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Estimation of pollution load from an industrial estate, south-western Nigeria

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The Ota industrial estate being one of the largest in the southwestern Nigerian, contributes significantly to its socio-economic development. This study is design to generate the much needed industrial emission data for efficient environmental monitoring and compliance. The industrial pollution projection survey (IPPS) and rapid pollution inventory survey (RPIS) models developed by the World Bank were used for the estimation of pollution loads. The results showed that a total of 6970 tons/yr of air pollutants (SO₂, NO₂, CO, VOC and PM), 10800 tons/yr of wastewater pollutants (BOD and TSS) and 1090 tons/yr of toxic pollution (air, land and water) were released into the environment from the industrial estate. Carbon monoxide accounted for the highest air pollution load representing 57.5%. About 64.0% of the total pollution load of the industrial estate was contributed by industries in the basic metal, iron, steel and fabricated metal works sector. There is need for industrial emission monitoring and enforcement for pollution control and abatement. Similarly, efficient and environmentally friendly waste management practices should be adopted within the confines of this all-important industrial estate.

Key words: Industrial pollution projection survey (IPPS), rapid pollution inventory survey (RPIS), models, industrial estate, industrial emission, carbon monoxide.

INTRODUCTION

Industrial pollution is fast becoming a major problem in many developing countries. The extensiveness of these problems is colossal to the economies. This is attributed to the absence of reliable and comprehensive system of monitoring of environmental data on industrial emissions, and secondly to inadequate resources. The enforcement of compliance on industrial emissions with relevant regulatory standards is therefore seen as ineffective. Recent advances, are been channelled on cheaper and reliable ways of generating environmental data on industrial emissions. Models are now gaining wide applications in this area (Chou-Ping et al., 2010). Although various models are currently in use, the industrial pollution projection survey (IPPS) model developed by the World Bank (Hettige et al., 1995) has gain considerably wide application. IPPS operates through sector estimates of pollution intensity (usually defined as pollution per unit of output and pollution per unit of employment). It exploits the fact that industrial pollution is heavily affected by the scale of industrial activity, technological application and its sectoral

composition. Results from IPPS model have been used in various developing countries where insufficient data on industrial pollution proved to be an impediment to setting up pollution control strategies and prioritization of activities. IPPS have been successfully applied for industrial pollution studies in the five largest economies of the western hemisphere (Kenneth and Roland-Holst, 2001; Tsigas et al., 2001), United Kingdom (Smith and Espinosa, 1996), Mexico (Beghin et al., 1995), Indonesia and Japan (Strutt and Kym, 2000; Lee and Roland-Holst, 1997), Uruguay (Ferrantino and Linkins, 1999), Vietnam (World Bank, 1996), Latvia (World Bank, 1993) and Ivory Coast in Africa (Economopoulos, 1979).

Nigeria, being the most populous nation in Africa is witnessing rapid industrial development mostly along its coastal cities. Ogun state is one of such industrialized states in the southwest Nigeria with Ota as its largest industrial city. Ota, the major and central town of Ado Ota Local Government of Ogun State (latitude 6° 32' N, longitude 2° 57' E) is a complex setting consisting of many industrial facilities, one of which is the Ota

Table 1. Classifications of industries.

ISIC	Classification	Sector codes	Number of industries
3121	Food, beverage and tobacco	FBT	2
3819	Basic metal, iron, steel and fabricated metal works	BMISFMW	11
3529	Chemical and paint	CP	4
3823	Wood processing and printing	WPP	5
3513	Domestic and industrial plastics	DIP	4
3829	Vehicles and mechanical works	VMW	1

industrial/housing estate. The estate covers approximately 22.8 km² of land mass. There are different industrial processing plants such as chemical, pharmaceutical, plastics, paper and printing, and metal and steel industries located in close proximity to residential buildings. There are thirty nine industrial sites within the estate, twenty seven of which are currently active while twelve are dormant. The nature of raw materials used by these industries poses great hazard to human health and the environment. Emissions from stacks, effluent discharge and open burning of solid waste are common practices within the estate, and considered environmentally unfriendly. Also the presence of industrial facilities in close proximity to residential houses and the lack of effective environmental data on industrial pollution monitoring give cause for concern. This lack of information makes difficult the identification of priorities of actions, and the implementation of cost-effective intervention. The study therefore aims at generating reliable and comprehensive environmental data on the different industrial pollutants generated within the confines of the estate using IPPS model. The results of the IPPS model will be compared with data for the RIPS model to establish any form of relationship.

MATERIALS AND METHODS

Data collection and inventory

Data for the estimation of pollution loads contributed by each of the 27 active industries were obtained from the companies' employees and management, and the Ogun State Ministry of Environment through personal meetings and questionnaires (World Bank, 1996). These data included; name of industry, number of employee, raw materials, products and annual production output. From these data, the various industries were classified into six sectoral groups according to the international standard industrial classification (ISIC) system (Table 1).

Pollution load estimation by modeling

The IPPS and RPIS models developed by the World Bank (Hettige et al., 1995; Economopoulos, 1979) were used to estimate total industrial air pollution load, wastewater pollution load, toxic and toxic metal pollution load from the Ota industrial/housing estate. Each classification contains a set of conventional pollution parameters. The total air pollution load contains; sulphur dioxide

(SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), volatile organic carbon (VOC) and particulate matter (PM). Industrial wastewater pollution loads contains; biochemical oxygen demand (BOD) and total suspended solids (TSS). Industrial toxic and toxic metal pollution loads relates to air, land and water components.

The IPPS modeling system operates through sector estimates of pollution intensity per unit of employment. Employment data from industries were combined with data on the lower bound pollution intensity coefficient to calculate pollution loads in tons/yr as given in the equation.

$$\text{Pollution loads (tons/yr)} = P_c \times N/C_r \quad \text{----- (1)}$$

Where P_c is pollution intensity coefficient per parameter (pounds/1000 employees per year), N is the number of employees and C_r is the conversion factor of pound to tons (2204.6).

In RPIS modeling system, pollution waste factor of all the major polluting industrial activities were multiplied with each corresponding production output to give the pollution loads in tons/yr.

RESULTS AND DISCUSSION

Industrial air pollution load estimation

Industrial air emissions consist of various environmentally unfriendly pollutants released into the atmosphere during primary and secondary production processes. Table 2 shows estimated total industrial air pollution load using IPPS model. The total air pollution load of the industrial estate was estimated at 6966.87 tons per year. Carbon monoxide accounted for the highest load of 4008.20 tons/yr representing 57.5% of the total load. The total emission load estimate of SO₂ (19.6%), NO₂ (12.7%) and VOC (10.2%) were very similar. Total particulate matter emission was insignificant representing only 0.05% of the total air emissions load of the estate. The Basic metal, iron, steel and fabricated metal works (BMISFMW) and Chemical and paint (CP) sectoral groups emit the highest amount of the total air pollution load of the estate. The scale of industrial activities and employment strength of these two sectors explains these high emissions load. The Domestic and industrial plastics (DIP) sector is by the nature of its raw material (chemical-based) the third largest generator of air pollutants within the estate, but the fourth in terms of employment strength. The Wood processing and printing (WPP) sector does not generate much air pollutants due largely to the nature of its

Table 2. Estimated total industrial air pollution loads using IPPS model.

Sector code	No. of industries		No. of employee		SO ₂		NO ₂		CO		VOC		PM		Total	
	No.	%	No.	%	Tons/yr	%	Tons/yr	%	Tons/yr	%	Tons/yr	%	Tons/yr	%	Tons/yr	%
FBT	2	7.4	83	2.6	3.57	0.3	3.63	0.4	0.77	<0.01	1.09	0.2	0.00		9.06	0.13
BMISFMW	11	40.7	1716	52.8	976	71.5	437.98	49.7	1600.86	39.9	206.85	29.2	2.67	81.4	3224.36	46.3
CP	4	14.8	744	22.9	246.64	18.1	81.53	9.3	2344.24	58.5	224.85	31.7	0.61	18.6	2897.87	41.6
WPP	5	18.5	474	14.6	0.62	<0.01	0.44	<0.01	9.22	<0.01	14.12	1.99	-	-	24.40	0.3
DIP	4	14.8	222	6.8	137.7	10	357.9	40.6	52.96	1.3	262	37	0.00	-	810.56	11.6
VMW	1	3.7	8	0.2	0.18	<0.01	0.07	<0.01	0.15	<0.01	0.22	<0.01	0.00	-	0.62	<0.01
TOTAL	27		3247		1364.71	19.6	881.55	12.7	4008.20	57.5	709.13	10.2	3.28	0.05	6966.87	-

Table 3. Comparison of IPPS and RPIS results (tons/yr) for calculated total air pollution loads.

Parameter	BMISFMW		DIP	
	IPPS	RPIS	IPPS	RPIS
SO ₂	970.61	658.56	46.5	0.00
NO ₂	287.26	900.66	120.9	0.00
CO	1539.0	247.5	17.86	0.00
VOCs	154.74	57.08	88.5	1.40
PM	2.67	2390.2	0.00	11.85
Total	2954.28	4254	273.76	13.25

processing technology. It has the third largest work force and contributes about the least total air pollution load of the estate. The BMISFMW sector recorded the highest load of SO₂, NO₂ and PM while CP sector generated the highest load of CO. Comparison of IPPS and RPIS results for total air pollution load is showed in Table 3. In BMISFMW sector, IPPS estimated 2954.28 tons/yr and RPIS estimated 4254 tons/yr of total air pollution load. The differential for these sectors was 18.0% which is incomparable to the 90.8% for the DIP sector in which IPPS recorded a total of 273.76 tons/yr as

against 13.25 tons/yr load for RPIS. The RPIS model estimated a higher PM load than IPPS, but had values of SO₂, CO and VOC lower than IPPS for the BMISFMW sector. The RPIS model estimation for DIP sector had all five pollutants lower than IPPS. Parametric t-test at 95% confidence limit showed no significant difference in total air pollution load for the BMISFMW sector, while the DIP sector showed significant difference. Generally, these pollutants are major respiratory disease initiators in humans. The synergetic effects of these pollutants will be very complex in

symptoms which could range from brain damage, respiratory disorder, headache, birth defect, fatigue and even death (Ferrantino and Linkins, 1999). SO₂ and NO₂ are known precursor of acid rain, NO₂ suppresses plant growth and damages leaf tissues, while particulates reduce visibility.

Industrial wastewater pollution load

Table 4 shows estimated total wastewater pollution loads using IPPS model. The total

Table 4. Estimated total industrial wastewater pollution loads using IPPS model.

Sector code	No. of industries		No. of employee		BOD		TSS		Total	
	No.	%	No.	%	Tons/yr	%	Tons/yr	%	Tons/yr	%
FBT	2	7.4	83	2.6	0.02	0.2	0.01	<0.01	0.03	<0.01
BMISFMW	11	40.7	1716	52.8	2.06	25.3	10588.4	98.4	10590.46	98.4
CP	4	14.8	744	22.9	0.39	4.8	149.45	1.4	149.84	1.4
WPP	5	18.5	474	14.6	0.04	0.5	1.43	<0.01	1.47	<0.01
DIP	4	14.8	222	6.8	5.63	69.2	18.18	0.2	23.81	0.2
VMW	1	3.7	8	0.2	0.00	0	0.01	<0.01	0.01	<0.01
	27		3247		8.14		10757.48		10765.62	

Table 5. Comparison of IPPS and RPIS results (tons/yr) for calculated wastewater pollution loads.

Parameter	BMISFMW		DIP	
	IPPS	RPIS	IPPS	RPIS
BOD	0.89	0.00	1.90	92.24
TSS	10554.65	357.74	6.14	53.9
Oil and grease	-	60.39	-	-
Nitrogen	-	-	-	-
Phosphate	-	3.08	-	-
Iron	-	29.3	-	-
Zinc	-	1.079	-	-
Chromium	-	2.315	-	-

wastewater pollution load was estimated at 10765.62 tons/yr, of which TSS and BOD represents 99.9 and 0.08% respectively. This relatively high TSS load in wastewater from the estate may impact negatively on the receiving surface water body by increase sedimentation on the water channel. The BMISFMW sector accounted for the highest TSS load of 98.4% with less than 1.63% coming from the other five sectors. The presence of fine particulates in wastewater arises from the various complex industrial processes of metals and steel products. The release of plasticizing agents, dyeing chemicals and resins from the CP sector may account for the about 1.39% TSS load from this sector. The nature of raw material, which are mainly organic in nature used by the DIP sector may account for high BOD in its wastewater representing 69.2% of the total load. The BMISFMW sector follows with 25.3% and CP with 4.79%. The high number of industries and employee's strength of the BMISFMW sector reflects to an extent the high load of wastewater pollution from this sector. Comparatively, there was significant difference in the BOD and TSS loads estimated by IPPS and RPIS models (Table 5). RPIS accounted for the least TSS loads. The RPIS model accounts for oil, phosphate and Cr which are pollutants in surface water bodies. The annual tonnage of 60.39 ton/yr of oil, Cr load of 2.315 ton/yr may significantly alter the natural eco-system of the Ota industrial estate.

Industrial toxic and toxic metal pollution load

Industrial waste toxins can be broadly grouped into toxic chemicals and toxic metals. The toxic chemicals are synthetic organic compounds such as organochlorine compounds, organophosphates and complex inorganic compounds, while Pb, Cd, Hg, As, Se, Cr, Bi, Pt, Ni and many other metallic elements are the toxic metals prevalent in industrial waste. The persistence and bio-accumulative tendency of these substances, their metabolite and residues in the environment (air, land and water) endangers the environmental ecosystem and human health. Some or all of these toxic chemicals and toxic metal compounds are either used in primary production processes or as by-products from industrial processes. Table 6 shows the estimated total industrial toxic and toxic metal pollution (tons/yr) using the IPPS model. The toxic pollution load of the environmental media (air, land and water) was estimated at 1090.55tons/yr. The highest contributors were the BMISFMW, DIP and CP sectors with 47.3, 26.4 and 25.4% respectively. The distribution ratio of this toxic pollution load to air, land and water was 4:6:3. These toxic chemicals are often non-biodegradable; their accumulation in soils is more extensive than in air and water which explains the high load on land. Their presence in the atmosphere may be explained by

Table 6. Estimated total industrial toxic and toxic metal pollution (tons/yr) using IPPS model.

Sector code	No. of industries	No. of employee	Toxic pollution				Toxic metal pollution			
			Air	Land	Water	Total	Air	Land	Water	Total
FBT	2	83	0.41	0.72	0.03	1.16	0.00	0.00	0.00	0.00
BMISFMW	11	1716	114.35	380.01	21.01	515.37	9.66	1.55	1.55	12.76
CP	4	744	132.29	141.13	3.10	276.52	0.35	0.15	0.15	0.65
WPP	5	474	5.83	3.72	0.03	9.58	0.02	0.13	0.13	0.28
DIP	4	222	151.2	125.4	11.06	287.66	0.03	6.53	0.14	6.70
VMW	1	8	0.17	0.08	0.01	0.26	0.00	0.04	0.00	0.04
	27	3247	404.25	651.06	35.24	1090.55	10.06	8.40	1.97	20.43

volatilization of organic and inorganic compounds at high operational temperature during manufacturing process. Once emitted into the atmosphere, the pollutants get dispersed and travel great distances while some settles on land, vegetation and water bodies.

The total toxic metal pollution load was estimated at 20.43tons/yr in the ratio of 5:4:1 in air, land and water (Table 6). The highest contributor to this toxic metal pollution load was the BMISFMW sector, followed by DIP and CP with 62.5, 32.8 and 3.18% respectively. This trend is similar to that obtained for the estimated total toxic chemical pollution load. The atmosphere and soil (land) is the major sink for toxic metals. The BMISFMW sector releases the highest amounts of toxic metals through the gaseous emissions as observe for the total air pollution load in Table 2. Refining of Pig and Wrought Iron from the BMISFMW sector explains the high toxic pollution and toxic metal pollution load. High operational temperatures release large quantity of toxic chemical and metals into the atmosphere with sludge and slag which are by-product of this process on land. DIP sector was the second largest contributor of toxic chemical pollution and toxic metal pollution into the Ota industrial estate environment. This status was justified by the nature of raw materials used in plastic and rubber production. Raw material such as pigment, plastics, biocides are known to contain toxic chemicals and metals, while vanishes, lacquers, paint pigment, alkyd resins from the CP sector are equally responsible for the toxic organic chemical and metals in the environment. Toxic chemical pollutions were greater for BMISFMW, DIP and CP sectors than their corresponding toxic metal pollutions. The RPIS model estimates the solid waste load for the BMISFMW sector to be 10889.4tons/yr with hazardous solid waste having 9004.8tons/yr and hazardous sludge 1884.6tons/yr. This further establishes the fact that the refining of pig and wrought iron from the BMISFMW sector produces sludge which is hazardous by-product, and therefore, its disposal on land contributes toxic pollution and toxic metal pollution load to soil.

In summary, the environment shows evidence of likely pollution arising from industrial activities within the estate.

The BMISFMW sector is the major source of the environmental pollutants. There is need for further studies to evaluate the relationship between these modelled data and experimental data. This will further give great insight into the degree of environmental impacts of these industries.

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