Turbidity	NTU	APHA 214A	Turbidity meter
TSS	mg/l	Gravimetric	Gravimetric
TDS	mg/l	APHA 2080	TDS meter
Conductivity	$\mu s/cm^{-1}$	APHA 145	Conductivity meter
DO	mg/l	APHA 4500C	Iodometric
Cl_2	mg/l	Titration	Titration
Nitrate (NO_3^-)	mg/l	APHA 419C	Diazotization
Sulphate (SO_4^{2-})	mg/l	APHA 427C	Colorimetric
Ca^{2+}	Mg/l	ASTM 93-77	AAS
K^+	mg/l	ASTM D93-77	AAS
Na	mg/l	ASTM D93-77	AAS
Pb^{2-}	mg/l	ASTM D3559	FAAS
CD^{2+}	mg/l	ASTM D511	AAS
Fe^{2+}	mg/l	ASTM D106C	FAAS
Mg^{2+}	mg/l	ASTM D511	AAS

Source: Department of Petroleum Resources (DPR), 2007

Data on ground water were collected from wells and boreholes. Sample of well water was taken from the well using a plastic bucket while, plastic crops were used to fetch water from the borehole taps. The water samples were collected into sterilized cans, put into cooler of ice blocks

and taken to the laboratory for analysis. The analysis involves the use of means and percentages. The results were presented in tables, percentages and regression analysis.

For purpose of this study, water samples were collected during the month of peak rainfall (July, 2018) and scanty rainfall (December, 2018). This is to enable the capture of immediate effect of the flared gases on the water quality in the study area. Eight samples of water were collected from four sample points. Each sample of water was collected between the early hours of 6 – 7 in the morning and was done after the first and second rain events for the months of July and December 2018.

Result of the Findings

Concentration of gas flared in the study Area

Table 2: Mean concentration of flared gases

	Pollutants from flared gases in parts per million (ppm)		
	SO_2	NO_2	CO
Mean observed pollutants	0.62±0.086	0.096±0.025	8.59±1.47
WHO standards	±0.00-0.01	±0.03-0.006	±3-10

Source: Author's Fieldwork, 2018

Table 2 indicates that the study area is characterized by high concentrations of gases, with a mean value of 0.62 and 8.59ppm for Sulphur Oxide (SO_2), Nitrogen Oxide (NO_2) and Carbon Monoxide (CO) respectively. However, the concentration of carbon monoxide is higher than other gases. SO_2 and CO gases exceeds the WHO standard limit.

Variation of flared gases in different areas of the communities.

Table 3: Variation in the concentration of flared gases in the Study Areas.

Communities	**Pollutants from flared gases in parts per million (ppm)**		
	SO_2	NO_2	CO
Ughelli urban	0.614±0.013	0.101±0.012	8.075±0.500
Agbarha – Otor	0.686±0.046	0.116±0.009	10.137±0.625
Erhwemukhowo-Warien	0.682±0.051	0.109±0.008	9.537±0.539
Evwreni	0.498±0.445	0.588±0.008	6.637±0.770
WHO standards	±0.00 – 0.01	±0.03-0.06	±3-10

Source: Author's Fieldwork, 2018

Table 3 reveals the variation in the concentration of flared gases in Ughelli North. In Ughelli urban, the average concentration of SO_2, NO_2 and CO_2 were 0.614, 0.101 and 8.075ppm respectively. In Agbarha-Otor, the average concentration of flared gases was found to be 0.680, 0.116 and 10.137ppm. In Erhwemukhowo-Warien it was 0.682 for SO_2, 0.109 for NO_2 and 9.537ppm for CO. The concentration of flared gases in all the four communities of Ughelli North

was found to be higher than the WHO recommended limits. The high rate of concentration of gases is as a result of pollution from vehicles, power plants diesel engines and refining flow stations in the various communities.

Water Quality Analysis

Borehole Water Analysis

Table 4: Mean values of the physicochemical parameters of bore-hole water

Parameters	Mean Values ± Std. Deviation	WHO Limits
Ph	5.69±0.93	7.0-8.5
Temperature (^{O}C)	28.6±0.51	30
Conductivity (uS/cm)	42.32±7.18	50
Turbidity (NTU)	3.93±3.76	6
BOD	4.34±0.60	2
COD (mg/l)	4.20±0.35	<4.0
TDS (mg/l)	33.92±10.02	500
Magnesium	2.67±1.37	30
Iron (mg/l)	0.65±0.43	0.3
Lead (mg/l)	<0.03	0.01
Chloride (mg/l)	26.31±12.31	50
Sulphate (mg/l)	4.16±3.62	200
Phosphate (mg/l)	2.15±1.31	0.5
Nitrate (mg/l)	2.41±1.79	50
Sodium (mg/l)	15.9±6.47	50
Potassium (mg/l)	7.07±3.94	10

Source: Author's Fieldwork, 2018

Table 4 shows the physicochemical characteristics of bore-hole water in Ughelli communities. The mean pH value of the bore-hole water is 5.69 which is lower than the WHO recommended pH water limit. This implies that most bore-holes in Ughelli North are acidic. This acidic nature of the bore-hole water is attributed to the presence of CO from flared gases in the environment. The mean conductivity value of bore-hole water is 42.32μs/cm which is lower than the WHO recommended limit. The lower values are attributed to high rate of evapotranspiration within the area.

The mean turbidity value is 3.93mg/l, TDS value is 33.92 mg/l, magnesium value is 2.67mg/l, chloride value is 26.31mg/l, sulphate value of 4.16mg/l, nitrate value of 2.41mg/l, sodium value is 15.9mg/l and potassium value is 7.07mg/l falls within the limit recommended by WHO. The mean value of iron content of borehole water is 0.65mg/l, COD is 4.20mg/l, phosphate value is 2.15mg/l and BOD value is 4.34mg/l, therefore are higher that the recommended limit value by WHO.

Table 5: Mean values of the physicochemical parameters of well water

Parameters	Mean Values ± Std. Deviation	WHO Limits
Ph	5.50 ± 0.93	7.0 – 8.5
Temperature (^{O}C)	28.52 ± 0.54	30
Conductivity (uS/cm)	43.42 ±7.64	50
Turbidity (NTU)	3.95 ±3.76	5
BOD	4.30 ± 0.60	2
COD (mg/l)	4.17 ± 0.31	<4.0
TDS (mg/l)	33.66 ±11.32	500
Magnesium	2.87 ± 1.26	30
Iron (mg/l)	0.77 ± 0.37	0.3
Lead (mg/l)	<0.01	0.01
Chloride (mg/l)	26.29 ± 12.35	50
Sulphate (mg/l)	4.15 ± 3.64	200
Phosphate (mg/l)	2.11 ± 1.28	0.5
Nitrate (mg/l)	2.40 ± 1.77	50
Sodium (mg/l)	15.91± 6.43	50
Potassium (mg/l)	6.89±.76	10

Source: Author's fieldwork 2018 and WHO 2018

Table 5 shows the physicochemical characteristics of well water in Ughelli North community. The mean pH value of the well water is 5.50 which are lower than the WHO recommended pH water limit. This implies that the well water in Ughelli North community is acidic. This acidic nature of the well water can be attributed to presence of CO from gas flares in the environment. The mean conductivity value of well water is 43.42µs/cm which is lower than the recommended limit of WHO. The lower values are attributed to high rate of evapotranspiration within the area. The mean turbidity value is 3.95mg/l, TDS value is 33.66mg/l, magnesium value is 2.87mg/l, chloride value is 26.29mg/l, sulphate value of 4.15mg/l, nitrate value of 2.40mg/l, sodium value is 15.91mg/l and potassium value is 6.89mg/l falls within recommended value of WHO. The mean value of iron content of borehole water is 077mg/l, COD of 4.17mg/l, and BOD value of 4.30mg/l is higher than the recommended limit by WHO.

Effect of Gas flaring on water quality in Ughelli North Communities

Table 6: Result of Analysis of the relationship between SO_2 and water Quality

Model	R	R square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Df1	Df2	Sig. F Change
1	0.94a	.999	.987	.0096216	.999	284.357	14	1	0.42

a. Predictors: (Constant), Potassium, TDS, Temperature, Turbidity, COD, Iron, pH, BOD, Phosphate, Magnesium, Sodium, Conductivity, Nitrate, Chloride

Table 6 shows the effect of emitted gas (SO_2) on the ground water quality in Ughelli North communities. There is a strong positive correlation between SO_2 and ground water physicochemical properties in Ughelli North R = 0.94. Similary, with an r^2 value of 0.99, this implies that 99% of the ground water quality in Ughelli North Communities. The table shows that SO_2 has a significant effect on the pH of the water SO_2 reacts with water more by making it more acidic.

Table 7: Result of Analysis of the Relationship between NO_2 and ground water quality

Model	R	R square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Df 1	Df2	Sig. F Change
1	.993[a]	.985	.779	.0115244	.985	294.787	14	1	.015

a. Predictors: (Constant), Potassium, TDS, Temperature, Turbidity, COD, Iron, pH, BOD, Phosphate, Magnesium, Sodium, Conductivity, Nitrate, Chloride

Table 7 shows the effect of flared gases (NO_2) on ground water quality in Ughelli North communities. There is a strong positive correlation between NO_2 and physiochemical properties of ground water in the study area at R = 0.99 with an r^2 value of 0.98, implying that 98% of the poor water quality in the study area is attributed to the presence of NO_2. At $P<0.05$, from the analysis it thus shows that NO_2 has a significant effect on the water quality in the communities. The coefficient table shows that NO_2 has a significant effect on the pH of the water. NO_2 reacts with water more making it more acidic.

Table 8: Result of Analysis of the relationship between CO and ground water quality

Model	R	R square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Df 1	Df2	Sig. F Change
1	.995[a]	.990	.852	.55368	.990	7.184	14	1	.285

a. Predictors: (Constant), Potassium, TDS, Temperature, Turbidity, COD, Iron, pH, BOD, Phosphate, Magnesium, Sodium, Conductivity, Nitrate, Chloride

Table 8 shows the effect of emitted gas (CO) on ground water quality in Ughelli North communities. At $P>0.05$, the coefficient analysis is not significant, thus, the CO has no significant effect on the ground water quality in the studied area.

The study further revealed that gas flaring has a significant effect on the physicochemical properties of the water in Ughelli North. At $P<0.05$, and r^2 value of 0.99, implying that 99% of the poor water quality in Ughelli North is attributed to the presence of SO_2. The presence of SO_2 reacts with water, thus making it more acidic. Similarly, at $P<0.05$, and r^2 value of 0.98, it implies that 98% of water quality in Ughelli North is also attributed to the presence of NO_2. The physicochemical characteristics of water in Ughelli North were highly affected by the presence of flared SO_2 and NO_2.

Conclusion

This study examined the effect of gas flaring on ground water quality in Ughelli North communities. Findings from the study show that the physic-chemical properties of borehole and well water are influenced by increase in gas flaring activities. Parameters such as pH, and temperature were lower in the peak of the rains. The physicochemical concentration of these parameters in the boreholes, are shown in the result analysis. The findings further showed that SO_2, and NO_2 has a significant effect on the water quality in Ughelli North as the sources of water supply were acidic. The result also showed that sampled water was polluted by this flared gases which signifies that the source of water pollution is from the non-point which is gas flaring.

Recommendations

Based on the findings of this study, the following recommendations were made to achieve a suitable water quality as follows:

- There should be consistent water monitoring and proper regulatory guidelines to check pollution status.
- The general public should be sensitized on the dangers of drinking water due incessant gas emission and the need for water treatment in order to minimize the risk of water related problems.
- The inhabitants of the study areas should be informed of the necessity to treat their water through disinfection, filtration and boiling before consumption. Not only that, gas collector chambers should be built to trap flared gases.
- Appropriate laws should be enacted in order to reduce gas flaring in the area. In order to achieve this, strong legislation on water pollution be made in which polluters pay high penalty and more so, they should be made to adopt good practice in gas flaring.
- Based on the result from this study, an impact prediction and proper assessment of oil companies operating within the areas should be carried out by regulatory bodies such as the Federal Environmental Protection Agencies and Department of Petroleum Resources.

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