Cogent Engineering Volume 7, 2020 - Issue 1

CHEMICAL ENGINEERING

Modelling of sweet gas flaring and the resultant gaseous emissions with their emission factors

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Article: 1815931 | Received 16 Apr 2020, Accepted 05 Aug 2020, Published online: 21 Sep 2020

- https://doi.org/10.1080/23311916.2020.1815931

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Abstract

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Data from literature and a stoichiometric material balance model were employed to estimate associated emissions with flaring of sweet gas in Nigerian oil and gas companies. Emission factors were obtained using AP 42 formula. Results showed that thousands of tonnes, ranging from 6500 to 22,000 tonnes of natural gas were flared from 1997 to 2016. At flaring stack efficiencies of 97% and 98%, the associated emissions are: CH_4, C_2H_6, C_3H_8, iC_4H_{10}, nC_4H_{10}, iC_5H_{12}, nC_5H_{12}, C_6H_{14}, C_7H_{16}, C_8H_{18}, C_9H_{20}, CO_2, and N_2 from unburnt natural gas and in addition to CO_2, CO, N_2, NO, NO_2, H_2O and H_2 from incomplete combustion. At both flaring stack efficiencies, the amount of emissions from unburnt condition ranged from1,608 tonnes N_2 to 9,146 tonnes CO_2 all higher than any emission standards in the world, while the amounts of emissions from incomplete combustion ranged from 467,964 tonnes for CO_2 the lowest to 2,476,011 tonnes for N_2 the highest all higher than any emission standards in the globe. Emission factors of emissions from unburnt natural gas ranged from 0.000090 tonne/tonne for $C_{10}H_{22}$ to 0.026235 tonne/tonne for CH_4 while those of the emissions from incomplete combustion ranged from 0.10285 tonne/tonne for H_2 to 1.13137 for CO_2 tonne/tonne. It was observed that thousands of tonnes of emissions are released into the atmosphere during flaring of sweet natural gas either at complete or incomplete combustion. It is recommended that flaring of natural gas should be reduced to a minimal level to safeguard the environment.

Keywords:

modellingnatural gasgas flaringemissionsemission factorsenvironmental degradation

1. Introduction

Gas flaring is one of the most challenging energy and environmental matters in front of the world today whether regionally or globally (World Bank, 2004). Nigeria is one of the highly endowed nations with natural resources such as natural gases, petroleum and mineral deposits. In some instances, these have been blessings, and in others they are nothing but constant sources of woes to the nations that are located where these resources may be found. Of these natural sources, some are a windfall for these countries, while others have to be struggling to deal with the attendant menace such as diseases and environmental pollution that come with the resources (Human Development Report, 2011).

In Nigeria, there is no standing legal framework that prohibits gas flaring in spite of the environmental consequences associated with it. The existing laws that appear to regulate gas flaring in Nigeria are not effective as they do not completely prohibit gas flaring but only provide monetary penalties for continued flaring of gas by oil and gas companies in Nigeria (Udok & Akpan, 2017). The Judiciary, therefore, appeared to have championed the cause for the abolition of gas flaring in Nigeria. In 2017, Udok and Akpan examined the legal framework for gas flaring in Nigeria and further identifies the problems and prospects associated with the flaring of gas in Nigeria and made useful recommendations which are being implemented.

In both onshore and offshore oil and gas explorations, procedures of flaring of natural gas are conducted (Farina, 2010; GGFR, 2002) with the intent of facilitating the reduction of pressure in the well and viewed by some as a safety precaution, but in most instances is conducted as a means of disposing excess natural gas where there is inadequate infrastructural facilities for utilization of this gas. Flaring of natural gas in Nigeria adds approximately 1% to the worldwide CO which poses extensive issues for the environment (World Bank, 2010), and is viewed as a pathway to issues associated with absence of consumer goods, cultural and ethnic perceptions towards flaring as vast opportunity for economic benefit (World Bank, 2010).

Several researchers have worked on impact of flaring of natural gas in Nigeria and in the world at large. Omoniyi and Ubale (2015) investigated the various ways in which gas flaring affects the populace of the Niger Delta region of Nigeria, which is the bedrock of Nigeria's current oil and gas resources. O.S. Ismail and Umukoro (2012) presented material balance equation and predicted results for non-hydrocarbon emissions such as CO_2, CO, NO, NO_2 and SO_2 from flaring of 12 natural gas samples representing composition of natural of global origin. Gaseous emission estimates and patterns were modelled by coding material balance equation for six reaction types and combustion conditions with a computer program. In 1999, Li and William gave several reactions taking place in combustion of natural gas. Research has shown that during combustion reaction, several intermediate products are formed, and eventually, most of

them are converted to CO_2 and water. Some stable intermediate products and other by-products such as hydrocarbon, CO, H_2, NO, NO_2, SO_2 etc would escape as emissions (Kahforoshan et al., 2008). The impact of infrared radiation emanated from flaring of natural gas is also of great concern as there are limits to which ecosystem can endure the heat fluxes emitted (O. S. Ismail & And Fagbenle, 2009).

It is indicated in Oo et al. (2019) that increasing atmospheric carbon dioxide and other greenhouse gases through anthropogenic activities, and human activities like land-use changes, production of industrial effluents and other activities due to the development of society cause to change in global as well as regional climate. Mulenga and Siziya (2019) opined that climate change may worsen existing indoor air problems and create new problems by altering outdoor conditions that affect indoor conditions. Since climate change is due to both natural variability and human-induced contributions, public health professionals through their expertise in health promotion and behaviour change can play a vital role in promoting lifestyle choices that will decrease greenhouse gas emissions. The fact that greenhouse gases are imposed on the atmosphere by anthropogenic activities, green building rating tools (GBRTs) have become the essential need to cope up with the sustainable development goals, climate change, and natural resource degradation through buildings (Khan et al., 2019). Elehinafe et al. (2017) investigated the calorific values of sawdust of different wood species found in southwestern Nigeria with a view to considering their suitability as energy sources to reduce dependence on fossils that lead to emissions of greenhouse gases.

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