The Health and Environmental Implications of Thermal Power Generation in Nigeria

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Abstract

Nigeria is a highly populous country and is rich in fossil fuel resources, but the management of its energy infrastructure is grossly inadequate. Lack of or low level of awareness of the health and environmental hazards associated with burning of fossil fuels by individuals, public and private sectors in the country is becoming increasingly alarming. The environmental and health segments of the surrounding region of Nigeria have been obviously affected by the various thermal power plants installed for electricity generation. The decay of the environment and human health is highly attributable to the release of large amount of CO, CO_2, SO_x, NO_x,, CFCs, HCs and suspended PMs which disperse over 25Km radius. These pollutants and green house gases emitted from various thermal power plants cause respiratory and related ailments in human beings, animals and plant kingdoms. Some of these ailments include asthma and bronchitis, human neurological problems and increased premature deaths. Other problems caused by these pollutants include acidification of streams, lakes and oceans which harm aquatic lives; damage to forest through acidification of soil, depletion of soil nutrients and direct injury to sensitive tree leaves and needles and harm to buildings, statues and monuments through speedy weathering.

Keywords: Thermal Power Plants, Pollutants, Emissions, environment.

1.0 INTRODUCTION

Nigeria is one the countries located within the Sub- Saharan Africa with the population of 170 million people as of 2012.And the population is projected to reach 0.5-1 billion people by 2100 (UN, 2013). This rapid growth in Nigeria poses a range of environmental concerns as well as air quality. Power generating units are mega projects which require not only huge capital investment but also various natural resources like fossil fuel and water, thus creating immeasurable and extensive impacts on the environment and generate tremendous stress in the local ecosystem. In Nigeria, over 50% of power generated is from thermal power plants(TPP). This however gives an idea of the fact that Nigeria is yet to invest considerably in the area of alternative energy technologies available instead of relying majorly on combustion of fossil fuels for power generation all year round. Most TPP in Nigeria utilize natural gas for their operations. There are plans to site coal-fired power plants of 1200MW capacity in Kogi, Enugu and Gombe States as declared by the Managing Director of the Nigerian Coal Corporation (Ejiofor, 2012). These fossil fuel power plants generate substances that pollute the air and the environment. The use of fossil fuels such as petroleum has a negative impact on Earth's biosphere

as when burned, petroleum releases greenhouse gases into the air which in turn damages ecosystems (The Hindu, 2011, cited by Numbia, 2014).WHO (2006) estimates that dirty air kills more than half a million people in Asia each year of which burden falls heaviest on the poor as reported by Ogawa (2006) and cited by Raheem et al., (2011). This pollution related problems should also be considered to be applicable to Africa, especially Nigeria where there is high population density, large emissions and a very low awareness of the public of the health hazards associated with these pollutants. Some of the pollutants and greenhouse gases emitted by the TPP in Nigeria are: oxides of Sulphur (SO_x) particularly SO_2, Oxides of Nitrogen (NO_x), Suspended Particulate Matters (SPMs), Unburnt Hydrocarbons (HCs), Carbon dioxide and Carbon Monoxides (CO_2& CO), Chlorofloro Carbons (CFCs) and Unburnt Carbon particles (Soot) (Zielinska et al, 2004). Thermal Power generation contributes over 60% of SO2, 20% of NO_x, 25% of manmade mercury and over 30% of excess CO_2 to the environment (Pokale, 2012). Globally, fossil fueled TPP have been identified to be among the major contributors of environmental pollution which has a lot of impact on human health.

This article looks at some of the major emissions from thermal power plants in some major cities in Nigeria and their effects on health and the environment. It is aimed at advising the government concerning the dangers of relying so much on fossil fuel-based electricity generation without considering investing more on non-conventional energy sources.

2.0 SOME CITIES IN NIGERIA WITH HIGH EMISSION OF POLLUTANTS

Fig. 1 shows some of the major states in Nigeria that are highly industrialized and heavily populated. The states, Kano from the north-west and Lagos from the south-west enjoy the highest population densities. Other states are the Niger Delta states in the south- south. The majority of Nigeria's industries are concentrated in 5 cities - Kano and Kaduna in the north, Lagos in the southwest, Warri and Port Harcourt in the Niger Delta. Oil and gas production is concentrated in the Niger Delta.

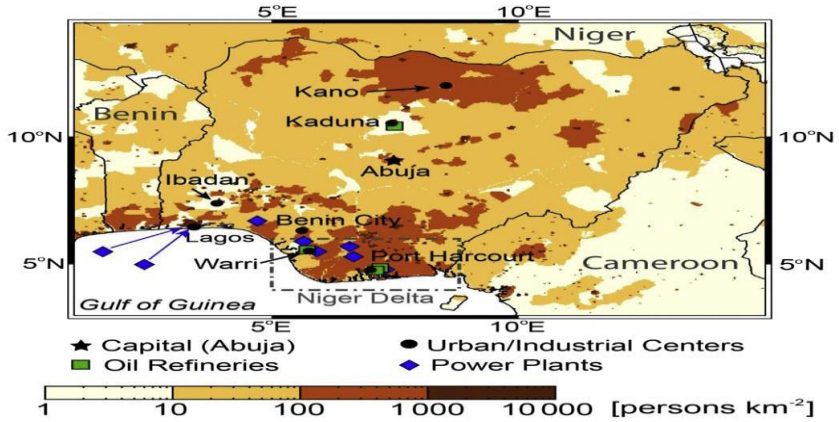

Fig. 1. Nigerian map showing major emission centers. The population density map is for 2000 (CIESN, 2005, cited by Marais et al., 2014).

The megacity Lagos has higher emissions of non-methane volatile organic compounds (NMVOCs) than megacities in China and India (Hopkins et al., 2009). Baumbach et al. (1995) measured average benzene concentrations in Lagos of 80 ppbv, which is 8 times more than the highest concentrations found by Barletta et al. (2005) in Chinese cities. Efe, (2008) confirmed that the annual mean ambient particulate air pollution in 17 major cities in Nigeria was five times higher than the WHO, (2005) safe limit of 20µg/m^3 for particulate matter. The study reported that the northern cities have generally higher concentrations of particulate matter, with annual mean of 132 µg/m^3 in Maidugiri, 130 µg/m^3 in Sokoto and 128.3 µg/m^3 in Bauchi and 128.1 µg/m^3 in Kano. In the southern cities, the values span from 118.3 µg/m^3 in Port Harcourt to 122 µg/m^3 in Benin City, Enugu, Warri and Lagos. The values

recorded in the middle belt area were 123.9 µg/m^3 in Jos, Minna and Yola and 124.3 µg/m^3 in Ilorin. The findings of this research showed that there were significant cases of eye infections and respiratory hazards of the examined individuals. The ratio of glyoxal (CHOCHO) to formaldehyde (HCHO) is termed RGF. Kasier et al., (2015) concludes that satellite-based observations of RGF can be used. And Marais et al., (2014) reports that Satellite observations of HCHO and CHOCHO reveal very large sources of anthropogenic non-methane volatile organic compounds (NMVOCs) from the Lagos megacity and oil/gas operations in the Niger Delta. According to this source, satellite observations show large seasonal emissions of carbon monoxide (CO) and nitrogen dioxide (NO2) in (December-February).

Basically, inadequate electricity distribution results in dependence of industries and households on diesel-powered backup generators (BUGs), kerosene, and fuel-wood (Ikeme and Ebohon, 2005; Akinlo, 2009). The electricity industry in Nigeria, dominated on the supply side by the Power Holding Company of Nigeria (PHCN), formerly National Electric Power Authority (NEPA), has remained largely inefficient in service delivery, innovation and management (Akpan, 2012). And according to (Ikeme and Ebohon, 2005), BUGs are used by 97% of businesses and in 1990 accounted for 30% of the nation's grid capacity (cite by Marais et al., 2014). Fig. 2 shows the installed capacity and total generation of electricity in Nigeria from 1970 to 2008.

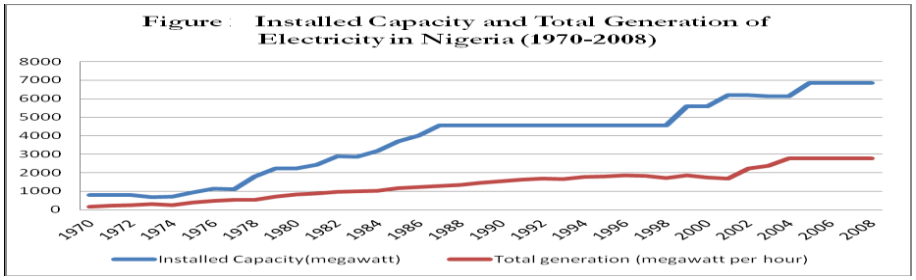

Fig. 2- *Source:* CBN Statistical Bulletin, 2007 & CBN Economic Report for the first half of 2008.

3.0 TPP POLLUTANTS, SOURCES AND HEALTH IMPLICATIONS

3.1. OXIDES OF SULPHUR AND NITROGEN (SOx and NOx)

Sulphur dioxide is generated as a result of combustion of fossil fuels containing sulphur or sulphides while nitrous oxides are as a result of high temperature of combustion. Particulate matter is the term used for a mixture of solid particles and liquid droplets found in air. These are mainly fine particles that are smaller than 2.5 microns in diameter (PM2.5). Fine particles formed in the atmosphere by the conversion of SO_2 and NOx emissions scatter light and create hazy conditions, decreasing visibility and contributing to regional haze as seen in fig. 3.

Figure 3 Poor visibility as result of smog (A. Ramey/Woodfin Camp and Associates, Inc.)

Visibility impairment spoils scenic vistas across broad regions of the country, including in many National Parks and wilderness areas. Regional haze is also responsible for impaired urban vistas nationwide. This happens especially in heavily industrialized cities in Nigeria. For example, on the 13th of October, 2005, schools were closed in Nigeria's biggest city, Lagos, by authorities, as a precautionary measure after a dense cloud of smog blanketed many parts of the city

.SO_2 and NO_x emissions react in the atmosphere to form acidic compounds that harm lakes and streams. Acidification (low pH) and the chemical changes that result, including higher aluminum levels, make it difficult for some fish and other aquatic species to survive, grow, and reproduce. Acid deposition harms forests and trees by directly damaging plant tissues. It can combine with other pollutants, such as ozone, to weaken trees and make them vulnerable to threats such as pests, which cause mortality. Acid deposition can also affect forest ecosystems indirectly by changing the chemistry of forest soils, including the leaching of plant nutrients from soils. It can also elevate levels of aluminum in soil water, which impairs the ability of trees to use soil nutrients and can be directly toxic to plant roots. Acid deposition and particles damage materials and cultural resources. A significant number of properties of aesthetic and historical value including monuments, buildings, and statues, are potentially at risk for damage from air pollution. Fig.4 shows the damaging effects of acid rains on plants.

Fig. 4. Negative effects of pollutants on plants and the quality of wheat crops (Source: Science, Twanna Harps)

3.2 OZONE (O_3)

NO_x and volatile organic compounds react in the atmosphere in the presence of sunlight to form ground-level ozone. Ground-level ozone is a major component of smog in our cities and in many rural areas as well.

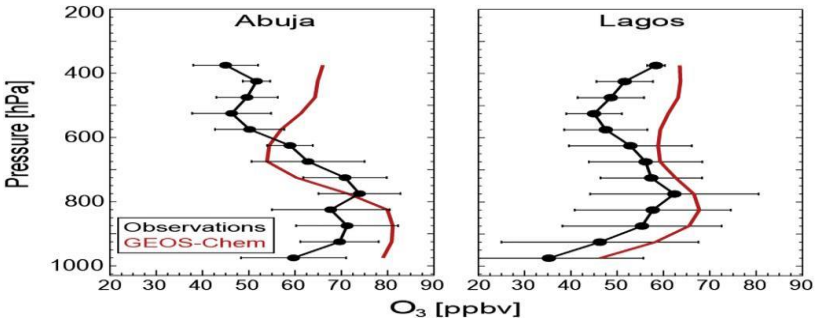

Fig.7.Mean vertical profiles of O_3 concentrations over Abuja and Lagos in January –February, 2003-2004 (Marais et al., 2014).

Though naturally occurring ozone in the stratosphere provides a protective layer high above the earth, the ozone that we breathe at ground level has been linked to the following respiratory illnesses:(a) Decreases in lung function, resulting in difficulty breathing, shortness of breath, and other symptoms

(b) Respiratory symptoms, including bronchitis, aggravated coughing, and chest pain (c) Increased incidence/severity of respiratory problems (e.g. aggravation of asthma, susceptibility to respiratory infection) resulting in more hospital admissions and emergency room visits (d) Chronic inflammation and irreversible structural changes in the lungs that, with repeated exposure, can lead to premature aging of the lungs, immune system impairment and cardiovascular diseases.

3.3. CARBON DIOXIDE (CO_2)

One of the most important human impacts on our environment is the relatively rapid increase in atmospheric carbon dioxide caused by our profligate use of fossil fuels in automobiles, power plants, as well as several other activities which produce CO_2. CO_2 is a non- toxic gas, but its emission is of interest as small increase of CO_2 concentration in the atmosphere can significantly result in increase in ambient temperature and consequent climatic changes. Of the fossil fuels, coal is much more carbon intensive than oil or natural gas, resulting in greater volumes of carbon dioxide emissions per unit electricity generated. The Intergovernmental Panel on Climate Change (IPCC) states that CO_2 is a greenhouse gas and that increased quantities within the atmosphere will lead to higher average temperature on a global scale (global warming) (Solomon, 2007). If atmospheric concentrations of CO_2 continue to grow to toxic levels, it then becomes a problem to animal life, including humans. The environment absorbs CO_2 from human and natural activities. These are known as 'sinks'. On land, trees are the main absorbers of CO_2 – through the process of photosynthesis. Unfortunately, their efficiency is being reduced due to deforestation practices, thereby causing a greater amount of carbon dioxide to be absorbed by the atmosphere. Increase in CO_2 concentration is likely to accelerate the rate of climate change, i.e. an indirect implication of global warming.

Figure 1.Coal-fired power plant (Photograph by Lester Lefkowitz, Corbis)

If this increase becomes severe, it could enhance the greenhouse effect, leading to the global warming trend. This warming might be enough to melt part of the polar ice caps and raise the level of the oceans and turn part of the now temperate zones into deserts. As it is fully oxidized, it is not very reactive and in particular not flammable. At concentration of 2,500 ppm to 5,000 ppm, CO_2 can cause headaches. At extremely high levels of 100,000 ppm, people lose consciousness in ten minutes, and at 200,000 ppm, CO_2 can lead to death.

3.4. CARBON MONOXIDE (CO)

CO is a poisonous gas and is generally classified as an asphyxiant. The atmospheric background of CO is 0.1 ppm. It is produced by incomplete burning of the carbon in fossil fuels. CO binds to hemoglobin, reducing blood's ability to carry O_2. Exposure to carbon monoxide can result in fatigue, headaches, dizziness, loss of consciousness, and even death at very high concentrations (Schwela 2000). According to This Day Live,(2014), a toxicologist

at the Lagos State University Teaching Hospital (LASUTH), Ikeja, Dr. Olatunji Ekemode, recently raised alarm over the growing number of recorded deaths in Nigeria due to CO inhalation as a result of the use of generators in badly ventilated environment. Table 1 shows the health effects of CO at various concentrations in the blood.

Table 1.Health effects of CO at various levels in the blood

COHb level (%)	CO level (ppm)	Effects
<1.0	<5	No apparent effect
1 to 2	5 to 10	Some evidence of effect on behavioural performance
2 to 5	10 to 30	Central nervous system affects impairment of time interval discrimination, visual perception, brightness discrimination and psychomotor functions.
>5	>30	Cardiac and pulmonary functional changes
10 to 25	30 to 200	Headaches and dizziness
25 to 40	200 to 400	Loss of consciousness
40 to 60	400 to 750	Respiratory failure, coma, death after several hours
>65	>1000	Rapid death

Note: COHb is an acronym for carboxyhemoglobin which is a stable complex form of carbon monoxide that forms in red blood cell.

3.5. PARTICULATE MATTER (PM)

Particulate air pollutants include finely divided solids and liquids dispersed in gaseous media. Dust, smoke, fly ash, flumes, etc., are examples of solid particulates; while mist, spray, fog, etc., are liquid particulate air pollutants. For fine particulate matter with diameter below 2.5 micrometer and ultra-fine particles with a diameter below 0.1 micrometer, the contribution is even higher (Gilman 2002).There are different types of particulate matter depending on the chemical composition and size. The dominant form of PM from coal-fired plants is the coal fly ash but secondary sulphate and nitrate also comprise a major portion of the PM from coal-fired plants (Grahame and Schlesinger, 2007).Effects of particulate matter on health and environment are immense and some of them are listed below:

(a) The fine particles (< 3μm in size) are the worst as they can penetrate deep into the lungs through the respiratory tract. Once they are lodged into the lungs, they can cause severe breathing trouble by physical blockage and irritation of the lung capillaries which can lead to increased problems with asthma, chronic bronchitis, airway obstruction and gas exchange (Nel, 2005) (b) Higher rates of mortality (c) Reduction in visibility.

3.6. HYDROCARBON COMPOUNDS (HCs)

Hydrocarbons are those organic compounds which contain only carbon and hydrogen. Like CO, they represent unburned and wasted fuel. Most of the major chemicals in gasoline and other petroleum products are hydrocarbons, which are divided into two categories— aliphatic and aromatic. Aliphatic hydrocarbon group contains alkanes, alkenes and alkynes. The alkenes, generally called olefins, are unsaturated and highly reactive in atmosphere. Alkenes react with nitrogen dioxide at high concentrations in the presence of sunlight to form secondary pollutants such as PAN (peroxyacetyl nitrate) and ozone. The alkynes, though highly reactive, are relatively rare and thus not of major concern in air pollution. Aromatic hydrocarbons are biochemically and biologically active, and some are potentially carcinogenic. They are derived from or related to benzene. Though aromatics do not display the reactivity characteristics of unsaturated aliphatic hydrocarbons, but the polynuclear group of aromatic hydrocarbons are carcinogenic. Hydrocarbons are considered to be major pollutants because of their role in the formation of photochemical smog. Analysis showed that the poly-nuclear

group of aromatic hydrocarbons are carcinogenic in nature. Ethylene is one of the very few hydrocarbons that can cause plant damage even at low concentrations. Tomato and pepper plants and orchids can be severely damaged if they are exposed to ethylene (0.01 to 0.3 ppm) for longer duration.

3.7. CHLOROFLUOROCARBONS (CFCs)

CFCs are a part of the group of chemicals known as the volatile organic compounds (VOCs).They are unlikely to have any direct impact on the environment in the immediate vicinity of their release. As VOCs, they may be slightly involved in reactions to produce ground level ozone, which can cause damage to plants and materials on a local scale. At a global level however, releases of CFCs have serious environmental consequences. Their long lifetimes in the atmosphere mean that some end up in the higher atmosphere (stratosphere) where they can destroy the ozone layer, thus reducing the protection it offers the earth from the sun's harmful UV rays. CFCs also contribute to Global Warming (through "the Greenhouse Effect"). Although the amounts emitted are relatively small, they have a powerful warming effect (a very high "Global Warming Potential"). CFCs enter the body primarily by inhalation of air containing chlorofluorocarbons, but can also enter by ingestion of contaminated water, or by dermal contact. Their inhalation at high levels can affect the lungs, central nervous system, heart, liver and kidneys. Symptoms of exposure to CFCs can include drowsiness, slurred speech, disorientation, tingling sensations and weakness in the limbs. Exposure to extremely high levels of chlorofluorocarbons can result in death. Ingestion of CFCs can lead to nausea, irritation of the digestive tract and diarrhea. Dermal contact with chlorofluorocarbons can cause skin irritation and dermatitis.

3.8. MERCURY

Human activity is the main cause of mercury releases, particularly coal-fired power stations, residential coal burning for heating and cooking, industrial processes, etc. Once in the environment, mercury can be transformed by bacteria into methylmercury (Zwietering et al 1990). People may be exposed to mercury in any of its forms under different circumstances. However, exposure mainly occurs through consumption of fish and shellfish contaminated with methylmercury and through worker inhalation of elemental mercury vapour during industrial processes. Cooking does not eliminate mercury. The primary health effect of methylmercury is impaired neurological development. Therefore, cognitive thinking, memory, attention, language, and fine motor and visual spatial skills may be affected in children who were exposed to methylmercury as foetuses. Elemental and methylmercury are toxic to the central and peripheral nervous systems. The inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys, and may be fatal. The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract, and may induce kidney toxicity if ingested. Neurological and behavioral disorders may be observed after inhalation, ingestion or dermal exposure of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. Mild, subclinical signs of central nervous system toxicity can be seen in workers exposed to an elemental mercury level in the air of 20μg/m3 or more for several years. Kidney effects have been reported, ranging from increased protein in the urine to kidney failure.

4.0 CONTROL MEASURES

There are control techniques available for the control of the above enumerated emissions which depend on the type and nature of the pollutant involved. For the control of particulate matter, the following devices are used: (a) mechanical collectors in the form of dust cyclones (b) electrostatic precipitators (ESP) (c) particulate scrubbers (d) water sprayer at dust generation points, etc. ESP has been reported to be highly efficient air pollution control device which is capable of removing up to 99% of the particles in a gas stream (White, 1982). NOx are generated by the oxidation of Nitrogen as a result of high temperature of combustion and for their control, some methods like combustion modification and post combustion techniques such as boiler derating, burners out of service, oxygen and combustion trim, steam injection, flue gas recirculation, low NOx burners, etc., are used. Some techniques such as Selective Catalytic Reduction with Flue-gas Desulfurization or Activated Carbon Injection with Fabric Filters or ESP can be used for the reduction of mercury. In the case of CO and VOCs, the most pronounced technique is catalytic oxidation which is used to reduce the CO to CO_2 and VOCs to CO_2 and H_2O. The CO and VOC catalyst is installed at the discharge of gas turbine. However, as for CO_2 control, Carbon Capture and Storage or Sequestration (CCS) and Carbon Capture and utilization (CCU) are used. CCS is the process of capturing waste CO_2 from large point sources such as fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere, normally an underground geological formation. While CCU is all about capturing waste CO_2 and allowing it for beneficial uses. Carbon footprint can also be reduced by planting of trees and reduction in deforestation practices since trees absorb CO_2 through the process of photosynthesis and serve as carbon sinks.

5.0. CONCLUSION

As the population of Nigeria keeps growing, the need for the erection of more buildings for housing, commerce and industry equally increases. The resultant effect of this change is a rise in demand for an increased electric power availability; the achievement of which will only be accompanied by more harmful emissions. The environmental and health impacts of thermal power plant emissions are devastating. Obviously, the major population centres and industrial point sources in Nigeria have been adversely affected by the various thermal power plants installed for electricity generation and other industrial activities. Environmental deterioration is highly attributable to the emission of large amount of *CO, CO_2, SO_x, NO_x,, CFCs, HCs* and suspended PMs into the atmosphere. These pollutants and green house gases cause harm to humans, animals and plant kingdoms. They are associated with acidification of streams, lakes and oceans thereby harming aquatic life and damage to buildings and other objects of aesthetic value.

It is disheartening that Nigerian government and private sectors seem to have done relatively little with a view to ensuring that the environmental hazards and health consequences associated with these emissions are mitigated. It is therefore suggested that the government should make strides in the area of policy enforcement regarding the prohibition of practices like deforestation, bush burning and encourage the installation of some known gadgets at thermal power plant stations that help to ameliorate the level of emissions of these pollutants into the atmosphere. There is also a need for the launching of an enlightenment campaign concerning the public on the use of generators in badly ventilated environments. In addition, government should invest on other sources of power generation that are renewable in nature. It is very evident that Nigeria has these renewable, pollutant- free energy sources in abundance. These are: solar power, wind power, tidal, hydroelectric power, etc.

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