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The health impact and lung function indices of adult residents of Ibeno Community exposed to gas flaring in south-south Nigeria

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Abstract

Background: Epidemiological studies indicate that exposure to air pollution caused by gas flaring may have an association with an increased risk of adverse respiratory effects. This study investigates the effects of gas flaring on the lung health of Ibeno community residents, Akwa Ibom State focusing on respiratory symptoms and lung function indices

Methods: A total of 386 adult resident in Ibeno for at least two years and 386 age, sex and height matched controls resident in Etinan, also for at least two years were recruited to a cross-sectional survey comparing their respiratory symptoms and lung function indices. The study was conducted between March and May 2014 using spirometer and questionnaire as investigative tools. Both descriptive and inferential statistics were used to analyze the data.

Results: Most of the respondents in both exposed and control communities were aged 18-30 years, with a height range of 161-170cm. Both exposed and controls subjects experienced similar symptoms suggestive of respiratory disorders, however the prevalence was higher among exposed subjects than controls: cough- 57(14.8%) vs. 39(10.1%); breathlessness 58(15%) vs. 28(7.3); wheezing 22(5.7) vs. 12(3.1). The respondents from the exposed community were mostly traders and fishermen while the controls were predominantly farmers. The PEFR, FVC and FEV1 (mean ± SD) for the subjects were 300.6±2.15 l/min, 2.58±8.43 and 2.01±0.76 respectively; while the PEFR, FVC and FEV1 for the controls were 342±2.16l/min, 2.27±0.82 and 2.13±0.75 respectively.

Conclusion: In view of these findings, there is evidence that prolonged exposure to air pollution from gas flaring impacts negatively on lung function reflected as reduced PEFR, FEV1, and worsening respiratory symptoms among residents in the exposed community. There is need for the government to speed up the implementation of polices regarding the reduction of flaring of natural gas associated with oil production. There is also a need for further research to be carried out on the long term effects of chronic exposure to gas flaring on lung health and methods of interventions to minimize or possibly eliminate these effects.

Introduction

Air pollution caused by gas flaring is a global problem associated with negative impacts on the environment as well as respiratory morbidity and mortality. It has been estimated that air pollution contributes to 6% of total mortality.[1] Gas flaring generates smoke which is a recognized source of toxic exposure. Smoke is a vaporous colloidal system formed when a material undergoes combustion, and is composed of a collection of emitted noxious gases, airborne solid and liquid particle whose distribution is determined by size, breathing mechanics and total volume.[2] The exact composition of smoke depends on the nature of the burning fuel and the conditions of combustion.[2,3]

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Combustion can be complete or incomplete depending on the amount of oxygen available. For most fuels such as diesel oil, coal or wood, pyrolysis occurs before combustion.[4] During incomplete combustion, products of pyrolysis remain unburnt and contaminate the smoke with noxious particulate matter and gases. Pyrolysis is a thermo-chemical decomposition of organic materials at elevated temperature without the participation of oxygen.[5]

The entire respiratory system is continuously exposed to particulate and infective agents and is protected by a well-developed physiological barrier. However, these protective barriers can be overwhelmed in adverse situations leading to untoward effects on the respiratory system.

Gas flaring is widely used for the disposal of natural gas in petroleum producing areas where there is no infrastructure to make use of the gas.[6] It is the burning of natural gas that is associated with crude oil when it is pumped from the ground, and is a cheap way to separate the identified product, crude oil from the associated natural gas. Gas flaring can also be performed as part of the completion and testing of natural gas well to assess a well's capability.[6,7] It is the usual option where insufficient investment was made in infrastructure to utilize the associated gas. Gas flaring in Nigeria has been practiced since oil exploration began in the sixties.8 After Russia, Nigeria flares more gas than any other country in the world in terms of total volume of gas flared. Nigeria flares over 75% of the associated gas it produces and this represents a pollution equivalent to 45 million tons of carbon dioxide per day. Currently there are over 123 flaring sites in the Niger Delta region and Nigeria has been regarded as one of the highest emitter of greenhouse gases in Africa.[8,9] Gas flaring not only wastes a potentially valuable source of energy; the carbon emissions it adds to the atmosphere leads to global warming and its concomitant effects.

The efficiency of flares can be dependent on several factors like composition of the flare stream, flow rate of gases, wind velocity, ambient turbulence, presence of hydrocarbon droplets in the flare stream and presence of water droplets in the flare stream.[10] Flaring combustion is typically incomplete releasing substantial amount of soot and carbon monoxide which contribute to air pollution problems. Gas flaring is generally discouraged as it releases toxic components into the atmosphere and contributes to climate change.[11] In Western Europe, 99% of associated gas is used or re-injected into the ground. If properly stored, associated gas can be used as an energy source for community projects. Flaring in Nigeria has grown proportionally with oil production. Gas flares also have potentially harmful effects on the health and livelihood of the communities in their vicinity as they release a variety of poisonous chemicals including nitrogen dioxides, particulate matter, sulphur dioxide, volatile organic compounds like benzene, toluene, xylene and hydrogen sulphide as well as carcinogens like benzapyrene and dioxin.[12-14] Humans who are exposed to such substances can suffer from a variety of respiratory problems. These chemicals can aggravate asthma, chronic obstructive pulmonary disease (COPD), hay fever and also lead to increased mortality both in children and adults. Benzene is a recognized cause of leukemia and bronchial carcinoma. As outdoor air pollution became a well-known public health problem, efforts have been geared towards reducing air pollution over the years. Air quality is particularly important for subpopulations that are more susceptible (i.e. children, the elderly, subjects with cardiorespiratory diseases) or at a higher risk of specific exposures (occupational exposure). A prior study on Air Quality Index (AQI) pattern around petroleum production facilities in the Niger Delta area of Nigeria, 2010 reported that AQI from measured Carbon monoxide in the study area ranged between 1 and 44 (between distances 50-500 metres of petroleum flow stations) an indication of good AQI, however at the 60 metres distance, AQI was 210 (unhealthy).[16] This report is not in keeping with findings from a comparative study of emission levels in Lagos and the Niger Delta area in 2000.[17] The results obtained showed that carbon monoxide (CO) levels in the selected Niger Delta communities were 5.0-61.0ppm and 1.0-52ppm; levels of other critical pollutants were above the Federal Environmental Protection Agency (FEPA) recommended limits. This finding was also in line with the findings of an earlier study in 1996 in a typical air quality assessment of the Niger Delta which showed that levels of volatile oxides of carbon, nitrogen and sulphur and total particulates exceed existing FEPA standard.[18] Despite these efforts, epidemiological studies continue to show associations between adverse health effects and air pollutants, even at concentrations near or below the current national standards.[15] Another study in Delta State (in the Niger Delta) revealed adverse effects of exposure to gas flaring in the study population as evidenced by a significant decline in lung function using peak expiratory flow rate measurement across all age groups.[19] The use of asbestos based materials for roofing by residents of these gas flaring communities to repel acid-rain deterioration has its attendant risk as asbestos exposure is known to increase the risk of developing lung cancer, pleural and peritoneal mesothelioma and asbestosis.[20-23] Ibeno, host community to an oil producing company in Akwa Ibom State is located in the South-south zone of Nigeria, and is one of the largest fishing settlements on the Nigerian coast. It occupies the largest Atlantic coastline of more than 129km in Akwa Ibom State, with a population of 74,840. Residents of this community have been exposed to gas flares for over thirty years.

Table 1: Distribution of respondents based on socioeconomic characteristics

Item	Variable	Subject	Control	Total
1	**Sex**			
	Female	226(58.5)	215(55.7)	441(57.1)
	Male	160(41.5)	171(44.3)	331(42.9)
	Total	**386(100.0)**	**386(100.0)**	**772(100.0)**
2	**BMI**			
	Under Weight(<18.5kg/m^2)	12(3.1)	53(13.7)	65(8.4)
	Normal(18.5-24.9kg/m^2)	184(47.7)	185(47.9)	369(47.8)
	Overweight(25-29.9kg/m^2)	128(33.2)	92(23.8)	220(28.5)
	Obesity(=30kg/m^2)	62(16.1)	56(14.5)	118(15.3)
	Total	**386(100.0)**	**386(100.0)**	**772(100.0)**
3	**Age (in years)**			
	18-31	153(39.6)	122(31.6)	275(35.6)
	32-44	110(28.5)	118(30.6)	228(29.5)
	45-57	76(19.7)	108(28.0)	184(23.8)
	58-70	38(9.8)	28(7.3)	66(8.5)
	71-83	9(2.3)	10(2.6)	19(2.5)
	Total	**386(100.0)**	**386(100.0)**	**772(100.0)**
4	**Height (in cm)**			
	140-150	34(8.8)	35(9.1)	69(8.9)
	151-160	137(35.5)	123(31.9)	260(33.7)
	161-170	158(40.9)	133(34.5)	291(37.7)
	171-180	49(12.7)	87(22.5)	136(17.6)
	181-190	8(2.1)	8(2.1)	16(2.1)
	Total	**386(100.0)**	**386(100.0)**	**772(100.0)**
5	**Education**			
	Nil	13(3.4)	11(2.8)	24(3.1)
	Primary	177(45.9)	112(29.0)	289(37.4)
	Secondary	151(39.1)	176(45.6)	327(42.4)
	Tertiary	45(11.7)	87(22.5)	132(17.1)
	Total	**386(100.0)**	**386(100.0)**	**772(100.0)**
6	**Years of Residency**			
	2-29 years	220(57.0)	180(46.6)	400(51.8)
	30-56 years	127(32.9)	172(44.6)	299(38.7)
	57-83 years	39(10.1)	34(8.8)	73(9.5)
	Total	**386(100.0)**	**386(100.0)**	**772(100.0)**

The pattern of respiratory symptoms among Ibeno residents and those of similar communities devoid of gas flaring

The result of the study in table 2 also showed that more of the exposed subjects had symptoms of cough, chest pain, breathlessness and wheezing (14.8, 9.6, 15.0 and 5.7 respectively) compared with the controls (10.1, 1.6, 7.3 and 3.1 respectively). Most of the exposed subjects also had chronic symptoms of cough (lasting more than two months) and chest pain. Interestingly, most of the subjects had a family history of asthma (2.6) compared with the controls (1.0) as shown on table 2, items 1-6.

Table 2: Distribution of respondents according to pattern of respiratory symptomsamong Ibeno residents and those of similar community devoid of gas flaring

Item	Variable	Subject	Control	Total
1	**Cough**			
	Absent	329(85.2)	347(89.9)	676(87.6)
	Present	57(14.8)	39(10.1)	96(12.4)
2	**Cough duration**			
	Absent	329(85.2)	347 (89.9)	676(87.6)
	Acute	39(10.1)	30(7.8)	69(8.9)
	Chronic	18(4.7)	9(2.3)	27(3.5)
3	**Chest pain**			
	Absent	349(90.4)	380(98.4)	729(94.4)
	Present	37(9.6)	6(1.6)	43(5.6)
4	**Chest pain duration**			
	Absent	350(90.7)	380(98.4)	730(94.6)
	1 month	17(4.4)	5(1.3)	22(2.8)
	=6 months	19(4.9)	1(0.3)	20(2.6)
5	**Breathlessness**			
	Absent	328(85.0)	358(92.7)	686(88.9)
	Present	58(15.0)	28(7.3)	86(11.1)
6	**Wheezing**			
	Absent	364(94.3)	374(96.9)	738(95.6)
	Present	22(5.7)	12(3.1)	34(4.4)
7	**Asthma**			
	Absent	376(97.4)	382(99.0)	758(98.2)
	Present	10(2.6)	4(1.0)	14(1.8)

Comparative assessment of lung function indices of residents and non- residents of Ibeno community

The independent T-test was used to compare the mean of the ventilatory parameters of the subjects and controls (Table 3). There was a statistically significant difference in PEFR among subjects and controls (p-value= 0.000).Mean FEV1 was also significantly lower between the exposed subjects (2.01± 0.76) compared with that of the controls (2.13±0.75), p=0.027. Both obstructive and restrictive pattern of ventilatory defects were seen more among respondents from the exposed community, than the controlled community. However, the difference was not statistically significant.

II. Relationship between FVC and its determinants

This subsection attempts to comparatively analyze the effects of sex, age, height, weight and duration of residency on the lung functions of the residents in both control and the communities with regard to Table 5. For the control communities, all the biodata variables had significant relationships with FVC,

Table 3a: Distribution of respondents based on comparative analysis of lung function index of residents and non-residents of Ibeno community

Item	Lung function indices	Mean of exposed	Mean of control	T-test value	Sig. (2-tailed)	Remark
1	PEFR (l/min)	300.6 ± 2.15	342± 2.16	4.446	0.000	Significant
2	FVC (l)	2.58 ± 8.43	2.27 ± 0.82	-0.721	0.471	Not Significant
3	FVC% p	88.25±302.43	75.84±23.64	-0.697	0.422	Not Significant
4	FEV1 (l)	2.01±0.76	2.13±0.75	2.221	0.027	Significant
6	FEV1_FVC	93.64 ± 11.89	94.21 ± 8.39	0.763	0.446	Not Significant
7	FEV3 (l)	2.37 ± 5.05	2.36 ± 2.80	-0.006	0.995	Not Significant
8	FEV3_FVC	100.34 ± 45.58	98.36 ± 7.12	-0.844	0.399	Not Significant
9	FEF25_75	3.18 ± 1.47	3.23 ± 1.23	0.531	0.595	Not Significant

FVC% p= FVC percentage predicted, **Df=770, Sig. (2-tailed) = P value=0.05 is significan**

Table 3b: Distribution of respondents based on comparative analysis of ventilatory defects of residents and non- residents of Ibeno community

Functional classification	Exposed		Total	Control		Total	Pooledtotal
	Male	Female		Male	Female		
Normal	66	52	118	70	68	138	256
Restrictive	89	161	250	98	140	238	488
Obstructive	2	6	8	2	5	7	15
Mixed pattern	3	7	10	1	2	3	13

Table 4: Showing multiple regression result on the relationship between PEFR and its determinants

Predictor variables	Standardized coefficients			
	Control		Exposed	
	Beta	Std Error	Beta	Std Error
Age	-.317***	.001	-.214***	.002
Duration of residency	-.053	.001	-.105**	.001
Weight	.180***	.001	.125***	.002
Height	.080	.002	.127**	.004
Sex	-.388***	.033	-.358***	.054
(Constant)	1.353***	.403	.526	.561

a. Dependent variable: ln PEFR

Note: *= statistically significance at 99% probability level**
****= statistically significance at 95% probability level**

while age and sex of the residents displayed a statistically significant relationship with FVC in the exposed group.

The predicted equation is presented as follows

FVC= -0.120 -0.336 (age) -.0.134 (Duration of residency) + 0.168 (Weight) + 0.182 (Height) -0.362 (sex) + e

III. Relationship between FEV_1 and its Determinants

This subsection attempts to comparatively analyze the effect of age, sex, height, weight and duration of residency on the lung functions of the residents in both control and the communities with regards to Table 6. For the control communities, all the biodata variables had significant relationships with FEV1, while age and sex of the residents displayed a statistically significant relationship with FEV1.

The predicted equation is presented as follows

FVC= -0.182 -0.368 (age) -.0.137 (Duration of residency) + 0.119 (Weight) + 0.199 (Height) -0.374 (sex) + e

Table 5: Showing multiple regression result on the relationship betweenFVC and its determinants

Predictor variables	Standardized coefficients			
	Control		Exposed	
	Beta	**Std Error**	**Beta**	**Std Error**
Age	-0.336***	0.001	-0.189***	0.002
Duration of residency	-0.134***	0.001	-0.093***	0.001
Weight	0.168***	0.001	0.080	0.002
Height	0.182***	0.002	0.304	0.003
Sex	-0.362***	0.033	-0.213***	0.050
(Constant)	-0.120	0.317	-1.857***	0.529

a. Dependent Variable: ln FVC

Note: *= statistically significance at 99% probability level**
**   **= statistically significance at 95% probability level**

Table 6: Showing multiple regression result on the relationship between FEV1 and its determinants

Predictor variables	Standardized coefficients			
	Control		Exposed	
	Beta	**Std Error**	**Beta**	**Std Error**
Age	-.368***	.001	-.251***	.001
Duration of residency	-.137***	.001	-.045	.001
Weight	.119***	.001	.111***	.001
Height	.199***	.002	.317***	.003
Sex	-.374***	.032	-.270***	.043
(Constant)	-0.182	.309	-1.853***	.447

a. Dependent Variable: lnFEV_1

Note: *= statistically significance at 99% probability level**
**   **= statistically significance at 95% probability level**

Discussion

Socioeconomic Characteristics of the Respondents

The study has shown that the mean age, height and sex distribution of both subjects and controls were comparable. However, the subjects were observed to have more overweight and obese individuals than the controls 33.2% and 16.1% vs. 23.8% and 14.5% respectively. There were also more underweight individuals in the control group than the exposed group (13.7% vs. 3.1%). This could be as result of improved nutrition as the exposed subjects have increased access to sea foods and unlike the controls are not involved in strenuous farming activities. Most participants among both exposed subjects and controls had spent most of their lives in the community, a few were married from other locations and some others were transferred from the workplace. The respondents were selected from three villages each from both the exposed and control communities. This suggests that they were chronically exposed to noxious air pollutants from childhood. In this scenario, even relatively small exposures could have a cumulative effect. Therefore, this could have a negative impact on lung growth and development, as well as accelerate the physiologic lung function decline with age.

Pattern of respiratory symptoms of the respondents

The symptoms indicative of respiratory disorders were similar in both exposed subjects and controls, though a higher prevalence was noted among the exposed subjects when compared with the controls: cough (14.8% vs.10.1%), chest pain (9.6% vs. 1.6%), and breathlessness (15% vs.7.3%), and wheezing (5.7% vs.3.1%).

The most prevalent respiratory symptoms were breathlessness and cough. There were also more respondents with a positive family history of asthma among the exposed subjects than controls (2.6% vs.1%). These findings suggest that the environment in the exposed community impacted more negatively on the lung health of the residents than that of the control community. Although cough chest pain, breathlessness and wheezing can occur in other conditions other than respiratory, an attempt was made to exclude participants with history or examination features suggestive of heart disease.

Comparative assessment of lung function indices among respondents

This study showed that the PEFR and FEV1 of the exposed subjects were significantly lower than that of the controls. This finding was in keeping with the findings of Ovaukporaye in a similar study done in the Niger Delta region, which noted a significant decrease in PEFR across all age groups in the study population.[19] This could be related to the negative effect of exposure to air pollutants, most likely from gas flaring. Although some studies have previously showed a decline in PEFR with increasing BMI, the current study did not demonstrate a statistically significant association between both parameters. There was no statistically significant difference between FVC values among both exposed subjects and controls; this may not be unrelated to the negative impact of chronic exposure to biomass fuels in both exposed and control communities. Lung function decline worsened with increasing age; the greatest decline was noted among the age group 58-70 years and 71-83 years, which suggests increased vulnerability to lung damage with age. Both obstructive and restrictive ventilatory defects were seen among respondents from exposed and non- exposed communities (mostly among females), but the difference was not statistically significant. Air pollution accelerates the already existing physiologic lung function decline with age as a result of decreasing lung elasticity. This is further complicated by the fact that most of the exposed population were born and raised in the same community and have probably suffered from the deleterious effects of air pollution right from childhood during lung growth and development.

The results of this study showed that between the two communities, sex of respondents showed the highest relative magnitude of influence on the PEFR, FVC and FEV1 and was followed by age and weight of the respondents. The significant predictors of PEFR in the current study were age, gender, height, and duration of residency. Across the predictor variables, a similar pattern of relative influence of the predictor variables was also found on sex and age. These findings are in keeping with the findings of previous studies. (46-50)The association between duration of residency and FVC and FEV1 showed a negative relationship which was statistically significant.

The study also showed a negative relationship between the status of exposure to gas flaring and other lung function indices measured which was statistically significant. These findings are consistent with previous studies that looked at PEFR and exposure to gas flaring in the Niger Delta.[19] Although this finding has not been consistently documented by all investigators in the Niger Delta (a previous study reported no significant difference between lung function indices of exposed respondents and controls),[20-22] a possible explanation for this could be the result of involvement of small airways in early exposure to toxic pollutants which regular spirometric measurements may not detect. The respiratory effects of air pollution from gas flaring depend on the type and mix of pollutants, the concentration in the air, the amount of time that an individual is exposed to the pollutant, how much of the pollutant the individual breathes in and how much of the pollutant penetrates the lungs.[24,25] The air flow pattern and approximate distance of deposition of the gas flaring bye products need robust investigation as that would suggest the likely points of severe impact among the distant communities other than the immediate Ibeno communities.

The results of the study showed that the mean age, height and sex distribution of both subjects and controls were comparable, although more of the respondents in the exposed community were overweight or obese compared with respondents from the control community. The respondents from the exposed community (a riverine area) were mostly involved in trading of sea foods, fishing or fish smoking, while the respondents from the control community were predominantly farmers, and had at least primary education. Most of the respondents from the exposed community experienced symptoms of cough, chest pain, breathlessness and wheezing. They also had more respondents with a positive family history of asthma. A comparative assessment of the lung function indices of residents of Ibeno and the control community showed statistically significant differences in PEFR, and FEV1. In this study, sex of respondents showed the highest relative magnitude of influence on the PEFR, FEV1 and FVC followed by age and weight of the respondents. The association between duration of residency and lung function indices also showed a negative relationship which was statistically significant. Based on the findings of this study, Ibeno residents had more respiratory symptoms than the controls and had lower PEFR and FEV1 values than the controls which were statistically significant. These are similar to findings from previous studies on gas flaring [26,27,28]

Conclusion

The study has revealed a severe adverse health impact and abnormal lung function indices of the indigenes of Ibeno, which are exposed continuously to gas flaring.

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