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Environmental Impact Analysis of the Emission from Petroleum Refineries in Nigeria

Oladimeji T. E.[1], Sonibare J. A.[2], Odunfa K. M.[3] & Oresegun O. R.[1]

[1] Chemical Engineering Department, Covenant University, Ota, Ogun State Nigeria

[2] Chemical Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria

[3] Mechanical Engineering Department, University of Ibadan, Ibadan, Nigeria

Correspondence: Oladimeji Temitayo Elizabeth, College of Engineering, Covenant University. Ota, Ogun State. Nigeria. Email: temitayo.fatoki@covenantuniversity.edu.ng

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Abstract

Health and environmental hazards, a thing of global concern have been the major characteristics of the petroleum refinery areas worldwide, Nigeria inclusive. This is as a result of the emissions from petroleum refineries which resulted into air quality degradation of the host environment. This problem which has equally affected the climatic conditions of the petroleum producing areas is more pronounced in Nigeria due to lack of implementing adequate policies to protect the host environment. This study is carried out to investigate the atmospheric conditions of the petroleum refineries and identify the environmental impact of emissions of criteria pollutants from the proposed project in the area of influence. Emission inventory of criteria pollutants was carried out on the four existing and twenty-three proposed petroleum refineries in Nigeria. Using no control-measure option, the estimated annual criteria air pollutants emissions from point sources in the existing refineries are 1,217 tons/annum for $PM_{10,}$ 45,124 tons/annum for SO_2, 167,570 tons/annum for $NO_{x,}$ 3,842 tons/annum for VOC and 242,469 tons/annum for CO. An additional 1,082 tons/annum of $PM_{10,}$ 168,944 tons/annum of SO_2, 688,687 tons/annum of $NO_{x,}$ 9,122 tons/annum of VOC and 569,975 tons/annum of CO were predicted to be added into the Nigeria airshed by the proposed petroleum refineries. The highest pollutant emitting state was predicted to be Rivers State with the highest number of refineries while the least pollutant emitting states were predicted to be Kaduna, Edo, Lagos and Anambra States with only one refinery in each of the state. The ability to adopt appropriate control measures will determine the rate of emission of criteria pollutants released into the country's airshed.

Keywords: criteria air pollutants, emission factor, emission inventory, Nigeria, refinery

1. Introduction

Nigeria is the highest producing nation in Afica with production rate of 2.35 million barrel per day (bbl/dy) (Klieman, 2012). International Monetary Fund (IMF) establishes that oil and natural gas export revenue account for 96% of total revenue in 2012, also it has been estimated that demand and consumption of petroleum in Nigeria grows at the rate of 12.8% annually, however, petroleum products are unavailable and expensive because a significant percentage of required petroleum products are imported while limited quantity is supplied to the nation due to instability in price and scarcity of the products. In view of this, it is necessary for the country to develop her refining potential (Sonibare *et al*., 2007). One of the strategies developed in Nigeria to increase her refining potential includes approval of more refineries to complement the existing ailing four state-owned refineries, which despite having a combine production capacity of 445,000 barrels per day (bpd), remain unable to meet the nation's petroleum products demand. Nigeria has four existing petroleum refineries (Table 1), while twenty-three proposed refineries (Table 2) have been licensed and are at various stages of completion (DPR, 2004; DPR, 2010). The more the refineries, the more the emissions generated, and the more dangerous it becomes on health and the environment which may result in degraded air quality of host environment, hence the need to control the rate of emissions in the refineries.

As petroleum refinery and petrochemical industries are most desirable for national development and improved quality of life, the unwholesome and environmentally unacceptable pollution effects of the waste from these industries are of major concern (Reinermann and Golightly, 2005). This is because, in the process of converting crude oil into petroleum and petrochemical products, wastes of different kinds are generated. These wastes are released to the environment in form of gases, particles and liquid effluent which becomes hazardous to the environment and to human health. Air emissions can come from number of sources within a petroleum refinery which include; equipment leaks (from valves, flanges, pump seals, drains and compressor seals), high-temperature combustion processes in the burning of fuels, the heating of steam and process fluids and the transfer of products. Numerous pollutants are emitted into the environment through normal emissions, fugitive releases, accidental releases or plants upsets from various refining operations such as separation, conversion and treatment processes (US DOE, 2007). About 900 cases of accidents in oil refining processes and exploration was reported in Nigeria in the year 2000 which is as a result of equipment failure and malfunctioning, deterioration and ageing of pipelines etc. Major components of these emissions are criteria air pollutants, which include particulate matter (PM), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO) and volatile organic compounds (VOCs).

From previous studies, the environmental and health implications of these pollutants cannot be overemphasized. During the past decades, criteria pollutants caused some health problems and damages to plants such as DNA breakdown in bone marrow cells, respiratory diseases and reduced lung function in humans (Zhongua *et al*., 2003), reduction of reproductive processes (Cape, 2003) in plants and formation of acid rain which deteriorates water quality and affect aquatic habitat (Johnson *et al*., 2003). About 2.5 million deaths per year was found to result from indoor exposures to particulate matter in rural and urban areas in developing countries, representing 4-5% of the 50-60 million global deaths that occur annually (WHO, 2002). The effects may not be confined to the local area of production but extend to regional as well as global scales due to possibility of long transportation (Mitra and Sharma, 2002).

This study aims at collection and collation of detailed information concerning the air pollutant emissions in existing and proposed petroleum refineries in Nigeria (Figure 1) using emission factor approach. This is for the purpose of determining the potential impacts of these emissions on air quality in Nigeria's airshed.

1.1 Petroleum Refineries and Air Emission Sources

A typical modern refinery takes in crude as feed through the heat exchangers (for temperature increase) and desalters (for salt water removal) into the atmospheric distillation column, where distillation process takes place under atmospheric pressure. In the distillation process, fractions get separated in increasing order of boiling points. The top products (highly volatile) get condensed in a reflux condenser with some portion of condensed fractions going back as reflux (Sonibare *et al*., 2007). Several other processes are required for the crude oil to be finally converted into the final products of different fractions. Several operations such as separation, conversion, treatments, feedstock and product handling involved in the petroleum refining process are potential sources of criteria air pollutants (James *et al*., 2001). The most significant point sources of emission in the petroleum refineries are fluid catalytic cracking units, steam boilers, process heaters, and flares. These sources emit various pollutants through catalytic cracking of hydrocarbons, combustions and equipment leaks of volatile compounds.

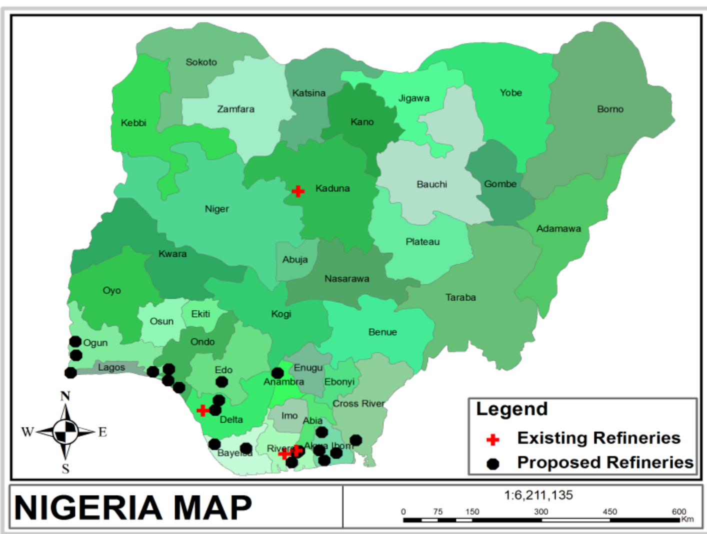

Figure 1. Existing and proposed petroleum refineries in Nigeria

Table 1. Existing refineries in Nigeria

S/N	Name of Refinery	Capacity (bbl/dy)	Year of Production	Location		
				Town	L.G.A	State
1	Kaduna Refining & Petrochemical Company	110,000	1980	Kaduna	Chikun	Kaduna
2	Port Harcourt Refining Company I	60,000	1965	Port Harcourt	Eleme	Rivers
3	Port Harcourt Refining Company II	150,000	1989	Port Harcourt	Eleme	Rivers
4	Warri Refining & Petrochemical Company	125,000	1978	Warri	Effunrun	Delta

Source: DPR (2001)

Table 2. Proposed Refineries in Nigeria

S/N	Name of Refinery	Capacity (bbl/dy)	Date of issue	Location		
				Town	L.G.A	State
1	Amakpe International Refinery	12,000	2004	Ikot Ekpene	Eket	Akwa Ibom
2	Amexum Corporation	100,000	2009	Ikang	Akpabuyo	Cross River
3	Antonio Oil	27,000	2009	Iwopin	Iwopin	Ogun
4	Chase Wood Consortium Nigeria Limited	70,000	2004	Eket	Eket	Akwa Ibom
5	Clean Water Refinery	60,000	2004	Onne	Eleme	Rivers
6	Gasoline Associate & International Limited Refinery	100,000	2009	Ipokia	Ipokia	Ogun
7	Ilaje Refinery & Petrochemicals	100,000	2004	Ilaje	Ilaje	Ondo
8	Niger Delta Refinery & Petrochemical Limited	100,000	2004	Niger Delta	Warri South	Delta
9	NSP Refineries and Oil Services Limited	120,000	2004	Ohali Ogba	Andoni	Rivers
10	Ode Aye Refinery Limited	100,000	2004	Ode Aye	Okiti Pupa	Ondo
11	Ologbo Refinery Company Nigeria Limited	12,000	2010	Ologbo	Ologbo	Edo
12	Orient Petroleum Resources Limited	55,000	2004	Aguleri Out	Anambra West	Anambra
13	Owena Oil & Gas Limited	60,000	2004	Ilaje	Ilaje	Ondo
14	Qua Petroleum Refinery Limited	100,000	2004	Ibeno	Ibeno	Akwa Ibom
15	Rehoboth Natural Resources Limited	12,000	2008	Immingiri	Yenekoa	Bayelsa
16	Resources Refinery & Petrochemical Limited	100,000	2004	Ikot Abasi	Ikot Abasi	Akwa Ibom
17	Rivgas Petroleum & Energy Limited	30,000	2004	Port Harcourt	Eleme	Rivers
18	Sapele Refinery Limited	100,000	2004	Okpe-Sobo	Sapele	Delta
19	South West Refinery & Petrochemical Company	100,000	2004	Ogun-water side	Iwopin	Ogun
20	Starrex Petroleum	100,000	2004	Onne	Onne	Rivers

	Refinery					
21	Tonwei Oil Refinery	200,000	2002	Ekeremor	Ekeremor	Bayelsa
22	Total Support Limited	12,000	2004	Free trade zone	Calabar	Cross River
23	Union Atlantic Petroleum Ref.	100,000	2002	Badagry	Badagry	Lagos

Source: DPR (2004); NNPC (2008); DPR (2010)

2. Methodology

This study involved preparation of detailed emission inventory with estimation of emissions of criteria air pollutants from point sources of existing and proposed refineries in Nigeria. An emission factor approach was used to determine the criteria air pollutant emissions in Nigeria's petroleum refineries and its contribution to the country's airshed.

Detailed information on process unit capacity from the existing and proposed refineries in Nigeria was obtained from previous research reports, company's website and Department of Petroleum Resources (NNPC, 2008; EIA, 2000; US DOE, 2007; DPR 2001; DPR, 2004). The emission factor of criteria pollutants for process units in the petroleum refinery in AP-42 of the United States Environmental protection Agency (US EPA, 1989) was used (Table 3). The process unit capacity was combined with the emission factor of pollutants for each process unit which is calculated as follows;

Table 3. Emission factor of pollutants for process units in petroleum refinery

S/N	Process Name	Pollutants					
		PM_{10}	SO_x	NO_x	VOC	CO	Unit
1	Process Heaters	7.4S	158.6S	55.0	0.3	5.0	1000 gallons burned
2	Fluid catalytic cracking unit	-	493	71	220	13700	1000 barrels processed
3	Flares	-	-	0.027	5.6	14.8	Valve in operation
4	Boilers	-	159.3S	67	-	5	1000 gallons burned

"S" means sulphur content "-" means no emission factor for the pollutant.

Source: US EPA (1989)

$$E = A \times EF_1 \left[1 - \left(\frac{D}{100}\right)\right] \quad (1)$$

where

E = Emission Estimate for the Process Unit (tons/yr)

A = Activity Rate (bbl/yr)

EF_1 = Controlled Emission Factor (lbs /bbl)

D = % Control Efficiency

Due to lack of information on the level of efficiency of the control device, control efficiency was assumed to be zero for "worst case" scenarios and equation 1 became:

$$E = A \times EF_2 \quad (2)$$

where

EF_2 = Uncontrolled emission factor (lbs/bbl)

Total emissions of the criteria pollutants in tons/yr from point sources of existing and proposed refineries were determined using equation (2) and the result is shown in Table 4-5.

3. Results and Discussion

The total estimated annual criteria air pollutants from point sources in the existing refineries are 1,217 tons/annum for PM_{10}, 45,124 tons/annum for SO_2, 167,570 tons/annum for NO_X, 3,842 tons/annum for VOC and 242,469 tons/annum for CO (Table 4). An additional 1,082 tons/annum of PM_{10}, 168,944 tons/annum of SO_2, 688,687 tons/annum of NO_x, 9,122 tons/annum of VOC and 569,975 tons/annum of CO (Table 5) were predicted to be added into the Nigeria airshed by the proposed petroleum refineries. Since emission rates are directly proportional to process unit capacity/ activity rate from equation (2), Tonwei Oil Refinery proposed to operate at 200,000 bbl/dy will release the maximum emission of air pollutant while Amakpe Refinery, Total Support Refinery, Ologbo Refinery and Rehoboth Refinery proposed to operate at the same capacity of 12,000 bbl/dy will release the minimum emission of air pollutants. Also, the highest emitting state is Rivers state with the highest number of refineries (2 existing and 4 proposed refineries) while the least emitting states are Kaduna, Edo, Lagos and Anambra States (1 existing and 3 proposed refineries respectively) with only 1 refinery in each of the state. The significant point sources of these emissions are fluid catalytic cracking units (FCCU), process heaters, steam boilers and flares. From the criteria pollutants emitted, CO emission is the highest due to higher rate of incomplete combustion of fuel in the refinery units while particulate matter, which has to do with solid and liquid droplets suspended in air is the least emitted.

Criteria Air Pollutants (CAPs) includes the common air pollutants all over the world which could endanger public health and environment and it originates from various sources in the refinery such as the fluid catalytic cracking units, steam boilers, process heaters and flares e.t.c. (James *et al*., 2001). The CAPs on its environment indicated the potential for petroleum refinery to create an elevation in ambient concentrations - both indoor and outdoor in Nigeria, though composition could be impacted by local emissions (Zielinska and Fujita, 2003). Na *et al*. (2001) established a strong link between downtown hydrocarbon levels and nearby petrochemical complex while Kajihara *et al*. (2003) also noticed a decrease in ambient benzene level with a reduction in benzene concentration discharged into the atmosphere. Possible impacts of anticipated emissions of criteria air pollutants on human (Guo *et al.,* 2004), vegetation (Rao *et al.,* 2001) soil and water (Kim *et al*., 2001; Johnson *et al*., 2003) are strong enough for necessary control measures to be implemented in both operating and proposed Nigerian petroleum refineries. The ability to adopt appropriate control measures will determine how much emission of criteria air pollutants will be released into the country's airshed. Both technology and policy control options are recommended in order to reduce the criteria air pollutants in the Nigeria's airshed.

Table 4. Air pollutant emissions from point sources of existing petroleum refinery units

S/N	Refinery	Process Unit	Criteria pollutant emissions (tons/yr)				
			PM_{10}	SO_2	NO_x	VOC	CO
1	Kaduna Refining & Petrochemical Company (110,000 bpsd)	Fluid Catalytic Cracking	-	1,894.52	274.62	8,457.99	52,504.38
		Process Heaters	73.00	1,567.77	6,020.76	34.76	549.24
		Flares	-	-	0.04	0.11	0.18
		Steam Boilers	-	105,771.09	49,365.38	-	3,684.76
2	Port Harcourt Refining Company I (60,000 bpsd)	Fluid Catalytic Cracking	-	434.52	69.52	194.67	12086.71
		Process Heaters	20.85	465.81	1793.72	10.43	163.38
		Flares	-	-	0,011	0.03	0.07
		Steam Boilers	-	2071.81	9688.14	-	723.04
3	Port Harcourt Refining Company II (150,000 bpsd)	Fluid Catalytic Cracking	-	3,597.85	517.96	1,609.48	100009.99
		Process Heaters	128.62	2,787.90	10,710.15	59.09	973.34
		Flares	-	-	0.07	0.14	0.05
		Steam Boilers	-	9,309.24	43,476.71	-	3,246.76
4	Warri Refining & Petrochemical Company (125,000 bpsd)	Fluid Catalytic Cracking	-	2,339.47	337.18	1,042.86	65,008.25
		Process	99.44	2,130.90	8,179.48	45.19	743.91

	Heaters					
	Flares	-	-	0.04	0.11	0.24
	Steam Boilers	-	7,953.52	37,361.46	-	277.40
Total Emissions		1,216.66	45,124.43	167,569.95	3,841.56	242,468.55

"-" means no emission for the pollutant.

Table 5. Air pollutant emissions from point sources of proposed petroleum refinery units

S/N	Refinery	Process Unit	[a]Criteria pollutant emissions (tons/yr)				
			PM_{10}	SO_2	NO_x	VOC	CO
1	Amakpe International Refinery (12,000 bpsd)	Fluid Catalytic Cracking	-	13.70	2.43	10.43	483.19
		Process Heaters	1.05	1.05	73.00	0.35	0.69
		Flares	-	-	0.0004	0.001	0.003
		Steam Boilers	-	560.05	2,602.24	-	209.24
2	Amexum Corporation (100,000 bpsd)	Fluid Catalytic Cracking	-	1206.24	173.81	542.29	33,576.52
		Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
3	Antonio Oil (27,000 bpsd)	Fluid Catalytic Cracking	-	10.43	1.74	6.95	333.72
		Process Heaters	3.48	93.85	361.53	1.99	34.76
		Flares	-	-	0.003	0.00007	0.011
		Steam Boilers	-	420.62	1,964.0	-	14.62
4	Chase Wood Consortium Nigeria Limited (70,000 bpsd)	Fluid Catalytic Cracking	-	590.95	83.42	264.19	13.90
		Process Heaters	31.28	636.14	2,436.81	13.90	222.48
		Flares	-	-	0.01	0.03	0.07
		Steam Boilers	-	2,930.43	13,678.8	-	983.8
5	Clean Water Refinery (60,000 bpsd)	Fluid Catalytic Cracking	-	434.52	69.52	194.67	12086.71
		Process Heaters	20.85	465.81	1793.72	10.43	163.38
		Flares	-	-	0,011	0.03	0.07
		Steam Boilers	-	2071.81	9688.14	-	723.04
6	Gasoline Associate & International Limited Refinery (100,000 bpsd)	Fluid Catalytic Cracking	-	1206.24	173.81	542.29	33,576.52
		Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
7	Ilaje Refinery & Petrochemicals (100,000 bpsd)	Fluid Catalytic Cracking	-	1206.24	173.81	542.29	33,576.52
		Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
8	Niger Delta Refinery & Petrochemical Limited (100,000 bpsd)	Fluid Catalytic Cracking	-	1206.24	173.81	542.29	33,576.52
		Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
9	NSP Refineries and	Fluid Catalytic	-	1,741.58	246.81	775.19	48,350.34

	Oil Services Limited	Cracking					
	(120,000 bpsd)	Process Heaters	86.9	1,866.71	7,164.43	38.24	650.05
		Flares	-	-	0.04	0.11	0.20
		Steam Boilers	-	8,294.19	38,738.66	-	2,892.20
10	Ode Aye Refinery Limited	Fluid Catalytic Cracking	-	1206.24	173.81	542.29	33,576.52
	(100,000 bpsd)	Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
11	Ologbo Refinery Company Nigeria	Fluid Catalytic Cracking	-	13.70	2.43	10.43	483.19
	Limited	Process Heaters	1.05	1.05	73.00	0.35	0.69
	(12,000 bpsd)	Flares	-	-	0.0004	0.001	0.003
		Steam Boilers	-	560.05	2,602.24	-	209.24
12	Orient Petroleum Resources Limited	Fluid Catalytic Cracking	-	368.48	55.62	163.38	10,167.86
	(55,000 bpsd)	Process Heaters	17.38	392.81	1,505.19	10.43	139.05
		Flares	-	-	0.001	0.03	0.04
		Steam Boilers	-	1,741.58	8,137.76	-	608.33
13	Owena Oil & Gas Limited	Fluid Catalytic Cracking	-	434.52	69.52	194.67	12086.71
	(60,000 bpsd)	Process Heaters	20.85	465.81	1793.72	10.43	163.38
		Flares	-	-	0,011	0.03	0.07
		Steam Boilers	-	2071.81	9688.14	-	723.04
14	Qua Petroleum Refinery Limited	Fluid catalytic cracking	-	1206.24	173.81	542.29	33,576.52
	(100,000 bpsd)	Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
15	Rehoboth Natural Resources Limited	Fluid catalytic cracking	-	13.70	2.43	10.43	483.19
	(12,000 bpsd)	Process Heaters	1.05	1.05	73.00	0.35	0.69
		Flares	-	-	0.0004	0.001	0.003
		Steam Boilers	-	560.05	2,602.24	-	209.24
16	Resources Refinery & Petrochemical	Fluid catalytic cracking	-	1206.24	173.81	542.29	33,576.52
	Limited	Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
	(100,000 bpsd)	Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
17	RIVGAS Petroleum & Energy Limited	Fluid catalytic cracking	-	107.77	13.90	48.66	3,024.29
	(30,000 bpsd)	Process Heaters	6.95	118.18	448.40	2.43	3,024.29
		Flares	-	-	0.003	0.001	0.01
		Steam Boilers	-	517.96	2,419.43	-	180.76
18	Sapele Refinery Limited	Fluid catalytic cracking	-	1206.24	173.81	542.29	33,576.52
	(100,000 bpsd)	Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
19	South West Refinery & Petrochemical	Fluid catalytic cracking	-	1206.24	173.81	542.29	33,576.52
	Company	Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
	(100,000 bpsd)	Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
20	Starrex Petroleum Refinery	Fluid catalytic cracking	-	1206.24	173.81	542.29	33,576.52

	(100,000 bpsd)	Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
21	Towei Oil Refinery (200,000 bpsd)	Fluid catalytic cracking	-	2,158.71	312.85	962.91	60,006.0
		Process Heaters	229.86	5,183.0	19,904.66	107.77	1,811.1
		Flares	-	-	0.11	0.20	0.70
		Steam Boilers	-	23,040.20	107,605.47	-	8,033.48
22	Total Support Limited (12,000 bpsd)	Fluid catalytic crack	-	13.70	2.43	10.43	483.19
		Process Heaters	1.05	1.05	73.00	0.35	0.69
		Flares	-	-	0.0004	0.001	0.003
		Steam Boilers	-	560.05	2,602.24	-	209.24
23	Union Atlantic Petroleum Refinery (100,000 bpsd)	Fluid catalytic crack	-	1206.24	173.81	542.29	33,576.52
		Process Heaters	59.09	1,296.62	4,977.90	27.81	451.90
		Flares	-	-	0.04	0.07	0.14
		Steam Boilers	-	5,760.05	26,902.24	-	2009.24
	Total Emission (tons/yr)		1,081.8	168,943.69	688,687.1	9,121.6	569,975.4

[a]Calculated by the authors "-"means no emission factor for the pollutant.

4. Conclusion and Recommendations

From the emission inventory carried out in Nigerian petroleum refineries, results revealed that petroleum refinery is one of the major sources of air pollution in Nigeria. The environmental and health impacts of these pollutants indicate that adequate control as to be put place, as more refineries are established, to ensure reduction in the emissions.

Boilers, process heaters, and other process equipment are responsible for the emission of particulates, carbon monoxide, nitrogen oxides (NO_x), sulphur oxides (SO_2), and carbon dioxide (CO). Fluid catalytic cracking units and other units release particulate matters (PM) while Volatile organic compounds (VOCs) are released from storage, product loading and handling facilities and fugitive emissions such as leaks from flanges, valves, seals and drains. These air emissions can be controlled in the refineries by taking the following measures;

i. NO_x emission reduction can be achieved by replacing furnace burners with low-NO_X burners and substitution of conventional liquid (nitrogen-containing) fuels with gaseous fuel (nitrogen-free).

ii. SO_2 emission reduction can be achieved by the introduction of Clean Fuels (low sulfur) specifications for petrol and diesel to lower sulphur dioxide emissions. Also through desulfurization of fuels or by directing the use of high-sulfur fuels to units equipped with SOx emissions controls

iii. CO reduction is implemented by controlling the oxygen levels in the CO burners which is the main source of CO emissions.

iv. VOC reduction involves the systematic leak detection and repair of any fittings that emit fugitive VOCs by replacing with more reliable equipment, including the environmentally friendly valve design, which tests proved to provide the best seal to prevent VOC fugitive leaks. Also losses from storage tanks and product transfer areas can be reduced by vapour recovery systems and double seals.

v. PM reduction is achieved by installing cyclones on the catalytic cracking unit stacks, this cyclones operate by creating a centrifugal force that physically separates the particulates from the rest of the gas, particulates that would previously have been emitted are now collected from the cyclones and are then available for reuse.

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