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Review Article

Environmental and Economic Impacts of Crude Oil and Natural Gas Production in Developing Countries

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Abstract: As much as the production of crude oil and natural gas generate enormous costs on the environment, it also directly impacts on the economy of the producing state. The later, among other reasons, is the motive for investing huge capital in the industry. This paper addresses the motives for the production of crude oil and natural gas; identifying the components of these products that are toxic to the environment and public health. Apart from highlighting the economic benefits accruing to the producing countries and her citizens, the study universally looked through the processes and products involved in crude oil and natural gas production and pointed out the impacts of these processes and products on the environment and the health of the public. It is believed that a complete understanding of the interplay between these processes and products with the environment will aid producing companies as well as governments of producing nations make better decisions on the strategies to minimize the effects of production activities on the environment and the health of the public.

Keywords: Crude Oil, Natural Gas, Production, Environment, Economics, Developing Countries, Costs, Impacts

1. Introduction

The growth of the crude oil and natural gas production industry over the past few years has been dramatic. Although in Nigeria recent attacks on oil and gas installations by militant groups have led to a decline in the total production, the recorded production increase in some other countries has been huge. Across the United States, total crude oil production increased from 2.4 billion barrels in 2012 to over 3.4 billion barrels in 2015 [1, 2]. At the same time, production of crude oil and natural gas in Nigeria declined from 860 million barrels to 765 million barrels and from 3.1 billion cubic feet to 3.0 billion cubic feet respectively [3, 4]. The primary reasons for the growth have ranged from advancement in technology, which has helped to unlock previously unrecoverable reserves in shales and deep offshore locations to the discovery of new reserves [5]. The economic benefits of oil and gas production activities (including multiplier effects) are estimated to include almost US $1.2 trillion in gross product each year as well as more than 9.3 million permanent jobs in the United States [6].

The consequence of this rise in global demand for crude oil and natural gas has been an increased production in attempt to meet the energy demand. From estimation, it has been found that to meet the projected increase in world oil demand, the total petroleum supply in 2030 is required to reach 118 million barrels per day from 80 million barrels per day as at 2003 [7]. New oil and gas reserves have been discovered in Kenya, Uganda, Mauritania, Tanzania and Ghana in the last few years. In some of these countries, production has already started. Oil and gas deposits in deep offshore locations in many developing countries are being produced today. The production of non-conventional oil and

gas deposits by fracking in shales has also been vigorous as more studies are focused on reducing the cost of production of oil and gas in shales.

Solids, liquids and gaseous forms of wastes and pollutants are generated from crude oil and natural gas production. The management of these wastes and pollutants is difficult except there is a concise laid down plan for the expected wastes and pollutants prior to production. Since the cost of management of waste and pollutants from crude oil and natural gas production is normally high, producing companies tend to avoid this cost. Production has emitted greenhouse gases to the atmosphere, released produced water into water bodies and spilled crude oil on the soil. These have posed challenges to the existence of plants and animals in producing communities in many developing countries.

Infrastructural development is about the greatest challenge of most developing countries as government struggle to provide good access roads and public transportation, schools and quality education, hospitals and medicines to the citizens. The discovery of crude oil and natural gas in these countries comes to the rescue as foreign exchange, taxes and royalties are earned from the production of oil and gas. Apart from the benefits to the state, citizens are provided with employment and sometimes scholarships, electricity, pipe-borne water and access roads by the producing companies.

In view of the dearth of infrastructure in most developing countries, the economic advantage of crude oil and natural gas production has always been the focus in these countries leaving the environmental impacts to the background. It is believed that a good review of the economic effects and the environmental impacts of oil and gas production will help inform decision makers in these countries of the need to formulate and implement structures geared towards protecting the environment from the negative effects of the processes and products of oil and gas production.

2. Crude Oil and Natural Gas Production

2.1. Origin and Motives for Crude Oil and Natural Gas Production

About 5000 – 6000 years ago, the ancient Sumerians, Assyrians and Babylonians used crude oil collected from large seeps at Tuttul on the Euphrates River as medicine for wound and as oil in lamps to provide light [8]. This represents the earliest recorded use of crude oil. Around the same time in Iran, between 6,000 and 2000 years BCE, the first discoveries of natural gas seeps were made [9]. Crude oil and natural gas demand grew with population and on August 27, 1859, Edwin L. Drake struck crude oil at his well near Titusville, Pennsylvania [10]. He found oil under ground and devised a way that could pump it to the surface. This became the origin of modern day crude oil production.

Crude oil and natural gas, collectively referred to as petroleum, are considered fossil fuels because it is believed that they were formed from the buried remains of plants and animals that lived and died millions of years ago [11, 12]. They are non-renewable sources of energy and are made up of a mixture of hydrocarbons. Crude oil is made up of mostly alkanes, cycloalkanes and various aromatic hydrocarbons. It also contains other organic compounds like nitrogen, oxygen, sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium [13]. Crude oil can range from light, volatile oils that are highly fluid to highly viscous oils. Most crude oil is dark brown or black but it could also occur in green, red or yellow colour [14]. On the other hand, natural gas is composed primarily of methane (85 - 95%) [15] but may also contain ethane, propane and heavier hydrocarbons. Small quantities of nitrogen, oxygen, carbon dioxide, sulfur compounds, and water may also be found in natural gas [16]. Natural gas is a colourless, odourless, tasteless but nontoxic gas that burns with a blue flame. Natural gas exists as either associated gas alongside liquid hydrocarbons (crude oil, condensate) or non-associated gas in dry gas wells that generally produce only natural gas [17]. It could also be found as coal bed methane in coal seams [18].

The 2016 International Energy Association (IEA) Market Report forecast worldwide average demand of nearly 96 million barrels of crude oil and liquid fuels per day [19]. In the same vein, global natural gas demand was estimated at just under 3 500 billion cubic metres (bcm) in 2014, and the IEA Medium Term Gas Market Report 2015 saw an average annual growth rate of 2% from 2014 to 2020 [20]. In the United States, crude oil and natural gas account for about 62% of the nation's energy needs [21]. Crude oil and natural gas are among the most important energy sources in the world and are used for many purposes other than fuel for energy and transport. Crude oil is commonly used for the production of gasoline, aviation fuel, diesel, heating oil, asphalt and propane [22]. It also serves as feedstock for the manufacture of chemicals, synthetic rubber and plastics. Natural gas is used as domestic cooking and heating gas (CNG), for power generation, production of hydrogen, automobile fuel for transportation, aviation fuel, and as feedstock for the petrochemical industry in the production of fertilizers, fabrics, glass, steel, plastics, paint and others [23].

2.2. Crude Oil and Natural Gas Production Process

Oil and gas production is the process of extracting the hydrocarbons and separating the mixture of liquid hydrocarbons, gas, water, and solids, removing the constituents that are non-saleable, and selling the liquid hydrocarbons and gas [24]. Production sites often handle crude oil from more than one well. Oil is nearly always processed at a refinery; natural gas may be processed to remove impurities either in the field or at a natural gas processing plant [25].

Edwin Drake's 1859 well near Titusville, Pennsylvania is popularly considered the first modern well not minding other discoveries earlier made about the same period by Scottish chemist, James Young in Derbyshire in 1848 and Georg Christian Konrad Hunaus in Wietz, Germany in 1858 [26]. There were also hand drilled well at Baku in 1848, hand dug

well in Poland in 1853 and another in Romania in 1857 [27]. Drake's well is probably singled out because it was drilled, not dug; because it used a steam engine; because there was a company associated with it; and because it touched off a major boom [28].

Crude oil production processes are usually designed with the Initial data obtained from the crude assays and well parameters. A few design yardsticks have changed over the years; today designs are made to ensure there is no flaring from the facility and produced water is re-injected back into the reservoir or treated to acceptable limit before discharge to water body in offshore locations (40 ppm oil in water according Nigeria DPR's EGASPIN) [29].

The oil and gas industry is a fully regulated industry. The regulations, set by the government, ensure public safety, environmental protection, resource conservation and fair and equitable resource development. In most developing countries where crude oil and natural gas are produced, one or more establishments are usually created to undertake the responsibility of monitoring and regulating oil and gas activities. These regulators develop and enforce regulations to protect the public and the environment, ensure industry does not waste the hydrocarbon resource, and that the government receives any entitled royalties. In Nigeria, the Department of Petroleum Resources is the oil and gas industry regulator [30].

Production of crude oil and natural gas require some special technological skills that may be difficult to be sourced from the locality where these oil fields are located hence most of the key personnel are hardly employed from the locality. Moreover, since crude oil and natural gas are usually transported away from the fields where they are produced to refineries and gas processing plants where they are processed into either feedstock for another manufacturing process or final products, the opportunities inherent in the location of refinery or gas processing plant in the location are also missed.

Oil spills, gas flares, effluent and waste discharges into the environment have undeniable negative effects on the environment and the health of the people locally, and the entire ecosystem, globally [31]. Oil spillage could occur on onshore or offshore locations where crude oil and natural gas are being produced. On land, it destroys crops and damages the quality and productivity of the soil used for farming purposes. Oil in water damages aquatic life and renders water unfit for drinking or other industrial, commercial and domestic purposes [32, 33]. The burning of associated gas has been acknowledged as extremely wasteful, environmentally damaging and directly linked to climate change and greenhouse effects [34, 35, 36]. Flaring creates noise pollution, elevated air temperatures, soot from incomplete combustion and therefore affects vegetation and people living near the flare sites [37]. Effluent and waste discharges due to crude oil and natural gas production are also threats to existence of plants and animals due to their toxicity [38].

The management of environmental issues is among the most challenging aspect of crude oil and natural gas production. Some of these challenges include protecting the atmosphere, managing land sustainability, combating deforestation, combating desertification and drought, sustainable mountain development, sustainable agricultural and rural development, conservation of biological diversity, management of biotechnology, protecting and managing the ocean, protecting and managing fresh water, safer use of toxic chemicals, managing hazardous wastes, managing solid wastes and sewage, and managing radioactive wastes [39].

2.3. Economic Effects of Crude Oil and Natural Gas Production

Oil and gas have remained the lifeblood of the world economy for over one hundred years accounting for over half of mankind's primary energy supply [40]. These high energy density and easily available fossil fuels have played important roles in some of the biggest industries like chemicals, transport, power, petrochemicals etc [41]. The availability of cheap, abundant energy lifts nations out of poverty and at such, energy security has become national priority for most nations. Crude oil and natural gas supply has become very important especially in the face of rising demand for energy for comfort and technological development.

The total measure of economic effects of crude oil and natural gas production on the host nation or community especially for developing countries could be best described by the impacts: direct, indirect and induced. The direct impacts are measured as the jobs, labour income and value added to the oil and gas industry whereas indirect impacts are measured with the same yardstick but occurring across the supply chain due to crude oil and natural gas production activities. Induced impacts are measured as jobs labour income, and value addition resulting from household spending of labour and proprietor's income earned either directly or indirectly from crude oil and natural gas production activities [42].

Crude oil and natural gas production activities have been found to make enormous economic contributions that benefit both the host nations and the citizenry. Some of the ways through which crude oil and natural gas production contribute to the economy include.

2.3.1. Taxes

Oil and gas companies, involved in crude oil and natural gas production, pay billions of dollars in taxes to the government of their host countries every year. These funds help pay for important government services, such as education, health care and provide infrastructure that benefit the citizens of the country. In 2013, Canada's oil and natural gas industry paid a total of $18 billion to federal, provincial and local governments in the form of taxes and royalties [43].

2.3.2. Oil and Gas Royalties

Royalty is the share the government receives from companies producing crude oil and natural gas from the

nation's reserves. The amount is usually dependent on the volume of crude oil or natural gas produced.

2.3.3. Employment and Job Creation

The oil and gas industry employs millions of people all over the world. These are usually high-paying jobs that make a great percentage of them live above the average income, spend within the community and pay taxes to the governments.

2.3.4. Gross Regional Product (GRP)

The total change in value added generated by direct spending. GRP is conceptually the same type of measure as gross domestic product (GDP), which is also a measure of value added and indicates the market value of goods and services, at purchaser prices, produced by all economic resources located in the country. Crude oil and natural gas production have been found to increase the GRP of the states and in turn the GDP of the country.

2.3.5. Local Expenditure on Goods and Services

The periodic injection of purchasing power through its local expenditure on goods and services by the oil and gas production industry is another way of contributing to the economy of the host country. Payments to local contractors for goods and services and for direct purchases has the capacity to stimulate the economy and also exert secondary influences, through multiplier process on the level of output and employment in other related sections of the economy.

2.3.6. Provision of Foreign Exchange Reserves

Since crude oil and natural gas are sold in international markets, producing countries has the potential to earn and save foreign exchange in reserves. This puts the country's economy in healthy position and gives her the capacity to finance the foreign exchange cost of any development program.

2.3.7. Contribution to Power Supply and Public Utilities

Natural gas could be used to power turbines for the generation of electricity. Associated gas is still being flared today in many oil fields in developing countries: this could be turned to power and used for industrialization of the producing community. In some cases, producing companies have supplied electricity to the host communities to aid development.

2.3.8. Investment

Most oil and gas companies are quoted at the various stock exchange markets. This makes it possible for citizens to invest in these stocks and enjoy the privilege of the innovation, growth and dividends associated with such investment.

Crude oil and natural gas production is done either on land or on water. The area occupied for this purpose would have been used for the purpose of farming and fishing respectively. In most communities where oil and gas production activities are being carried out, the traditional occupations of the people prior to oil and gas discovery are being abandoned. The country, in some cases, may even resort to total reliance on the production of oil and natural gas for economic growth leading to a mono product economy. For example, Nigeria is currently in this dilemma as over 70% of the country's earning is crude oil and natural gas dependent [44].

Although a great deal of the expertise required to produce crude oil and natural gas is sourced from locations far from the field; in some cases overseas, the industry most of the times provides the host and surrounding communities with employment for unskilled and low skilled labour. There are opportunities to learn from the best hands in the industry and get exposed to the most recent technologies on the various operations. In cases where the production of crude oil and natural gas is done in onshore locations, minor sub-contractors from the host and adjoining communities are usually given priority after pre-qualification. In all, the communities benefit from employment, provision of infrastructure (in the form of corporate social responsibility from the companies), award of scholarships, shopping from employees of the company etc.

2.4. Environmental Impacts of Crude Oil and Natural Gas Production

Environmental impacts that occur during production of crude oil and natural gas would mostly occur from long-term habitat change within the oil and gas field, production activities (including facility component maintenance or replacement), waste management (e.g produced water), noise (e.g from well operations, compressor or pump stations, flare stack, vehicle and equipment), the presence of workers and potential spills [45]. These activities could potentially impact on the resources as explained below:

2.4.1. Noise

The main sources of noise during the production of crude oil and natural gas would include compressor and pumping stations, producing wells (including occasional flaring), and vehicle traffic. Compressor stations produce noise levels between 64 and 86 dBA at the station to between 58 and 75 dBA at about 1 mile (1.6 kilometers) from the station [46]. The primary impacts from noise would be localized disturbance to wildlife, recreationists, and residents. Noise associated with cavitation is a major concern for landowners, livestock, and wildlife [47].

2.4.2. Air Quality

The primary emission sources during the production of crude oil and natural gas would include compressor and pumping station operations, vehicle traffic, production well operations, separation of oil and gas phases, and on-site storage of crude oil. Emissions would include volatile organic compound (VOCs), nitrogen oxides, sulfur dioxide, carbon monoxide, benzene, toluene, ethylbenzene, xylenes, polycyclic aromatic hydrocarbons (PAHs), hydrogen sulfide, particulates, ozone, and methane [48]. Venting or flaring of natural gas (methane) may occur during oil production, well

testing, oil and gas processing, cavitation, well leaks, and pipeline maintenance operations. Methane is a major greenhouse gas. Air pollution during oil and gas production may cause health effects and reduce visibility.

2.4.3. Cultural Resources

Production of crude oil and natural gas could also impact on the cultural resources by unauthorized collection of artifacts and the alteration of visual image [49]. The presence of the aboveground structures alters the associated landscape component of the cultural resources. Damage to localities caused through off-highway vehicle (OHV) and the potential for indirect impacts (e.g, vandalism and unauthorized collecting) also exist.

2.4.4. Ecological Resources

The adverse impacts to ecological resources during production of crude oil and natural gas could occur from: disturbance of wildlife from noise and human activity; exposure of biota to contaminants; and mortality of biota from colliding with aboveground facilities or vehicles [50]. The presence of production wells, ancillary facilities and access road reduces the habitat quality, disturbs the biota and thus affects ecological resources [51]. The presence of an oil or gas field could also interfere with migratory and other behaviors of some wildlife. Discharge of produced water inappropriately onto soil or into surface water bodies can result in salinity levels too high to sustain plant growth. Wildlife is always prone to contact with petroleum-based products and other contaminants in reserve pits and water management facilities [52]. They can become entrapped in the oil and drown, ingest toxic quantities of oil by preening (birds) or licking their fur (mammals); or succumb to cold stress if the oil damages the insulation provided by feathers or fur. In locations where naturally occurring radioactive material (NORM)-bearing produced water and solid wastes are generated, mismanagement of these wastes can result in radiological contamination of soils or surface water bodies [53].

2.4.5. Hazardous Materials and Waste Management

Industrial wastes are generated during routine operations (lubricating oils, hydraulic fluids, coolants, solvents, and cleaning agents). These wastes are typically placed in containers, characterized, labeled and possibly stored briefly before being transported by a licensed hauler to an appropriate permitted off-site disposal facility as a standard practice [54]. Impacts could result if these wastes were not properly handled and were released to the environment. Environmental contamination could occur from accidental spills of herbicides or, more significantly, oil. Chemicals in open pits used to store wastes may pose a threat to wildlife and livestock. "Fracking" fluids can contain potentially toxic substances such as diesel fuel (which contains benzene, ethylbenzene, toluene, xylenes, naphthalene, and other chemicals), PAHs, methanol, formaldehyde, ethylene glycol, glycol ethers, hydrochloric acid, and sodium hydroxide [55]. Sand separated from produced water must be properly disposed as it is often contaminated with oil, trace amounts of metals, or other naturally occurring constituents. Production could also cause accumulation of large volumes of scale and sludge wastes inside pipelines and storage vessels [56]. These wastes may be transported to offsite disposal facilities. Produced water can become a significant waste stream during the production of crude oil and natural gas. Regulations govern the disposal of this waste stream; the majority of it is disposed by underground injection either in disposal wells or, in mature producing fields, in enhanced oil recovery wells (i.e, wells through which produced water and other materials are injected into a producing formation in order to increase formation pressure and production). In some locations, produced water may carry NORM to the surface.

2.4.6. Health and Safety

Possible impacts to public health and safety during production include accidental injury or death to workers and, to a lesser extent, the public (e.g, from an OHV collisions with project components or vehicle collisions with oil or gas workers). Health impacts could result from water contamination, dust and other air emissions, noise, soil contamination, and stress (e.g, associated with living near an industrial zone). Potential fires and explosions would cause safety hazards. Cavitation could ignite grass fires. Increased or reckless driving by oil or gas workers would also create safety hazards. In addition, health and safety issues include working in potential weather extremes and possible contact with natural hazards, such as uneven terrain and dangerous plants, animals, or insects [57].

2.4.7. Land Use

Land use impacts during the production of crude oil and natural gas would be an extension of those that occurred during the drilling/development phase. Although it is possible for farmers or fisher men to carry out activities around the well locations, restrictions would always exist.

2.4.8. Paleontological Resources

The existence of access roads creates a threat to paleontological resources during oil and gas production allowing for unauthorized collection of fossils.

2.4.9. Socioeconomics

Although new jobs and businesses would be created and royalties and taxes paid to land owners and government, there is a potential negative impact on the value of properties located in the proximity of oil and gas field [58]. This effect increases as the number of wells increase.

2.4.10. Soils and Geological Resources

The main impact from production would be the depletion of recoverable oil and gas reserves. Possible geological hazards (earthquakes, landslides, and subsidence) could be activated by oil and gas extraction activities [59]. Although it is rare, the injection of produced water in disposal wells could trigger localized seismic activity [60].

2.4.11. Transportation

The impact of crude oil and natural gas production to transportation would be basically due to the daily vehicular movement of light trucks and cars used for surveillance and movement of materials. Heavy truck traffic would be limited to periodic visits to a well site for workovers and formation treatment.

2.4.12. Water Resources

During the life of a production well, the integrity of the well casing and cement will determine the potential for adverse impacts to groundwater [61]. If subsurface formations are not sealed off by the well casing and cement, aquifers can be impacted by other non-potable formation waters. Hydraulic fracturing fluids have the potential to contaminate groundwater drinking reservoirs [62]. Stimulation fluids may penetrate away from the fracture and into surrounding formation. When stimulation ceases and production resumes, these chemicals may not be completely recovered and pumped back into the wellbore, and, if mobile, may be available to migrate through an aquifer. Most produced water is unfit for domestic or agricultural purposes (e.g, it is extremely salty or contains NORM or toxic compounds). If it is disposed of by release to the surface without treatment, it can cause soil and surface water contamination. The majority of produced water is disposed via injection in disposal wells or enhanced recovery wells [63].

2.5. Toxic Compounds Associated with Crude Oil and Natural Gas Production

Although crude oil and natural gas have played great roles in transportation, electricity production, industrial power, military and medical applications; they are also raw materials for production of weapons of war, reasons behind some political unrest and human rights violations, and have caused environmental degradation and some human diseases [64].

The operations leading to the production of crude oil and natural gas could lead to the emission of some compounds that constitute risk to the environment and public health. Some specific compounds associated with oil and gas production, their sources and potential effect on health are:

2.5.1. Benzene

This is a well-established carcinogen with specific links to leukemia as well as breast and urinary tract cancers [65]. Exposure to benzene reduces red and white blood cells production in the bone marrow, decreases auto-immune cell function (T-cell and B-cells), and has been linked to sperm-head abnormalities and generalised chromosome aberrations [66]. Benzene is a commonly used petrochemical solvent in the production of crude oil and natural gas especially in fracking operations [67].

2.5.2. Sulphur IV Oxide

This compound combines with the oxides of nitrogen to form particulate matter which has been known to contribute to serious health problems including cancer of the lung and cardiopulmonary mortality [68]. Exposure of children to SO_2 even at lower levels over time has been found to cause asthma. Sulphur IV Oxide is released by combustion of crude oil and natural gas at the flare stack during production [69].

2.5.3. Oxides of Nitrogen (NO_x)

NO_x are involved in the formation of particulate matter and also contribute directly to thousands of hospitalisations, heart attacks and deaths annually [70]. Inhalation of NO_x is associated with emphysema and bronchitis [71]. Flaring is the chief source of NO_x during the production of crude oil and natural gas.

2.5.4. Formaldehyde

This compound is another carcinogen with known links to leukemia and rare nasopharyngeall cancers [72]. Studies have linked spontaneous abortions, congenital malformations, low birth weights, infertility and endometriosis to formaldehyde exposure [73]. It also contributes to ground-level ozone and is commonly used in fracking.

2.5.5. Polycyclic Aromatic Hydrocarbons (PAH)

This is an entire class of toxic chemicals, linked together by their unique chemical structure and reactive properties. Many PAHs are known human carcinogens and genetic mutagens. In addition, there are particular prenatal health risks: prenatal exposure to PAHs is linked to childhood asthma, low birth weight, adverse birth outcomes including heart malformations and DNA damage. Recent studies link exposure to early childhood depression. The main source of PAHs during production is spills.

2.5.6. Silica

Crystalline silica is a known human carcinogen; breathing silica dust can lead to silicosis, a form of lung disease with no cure. Silica is commonly used, in huge amounts, during fracking operations. Each stage of the process requires hundreds of thousands of pounds of silica quartz–containing sand. Millions of pounds may be used for a single well.

2.5.7. Radon

This is a colourless, odourless, tasteless radioactive gas which causes lung cancer. It is the second largest cause of lung cancer in the U.S. after cigarette smoking [74]. There is no known threshold below which radon exposures carries no risk. Radon is released into groundwater and air during natural gas production especially by fracking.

2.5.8. Hydrofluoric Acid (HF) / Hydrogen Fluoride

Hydrofluoric acid (HF) is one of the most dangerous acids known. HF can immediately damage lungs, leading to chronic lung disease; contact on skin penetrates to deep tissue, including bone, where it alters cellular structure. HF can be fatal if inhaled, swallowed, or absorbed through skin [75]. Hydrofluoric acid is used for well simulation during crude oil and natural gas production [76].

2.5.9. Hydrogen Sulphide (H_2S)

This is a colourless gas with a rotten egg smell but

odourless at concentrations above 150ppb as it quickly impairs olfactory sense. It is heavier than air, very poisonous, corrosive, flammable and explosive. As the concentration of H_2S being inhaled increases, it could lead to pulmonary edema, respiratory paralysis, collapse and even death [77]. H_2S could be released from leaking Christmas trees at the wellhead, pumps, piping, separation device, oil storage tanks, waste water storage tanks, intentional venting and flaring during production [78].

2.5.10. Carbon Dioxide, Carbon Monoxide, Volatile Organic Compounds (VOCs), and Particulate Matter (PM)

These compounds are generated by burning of crude oil and natural gas during production process have negative impacts on the environment and human health: Carbon dioxide is a greenhouse gas and a source of global warming; VOCs contribute to ground-level ozone, which irritates and damages the lungs; PM results in hazy conditions in cities and scenic areas, and, along with ozone, contributes to asthma and chronic bronchitis, especially in children and the elderly [79].

2.5.11. Methane

Methane is the major constituent of natural gas. It is a colourless gas which is odourless at low concentration but has a sweet smell high concentrations [80]. It is a greenhouse gas that has very high global warming potential (about 21 times that of carbon dioxide) [81]. It could lead to suffocation and death at high concentration in enclosed space [82]. It is released into the atmosphere by venting operations and leaking valves during crude oil and natural gas production.

3. Strategies for the Protection of the Environment

The release of these toxic compounds into the environment is principally caused by flaring, venting, improper cementing or sealing of well bore, lack of maintenance of production facilities, inefficient produced water and solid waste management scheme, poor handling of crude oil and natural gas leading to spills and leaks and non-adherence to regulations. In order to limit the release of these toxic compounds into the environment, the following strategies have been proposed:

- Commercialization of associated gas, application of new technologies, re-injection of associated gas, regulations, legislations and promotion of best practices are some of the ways used to reduce flaring and venting in crude oil and natural gas production processes.
- Proper management of well drilling and workover processes as well as integrity checks on oil and gas wells before abandonment will help check seepage of oil and gas into ground water while improved well control procedure will prevent blowouts.
- Valves and pumps are common in oil and gas production processes. Operation and maintenance plans are usually prepared for the valves, pumps and other equipment to ensure they are in good condition; and not leaking out fluids.
- Produced water management facilities are usually incorporated into most production process. It could be either produced water injection system or treatment to an allowable limit before discharge into water body, in the case of offshore locations.
- Good and efficient crude oil and natural gas handling procedure is developed for the production facility making sure that all regulations with regards to production of crude oil and natural gas are complied with.

4. Discussions

Since the first modern well was drilled by Edwin Drake in Titusville, Pennsylvania, crude oil and natural gas demand have continued to increase leading to discovery and production of more reserves in various parts of the world; including deep offshore locations. The rise in the volume crude oil and natural gas production over the years has been in response to industrialization and demand for energy.

Production of crude oil and natural gas may lead to oil spills, gas flares and effluent and waste discharge into the environment. These have undeniable negative effects on the environment and the health of the public, locally and the ecosystem, globally. The management of these wastes and pollutants as well as the ensuing environmental and public health issues is among the most challenging aspect of crude oil and natural gas production.

The production of crude oil and natural gas has been beneficial to the economies of every producing nation. Petroleum production companies have provided high paying jobs to the citizens, paid taxes and royalties to government, provided infrastructure around their areas of operation and awarded scholarships to citizens. Notwithstanding the economic benefits enjoyed from the companies, the activities have also posed threats to public health and ecosystem by the release of various toxic compounds into the environment hence the need for improvement on the existing methods especially in developing countries such as Trinidad and Tobago, Nigeria etc. These improvements are basically based on new technologies and techniques / procedures.

5. Conclusions

In view of the reliance of the world on crude oil and natural gas for energy and raw materials, the industry has continued to research on ways of optimising the production of crude oil and natural gas at very minimal cost to the environment. The producing nations, including developing countries, have also promulgated regulations to allow the extraction of crude oil and natural gas from the reservoir follow certain procedures that ensure conservation of the natural resource and preservation of the environment.

The possibilities of failures which might lead to contamination of the environment with either crude oil, natural gas, produced water, solid wastes or some other compounds used for production purposes exist. In preparation for this failures, contingency plans need to be made prior to commencement of production while remediation technologies have to be prepared to put affected land and water back to their natural states.

Crude oil and natural gas production in most developing countries has provided immense economic benefits to both the country and the citizens. It is therefore appropriate that the government and decision makers become abreast of the full implication of the oil and gas production activities to ensure that production is sustained but in a way that is friendly to the environment and the health of the public.

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