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Effect of wind on temperature variation around the gas flare point at Nkali flow station in Nigeria

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Abstract
This study determined the effect of wind on temperature variation around a gas flare point. The study location is Odagwa a community hosting Shell Petroleum Development Company's flow station. Temperature measurements were taken within 400m radius from gas flare point in the North, South, East and West directions during day time. The mercury in glass thermometer, merlin digital anemometer brass model, hand held digital compass model 21E and etrex global positioning system were used to obtain temperatures, wind speed, wind direction and geographical coordinates respectively. Results show the following range of values for temperatures at various distances from flare point; D1; 40m (40.2-52.2 ºC), D2; 80m (40.2-49.3 ºC), D3; 120m (38.2-43.1 ºC), D4; 160m (38.2-41.2 ºC), D5; 200m (31.1-31.3 ºC), D6; 240m (30.1-31.1 ºC), D7; 280m (28.8-32.2 ºC), D8; 320m (28.6-32.1 ºC), D9; 360m (29.1-32.1 ºC) and D10; 400m (28.5-31.1 ºC). Wind direction was predominantly South West. A high negative correlation was obtained between distance from gas flare point and temperatures in North, South, West and East directions (R^2=-0.88, - 0.92, - 0.89, - 0.877 respectively). Plants and animals within the first 200m from flare point are likely to suffer from heat stress and related impacts. Odagwa is an agrarian community hence the arable land within 500m radius from flare point should be put into use other than crop and animal farming. A forest reserve should be developed around the community to provide natural habitat for migrating animals and create a micro climate to check climate change.

Keywords: Gas Flaring, Temperature, Wind and Distance.

Introduction

Associated Petroleum Gas (APG) also known as flare gas or associated gas (oil field glossary, 2011) is a form of natural gas which is commonly found associated with deposits of petroleum (Roland, 2010) [22]. Associated Gas is produced during crude oil production. Mokhatab *et al* (2006) [15] stated that crude oil cannot be produced without associated gas which comes out of solution as pressure is reduced on the way to and on the surface. Associated gas serves as energy in driving crude production from the oil wells. The associated gas is released as a waste product from the petroleum extraction industry, due to complexities in the management of the gas. It is simply burnt off in Gas flares. The associated gas is composed of 81% methane (CH_4), 5% Ethane (C_2H_6), 6% Propane (C_3H_8), 4% Butane (C_4H_{10}), 1% Nitrogen (N_2), > 0.15%CO_2. (Gazprom, 2010).

Nigeria is the second largest offending country after Russia in terms of total volume of gas flared. In 2004, Nigeria's volume of gas flared was equivalent to one-sixth of total gas flared in the world. Between 1996 and 2006, a period during which awareness of the negative impacts of gas flaring grew on the global climate, the global emission volume ranged between 150 – 170 billion cubic meters (BCM), Nigeria's share of the total volume was approximately 24.18BCM of gas while USA was 2.8 BCM (World Bank, 2007) [24].

Nigeria flares more natural gas associated with oil extraction than any other country with estimates suggesting that of the 3.5 BCF (99Mm^3) of associated gas (AG) produced annually 2.5 BCF (71Mm^3, or about 70%) is wasted via flaring. Though statistical data associated with gas flaring is unreliable but AG wasted during flaring is estimated to cost Nigeria US$ 2.5B annually (FoEI, 2013) [7].

Companies operating in Nigeria prefer to exploit natural gas from the Non Associated deposits probably because it is costly to separate commercially viable AG from oil hence gas flaring becomes a better alternative to increase crude production.

Flaring is a public and environmental concern, not only does it emit pollutants into the environment, it is a source of waste of invaluable energy resources as well as source of noise, heat, odour and smoke that compromises the outdoor comport of residents (Mokhatab *et al*, 2006) [15].

Atmospheric conditions offer some removal mechanisms for pollutants emitted into the atmosphere. Akhionbare (2009) [2] identified dispersion, gravitational settling, flocculation, absorption, rain out and adsorption as some of the removal mechanisms. Dispersion is the process by which contaminants move through air spreading a plume over a large area, it could be vertical or horizontal (Dara, 2006) [6]. Vertical dispersion occurs as a function of adiabatic lapse rate which is the rate at which air cools as it rises in altitude. It is independent of ambient temperature hence the name adiabatic (Bhatia, 2009) [4]. The author showed that the difference between ambient lapse rate and adiabatic lapse rate determines the stability of the air and the speed with which pollutants will disperse.

According to Narayanan (2009) [16], when the ambient lapse rate equals the adiabatic lapse rate, the atmosphere experiences neutral stability. Super adiabatic condition prevails when ambient lapse rate is more than adiabatic lapse rate, the atmosphere experiences sub-adiabatic condition when ambient lapse rate is less than adiabatic lapse rate this leads to a special condition called temperature inversion. Super adiabatic atmospheric conditions are unstable and favours dispersion while sub-adiabatic conditions trap pollutants at ground level due to poor dispersion.

In this study the effect of wind characteristics on temperature variation around Nkali flow station flare point will be determined.

Materials and Methods

Description of study area

Odagwa the study site is a community in Etche Local Government Area of Rivers State. Etche L.G.A. is located at North-Eastern part of Rivers State, Nigeria. It lies within latitude $4^0 45$'N to $5^0 17$'N and longitude $6^0 55$' E to $7^0 17$'E and covers about 641.28km^2 of land area (Nwankwoala and Nworgu, 2009) [19].

Etche is one of the 24 Local Government Areas of Rivers State. It has a population of 295,200 people (NPC, 2006). It has 19 electoral wards including Akwa/Odagwa, Ulakwo and Obite. The L. G. A. has five clans and about 35 communities. Odagwa, Ulakwo and Akwa belong to the Ulakwo / Umuselem clan.

Etche has its L.G.A. headquarters at Okehi. It is bounded in the North by Imo State, East by Imo River and Omuma L.G.A., South by Obiakpo and Oyibo L.G.A.'s and West by Ikwerre L.G.A.

Agriculture is the economic mainstay practiced as farming, fishing, lumbering and hunting. Other economic activities include petty trading, sand mining, transportation, agro-processing, construction and educational activities. Oil and Gas exploration and exploitation have been going on in Etche since the inception of oil exploitation in Nigeria dating back to 1958. The area is characterized by the tropical rain forest vegetation (Nworgu, 2001) [20]. The Popular trees in the area include Iroko, Obeche and Mahogany. Plant species are scattered, heterogeneous and exist in different heights. The vegetation supports tree crops (citrus, rubber, cocoa, oil palm), arable crops and vegetables.

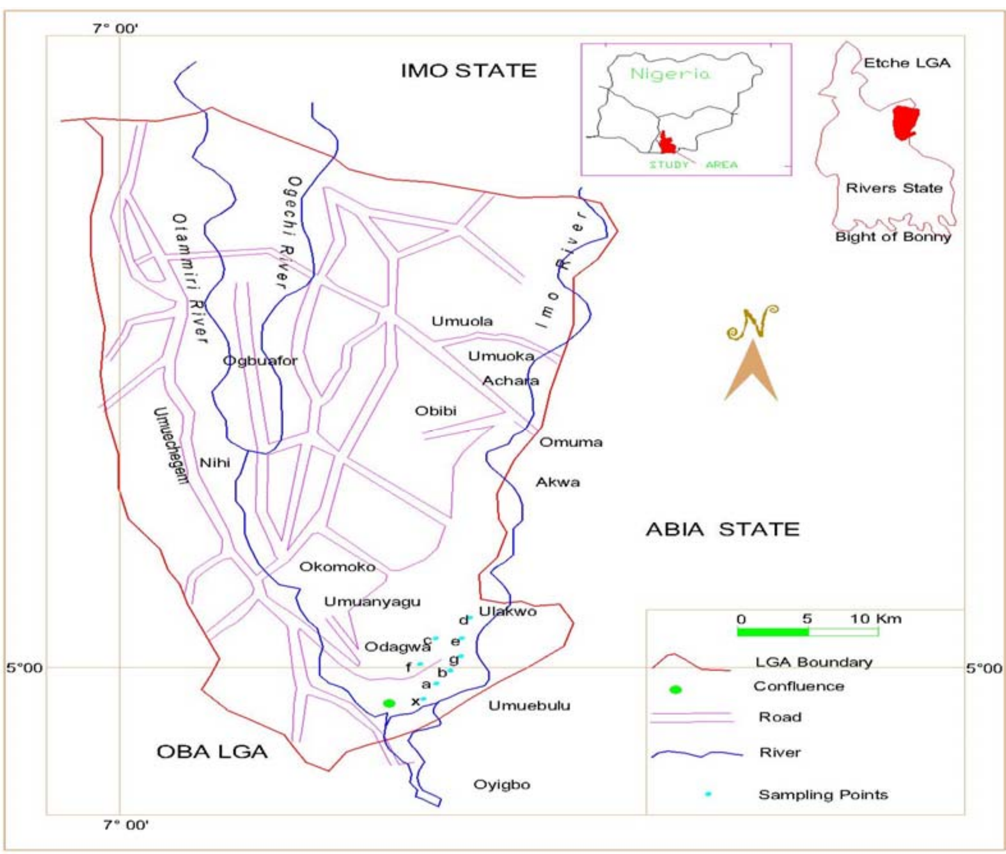
The area has gently rolling topography below 200m above sea level, it belongs to the Niger Delta Coastal Plain and classified as low land.

The Etche area is drained by the Otammiri, Ogochie and Imo Rivers. These rivers flow South wards to join the Niger and subsequently the Atlantic Ocean.

The area is characterized by sedimentary rock formation and the alluvian deposits comprising of tertiary and quaternary marine or continental deposits.

Extensive petroleum deposits mask the underlying geological structure (Nworgu 2001) [20]. The soil type prevalent in the area can be classified as coarse, loamy, highly weathered, less water logged, moderately acidic and low soluble salt content (Obinna, 2010).

The weather and climate of the area is characteristic of the tropical equatorial climate. Amount of rainfall in the area is between 2000mm to 4000mm annually with two peaks in June / July and September (Nwankwoala and Nworgu, 2009) [19]. It has two major seasons, the long rainy season (March to July) and the long dry season (November to February) as well as two minor seasons the short rainy season (September to October) and short dry season (August). Humidity of the area ranges from 40% in dry season to 90% in rainy season. It has two distinct air masses, the tropical continental and tropical marine. Mean monthly wind speed is between 22.77 to 66.12 Knots, wind direction is dominated by the South Westerly wind throughout the year. Mean monthly minimum temperature is 21.1^0C to 24^0C while mean maximum monthly temperature is between 29.3^0C and 34.2^0C (NIMET, 2013).



Source: Fed Survey Maps, Rivers State.

Fig 1: Map of Etche LGA Showing the Sampling Points.

Meteorological Data Collection

Nkali flow station operates a ground flare system which releases by products at ground level. Data on mean monthly weather conditions for a year was collected from the study area. Temperature, wind speed and wind directions of sampling points were obtained using the following weather instruments.

Wind Speed and Direction

The wind speed and direction was determined using the Merlin digital anemometer, brass model and hand held digital compass, model 21E.

Temperature

The centigrade thermometer measuring 0^0C to 100^0C with mercury as thermometric liquid was used to obtain the temperature of the ambient air at heights of 0.5m, 1m and 1.5m at all points and mean temperature measurements were taken in the four cardinal directions.

Results and Discussion

Variation of Mean Temperature with Distance from Flare Point**:** The results were presented in tables 1, 2 & 3 and figures 2-8.

Table 1: Variation of Ambient Temperature with Distance from Gas Flare Point.

S/N	Parameter (M) Distance		Temperature (^{0}c)			
			North	South	West	East
1.	40	D1	50.1	45.1	42.2	52.2
2.	80	D2	47.3	40.2	42.1	49.3
3.	120	D3	43.1	38.2	40.6	43.1
4.	160	D4	39.4	38.1	38.2	41.2
5.	200	D5	31.2	31.3	31.2	31.1
6.	240	D6	30.6	30.1	30.2	31.1
7.	280	D7	30.4	28.8	30.1	32.2
8.	320	D8	30.1	28.6	30.1	32.1
9.	360	D9	31.1	29.1	30.1	32.1
10.	400	D10	31.1	28.5	30.1	30.8

Source: Field Work

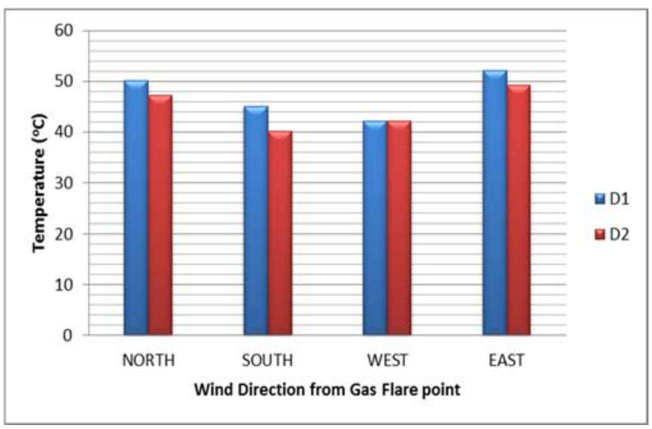


Fig 2: Temperature variation with wind direction at D1 and D2.

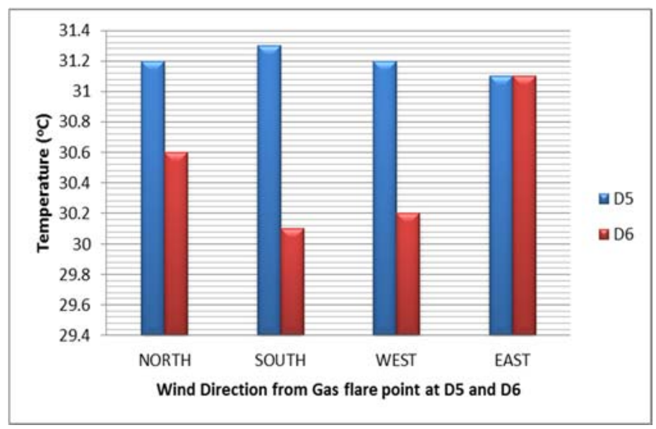


Fig 4: Temperature variation with wind direction at D5 and D6.

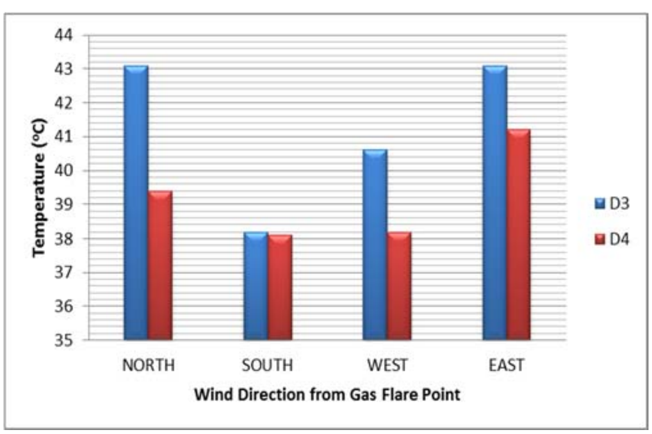


Fig 3: Temperature variation with wind direction at D3 and D4.

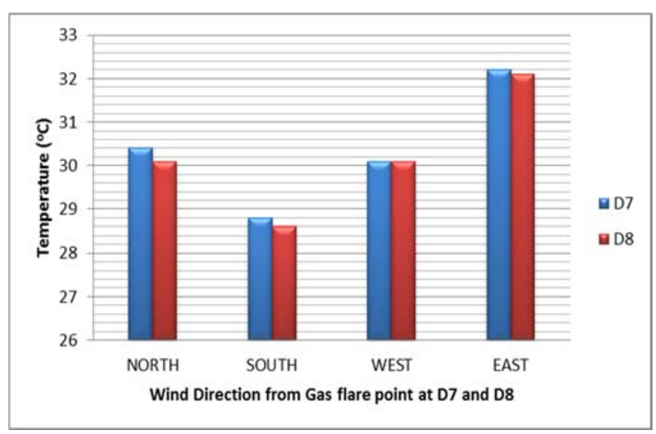


Fig 5: Temperature variation with wind direction at D5 and D6.

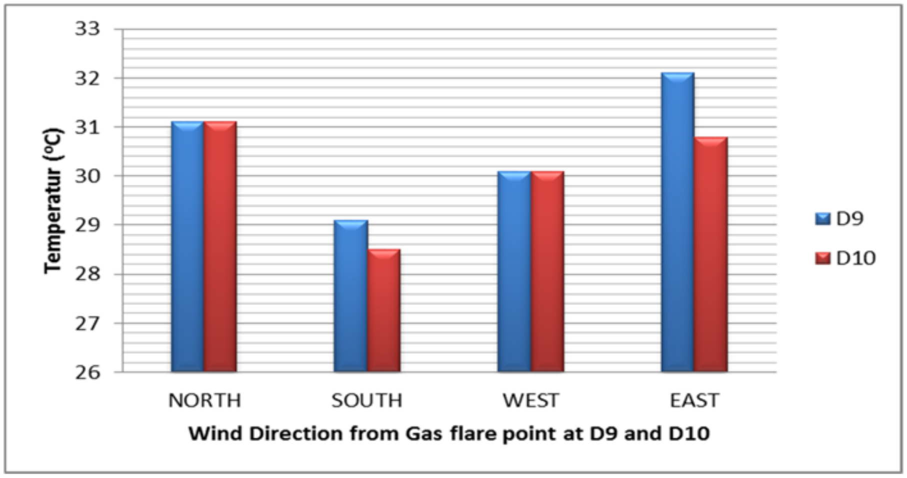


Fig 6: Temperature variation with wind direction at D9 and D10

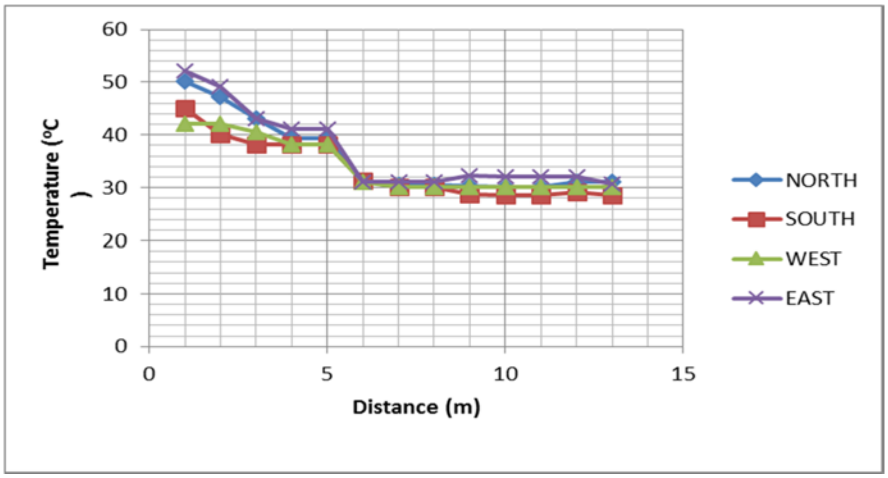


Fig 7: Variation of temperature with distance in various directions

The result of temperature variation in the ambient environment show that ambient temperature was above mean temperature of the area within the first 200m from gas flare point in the north, south, east and west directions. Temperature in the east direction was highest followed by north with west as lowest. Generally the temperature decreased with increase in distance from the flare point.

At D1; 40m (40.2-52.2 °C), D2; 80m (40.2-49.3 °C), D3; 120m (38.2-43.1 °C), D4; 160m (38.2-41.2 °C), D5; 200m (31.1-31.3 °C), D6; 240m (30.1-31.1 °C), D7; 280m (28.8-32.2 °C), D8; 320m (28.6-32.1 °C), D9; 360m (29.1-32.1 °C) and D10; 400m (28.5-31.1 °C).

A high negative correlation was obtained between distance from gas flare point and temperature in North, South, West and East directions (R^2= -0.88, - 0.92, - 0.89, - 0.877 respectively) (Table 3).

Monthly Variation of Wind Speed and Direction.

Results show that the wind speed had a continuous undulating trend. Wind Speed (22.77-66.12 knots). The south westerly trade wind dominated throughout the year.

Table 2: Monthly Variation of Temperature, Wind Speed and Wind Direction.

S/N	Month	Temperature		Wind	
		Min (0 °C)	Max (0 °C)	Speed (Knots)	Direction
1.	January	21.1	34.2	66.12	SW
2.	February	22.9	32.6	56.80	SW
3.	March	24	34.6	50.96	SW
4.	April	23.6	32.9	50.32	SW
5.	May	23.1	32.4	43.24	S
6.	June	22.8	30.2	40.33	SW
7.	July	23.0	29.3	42.18	SW
8.	August	22.6	29.9	54.89	W
9.	September	22.9	29.5	33.67	SW
10.	October	22.2	30.4	31.79	W
11	November	23.2	31.7	22.77	SW
12	December	21.7	32.7	35.29	N

Nigeria Meteorological Agency (2013)

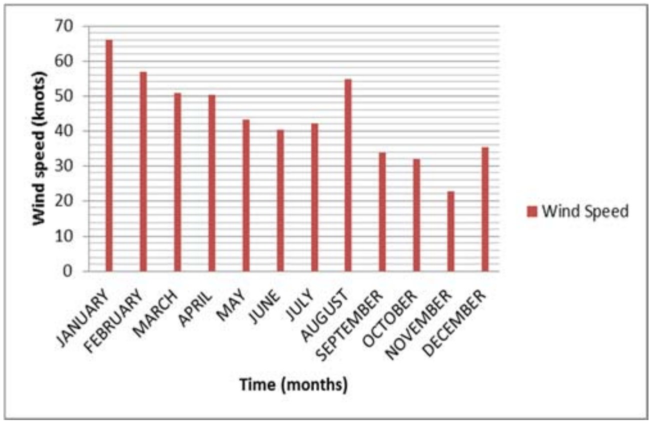


Fig 8: Monthly Variation of Wind speed.

Table 3: Result of Correlation Analysis of Weather Elements.

Parameter	Coefficient(R^2)	Relationship
Distance versus T. North	-0.882575078	Strong but inverse
Distance versus T. South	-0.923695471	Strong but inverse
Distance versus T. East	-0.877806648	Strong but inverse
Distance versus T.West	-0.898974596	Strong but inverse

Discussion

Variation of Ambient Temperature with Distance and Wind Direction around Flare Point.

Ambient temperature decreased with increasing distance from flare point for the first 240m in the North, South, East and West directions (Table 1, Fig1-7).

The temperature within the first 80m was highest in the East direction followed by the North direction. This could be as a result of the predominant South West (SW) wind that blows towards the North East direction.

Oseji (2010) [21] observed that gas flaring communities in Niger Delta experience about 1.4 ^{0}C surface temperature elevation above mean normal daily temperature. He further stated that it is more pronounced in the first 300m radius from flare point, causing gaseous pollutants to become more reactive affecting environmental flora and fauna. Increase in temperature due to gas flaring has undesirable effects on man and his environment, thermal radiation, stunted growth of crops and plants, migration of animal species, migration of inhabitants who are predominantly farmers due to discomfort and poor crop yield as some of the effects observed in the study area. Avwiri and Obeniro (1996) supported this view.

Effects of high temperatures on plants and animals

Denaturation of plant enzymes is expected from temperatures of 40 ^{o}C and above. Failure of only one critical enzyme system can cause the death of a plant. Yash and Keigth, 2004 reported denaturation of plant enzymes to be prominent at 40 ^{o}C. Denaturation of membrane proteins as well leads to injury of membrane from sudden heat stress, membrane rupture and loss of cellular contents (Ahrens and Ingram, 1988) [1]. Mishra and Singhal (1992) [14] observed the occurrence of peroxidation of membrane lipids at high temperatures causing heat stress. Most plants show reduction in photosynthesis at temperatures above 40 ^{o}C. Crop growth development is low in the first 300m from flare point but within 10 to 30 ^{o}C it has a direct linear relationship with temperature while above 30 ^{o}C the relationship is non linear. Bhullar and Jennar (1985) [5] found out that temperature above 34 ^{o}C causes reduced dry matter accumulation in plants. Grain crops show a declined yield with temperatures above 34 ^{o}C. Kropff *et al* (1993) [13] found out that crop growth stimulation show that rice yields decrease 9% for each degree rise in average temperature.

Vegetables die at a temperature of 46 ^{o}C and are negatively affected at temperatures above 34 ^{o}C as collaborated by the result of Kim D.C (2003) [12]. At temperatures above 32 ^{o}C, dry winds are introduced causing heat buildup in vegetables which leads to rapid water loss, heat injury and eventually tissue death.

Temperatures above 34 ^{o}C will cause the following episodes in plants; decrease in photosynthesis, increased respiration, cell membrane leakage (signaling change in protein synthesis), continued physical water loss, growth inhibition, plant starvation and poor crop yield.

High temperatures affect animals negatively especially through heat stress. Hansen P.J (2004) [9] identified that mammal as endotherms tolerate the highest temperatures as they function at high core temperatures that range from approximately 35 ^{o}C to 39 ^{o}C. There is less resistance to body temperatures above set point temperatures (Heldmaier *et al*, 2004) [10]. Death is likely to occur if temperatures exceed 40 ^{o}C because of disruptions in membrane fluidity, protein structure, for animals in which sweating and panting exist electrolyte and fluid loss (Jardine, 2007) [11].

The correlation results reveal a strong inverse relationship between temperature and distance from the flare point in the north, south, east and west directions.

The wind speed reduced and increased in a continuous undulating trend as the year progressed from January to December while wind direction was predominantly South West. Ubuoh (2012) [23] identified location, rainfall amount, rainfall frequency, wind direction and wind speed as factors that influence acid rain formation in the vicinity of gas flaring. Nkwocha *et al* (2010) [18] found that wind characteristics are factors affecting the level of impact of gas flaring while Garret *et al* (2007) observed that gas flaring leads to changes in meteorological conditions. Although the pollution by gas flaring is local, Narayanan (2009) [16] pointed out that meteorological conditions globalizes the effect of pollution from gas flaring.

Conclusion

Gas flaring activity in Odawa induced a temperature rise above mean ambient temperature. The rise was in all directions but was highest in eastern directions and lowest in the western direction due to the effect of south westerly wind blowing towards the north east direction.

Temperature in the four directions varied inversely with distance from flare point. Within the first 200m from flare point in all directions temperature of ambient air was between 31 ^{o}C to 52 ^{o}C which is high and extreme condition for plant and animal survival.

Plants within this range of distance are likely to suffer from decrease in photosynthesis, increased respiration, cell membrane leakage (signaling change in protein synthesis), continued physical water loss, growth inhibition, plant starvation and poor crop yield while animals are likely to suffer heat stress which will lead to poor reproduction, irregular growth and development, disruption in membrane fluidity, protein structure and death.

Odagwa is an agrarian community hence the arable land within 500m radius from flare point should be put into use other than crop and animal farming. A forest reserve should be developed around the community to provide natural habitat for migrating animals and create a micro climate to check climate change.

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