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Impacts of Flaring of Associated Gas on the Environment

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Abstract

A brief and concise "environmental scientist" point-of-view on the effects of associated gas flaring on the environment and then a consideration of the benefits of planned zero flaring of this same associated gas has been presented in a manner it is hoped will make for a true enlightenment. This paper could be a veritable resource material for government agencies and indeed anyone genuinely interested in the health of our environment.

Keywords: Natural gas, Pollution, Climate Change, Environment

Introduction

The Federal Government of Nigeria is committed to ensuring that hydrocarbon exploitation activities must proceed onward from 2008 with zero flaring of associated gas. One would agree that this is a welcome development since the technology to achieve this stated objective was first put to use some 11 years ago. This technology is now regarded as proven, around which the international flare standard API521 is based (Knot, 2004). The economic value of recovered gas that would otherwise be flared is enormous indeed considering the fact that gas is being touted as the viable, low-cost alternative energy source of the future (Egbobi, 2004). In reality Nigeria needs to optimize its annual gas production, as this is required to be effective feedstock for the different LNG trains. In tandem with this is the overall positive health of the environment, so to speak, that should then improve because eliminating routine flaring will contribute to overall CO_2 (principal culprit in the greenhouse effect) reduction as well as other toxic products of combustion like the NO_x and SO_x emissions. Natural gas is generally considered as a fossil fuel and by implication it is a non-renewable source of energy. The term "fossil" refers to any remains or evidence of ancient life. The fossil fuels (e.g. oil, coal, and fuels derived from oil shale and tar sand), then, are those energy sources that formed from the remains of once-living organisms. Natural gas is a natural-occurring gaseous mixture of hydrocarbon gases found in underground reservoirs. In its pure form, it is colourless, odourless, and it gives off a great deal of energy upon combustion. Natural gases is found either in associated form mixed with petroleum in a reservoir or in non-associated form where it is found on top of the crude in a reservoir (Egbobi, 2004; Dick and Wimpfen, 1980). Over the years many people have expressed concerns about the pollution effect linked with the combustion of fossil fuels. Table1 shows the gases that collectively make up what is known generically as "natural gas".

Table 1: Gases that constitute "natural gas"

Hydrocarbon Gases/Other Gases	% composition
Methane	70 – 95
Ethane	
Propane	0 – 20
Butane	
Heavier hydrocarbons	
Carbon dioxide	0 – 8
Oxygen	0 - 0.2
Nitrogen	0 – 5
Hydrogen Sulphide	0 – 5
Water Vapour	0 -5
Rare Gases	Traces

In the purest form, natural gas is almost dry methane (CH_4). Other hydrocarbon components are collectively called "natural gas liquids (NGLs)". As a source of energy the uses of natural gas include the production of liquefied natural gas (LNG), production of natural gas powered cells, production of methane to be used in making the acetylene compound and ammonia, and uses for iron ore reduction. Further uses are as compressed natural gas for automobile fuels and as fuel to power gas and steam boilers (in electricity generation). As NGLs natural gas is

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fractionated (or cracked) in the production of liquefied petroleum gas (LPG, also known as "cooking gas" or "bottled gas"); natural gas is also used for house heating (in temperate climates), and also for crop-drying (Egbobi, 2004).

Gas Flare Chemistry

In the development of an oil well free or dissolved associated gas may not have been considered a principal interest from the early planning stage. What this means is that usually no gas handling and processing facilities are incorporated into the field development plants. As a result the associated gas is expelled through flaring by means of a flare boom outlet attached to the processing facilities (either fixed or floating). Associated gas is definitely not pure, and routine flaring increases the overall amount of toxic substances released into the atmosphere in the immediate vicinity where the hydrocarbon exploitation is taking place, Modern oil processing platforms can burn upward of 50,000m^3/d of gas that emanate from process purge gas, compressors, separators, and other equipment (Knot, 2004). As seen from Table1 associated gas is certainly not pure natural gas as would be desired commercially. The consequences of burning circa 50,000m^3/d from just a single processing facility multiplied by several such facilities developing several fields in a geologically homogeneous hydrocarbon-bearing province are grave indeed.

The atmosphere consists of three principal elements: nitrogen comprises over 76% of the total; oxygen, about 23%; the inert gas argon, close to 1% of it. Everything else in the atmosphere together makes up much less than 1% of it. Materials cycle through the atmosphere as they do through other natural reservoirs. One can speak of the residence times of gases or particles in the atmosphere just as one can discuss residence times of chemicals in the ocean. Continuous gas flaring adds various combustion products to the atmosphere, which are all undesirable both in the near- and long-terms (Montgomery, 1995; Fergusson, 1982; Garrels *et al.*, 1975; Gracdal *et al.*, 1986; Lippmann and Schlesinger, 1979; Newell, 1971; Perkins, 1974; Hodges, 1976).

Carbon Gas

Apart from the fact that carbon dioxide (Co_2) gas is a constituent of the generic natural gas as we know it, continuous flaring of associated gas releases a disproportionate amount of carbon dioxide (Co_2) gas into the atmosphere. Carbon dioxide is not generally regarded as a pollutant per se. Some is naturally present in the atmosphere. It is essential to the life cycles of plants, and it is not unhealthful to humans especially in the moderate concentrations in which it occurs. It is a natural end product of the complete combustion of carbon-bearing fuels:

$$\underset{\text{Carbon}}{C} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Carbon dioxide}}{CO_2} \quad (1)$$

As such, carbon dioxide is continuously added to the atmosphere through fossil fuel burning, as well as by natural processes, including respiration by all oxygen-breathing organisms. At one time, it was believed that natural geochemical processes would keep the atmospheric carbon dioxide level constant, that the oceans would serve as a "sink" in which any temporary excess would dissolve to make, ultimately, more carbonate sediments. It is now known that this is not true. Atmospheric carbon dioxide levels have increased more than 15% in the last century because of heavy fossil fuel combustion (gas flaring amongst) and as estimated 30 billion tons of anthropogenic carbon dioxide are added to the atmosphere each year (Montgomery, 1995). The principal concern is that the increased carbon dioxide concentration cause increased greenhouse-effect heating of the atmosphere. Consequent potentially harmful impacts on global climate and civilization include accelerated melting of global ice sheets (with attendant sea-level rise) and additional pressure on world agriculture due to heat and drought (Post *et al.*, 1990; Jaffe, 1975; Fergusson, 1982; Graedal *et al.*, 1986).

Sulphur Gases

The principal sulphur gas produce during gas flaring is sulphur dioxide (SO_2). This gas is also released during the refining of petroleum. Gas flaring is not the principal source of SO_2 because a greater percentage of the annual discharge of SO_2 into the atmosphere comes from coal combustion in factories and power generating plants. Sulphur dioxide concentration in the atmosphere is inimical to healthy plant life development. In laboratory experiments, root weights achieved by radishes (a kind of vegetable) dosed with sulphur dioxide gas for one to two days were lower by 90% compared to untreated plants, depending on the age of the treated plants at the time of exposure (Montgomery, 1995). Within a few days of its release into the atmosphere, sulphur dioxide reacts with water vapour and oxygen in the atmosphere to form sulphuric acid (H_2SO_4), which is a strong and highly corrosive acid. Much of this is scavenged out the atmosphere in the form of acid rain to contribute to acid runoff. As long as it remains in the air, sulphuric acid is severely irritating to lungs and eyes (Turk, 1983; Seinfeld, 1989; Robinson and Robbins, 1975; Perkins, 1974; Newell, 1971; Fergusson, 1982; Graedal *et al.*, 1986; Lippmann and Schlesinger, 1979; Garrels *et al.*, 1975; Hodges, 1976).

Nitrogen Gases

The geochemistry of nitrogen oxides in the atmosphere is complex. Since nitrogen and oxygen are by far the most abundant elements in air, it is not surprising that, at the high temperatures found in engines and furnaces, they react to form nitrogen oxide compounds (principally NO and NO_2). Nitrogen monoxide (NO) can act somewhat like carbon monoxide in the bloodstream (i.e. by replacing oxygen in the haemoglobin of blood cells), though it rarely reaches toxic levels. In time, it reacts with oxygen to make nitrogen dioxide (NO_2). Nitrogen dioxide reacts with water vapour in air to make nitric acid (HNO_3), which is both as irritant and corrosive. Flaring of natural gas adds several tons of nitrogen dioxide to the air each year and this is less than 10 percent of the nitrogen dioxide estimated to be produced by natural biological actions. However, most anthropogenic nitrogen dioxide production is strongly concentrated in urban and industrialized areas and may create serious problems in those areas (Fergusson, 1982; Graedal *et al.*, 1986; Garrels *et al.*, 1975; Hodges, 1976; Montgomery, 1995).

The most damaging effect of nitrogen dioxide is its role in the production of photochemical smog, sometimes also called "Los Angeles smog", after one city where it is common. Key factors in the formation of photochemical smog are high concentrations of nitrogen oxides and strong sunlight. Dozens of chemical reactions may be involved, both the critical one involving sunlight is the breakup of nitrogen dioxide (NO_2) to produce nitrogen monoxide (NO) and free oxygen atom, which reacts with the common oxygen molecule (O_2) to make ozone (O_3). Ozone is a somewhat unusual molecule made up of three oxygen atoms bonded together (Rowland, 1989; Cicerone, 1987). Ozone is a strong irritant to lungs, especially dangerous to those with lung ailments or those who are exercising and breathing hard in the polluted air. Significant adverse medical effects can result from ozone concentration below 1ppm. Ozone also inhibits photosynthesis in plants (Montgomery, 1995). The dual requirement of nitrogen dioxide plus sunlight to produce ozone at ground level explains why "ozone alerts" are more often broadcast in cities with heavy traffic, and during particularly hot weather, when sunshine is abundant and strong. It is truly regrettable that Nigeria's environmental monitoring agency has not advanced to the point of broadcasting such alerts locally.

Other Pollutants

Volatile, easily vapourized organic compounds (generally termed VOCs, volatile organic compounds) are a major components of the air pollution resulting from the associated flaring of natural gas. This is in the sense that activities that transport gas to the flare boom may also involve the release of a variety of organics including unburned hydrocarbons (could well be escaping gas). Each year hundreds of thousands of tonnes of VOCs leak into the atmosphere worldwide when loading shuttle tankers offshore (Offshore Engineer, 2004). Unburned hydrocarbons are not themselves highly toxic, but they play a role in the formation of photochemical smog and may react to form other compounds that irritate eyes and lungs.

Climate Change Effect of Air Pollution Resulting from Gas Flaring

Air pollution can affect weather in terms of reducing visibility, modifying air temperature, making rain more acidic and causing a local increase in the amount of rainfall that a particular area experiences. This is particularly true when particulates are part of the pollution. Water vapour in the air condenses most readily when it has something to condense on. This is the principle behind cloud seeding: fine, solid, crystals are spread through wet air, and water droplets form on and around these seed crystals. Particulate pollutants (e.g. soot, smoke, and ash from fossil fuel combination; dust released during industrial processes and other solids from accidental and deliberate burning of vegetation) can perform a similar function. Air pollution problems are naturally more severe when air is stagnant and pollutants are confined. This can be of particular concern in densely populated cities like Warri and Port Harcourt where onshore oil exploitation activities have been going on for several decades. These cities experience particularly humid conditions most of the year. Let us now consider two atmospheric conditions of particular significance as concerns weather.

The Phenomenon of Thermal Inversion

Thermal inversion is a particular atmospheric condition that can contribute to acute air pollution episode. Within the lower atmosphere, air temperature normally decreases as altitude increases. In a thermal inversion, there is a zone of relatively warmer air at some distance above the ground. That is, going upward from the earth's surface, temperature decrease for a time, then increase in the warmer layer (i.e. inversion of normal pattern), and then ultimately continue to decrease at still higher altitudes. Inversions may become established in a variety of ways. Warmer-air moving in over an area at high altitude may move over colder air close to the ground, thus creating an inversion. Rapid cooling of near-surface air on a clear, calm night may also lead to a thermal inversion. Most air pollutants, as they are released, are warmer than the surrounding air. Warm air is less dense than colder air, so ordinarily, warm pollutant gases rise and keep rising and being dispersed through progressively cooler air above. When a thermal inversion exists, a warm-air layer becomes settled over a cooler layer. The warm pollutant gases rise only until they reach the warm-air layer. At that point, the pollutants are no longer less dense than the air above, so they stop rising. They are effectively trapped close to the ground and simply build up in the near surface air (Montgomery, 1995). Sometimes, the cold/warm air boundary is so sharp that it is visible as a planar surface above the polluted zone. Infact, M. T. Usman (personal communication) pointed out such a planar surface is a common sight over Bosso town, Minna, as you approach from the Ahmadu Bahago Secondary School-Randan Ruwa axis. He further remarked that pollution arising from thermal inversion can be worsened by the aforementioned inversion of the usual pattern of temperature gradient (vertical component), and an effect that is exercebated in the absence of a differential pressure in the air mass enveloping an area (horizontal component). If a pressure difference exists in any air mass, warm pollutant gases that would otherwise accumulate over a cooler air mass below would be blown away quickly.

We have just considered how the phenomenon of thermal inversion can concentrate pollutants more strongly over any given area. We are then justified in expressing great trepidation about the health hazards to the population of cities in the vicinity of wanton gas flaring that has been going on almost uninterrupted for decades now: Warri, Port-Harcourt, and Eket should be considered in this regard, too. Any environmental scientist knows that every one of the half-dozen major acute air-pollution episodes in the last century has been associated with a thermal inversion, as have many milder ones. We must acknowledge that these major air pollution episodes are the documented ones and thus we infer that the last statement refers to pollution cases in developed and industrialised countries since proper environmental record-keeping as an art has not fully developed in Nigeria yet. While the culprits for major pollution disasters in the developed world are surely exhaust gases from automobiles (combustion of fossil fuels) and factories (also combustion of fossil fuels), any major environmental disaster linked to pollution in any of our major cities most surely come from flaring of associated gas. We say this because the per capita vehicle ownership and industrial activities in any of Nigerian major cities are very much less that those of the developed countries. Inversion can persist for a week or longer once established, because the denser, colder air near the ground does not tend to rise through the lighter, warmer air above.

The incidence or occurrence of thermal inversion means that pollutant gases are not blown away as fast as they are produced. Certain pollutants in combination with atmospheric moisture yield acidic precipitation (Graves, 1980). The obnoxious incidence of acid rainfall at Onne town (Near Port-Harcourt) is evidence of the occurrence of thermal inversion in a city plagued with gas flaring like Port-Harcourt. The principal author has stayed for sometime at Onne and one basic health rule here is: "Never, ever drink rainwater!" This is shocking because nearly everywhere all over Nigeria, rainwater source is surely the one to be trusted because most other sources are questionable.

The Phenomenon of Acid Rain

Acidity is reported on the pH scale. The pH of a solution is inversely proportional to the hydrogen-Ion (H^+) concentration in the solution. Neutral liquids, such as pure water, have a pH of 7. Acid substance have pH values less than 7; alkaline solutions, like solutions of ammonia, have pH values greater than 7. All natural precipitation is actually somewhat acidic as a result of solution of gases (for instance, CO_2) that make acids (such as carbonic acid H_2CO_3). Acid rain, then, is rain that is more acidic than normal. While many gases in the air contribute to the acidity of rain, discussions of acid rain focus on the sulphur gases that react to form atmospheric sulphuric acid (Graves, 1980; Montgomery, 1995).

Acid rain can contaminate water supplies, stunt or kill plants and animals, and damage structures through its corrosive effects. Acid rain can be a source of groundwater pollution because many toxic metals and other substances are more soluble in acidic water. Acidic water more readily leaches potentially toxic metals from soils, transferring them to surface or groundwater supplies, and reduces the capacity of soils to neutralize further additions of acids. Acid water leaching nutrients from lake-bottom sediments may contribute to algal bloom. Though its source is air pollution, its consequences thus include water pollution (Mohnen, 1988; Schindler, 1988). Metals that may be linked to acid include mercury, lead, zinc, selenium, copper and aluminum. The accumulative properties of the heavy metals in turn raise concerns about toxic levels in fish and consequent risks to humans and other fish eaters (Davies, 1983). These are of particular concern to riverine communities and coastal towns cities of Nigeria where one form of subsistence or another (be it agricultural or fishing) is a mainstay in the lives of the greater percentage of the population.

Conclusion and Recommendation

Benefits Derivable From Planned Zero Flaring of Associated Gas

Based on the foregoing discussion, it is easy to see that zero flaring of associated gas would translate to a cleaner and healthier environment, more acceptable weather, and above all the long-term benefits of good health that the population already burdened by this menace would enjoy. Pollution arising from gas flaring can be costly in health terms: this can result in sizeable costs in illness, medical expenses, absenteeism, and loss of production. In Nigeria all these are somewhat harder to quantity because we lack an effective monitoring system to determine what is being exercebated as a result of the effect of general air pollution arising from a variety of sources, principal of which are activities that encourage gas flaring.

The health impacts of air pollution can be manifested in a myriad of ways: when combustion products level in the atmosphere is termed "hazardous" it means that premature death of the ill and elderly can occur quite easily. Also healthy people will experience adverse symptoms that affect their normal activity. A health effect descriptor of "very healthful" indicates significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population. "Unhealthful" generally connotes mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population (U.S. Environmental Protection Agency, 1980). We recognize herein that the Federal Government must encourage our own Environmental Protection Agency (EPA) to be such an effective watchdog on the quality of the air we breathe, one on par and as parallel to what NAFDAC is to food and drug quality.

On our part we would have contributed our small measure to halting the trend of global warming if we take positive measures to drastically cut our CO_2 emission by adopting the planned zero flaring policy to its full essence. One possible consequence of global warming (i.e. changes in global precipitation patterns) could cause some arid lands to become dryer still, making them deserts incapable of supporting much plant or animal life. As was pointed out in the "introduction" section Nigeria needs to optimize its annual gas production as this is required to be effective feedstock for the different LNG trains. Finally Knot (2004) has pointed out that installation of a flare gas recovery system costs anywhere between ₦130m to ₦520m, with the system paying for itself in two to four years time. One just wonders why our government hadn't thought of this much earlier on.

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