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Baseline black carbon emissions for gas flaring in the Niger Delta region of Nigeria

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ABSTRACT

Obnoxious gases, particulates and enormous heat are the products of gas flaring causing environmental pollution and human health problem. Black carbon (BC) is an aerosol formed from the incomplete combustion of fossil fuel, biomass and biofuel. This present study aims to provide baseline emission inventory for the amounts of BC released into the atmosphere via gas flaring in the Niger Delta region for a period of 49 years (1965 – 2013); spanning five decades. Emission factors and volume of gas flared for each year for a 49-year period were sourced from literature and were employed to empirically estimate the amounts of BC emitted. For this said period, 55% of the gas produced was flared releasing an enormous amount of 4.56×10^5 tons (4.11×10^8 tons CO_2 equivalent) of BC into the environment. It was observed that the amounts of BC released into the environment increased progressively ($5.06 \times 10^4 - 1.27 \times 10^5$ tons) for the first decade (1965–1974) of gas flaring to the fourth decade (1995–2004) with a significant reduction (8.74×10^4 tons) in the amounts of BC emitted in the fifth decade (2005–2013). Of the probable solutions proffered to reduce BC emission through gas flaring is the utilization of the gas as transportation fuel (compressed and liquefied natural gas) in the country.

1. Introduction

The burning of fossil fuel (coal, oil and gas) has led to the warming up of the environment through the emissions of carbon dioxide (CO_2) as the main greenhouse gas. Nigeria is one of the highest emitter of greenhouse gases in Africa and among the highest CO_2 emitters in the world (Orimoogunje et al., 2010). One of the environmental problems associated with crude oil exploration and exploitation in Nigeria is linked to gas flaring. Atmospheric contaminants from gas flaring include oxides of nitrogen, carbon and sulphur (NO_x, CO_2, CO, SO_x), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide (H_2S) (Orimoogunje et al., 2010). Nigeria is one of the world's biggest flarer of Associated Gas (AG) with many gas flaring points that release over 23 billion cubic metres (bcm) of gas per annum (Nkwocha and Pat-Mbano, 2010). The Niger Delta is endowed with an estimated reserve of about 23 billion barrels of oil and 183 trillion cubic feet (tcf) of natural gas. The largest flaring activities occur in the Niger Delta region of Nigeria which covers an area of about 75,000 km^2 (Sonibare et al., 2008). It is generally accepted that flaring and venting of gas contribute significantly to greenhouse gas emissions, with negative impacts on the environment (Ologunorisa, 2001).

Gas flaring has commenced since the petroleum exploration in the Niger delta area of Nigeria in 1956 (Ologunorisa, 2001). In 2004, a total amount of 160 bcm of gas was flared, of which Nigeria flared over 14% and ranked second only to Russia (Elvidge et al., 2009; World Bank, 2007). This quantity of gas is enough to meet Nigeria's energy needs and leave a healthy balance for export. Through this obnoxious act, the country has lost about $72 billion in revenues for the period 1970–2006 or about $2.5 billion annually (Bassey, 2008). All these go up in smoke yearly, leaving death and destruction in its path. Globally, the absence of an efficient regulatory framework, inaccessibility to domestic and international markets and limited finances to carry out gas flaring reduction projects are key reasons for the continuous flaring of gas (World Bank, 2002). However, in Nigeria, all these reasons appear to hold true in addition to inadequate capabilities and overlapping responsibilities of government institutions, unclear operational procedures and political instability and corruption (Edino et al., 2010; Ishisone, 2004; Omakaro, 2009; World Bank, 2002).

Recognizing the enormous financial loss resulting from the flaring of AG and the resultant environmental damage, the Government of Nigeria promulgated the AG Re-injection Act and the

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AG Re-injection (Amendment) Act in 2004, which compelled all oil producing companies in Nigeria to submit detailed plans for gas utilization (Onwukwe, 2009). The Government's aim is to attain zero flaring by 2008 in order to reduce pollution and monetize its gas reserves. The Government directive of reducing flared gas by 2008 has witnessed a drastic reduction in the amount of flared gas. This reduction resulted from gas utilization projects embarked upon by the oil operators and Government, whose primary targets are overseas gas markets. Unfortunately, this target was not met (Onwukwe, 2009).

Studies have reported gas flaring to having serious economic, social and health implications for Nigeria and the world in general, due to its negative environmental degradation and its contribution to climate change (Ologunorisa, 2001; Abdulkareem, 2005; Edino et al., 2010; Orimoogunje et al., 2010; Omakaro, 2009; World Bank, 2007). Gas flaring is also reported to cause acid rain within the flare's microenvironment (Ologunorisa, 2001; Odjugo and Osemwenkhae, 2009). Another impact of gas flaring reported is the destruction of vegetation, wild life and ecological destabilization (Ologunorisa, 2001; Abdulkareem, 2005; Odjugo and Osemwenkhae, 2009). Gas flaring is found to have significantly affected the health of the inhabitants around oil rich zones causing ailments like respiratory problems, skin disorders, intestinal diseases, child deformities and other health risks (Ologunorisa, 2001; Madueme, 2010; Odjugo and Osemwenkhae, 2009). Therefore, governments need to help reduce this practice in developing countries by developing an appropriate legal, regulatory and financial environment that promotes the utilization of gas (World Bank, 2002). The Niger Delta is an area of global importance for biodiversity conservation, due to its extraordinary biodiversity (Ugochukwu and Ertel 2008). The region's biodiversity is under grave threat owning to the rapid rate of environmental degradation caused by oil and gas exploration activities.

Black carbon (BC) emissions are caused by incomplete combustion of fossil fuels, biofuels and biomass. BC is the most strongly light-absorbing component of particulate matter (PM). A particle (aerosol) rather than a greenhouse gas, it is the second largest climate forcer in today's atmosphere, following carbon dioxide. BC's contribution to global warming is approximately 70% of carbon dioxide's contribution. Although BC remains in the atmosphere for only a few days, one gram of BC warms the atmosphere several hundred times more during its short lifetime than one gram of carbon dioxide does during 100 years. Total global emissions of BC using bottom-up inventory methods are 7500 Gg yr^{-1} in the year 2000 with an uncertainty range of 2000 to 29,000 (Bond et al., 2013).

BC emissions come from industry, transportation, residential cook stoves and open burning. BC contributes to global warming in two ways. First, dark BC heats the air by absorbing radiation from sunlight. Second, cloud droplets form around BC particles which increases the level and degree of cloud formation, and disturbs the thermal gradient. A recent study concluded that BC had a net climate forcing of $+1.1$ W m^2, making it the second most important contributor to climate change after CO_2 (Bond et al., 2013). BC, as part of $PM_{2.5}$, has adverse impacts on human health, ecosystems and visibility. BC particles can penetrate into the human body through the lungs with inhalation, through the gastrointestinal tract with water and food contact, and through skin and mucosa.

BC formation is the result of a very complex process, involving several steps of chemical and physical particle growth and then destruction. Although the mechanisms of soot formation in gas flares are still not fully understood, key influencing parameters include exit velocity of gas from the flare, flare gas composition, wind conditions, flare stack diameter, and flare tip design. Gas flaring is likely one of the largest sources of BC emissions from the oil and gas sector. This practice, although increasingly controlled in many countries, persists in many regions, the most notable being the Niger Delta in Nigeria and West Siberia in Russia (Levitsky, 2011).

Subject to the above, fast action deems necessary for BC mitigation in order to slow global and regional warming and improve the health and air quality of poor rural and urban areas throughout the world. This study was aimed at providing a baseline BC emission inventory from the gas flaring activities in Nigeria for the past 49 years and to assess the health implications of this obnoxious act, and hence, to proffer possible solutions to this unpleasant problem. It is worth noting that to the best of our knowledge, no national, regional and sectoral inventory exists for BC emissions in Nigeria and most importantly, that of gas flaring in the Niger Delta region.

2. Calculation

2.1. Study area

This present work was carried out to investigate the serious and current global sensitive issue of BC emission in the light of gas flaring in the Niger Delta region of Nigeria. This region remains the sole area for oil and gas production in Nigeria, which has accounted for over 90% of the country's foreign earning for more than three decades now. This region is the largest wetland in the country and the third largest wetland in the world, and it is known for its unique bio-diversity.

2.2. Data collection and data processing

The data utilized in this study were garnered from published articles and bulletins released on the website of Nigeria National Petroleum Company (NNPC) for information on gas produced, gas utilized, gas flared and percent gas flared in Nigeria. The data covered a period of 49 years (1965 − 2013). Although NNPC gave the volumes of the gas produced, gas utilized and gas flared for this period in thousand cubic feet but we have converted them to million cubic metres (mcm), so that it can be in standard international unit (SIU). These data were divided into five decades (1965–1974, 1975–1984, 1985–1994, 1995–2004, 2005–2013) for detailed and in-depth understanding of the subject. Microsoft Excel (Window 7) was employed as the statistical tool to calculate and analyse the data. Also, the correlation between the volumes of gas produced and the volumes of gas flared for the entire 49 years was calculated.

2.3. Black carbon estimation

The BC emitted through gas flaring activities in the Niger Delta area of Nigeria was estimated for the period under consideration using Eq. (1). Emission factors of 0.51 kg of BC/10^3 m^3 and 2.5632 kg of BC/10^3 m^3 for gas flaring processes as reported in literature were utilized (McEwen and Johnson, 2012). In this present study, 0.51 kg of BC/10^3 m^3 was used as the baseline emission factor while 2.5632 kg of BC/10^3 m^3 was used as the upper bound emission factor.

$$\text{Black carbon(kg)} = \text{Emission factor}\left(\frac{\text{kg of BC}}{10^3\text{m}^3}\right) \times \text{Vol. of gas flared}\left(\text{m}^3\right) \quad (1)$$

The yearly and decade by decade BC emissions in the region for the entire period under study, and the monthly emissions for year 2013 were reported.