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EMISSION INVENTORY OF ELECRICITY GENERATION FROM THERMAL POWER PLANTS IN NIGERIA

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Abstract: An emission factor approach was used in this study to quantify the emission of uncontrolled air pollutants discharge into the atmosphere from all the existing thermal plants in the country. The air pollutants examined were carbon monoxide (CO), oxides of nitrogen (NO_x), particulate matter (PM), sulphur dioxide (SO_2), and volatile organic compounds (VOCs); The estimated annual criteria air pollutants emissions from point sources in the existing thermal power plants ranges 47.76 – 26747.41, 80.28 – 44727.62, 1.80 – 1004.51, 0.92 – 512.66, 0.55 – 310.57 ton/ annum for CO, NO_x, PM, SO_2, and VOCs, respectively. From the specific data, the study discovered that, the higher the production capacity, the higher the emissions generated. Identification of sources of emissions assists in adopting efficient control technology during the design stage. The ability to adopt appropriate control measures will determine how much emission of criteria air pollutants released into the country's airshed. Both technology and policy control options are recommended in order to reduce criteria air pollutants from thermal power plants for adequate air quality in support of environmental assessment and mitigation planning.

Keywords: Criteria Pollutants, Emission Factor, Emission Inventory, Nigeria Thermal Power Plants

1. Introduction

Electricity generation from thermal power plants in Nigeria has been almost entirely derived from combustion of its abundant Natural gas resources. The consumption of these resources, and the emissions produced consequently, are known to have impact on the health of the local, regional, and global environment. Energy is an indispensable fundamental input to modern life, One only has to experience a power outage to be reminded of the role electricity play in every sphere of

human endeavour (Emre, 2007). Elecrtic power generation from thermal power plants being adopted by major stakeholders in Nigeria quest for stable electricity supply to the national grid emit air pollutants into the atmosphere (Sonibare, 2010). Emission from thermal power plants affects the environment in many ways, with every diverse impact from different fuel sources (Stern *et al*, 1994). Major components of these emissions are air pollutants, which include carbon monoxide, oxides of nitrogen, particulate matter, sulphur dioxide, and volatile organic compounds (Sonibare, 2010). These pollutants can cause death if large amount of their concentration is inhaled, especially carbon monoxide which is known to be the third most frequent cause of acute poisoning death globally (Raub *et al*.,2000).
Total electricity generation in Nigeria was 7931.5MW (Table 2) and increasing countinuously due to the rapid increase in population in the country to the required 30,000 MW (Sonibare, 2010), the adoption of electric thermal power plants in order to meet the increasing demand on electricity generation has brought about the idea of investigating the atmospheric emission from thermal power plant in the country.

Efficient environmental management and assessment plans are necessary to mitigate their adverse effects. In the light of this an emission inventory of data was necessary to evaluate the status of the existing situation or problems, and to assess effective policies to solve all the problems.

In this study, annual gaseous emissions from all existing and proposed thermal power plants were assessed, the approach used for identifying the types and estimating the quantities of emissions is emission factors. Thereafter, the emission factors were applied to all thermal power plants in the national grid according to capacities installed of power plants for estimating gaseous emissions of the electricity generating sector in Nigeria.

1.2 Description of the Study Area

Nigeria currently has 21 thermal generating plants (Table 1), the tables shows the plant name, plant capacity and location (state and local government area) of the plants. Egbin Thermal Power Plant is located about 40km North East of the city of Lagos in Ijede Local Council Development Area, Ikorodu Local Government Area of Lagos State. The Plant was commissioned in 1985 and consists of six (6) units of 220MW steam turbines (with total installed capacity of 1320MW. (Egbin Operation Manuals, 1986), The station was commissioned on oil firing. Gas firing started in October 1988 after piping natural gas from Delta state. Sapele Thermal Power Plant is located in the city of Ogorode in Sapele Local Government Area of Delta State. The Plant was commissioned in 1978 with total installed capacity of 1020MW (Adegboyega, 2011).
To improve on electricity generation in the country, another 26 thermal power plants has been licensed under the integrated power projects (NIPPs) by the Federal Government and Nigerian electricity regulation commission (NERC) under the deregulation programme

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(NERC, 2008) as shown in Table 2

Table 1 Existing thermal power plants in Nigeria

S/N	Plant Name	Plant Type	Status	Location State	Location Local govt	Location Town	Installed capacity (MW)
1	Egbin	Thermal	Existing	Lagos	Ikorodu	Ikorodu	1320
2	Egbin AES	Thermal	Existing	Lagos	Somolu	Somolu	270
3	Sapele	Thermal	Existing	Delta	Sapele	Ogorode	1020
4	Okpai	Thermal	Existing	Delta	Ndokwa East	Okpai	480
5	Afam	Thermal	Existing	Rivers	Oyigbo	Afam	702
6	Delta	Thermal	Existing	Delta	Ughelli south	Ughelli	840
7	Omoku	Thermal	Existing	Rivers	Egbema ndoni	Omoku	150
8	Ajaokuta	Thermal	Existing	Kogi	Ajaokuta	Ajaokuta	110
9	Geregu	Thermal	Existing	Kogi	Ajaokuta	Geregu	414
10	Omotosho	Thermal	Existing	Ondo	Okitipupa	Omotoso	335
11	Papalanto	Thermal	Existing	Ogun	Obafemi owode	Papalanto	335
12	NNPC/Agip	Thermal	Existing	Delta	Ndokwa east	Okpai	480
13	NNPC/Shell	Thermal	Existing	Rivers	Oyigbo	Afam	642
14	Dangote obajana	Thermal	Existing	Kogi	Kabba Bunu	Obajana	350
15	Eleme power plant	Thermal	Existing	Rivers	Eleme	Eleme	95
16	Ewekoro power	Thermal	Existing	Ogun	Ewekoro	Ewkoro	12.5
17	Omoku power	Thermal	Existing	Rivers	Egbema Ndoni	Egbema Ndoni	150
18	Trans amadi power	Thermal	Existing	Rivers	Port harcourt	Port harcourt	136
19	Tower power utility	Thermal	Existing	Ogun	Ado Odo/Ota	Ota	30
20	Akute thermal plant	Thermal	Existing	Ogun	Ifo	Akute	20
21	Ijora	Thermal	Existing	Lagos	Ifelodun apapa	Ijora	40

1.3 Technologies for Generating Electricity

Turbine, is the prime mover required to generate electricity, mechanically, turbine extracts energy from fossil fuel (natural gas) and convert the energy stored in the fuel to useful work to generate electricity which essentially relies on burning the fuel (Emre, 2007). Generally, turbines have a series of blades mounted on a shaft against which fluids are forced, thus rotating the shaft connected to the generator to produce electricity. Gas turbine (combustion-turbine) relies on the expansion of very high temperature compressed gas through a gas turbine that is coupled to the generator (Figure 1). Air is compressed and mixed with the fuel (natural gas), and burnt in a combustion chamber prior to expansion through the turbine. It is in this process that air pollutants are generated. How much of these pollutants generated depends on the way the fuels are burned, on the fuels themselves, and on the way the energy released during the burning process. Throughout Nigeria, the electricity generation systems relies majorly on gas turbines as prime mover (Sonibare, 2010). The other method is to use the hot gases to heat water and produce steam at high temperature and pressure (steam turbine). The steam then drives a turbine or generating unit to produce electricity. In this case, combustion is said to be external (USEPA, 1995).

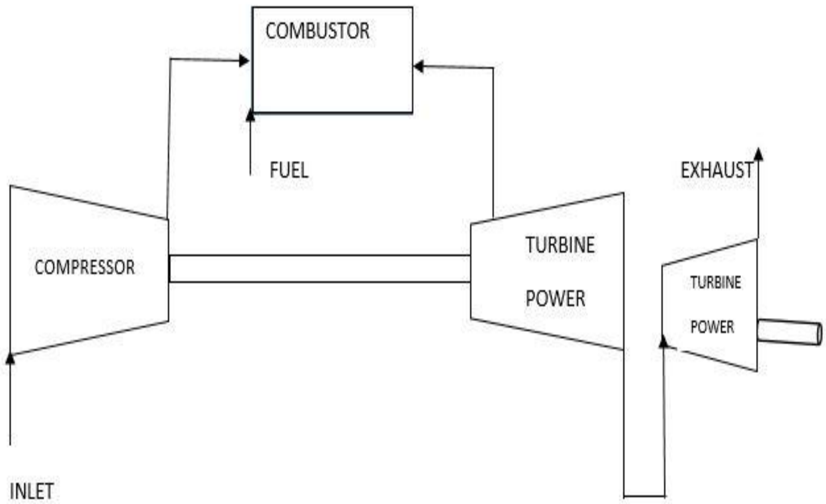

Figure 1: Gas Turbine Schematic Diagram
Source; This Study

2.0 Methodology

Estimation of emissions (emission inventory) of air pollutants from operating and proposed thermal power plants in Nigeria was done using emission factors of stationary gas turbines for electricity generation in AP-42 of the United States environmental protection agency (EPA, 1995) (Table 3). Other inputs were the thermal plants capacity (Tables 1), potential natural gas consumption rates of about 0.39 MMScf for 1 MW (Sonibare and Akeredolu, 2006), and the number of days the plants will be available for operation per annum which was taken to be about 300 days. The worst case scenario assuming 100% of the thermal power plant capacity on generation was used.

Table 3 Emission factors used in emission computation

Parameter	Emission Factor Ibs/MMScf
CO	*180*
NO_X	*301*
PM	*6.78*
SO_2	*3.45*
VOC	*2.09*

Source : Extracted from Table 3. 4-1 of EPA (1995).

Emission inventories are the foundation of air quality management. They are developed using emission factors (*EF*s) and associated activity (*A*) information. Emission factors are the mass of pollutant emissions released per unit of the associated process variable. Activities are the related process variable,such as mass of fuel consumed or output produced (Miller, 2006). The emissions (*E*) are then calculated as:

$Emission_{pollutant} = Activity * Emission\ Factor_{pollutant}$

Or

$$E = A \times EF \qquad \text{equation 1}$$

Where

E = emissions, in units of pollutant per unit of time,

A = activity rate, in units of weight, volume, distance or duration per unit of time,

EF = emission factor, in of pollutant per unit of weight, volume distance or duration.

3.0 Results and Discussion

Annual emission generated from thermal power plants using the emission factors approach were reported in Table 4. Uncontrolled calculated emissions ranged between 47.76 – 26747.41, 80.28 – 44727.62, 1.80 – 1004.51, 0.92 – 512.66, 0.55 – 310.57 ton/ annum for carbon monoxide (CO), oxides of nitrogen (NO_x), particulate matter (PM), sulphur dioxide (SO_2), and volatile organic compounds (VOCs), respectively. From the results, overall emission increases as generation capacity increases, since emissions are directly proportional to the volume of a gas required for combustion. The gaseous inventory results showed the significant contribution from thermal power plants among other factors. Power plant with the lowest electricity generation was estimated to generate the lowest emission rate while, those with highest production capacity were predicted to generate the highest emission rate. From the emission inventory of the thermal power plants, NO_x has the highest emission rate while VOCs has the least emission rate. Also, Lagos State has the highest number of thermal power plants, hence will experience the highest level of pollution. The higher the production capacity, the higher the emissions generated.

Table 4: Calculated levels of criteria air pollutants from thermal power plants in Nigeria

Power Plant/ State	Installed Capacity(MW)	Status	Fuel type	parameters	Emissions $\frac{ton}{annum}$	Emissions $\frac{g}{sec}$
Sapele/ Delta	1020.00	Existing	Natural gas	CO	9743.70	375.91
				NO_x	16293	628.61
				PM_{total}	365.99	14.12
				SO_2	186.88	7.21
				VOC	113.14	4.365
Egbin/ Lagos	1320.00	Existing	Natural gas	CO	12609.50	485.48
				NO_x	21085.00	813.50
				PM_{total}	473.56	18.27
				SO_2	241.68	9.33
				VOC	146.41	5.65
Afam/Rivers	969.60	Existing	Natural gas	CO	9262.13	357.34
				NO_x	15448.50	597.55
				PM_{total}	347.85	13.42
				SO_2	177.55	6.85
				VOC	107.57	4.15
Delta- ughelli /Delta	912.00	Existing	Natural gas	CO	8711.97	336.11
				NO_x	14568.34	562.05
				PM_{total}	327.11	12.62
				SO_2	166.93	6.44
				VOC	101.08	3.90
Ijora / Lagos	40.00	Existing	Natural gas	CO	382.06	14.70
				NO_x	638.93	24.65
				PM_{total}	14.36	0.55
				SO_2	7.34	0.28
				VOC	4.41	0.17
Calabar	561.00	Planning	Natural gas	CO	5358.96	206.75
				NO_x	8961.58	345.74
				PM_{total}	201.14	7.76
				SO_2	102.64	3.96
				VOC	62.21	2.40
Ibom power	188.00	Existing	Natural gas	CO	1796.00	69.29
				NO_x	3003.09	115.86
				PM_{total}	67.39	2.60
				SO_2	34.21	1.32
				VOC	20.74	0.80
Papalanto	335.00	Existing	Natural gas	CO	3200	123.46
				NO_x	5351.44	206.46
				PM_{total}	120.27	4.64
				SO_2	61.43	2.37
				VOC	37.07	1.43
Ewekoro	12.50	Existing	Natural gas	CO	119.41	4.61
				NO_x	199.68	7.70
				PM_{total}	4.48	0.17
				SO_2	2.29	0.09
				VOC	1.39	0.05
Omotoso	335.00	Existing	Natural gas	CO	3200	123.46
				NO_x	5351.44	206.46
				PM_{total}	120.27	4.64
				SO_2	61.43	2.37
				VOC	37.07	1.43
Geregu	424.00	Existing	Natural gas	CO	4050.26	156.26
				NO_x	6773.16	261.31
				PM_{total}	152.15	5.87
				SO_2	77.65	3.00
				VOC	46.92	1.81

Akute thermal plant	12.00	Operating	Natural gas	CO	114.63	4.42
				NO_x	191.69	7.40
				PM_{total}	4.31	0.17
				SO_2	2.18	0.84
				VOC	1.33	0.05
Dangote obajana	350.00	Existing	Natural gas	CO	3343.44	128.99
				NO_x	5590.95	215.70
				PM_{total}	125.56	4.84
				SO_2	64.08	2.47
				VOC	38.82	1.50
Omoku power	150.00	Existing	Natural gas	CO	1432.90	55.28
				NO_x	23.96	92.44
				PM_{total}	53.81	2.08
				SO_2	27.46	1.06
				VOC	16.64	0.63
NNPC/Agip	480.00	Existing	Natural gas	CO	4585.25	176.90
				NO_x	7667.65	295.82
				PM_{total}	172.11	6.64
				SO_2	87.87	3.39
				VOC	53.14	2.05
NNPC/Shell	642.00	Existing	Natural gas	CO	6132.67	236.60
				NO_x	10255.51	395.66
				PM_{total}	233.28	9.00
				SO_2	117.42	4.53
				VOC	71.28	2.75

From the results of the emission inventory, it can be seen that the thermal power plants are the major sources of gaseous emissions. Among these gaseous emissions, the largest emission is from NO_x and CO. The NO_x and CO emitted from natural gas combustion is very higher than expected. This is not surprising since the carbon content of natural gas is higher compared to unit of heat input. Emission from thermal power plant are generally high while using natural gas as a fuel. The factor was significant information for the decision of policy makers. They can use the factor for planning to control the emissions from power generation by using appropriate proportions of fuel type. Finally, the policy will be covered for all point of view both environment, economic and reliable of grid system as well.

4.0 Conclusion

The study focussed on emission inventory from thermal power plants in Nigeria. Annual emissions of CO, NO_x, PM, SO_2 and VOCs were calculated. Then emission factors of stationary gas turbines for electricity generation in AP-42 of the United States environmental protection agency (EPA, 1995), were used, emission inventories of the electricity generating from thermal power plant was conducted at each thermal power plant. From the results, it can be concluded that annual gaseous emissions increased due to increasing electricity generation, hence increased fuel consumption. In terms of contribution of emission to the atmosphere, thermal power plants releases larger quantity of emission.

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