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Estimation of Air Pollution Load Exerted by Selected Industries in Trans-Amadi Industrial Layout, Port Harcourt

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ABSTRACT
A study on the estimation of pollution load (PL) exerted by criteria air pollutants and toxic metals around the Trans-Amadi Industrial Layout in Port Harcourt, Rivers State of Nigeria was conducted. Pollution loads were evaluated using the Industrial Pollution Projection System. Industries were categorized using the International Standard Industrial Classification Code. Data were obtained from the Manufacturer's Association of Nigeria and relevant Government Agencies. Results showed that, based on number of employees, the Food Beverage and Tobacco sector with ***the*** *highest number of employees exerted PLs of 94%, 90%, and 56% of SO_2, NO_2, and total suspended particles (TSP) respectively. This was sequentially followed by the Motor Vehicles and Miscellaneous (MVM), Basic Metal, and Chemical and Chemical allied Products/Paints sectors exerting 42%, 36%***,*** *and 32%, of VOCs, CO, and fine particulate matter (FPM) respectively. Based on production output, the MVM sector with* ***a*** *production output of 1,800tons/year exerted PL of 84%, 82%, 63%, and 45% of CO, FPM, NO_2, and VOC respectively while the 'Others' and Food and Manufacturing Industry sectors with 3,200 tons/year and 1,200 tons/year exerted PL of 65% and 31% of SO_2 and TSP respectively. The Electrical/Electronic* ***and*** *'Other sectors exerted the most PL of toxic metals, with cumulative percentage of 34% and 62% respectively. These results indicated that, while* ***the*** *number of employees had a dominant influence on PLs of SO_2, NO_2, and TSP, the production output had a dominant influence on PL of CO, FPM***,*** *and VOC, and the 'Others' sector plays a major role in toxic metal pollution.*

KEYWORDS: Air pollution, Criteria pollutants, IPPS, Pollution intensity, Pollution load.

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1.0 INTRODUCTION
Rapid industrialization and urbanization contribute immensely to the economic prosperity of any nation as well as improve the living standards of its citizens. However, the presence of industries comes with environmental challenges with untold effects on humans through the release of toxic and hazardous (solid, liquid, and gaseous) substances into the air, water, and land environment referred to as air, water, and land pollution respectively. Air pollution is the most relevant environmental cause of disease and premature death in Africa and the world over. It is worthy of note that diseases caused by air pollution are responsible for about 9 million premature deaths recorded in 2015, and 16% deaths worldwide (Paolocci *et al.,* 2020). Industrial air pollution is therefore fast becoming a serious source of concern as physical and biological environments are damaged by the heat and pollutants in the air. According to the World Health Organization (WHO), critical air pollutants include sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO), fine particulate matter (FPM), total suspended particles (TSP), and volatile organic carbons (VOCs).

Particulate air pollution is regularly and independently related to the most serious health effects, such as lung cancer and other

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cardiopulmonary mortality. According to Cohen *et al.,* (2005) estimate of the global burden of disease due to outdoor ambient air pollution by fine particulate matter ($PM_{2.5}$), causes about 3% of mortality from cardiopulmonary disease, about 5% of mortality from cancer of the trachea, bronchus, and lung, and about 1% of mortality from acute respiratory infections in children under 5 years of age, worldwide. These reports align with Sam *et al.,* (2016) on degradation of air quality due to the emission of fine particulate into the environment which made man vulnerable to toxic substances leading to illness and eventually loss of life. Aside from health implications, particulate air pollutants have environmental effects such as impaired visibility and acid deposition on water and land ecosystem (Jimoda, 2012).

VOCs and NO_x are precursors of ground-level ozone (O_3); one of the most important secondary air pollutants due to its harmful effects on humans, plants, and the environment. In humans, ground-level ozone exacerbates respiratory problems such as coughing, chest tightness, and other asthmatic symptoms. Ground-level ozone interferes with the process of photosynthesis in plants resulting in low crop yield. Built environments are also affected by ground-level ozone as it damages rubber compounds and fades paints (Zhang *et al.,* 2019). Prime sources of VOCs are associated with manufacturing industries, road traffic, petrochemical industries, fossil fuel combustion, printing, and solvent usage (Li *et al*., 2018) with vehicular traffic emitting the highest VOCs in urban areas (Montero-Montoya *et al*., 2018).

Carbon monoxide (CO) is a colourless and odourless gas. It is not a greenhouse gas but has adverse effects on human health and is associated with ground ozone formation and greenhouse gases (Sobieraj *et al*., 2022). There are natural and anthropogenic sources of CO. It is estimated that 40% of global CO is from natural sources while the remaining 60% is from anthropogenic activities (Khalil & Rasmussen, 1990). Common anthropogenic activities that emit CO include biomass combustion, fossil fuels, waste incineration, transport, and industrial processes. The chief source of CO is vehicular transport (Sobieraj *et al.,* 2022). Metal, electricity generation, food manufacturing, chemical production, petroleum refining, and plaster and concrete manufacturing industries are some industries associated with CO emissions.

Port Harcourt has a flash point called Trans-Amadi Industrial Layout, the hub of manufacturing industries in Rivers State. The increasingly seeming lack of space to accommodate more industries led to the spread across the neighbouring communities. Industries within the layout and its surrounding environment generate undetermined amounts of industrial pollution load and effects (Odesanya *et al.,* 2012). This is because the traditional sampling and chemical analysis for industrial pollution assessment and environmental monitoring is expensive, tedious, time consuming, resource intensive and usually not affordable by developing countries (Oketola & Osibanjo, 2009). The resultant effects are ineffective regulatory standards and the lack of reliable and comprehensive environmental monitoring data for the enforcement of environmental compliance on industrial emissions.

To overcome the challenge of industrial pollution assessment and environmental monitoring for public health protection and safeguarding of ecosystems, a team of environmental experts from a section of the World Bank developed the Industrial Pollution Projection System (IPPS). IPPS was developed to explore environmental pollution based on industrial activities, sectoral composition, and type of process technology used in production. IPPS converts available industrial activities such as production output and employment data in combination with pollution emissions, human toxic, and eco-toxic factors to determine pollution intensity (Odesanya *et al.,* 2012). The

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IPPS tool helps researchers to understand the levels of pollution in various industrial areas in developing countries, and issue policy advice with more clarity (Aguayo *et al.,* 2001; Oketola & Osibanjo, 2007; Odesanya *et al.,* 2012). The IPPS pollution load which is pollution per unit of number of employee or pollution per unit of production output (Dasgupta *et al.,* 2000), is site specific and Trans-Amadi Industrial Layout in Port Harcourt is one of the progressively developing industrial areas due to the presence of several manufacturing industries. The aim of this study, therefore, is to estimate the pollution load of air pollutants using the IPPS tool to generate reliable and comprehensive environmental data on the air pollutants generated around selected industries within the Trans-Amadi Industrial layout of Port Harcourt.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

Port Harcourt is a city in the southern Nigeria coastal zone and the capital of Rivers State. Trans-Amadi Industrial Layout in Port Harcourt has a geographical span that lies between latitude 4.83^{0}N and 7.04^{0}E longitude of the rainforest tropics with an area of 2,500 acres (Anonymous, 2018). The target population of the study area is comprised of 50,000 people inclusive of visitors and the inhabitants of the area. Trans-Amadi is surrounded by 9 communities bordered by D/Line in the Southwest, Woji Township in the East and Rumuola to the Northwest as shown in Figure 1. Neighbouring communities affected the most by industrial activities are Oginigba, Elekahia, Azuabie, and Nkpogu. These communities are the most exposed to various health risks associated with toxic chemical inhalation, black carbon soot, polluted water, land, and air (Berewari & Obiechina, 2019). The study area has a bimodal climate made up of dry and wet seasons. Normally moisture-laden due to the high annual rainfall, the region produces surface runoff. Rivers State falls within the lowland rainforest with an ecological expanse that is characterized by 2500mm of mean annual rainfall; and with 27.5^{o}C of mean daily minimum temperature, and a mean daily maximum temperature of 31.5^{o}C (Chinago, 2020; Ayotamuno *et al.,* 2006).

2.2 Data Collection and Analysis

The major industries in the study area were categorized as follows; Food, Beverage and Tobacco (FBT), Motor Vehicles and Miscellenous (MVM), Chemical and Chemical allied Products (CCP)/Paint Industries, Electric and Electronics Sector (EES), Basic Metals Sector (BMS), Food and Manufacturing Industry (FMI), and Other Industries ("Others"). The categorization of the major industries was based on the International Standard Industrial Classification (ISIC) code as documented by Etim (2012). Number of employees and unit production output for the selected industries within the Trans-Amadi Industrial Layout and its neighbouring surroundings were used to estimate air pollution load. These data were obtained from the Manufacturer's Association of Nigeria (MAN), a few industries and other relevant government agencies.

2.3 Criteria Air pollutants and Air Pollution Load Estimation

The IPPS tool for the determination of air pollution intensity and polllution load was based on the six USEPA's criteria pollutants namely; CO, FPM, NO_2, SO_2, TSP, and VOCs. Air pollution loads in the study area were estimated based on economic parameters including number of employees and product unit output as presented by Hettige *et al.,* (1994) in Equations 1 and 2 respectively.

$$PL = \frac{1}{2204.6\times1000}(PI \times TEM) \quad (1)$$

$$PL = \frac{1}{2204.6}(PIF \times Unit\ of\ output) \quad (2)$$

Where PL is the pollution load of specific pollutants in tons/yr. PI is pollution intensity of

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the lower band per thousand employees in that sector, TEM is total number of employees in that sector while PIF is pollution intensity factor of that sector and 2204.6 is conversion factor from pounds to tonnes.

2.4 Emission Standards for Industries

Industrial emission standards are critical in air quality strategy. These standards are governmentally promulgated to tackle the environmental impacts of harmful emissions from industrial plants by setting baseline requirements for acceptable concentrations of pollutants within the exhaust gases emitted by a facility, and within ambient air at the site (Stern, 2003). The WHO and the European Union (EU) maximum allowable limits and USEPA air quality rating were used. Table 1 shows the WHO and EU air quality guidelines while Table 2 describes the rating of these air pollutants. These standards were used to compare and describe the results of this study.

Table 1: WHO and EU Air Quality Guidelines

Pollutant	Averaging time	WHO 2005	EU
$PM_{2.5}$	Annual	10	25
($\mu g/m^3$)	Daily	25	-
PM_{10}	Annual	20	40
($\mu g/m^3$)	Daily	50	50
NO_2	Annual	40	40
($\mu g/m^3$)	Daily	-	-
SO_2 *($\mu g/m^3$)*	Daily	20	125
CO (mg/m^3)	8hours	-	10
TSP	Annual	-	-
($\mu g/m^3$)	Daily	-	150

Source:(European Commission, n.d; WHO, 2021). n.d means not dated.

3 RESULTS AND DISCUSSION

3.1 Effect of Number of Employees and Production Output on Air Pollution Intensity

The intensity of emission of the six criteria air pollutants into the air environment of the study area by the various industrial sectors activities are presented in Table 3. It was observed that the pollution intensities (PIs) of SO_2, NO_2, CO, and VOC for all the investigated industrial sectors exceeded the limits as recommended by WHO and EU while PIs of FPM and TSP for all industrial sectors were below the recommended limit except for PI of FPM for CCP/Paints and PI of TSP for EES and FMI. Consequently, the air quality index rating for all criteria pollutants except FPM was rated very poor. FPM showed an air quality index rating of very good for all industrial sectors except CCP/Paints that showed moderate rating. This is consistent with the non-hazy, clear visibility of the industrial layout. Table 3 also displays the number of employees and production output for the various industrial sectors with ranking orders as:$FBT > MVM > FMI > BMS > EES > Others > CCP/Paints$

Table 2: Air Quality Index (AQI) and Rating for Priority Pollutants

Class of AQI	Very good	Good	Moderate	Poor	Very poor
AQI Rating	A	B	C	D	E
FPM *($\mu g/m^3$)*	0-50	51-71	72-100	101-150	*>150*
CO (ppm)	0-2	2.1-4.0	4.1-6.0	6.1-9.0	*>9.0*
NO_2 (ppm)	0-0.002	0.02-0.03	0.03-0.04	0.04-0.06	*>0.06*
SO_2 (ppm)	0-0.002	0.02-0.03	0.03-0.04	0.04-0.06	*>0.06*
VOC (ppm)	0-0.3	0.3-1.0	1.0-3.0	3.0-10.0	*>10*

***Source**: (USEPA, 2000; Abam & Unachukwu, 2009)*

and $Others > FBT > MVM > FMI > CCP/Paints > BMS > EES$ respectively. The variation in the ranking order between the number of employees and production output indicates that both parameters were not strongly linearly correlated. This was validated by the correlation value of $r = 0.42$ as shown in Table 4. FBT with the highest number of employees was the only sector with several employees over a thousand and gave the highest PIs for SO_2 and NO_2, while BMS with 105 employees gave the highest PIs for CO. EES with less than 100 employees gave the highest PI for TSP while CCP/Paints with the least number of employees (61) gave the highest PI for VOC and FPM. As displayed in Table 4, the number of employees had strong linear correlations with PIs of SO_2 ($r = 0.98$) and NO_2 ($r = 0.87$) like the work of Etim (2012) whereby the sector with the highest number of employees released the highest SO_2 and NO_2. Pollution intensities of FPM and VOC did not show a strong linear correlation with the number of employees nor output production while that of CO and TSP were strongly inversely correlated with output production by -0.74 and -0.78 respectively. This suggests that the emission of CO and TSP decreased with increased production output and was attributed to the use of improved technology in line with the technical effect of the Inverted U-Shaped relationship between economic growth and environmental degradation (Kuznet, 1995).

3.2 Estimation of Pollution Load with Respect to Number of Employees and Production Output of Industrial Sectors

Air pollution load, which is the amount of stress placed on the air environment by the released air pollutants, was determined based on the number of employees and production output as expressed in Equations 1 and 2. Results of pollution load based on number of employees (Table 5) of the various sectors showed that the FBT sector exerted the most stress on the air environment with 94%, 90%, and 56% pollution loads of SO_2, NO_2, and TSP respectively and this is similar to the work of Alfaro-Alfaro *et al.,* (2021). FBT was sequentially followed by the MVM, BMS, and CCP/Paint sectors exerting 42% of VOC, 36% of CO, and 32% of FPM respectively on the air environment. The 'Others' sector exerted the least stress on the air environment (Figure 2). Results of air pollution load for the criteria air pollutants as exerted by various industrial sectors based on production output are shown in Table 6. The MVM sector with a production output of 1,800 tons/yr. and a total pollution intensity factor of 11,461ppm (Table 6) was observed to exert the most stress on the air environment with 84%, 82%, 63%, and 45% pollution loads of CO, FPM, NO_2, and VOC respectively (Figure 3). As expected, the BMS and MVM sectors associated with metal manufacturing and processing impacted the most load of CO on the air environment based on employment and production output respectively. The 'Others' sector with a production output of 3,200 tons/yr. impacted the air environment with 65% of the SO_2 pollution load, while three sectors including FMI, MVM, and 'Others' cumulatively contributed 82% of the pollution load exerted by TSP with FMI contributing 31% as the highest contributor. The highest pollution load of TSP based on the number of employee and production output (56% and 31% respectively) for FBT and FMI sectors was attributed to high temperature around steam boilers and the use of high organic matter.

There was no available data for the production output for the EES sector, so the pollution loads of this sector could not be determined. Figures 2 and 3 showed that the sectors with the highest single pollution loads based on number of employees and production output were FBT and MVM respectively, which conforms with the works of Odesanya *et al.* (2012) and Oketola & Osibanjo (2009). However, the sectors with the least pollution load based on number of employees and production output were 'Others and CCP/Paints respectively. The impact of the various industries on the air environment could be attributed to the scale effect of the Inverted U-Shaped Environmental Kuznet Curve (EKC) hypothesis (Kuznet, 1995).

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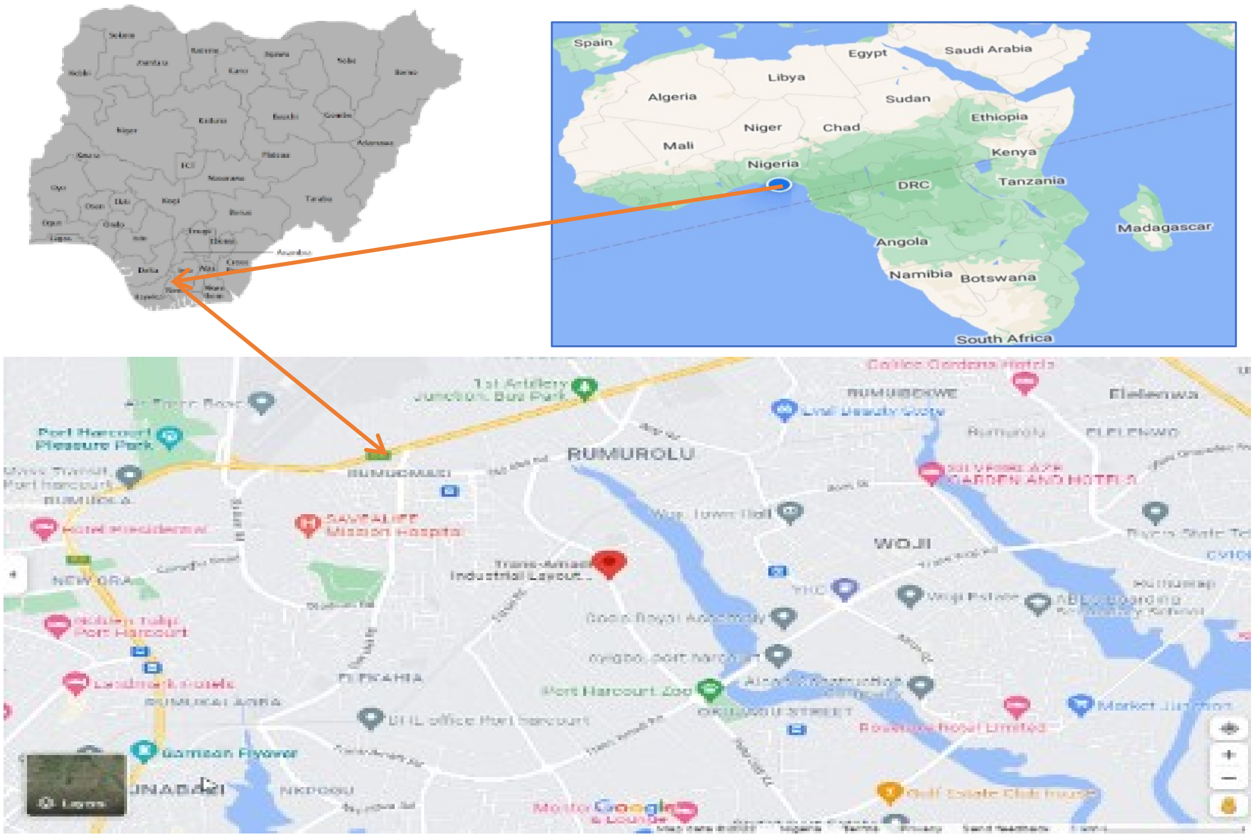

Fig. 1: Google Map (2022) showing Trans-Amadi Industrial, Port-Harcourt, Nigeria

Table 3: Pollution Intensity from Different Industrial Sectors

Industri Sector	No. of Employe es	Producti on output (tons/yr)	PI SO_2 (ppm)	PI NO_2 (ppm)	PI CO (ppm)	PI VOC (ppm)	PI FPM ($\mu g/m^3$)	PI TSP ($\mu g/m^3$)
BMS	105	230	161	362	1850	186	7	129
CCP/Paints	61	800	246	217	31	1819	74	146
EES	95	N/A	391	846	1772	412	11	306
FBT	1157	2,500	2146	1690	105	176	3	118
FMI	113	1200	132	439	94	132	12	196
MVM	230	1,800	279	141	189	1298	12	140
Others	70	3,200	29	14	11	408	0	7

Note: PI SO_2 - Pollution intensity Sulphur dioxide, PI NO_2 - Pollution intensity Nitrogen dioxide, Pollution intensity CO, Carbon monoxide, Pollution intensity VOC - Volatile organic carbon, Pollution intensity FPM - Fine particulate matter, Pollution intensity TSP - Total suspended particles, N/A - Not Available

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Table 4: Correlation Between Criteria Air Pollution Intensity and Total Number of Employees

	TEM	Unit output	**SO_2**	**NO_2**	**CO**	VOC	FPM	TSP
TEM	1							
Unit output	0.423	1						
SO_2	0.984	0.314	1					
NO_2	0.869	0.037	0.924	1				
CO	-0.257	-0.742	-0.178	0.094	1			
VOC	-0.281	-0.090	-0.250	-0.435	-0.346	1		
FPM	-0.282	-0.338	-0.198	-0.261	-0.235	0.819	1	
TSP	-0.137	-0.782	-0.023	0.291	0.526	-0.036	0.127	1

TEM: total number of employees

Table 5: Air Pollution Load by Selected Industrial Sectors based on Number of Employees

Industry	**SO_2 (ppm)**	**NO_2 (ppm)**	**CO (ppm)**	**VOC (ppm)**	**FPM (ppm)**	**TSP (ppm)**
FBT	1.126246	0.886932	0.055105	0.092367	0.001574	0.061928
FMI	0.006766	0.022502	0.004818	0.006766	0.000615	0.010046
CCP/Paints	0.006807	0.006004	0.000858	0.050331	0.002048	0.00404
MVM	0.029107	0.01471	0.019718	0.135417	0.001252	0.014606
EES	0.016849	0.036456	0.07635	0.017754	0.000474	0.013186
Other Industries	0.000921	0.000445	0.000349	0.012955	0.000011	0.000222
BMS	0.007668	0.017241	0.088111	0.008859	0.000333	0.006144

Note: Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Volatile organic carbon (VOC), Fine particulate matter (FPM), Total suspended particles (TSP)

Table 6: Air Pollution Load by Selected Industrial Sectors based on Total Output

Industrial Sectors	Total output (tons/yr)	Air Pollutants (ppm)					
		SO_2	NO_2	CO	VOC	FPM	TSP
FBT	2,500	370	220	30.4	830	300	105
FMI	1,200	650	410	365	210	360	450
CCP/Paints	800	123	67.8	42.1	27.4	12.1	4.68
MVM	1,800	2,300	1450	2,860	1200	3,410	241
EES	NA	NA	NA	NA	NA	NA	NA
BMS	230	1,890	87	120	141	340	175
Others	3,20	3,650	127	125	72	11.5	140

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The EKC hypothesis explains that the effect of economics on environmental pollution undergoes three phases as influenced by scale, composition, and technical effects. The scale effect often occurs at the start of economic growth and is associated with the increase in demand for the conversion of natural resources into production processes that fuel economic growth. This results in the generation of industrial waste in solid, liquid and/or gaseous forms that could harm the environmental quality. Implying that, as the number of employees and production output as parameters of economic growth increase, it is accompanied by an increase in environmental degradation. However, with the technical effect, economic growth does not necessarily translate into environmental degradation. This is because improved technologies for increased production output and environmental sustainability are employed, and the technical effect is often at an advanced stage of the economic growth of the industries.

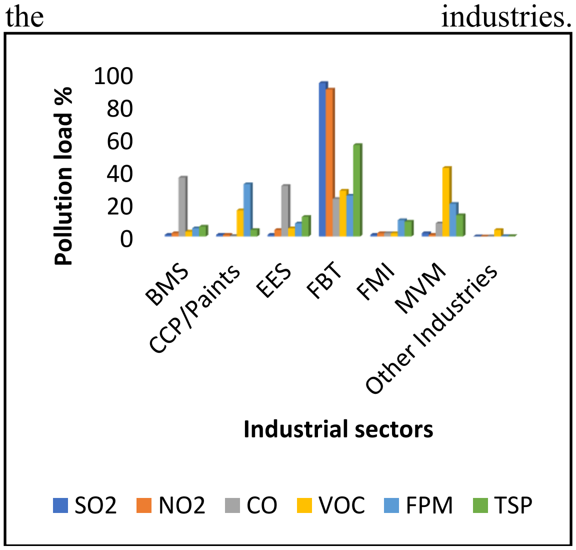

Figure 2: Air Pollution Load of Six Criteria Pollutants Based on Number of Employees by Various Industrial Sector

SO_2, NO_2, and VOCs are essential raw materials in the FBT sector. SO_2, is widely used as a preservative and antioxidant (Grogan, 2015; Pelonnier-Magimel *et al.,* 2020), NO_2 is commonly used as organic solvents while VOCs are used in tobacco extraction and decaffeination of tea leaves and coffee. According to Ezeh *et al.,* (2020) the largest sources of SO_2 in the atmosphere as released by the FBT sector are burning of fossil fuel for transportation, electricity generation and steam boilers in food processing. Burning of fossil fuel for process equipment and electricity generation also releases primary FPM that reacts with the oxides of sulphur and nitrogen, ammonia, and VOCs to form secondary particulate matter (SPM). SPM is also classified as FPM but is referred to as SPM because these fine particles contain secondarily formed aerosols (gas to particle conversion), combustion particles and recondensed organic and metal vapours. The strong direct linear correlations between SO_2 and NO_2 (0.92) and between FPM and VOC (0.82) as shown in Table 4 suggests that the emission of both pairs of pollutants by the FBT sector could be.

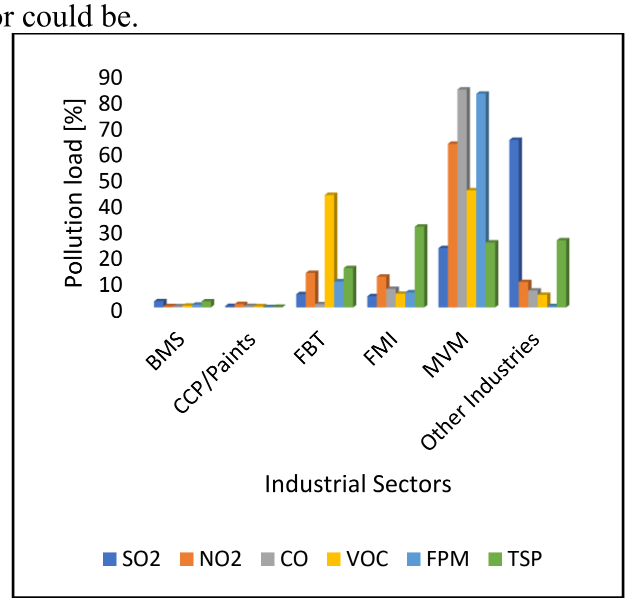

Figure 3: Air Pollution Load Of Six Criteria Pollutants Based on Production Output by Various Industrial Sector

influenced by similar industrial activities. Aside from the FBT sector, other sectors

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associated with the emission of VOCs are CCP/Paints and MVM. VOCs are essential components of paints and paint manufacturing. It was therefore expected that the CCP/Paints sector would contribute largely to the VOC pollution load. On the contrary, the CCP/Paint sector only contributed 16% and 0.46% pollution load based on number of employees and production output respectively. The highest pollution load of VOC was impacted by the MVM sector with 42% based on number of employees and 45% based on production output. This sector was followed by the FBT sector with 28% on employment and 43% on production output which explained that the production of paints does not emit VOC as much as the use of paints in the car manufacturing process. According to Kim (2011), in the automotive industry, most of the emitted VOCs come from spraying metals and plastics for aesthetics and protection purposes making the painting operation almost inevitable. This is supported by the fact that, for the MVM sector, VOC pollution load based on production output was higher than the number of employees. Again, comparing the pollution load of VOC between FBT and CCP/Paints sectors, the higher pollution loads of VOC by the FBT explains that VOC pollution load in the air is not just influenced by its use but also how it is used.

3.3 Toxic Metal in Air Pollution Load Distribution with respect to number of employees and output

Aside from the six criteria pollutants of the air environment, certain metals have been labelled toxic. Pollution intensities of these metals as a cumulative figure for the various sectors and the pollution loads based on number of employees and production output are presented in Table 7. The pollution load percentages for number of employees and production output of these toxic metals were also estimated as displayed in Figures 4 and 5. The selected metal used in the estimation of toxic metals in air pollution load distribution include aluminum (Al), vanadium (V), zinc (Zn), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and Nickel (Ni) for the selected industrial sectors. As shown in Table 3 and Figure 4, the EES sector, with a total of 95 employees gave the highest pollution load of 0.000533 resulting in a 34% pollution stress of toxic metal on the air environment. Food-related industries gave the least pollution load as FBT and FMI showed 3% and 0% respectively. The pollution load of toxic metals concerning total production output had a ranking order as: $Others > CCP/Paints > MVM > BMS > FBT > FMI$. The 'Others' industrial sector with the highest output of 3,200 tons/yr gave 62% while food-related industries sectors gave the least.

Table 7: Air Pollution intensity and load of Toxic Metals by Various Industrial Sectors

Industrial sector	PI	PL_E	PL_O
BMS	2.84	0.000135	0.2963
CCP/Paints	13.76	0.000381	4.9932
EES	12.36	0.000533	N/A
FBT	0.08	0.000042	0.09072
FMI	0	0	0
MVM	1.94	0.000202	1.5840
Other industries	7.7	0.000244	11.1766

PL_E-pollution load due to number of employees; PL_O- pollution load due to output.

The results of the pollution load of the FBT and FMI are consistent with the fact that food and food-related industries should not be associated with heavy metals. The FBT with 3% and 0.5% pollution loads due to number of employees and output were attributed to tobacco manufacturing and not necessarily the food industries. Eneji *et al.,* (2013) and Ziarati

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et al., (2017) reported. that selected cigarettes contained some levels of Cadmium, Chromium and Lead.

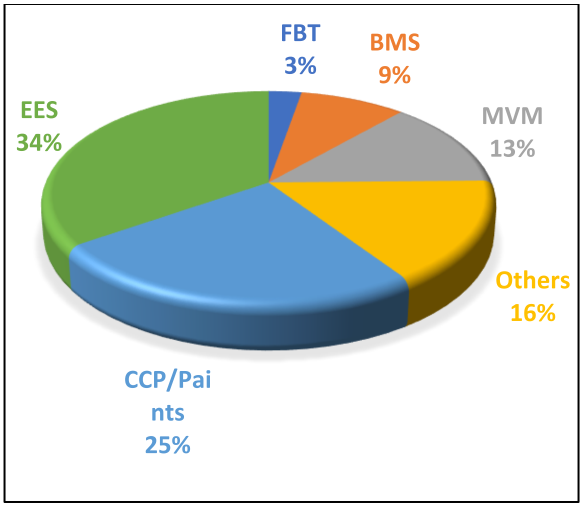

Figure 4: Percentage Contributions of Toxic Metals to Air Pollution by Selected Industrial due to number of employees.

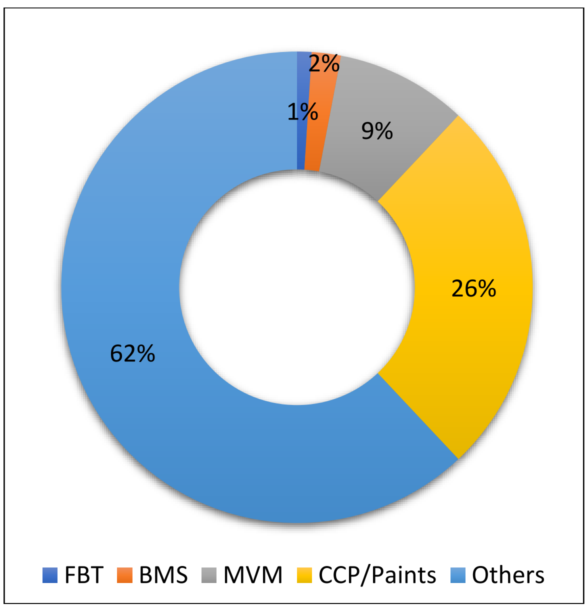

Figure 5: Percentage contributions of Toxic Metal Pollution Load by Various Industrial Selectors due to Output

The source of these heavy metals was attributed to easy uptake from soil by tobacco plants and stored in the leaves. The authors also pointed out that the contents of these heavy metals were within safe limits of human consumption by plant uptake. CCP/Paints and 'Others' sectors with a total production output of 0.004237 tons/yr and 0.002625 tons/yr exerted a pollution stress load of 25% and 16% respectively. This is attributed to the use of several chemicals and/or a combination of several chemicals leading to the release of heavy metals into the air.

4.0 CONCLUSION

This study estimated the pollution load of criteria air pollutants by selected industries in the Trans-Amadi Industrial Layout of Port Harcourt using an industrial pollution projection system (IPPS). In most cases, there was no direct correlation between the pollution intensity of a single criteria pollutant and number of employees or production output. The pollution load of any single criteria pollutant was dependent on industry sector activities including type of raw materials used, processes of operations, and high fossil fuel usage for energy generation and unit operations. Based on the number of employees, the Food, Beverage, and Tobacco (FBT) sector exerted the most pollution load while the 'Others' sector gave the least pollution load.

On the other hand, based on output, the Motor Vehicle and Miscellaneous (MVM) and the Chemical and Chemical allied Product/Paint (CCP/Paints) sectors exerted the highest and least pollution loads respectively. The Electrical and Electronic sector (EES) and the 'Others' sector exerted the highest toxic metal pollution load based on the number of employees and output respectively. The Food Manufacturing industry (FMI) sector did not release any toxic metals and so did not exert any pollution load based on toxic metals, an indication that the food manufacturing industry sector is void of the use of toxic metal in their production process which is consistent with food safety and handling. Overall, the use of sustainable raw materials, processes, and green energy must be encouraged to reduce industrial air pollution.

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