Acid rain: an analysis on the cause, impacts and abatement measures Niger Delta perspective, Nigeria.

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Abstract—The attention on acid rain is imperative in cognizance of the fact that there is a rejuvenation of rain water harvesting in recent times for which several countries have embraced as either supplemental or replacement roles in water supply schemes. This study enumerates concisely the adverse effects of the acid rain phenomenon in Niger delta Nigeria, the trend of rain water acidity, the extent of impact with certain associated ailments and government abatement measures to curb or eliminate acid rain. Regression model employed to determine the correlations of gas flaring rate (since sulphur oxides, Nitrogen oxides, the precursors of acid rain emanate majorly from gas flaring and power plants) to rain water acidity, cough, diarrhea and poverty gave an overall P value of 0.02 indicating a good significance level for the model. Analysis on the influence of power plants on the acidity of rain water alongside government abatement measures for the control of the acid rain, revealed government focused attention on primary abatement against secondary measures and that the concentration of power plants in the southern region has a significant negative impact on the degree of rain water acidity in the region.

Key words: Acid rain, effects, abatement measures, Nigeria, Nox, Niger delta, policy, gas flaring

1 INTRODUCTION

The primary precursors of acid rain (dry or wet)are NO_X and So_2, these are two known atmospheric emissions associated with industrial and human anthropogenic activities of which gas flaring and power plants are major contributors. Acid rain and gas flaring are two synonymous terms peculiar to the Niger delta of Nigeria, probably due to the attributes of the latter to the former by several researchers, as the region is the core of oil and gas activities in the country. Attention to acid rain is paramount in view of the fact that there is a dynamic rejuvenation of rain water harvesting (RWH) in recent times for which over 65 countries and still counting are currently engaged in(). This may be linked to the increased demand for drinking and municipal water uses due to urbanization, scarce water resources and population growth among other reasons. Beyond this also is the fact that a good majority of Nigerians depend highly on rain water especially during the rainy season for their basic water needs. the value of RWH as either supplemental or replacement roles in water supply schemes has indeed prompted series of researches and consequently led to formulations, amendments, reforms in policy, programs, and plans in various places especially high RWH potential and scarce water terrain and regions.it will be merely stating the obvious to say that Nigerian ranks 2nd after Russia in gas flaring, most of which occurs within the Niger delta region, however, contentions has also arisen on the authenticity of the claim on acid rain from shell, a major oil producer in the country, arguing that the phenomena is nationally spread, and as such not resultant from their activities, besides the Nigerian crude is recognized as sweet,(low sulphur content). [9]reported the spatial variation of acid rain in the country with an average rain water PH of 5.3 increasing with about 0.5 northwards from the coast of Nigeria. The effects of these acidic emissions and acid rain abound, and are in concise highlighted hereafter. This report,[9] not only corroborates the insinuations that acid rain is wide spread in the country and that NO_x might be the predominant pollutant responsible for its occurrence(Nigeria ranks 69th of 141 in the world on NO_x emission per populated area ,about 0.24 thousand metric tons/squ (world resource institute data base)) ,but also suggest the reasonable contribution of other sources to this phenomenon. Emission from boilers in power plants and gas flares from oil producing outfits/platforms are major sources for the acidic pollutants of NO_x and SO_2, the precursors of acid rain. Acid rain refers to depositions in the form of rain fog, snow occurring downwind of areas where major emissions from anthropogenic activities take place [6], [11]. Acidic precipitations have been reported severally in Nigeria, specific to the Niger delta area include [9], [11] in Warri, [22] in the western Niger delta, [5] in Imo state, [10] in Bayelsa. World Bank, UN human development report and the Nigerian poverty profile report all indicate a rising incidence of poverty in the Niger delta region. This study therefore attempts to investigate the relationships, the rate / quantity of gas flared in the Niger delta region and the acid rain phenomenon as well as its contributions to certain health

effects associated with it and recognized to be prevalent in the region and the incidence of poverty. Previous related studies have only focused on specific states in this region, presuming a general situation for all other states in the region. We also examined government abatement measures on acid rain, and the influence of power plants on this phenomenon in the country.

2. Outlook on the effects of acid rain and gas flares in Nigeria.

Gas flaring involves the release of undesired gases most of which are toxic gases such as SO_2, NO_x, CO_2, CH_4 CH_5 into the atmosphere. Whereas, acid rain is basically rain water with a PH lower than 5.6 and usually occurs in areas with major emissions from anthropogenic activities. The effects of these occurrences abound. The following equations describe the occurrence of acid rain while the tables reflect a summarized effect of gas flaring and acid rain in the region.

SO_2 (g) + H_2O $\rightleftharpoons$ H_2SO_3 (sulphurous acid) ……. (1)

SO_2 (g) + 2OH $\rightleftharpoons$ H_2SO_4 (sulphuricacid) ……. (2)

CO_2 + H_2O $\rightleftharpoons$ H_2CO_3 (carbonic acid) …….. (3)

NO_2 + NO_2 $\rightleftharpoons$ HNO_3 (nitric acid) ……. (4)

Table 1. Concise effects of acid rain and gas flaring in Niger delta

Acid rain	Gas flaring
Damages sculptures and buildings	Depletes the ozone layer
Affects flora and fauna	Causes asthma, bronchitis, cancer,
Corrodes storage bowls, roofs	Noise effect
failure of aquatic life	Greenhouse effect
Chlorosis of leaf	Solar radiation exposure
Affects soil, removes essential nutrients	Food insecurity, due to soils reduced microorganism activities
causes acidosis, eye irritation, conjunctivitis, bronchitis, prolonged coughing and lung diseases	Economic loss when gas flared is quantified
Building, structures and cars discoloration	Niger delta crisis, such as pipeline vandalism, hostage taking, neglect of the region by successive govt.
Roof leakages	
Skin cancer, lesions, asthma	

3 3.0 Approach

This study utilized data from secondary sources via websites and publications like the natural gas associations,(NGA) oil and gas journals, policy documents, NBS (national bureau of statistics), world bank, and reports from Niger delta human development , ministry of environment, ministry of health,. It adopted the (NTCS) approach narrative textual case study which relies and sources data from internet, intranet, World Wide Web, online data bases, e libraries, for purpose of problem, identification and or solving or both. The gas flare rate from the various major oil producing companies of each state of the Niger delta were collected through this process for the years of 2003-2005, similarly, the PH of harvested rain water, poverty incidence rate, cough and diarrhea prevalence rate for the various states of the region were also obtained .Thereafter analysis were conducted using the multiple regression model with gas flare rate as the dependent variable while PH, poverty incidence , cough and diarrhea prevalence were the independent variables. The model equation takes the form

$$Y = \beta o+\beta 1x1 +\beta 2x2 +\beta 3x3 +\mu \quad \ldots\ldots (5)$$

Where Y is gas flare rate, x1 is PH, x2, cough prevalence, x3 is diarrhea prevalence and x3 is the poverty incidence in the region.

4.0 PH trend in the Niger delta region

Table 1 and figure 1 indicate a decreasing trend in PH on rivers and delta states having the lowest PH values of 4.56 and 4.99 with gas flare rates of 754786431bcf and 389895189bcf respectively, and accordingly signifying a more pronounced occurrence of acidic precipitation in these states as against other states. This is perhaps expected in view of the fact that these states represent the core of oil and gas activities in Nigeria, and most times activities in these states are even used as a yard stick for evaluating other states in the region. Although delta state ranks second in low PH values, it ranks fourth in gas flare rate, suggesting some external contribution to acidity from other sources, like industrial or power plants emissions .This has also being implied by other reporters. A similar explanation follows suite for Imo state having a PH of 5.05.the states of Edo, Akwa-ibom, Bayelsa and Ondo follow respectively with values of 5.11, 5.2, 5.26, and 5.33.

4.1 Trends in predominant health effects and poverty incidence

The ailments commonly associated with gas flaring and acidic precipitations as reported and observed include asthma, prolonged coughing, cancer, bronchitis, conjunctivitis, eye irritations amongst others, however

diarrhea has also been known to have caused high mortality rates especially amongst children also in this region.Hence our purpose for exploring any possible correlations with acid rain and gas flaring within this region. From table 3, the highest incidence of diarrhea is in Akwa-ibom state, followed by delta and river states, following after are Imo,Bayelsa, Edo, and Ondo states respectively. The highest incidence of diarrhea which occurred in Akwa-ibom state corresponds to a PH of 5.2, which is amongst the relatively high PH values within the region and moderately flared gas rate. This implies that the incidence of diarrhea isn't directly but perhaps indirectly connected to the occurrence of acidic rain or gas flaring in this region. This is also reflected in the values for the other states like Edo, delta, etc.

The poverty incidence rate also reflect a similar trend from table 3.the highest rate occurred in Akwa-ibom state while the least poverty incident state is Bayelsa state.

Insert figure1a and 1b

Insert table 2

4.2 Statistical analysis and discussions

From the regression statistics table shown in table 3 a high value of approximately 100% for R^2 indicates a very good fit for the model. It implies that over 99% of the independent variables in this case PH, cough, diarrhea prevalence rate and poverty incidence rate can be explained by the model. The model has a positive intercept but a negative coefficient on x1 variable (PH) and cough (x2) variable. This implies an inverse correlation relationship, first corroborating the facts that gas flaring contributes significantly to the occurrence of acid precipitations,[9] hence an increase or continuous gas flaring would result to a decrease in PH of rain water, apparently this would mean increased acidity of rain water and vice versa. This also suggest that at this rate rivers state would bear a greater degree of effects as it has the lowest PH values amongst the states in the region. Further still, the p value of 0.03 which is less than 0.05 indicates how significant this deductions are. The x2 variable representing the cough prevalence in the region also reflected an inverse correlation with Y but a linear correlation with x1 variable (PH), this would indeed suggest and also corroborate facts that acidic rain causes prolonged coughing and as such the more acidic rain water is when consumed, the more incidence or prevalence of coughing possible. The p value of 0.04 also presses further this fact. Of all the independent variable only variable x3(diarrhea) showed a direct linear correlation with Y the dependent variable, implying that a continuous and increased flaring would result in increased diarrhea incidence, although diarrhea is not a directly recognized ailment associated with gas flaring, it is recognized to be associated with acid rain as acid rain enhances the release of ions from metals, for instance iron toxicity which may result from the increased or excess iron extraction from iron pipes in contact with acid rain ,which when used to supply water for consumption is a contributing factor to diarrhea ,besides mobilized copper has been implicated in outbreaks of diarrhea in young children. [25] reported that diarrhea diseases ranks high as a major cause of illness and deaths amongst infants, young children and elderly in developing countries. In Nigeria 24% infant mortality, 19% of under 5 years death are due to diarrhea [13].thus the prevalence of diarrhea in this region can also be attributed to the gas flaring here which causes acidic precipitation. From table above the highest occurrence of diarrhea is in Akwa-ibom state with a PH of 5.2, and the least in ondo with a PH of 5.33.

The poverty incidence variable indicates an inverse correlation with Y with a p value of 0.18, which is greater than 0.05, suggesting an insignificant correlation. Thus implying that the poverty incidence rate in this region may not really be a function of the rate at which gas is flared, but perhaps political, or otherwise. The ANOVA table however gives an overall good significance level for the model with a value of 0.03, which is much lower than 0.05. The model equation is thus written as

$Y = 3116803546 - 501358206.3X1 – 12728115.1X2 + 39395114.64X3 – 5882578.342X4$

Insert table 3.

Insert table 4.

5.0 Abatement measures adopted by government.

Abatement measure are categorized as primary and secondary .[J.P Hutton and G.E Horlkos,1995] defined primary abatement as the reduction of sulphur emissions by such means as substituting low or sulphur free fuel, reduced use of sulphur fuel as a result of improved fuel efficiency in power stations, improved energy efficiency, in the rest of the economy, or any other measure reducing the output of electricity, while secondary abatement involves removal of sulphur from emissions either during burning or after burning employing devices like fluidized bed combustion or flue gas desulphurization respectively. The emphasis on sulphur fuel can also be extended to nitrogen rich fuels, as so_2 and Nox are the primary precursors of acid rain hence secondary abatement would imply the use of devices like low Nox burners, etc. This is more so in the Nigerian context where sweet crude is the case. The escalation of the adverse effects of this phenomena and the outcry of the populace prompted several responses from government. The following are measures and attempts in the form of policies, plans, or programs so far adopted by the government to help

mitigate or abate these effects. It should be noted that in spite of all these attempts the issues with gas flaring, and acid rain still persist, with potential of a worsened acid rain situation as about 60% the (NIPP) national integrated power plants are currently located within the Niger delta region. Power plants as stated earlier are major contributors to the emissions of NOx an acid rain precursor.

Insert table 5.

5.1 Discussing the abatement measures

A close look at table5 reflects the focus on primary abatement measures in the Nigerian context for acid rain control, most of the efforts has been centered on policies for primary abatement either in the context of eliminating completely flaring, or switching to low sulphur or nitrogen fuels, improved energy or fuel efficiency, with little focus on programs, and plans or secondary measures. From table 5 it can be deduced that about 57% of the total of 14 measures highlighted are policy oriented, 7% program oriented, and 35.7% plans oriented. furthermore, about 92.8% are targeted towards primary abatement, 28.6% on secondary, So far as the precursors of acid rain and its abatement is concerned ,not much efforts or measures has been initiated or implemented.as previously stated the basic culprits in the emissions of the precursors of acid rain are gas flaring and power plants, the regression analysis carried out above on the relationship of the impact of gas flaring on certain health effects and poverty index in the Niger delta revealed that continuous and increased flaring causes increased incidence of diarrhea and cough. shell had stated that a total elimination of gas flaring at any stipulated timeline is hardly feasible, that besides being highly capital intensive for cost of installing gas gathering equipment, gas flaring happens to be an inevitable activity during production operations, as such, at the most only 85% of gas flaring reduction can be achieved. The fact remains that 100% total elimination of flares is a course yet to be completely achieved by any nation globally, hence most advanced nations have also placed and directed emphasis on pollution emission reduction and abatement, in the area of secondary abatement measures.

5.2 The influence of power plants on acid rain

The NIPP (national integrated power plants) is a recent reform in the Nigerian power sector to ensure adequate and maximum utilization of natural gas that otherwise would have been flared to meet the power supply deficiency in the country. power plants are recognized as major contributors to emissions of the gases (Nox, believed to be the principal contaminant of rain water in Nigeria, although [11] had reported sulphur content in the acidic precipitation in the Niger delta) responsible for acid rain. Figure 2 shows that there is a concentration of power plants in the Niger delta region (SS), with about 60% of the NIPP located in this region. Of all the power plants only 2(5.7%) have installed in them pollution reduction/ control devices (Low Nox burners) one in the south south and the other in the south east, belonging to a group of oil producing companies, and NIPP respectively. Most oil producing companies also do not have these secondary abatement devices for controlling Nox and So_2 installed in their production facilities as their primary concerns is basically in the control of co_2 emissions since the Nigerian crude is sweet, it can be observed also that the lowest mean rain water PH of 4.94 exist in the SS having the largest number of power plants, followed by the SE and SW with 5.26, and 5.29 with 3 and 4 power plants respectively. although the NC has 6 power plants it has a mean RW PH of 5.46, this is likely because 3 of this plants are hydro, 1 coal and are either under construction or planned, hence the contribution of Nox to acidity from this plant is currently low .Northeast, and Northwest have the highest RW PH , and lowest number of power plants, having 1 and 2 respectively, all of which are still planned, the implication of the concentration of these power plants in this region especially when there is no enforcement on the installation of pollution reduction or control devices is that the acid rain phenomena will not only persist, but much more pronounced. this are all indications and pointers to the fact that as far as controlling or eliminating acid rain is concerned a lot still has to be done, especially in the area of secondary abatement. In the US there is the acid rain program which involves the trading of permits, for so2, by polluting industries, in Europe it takes the form of international corporation on combating this acidic emissions, the Chinese government incorporate emission reduction targets into their national policy, setting reduction targets for every of their five year development plans and are currently stiffening the enforcement on industries for the installation of these emission reduction devices.

Insert table 6。

Insert figure 2

6.0 Conclusion

The outcomes of this study include the facts that rain water acidity is most pronounced in rivers state of the Niger delta region, which also corresponds to the state with the highest gas flared rate, while ondo state has the least rain water PH. The concentration of power plants in the southsouth region of Nigeria contributes significantly (Nox emissions) to the acid rain phenomenon, as only two of the 19 plants have installed in them pollution control devices. Government so far have focused attention on primary abatement as

against secondary measures which has proven effective for most advanced countries like the US and in Europe and even china.it may therefore be imperative for policy makers to reform policies and embark on enforcement of the installation of pollution control devices in industries and especially the power plants in the country. This paper helps to bridge knowledge gap in this field and would be useful for policy makers, academicians, engineers, industries, and the public.

ACKNOWLEDGMENT

The support from the national natural science foundation of china (NSFC-JST 21261140334) and national science and technology major project water pollution control and treatment (No.2012zxo7202006-004) is highly appreciated.

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