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Assessment of Industrial Pollution Load in Lagos, Nigeria by Industrial Pollution Projection System (IPPS) versus Effluent Analysis

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1. Introduction

Lagos is the economic capital of Nigeria with over 70% of industries in the country located there. It is also the fastest growing city in Nigeria in terms of development and industrial infrastructure, forecast to be one of the three megacities in the world with population of over 20 million by the year 2025. The rapid growth and haphazard urbanization have led to an increase in waste generation and environmental pollution. The industrial pollution problems faced by Lagos with over 7,000 medium and large scale manufacturing facilities are directly related to the rapid industrial growth and the haphazard industrialization without environmental consideration (Oketola and Osibanjo, 2009a). Pollution abatement technologies are largely absent and the consequence is a gross pollution of natural resources and environmental media. Since effective environmental protection cannot take place in a data vacuum, Industrial Pollution Projection System (IPPS), which is a rapid environmental management tool for pollution load assessment, has been employed in this study to estimate industrial pollution loads and to ascertain the agreement between IPPS models and conventional effluent analysis.

It has been recognized that the developing countries lack the necessary information to set priorities, strategies, and action plans on environmental issues. Plant-level monitoring of air, water and toxic emissions is at best imperfect, monitoring equipment is not available and where available is obsolete; data collection and measurement methodology are questionable, and there is usually lack of trained personnel on industrial sites (Oketola and Osibanjo, 2009b; Hettige et al., 1994). In the absence of reliable pollution monitoring data, the World Bank has created a series of datasets that have given the research community the opportunity to better understand levels of pollution in developing countries, and therefore issue policy advice with more clarity (Aguayo et al., 2001). Hence, the World Bank developed the Industrial Pollution Projection System (IPPS), which is a rapid assessment tool for pollution load estimation towards the development of appropriate policy formulation for industrial pollution control in the developing countries, where insufficient data on industrial pollution proved to be an impediment to setting-up pollution control strategies and prioritization of activities (Faisal, 1991; Arpad et al, 1995).

IPPS is a modeling system, which has been developed to exploit the fact that industrial pollution is heavily affected by the scale of industrial activity, by its sectoral composition, and by the type of process technology used in production. IPPS combines data from industrial activities (such as production and employment) with data on pollution emissions to calculate the pollution intensity factors based on the International Standard Industrial Classification (ISIC) (Hettige et al., 1994). The IPPS has been estimated from massive USA database. This database was created by merging manufacturing census data with USEPA data on air, water, and solid waste emissions. It draws on environmental, economic, and geographic information from about 200,000 US factories. The IPPS covers about 1,500 product categories, all operating technologies, and hundreds of pollutants. It can project air, water, or solid waste emissions, and it incorporates a range of risk factors for human toxic and ecotoxic effects (Hettige et al., 1995).

There are wide ranges of industries and the pollutants introduced largely depends on the type of industry, raw material characteristics, specific process methods, efficacy of facilities, operating techniques, product grades and climatic conditions (Onianwa, 1985). The industrial sectors in Lagos based on the Manufacturer's Association of Nigeria (M.A.N) grouping are food, beverage and tobacco; textile, wearing apparel; pulp and paper products; chemical and pharmaceutical; wood and wood products; nonmetallic mineral products; basic metal; electrical and electronic; motor vehicle and miscellaneous; and domestic and industrial plastics (M.A.N., 1991).The Chemical and pharmaceutical sector is the most polluting industrial sector out of the ten major sectors based on the final ranking of IPPS pollution loads estimated with respect to employment and total value of output while basic metal, domestic and industrial plastics and textile wearing apparel sectors followed suit (Oketola and Osibanjo, 2009a). The chemical manufacturing facilities in the sector range from paint manufacturing industries, soap and detergents, pharmaceuticals, domestic insecticides and aerosol, petroleum products, toiletries and cosmetics, basic industrial chemicals while the basic metal manufacturing facilities are steel manufacturing, metal fabrication, aluminium extrusion etc.

The magnitude of environmental pollution problem is related to the types and quantity of waste generated by industries and the methods of management of the waste. As indicated earlier, there are over 7,000 industries in Lagos state with less than 10% having installed treatment facilities (Onyekwelu et al., 2003). Majority of these industries discharge their partially treated or untreated effluents into the environment and the Lagos Lagoon has gradually become a sink for pollutants from these industries. Industries utilize water for many purposes; these include processing, washing, cooling, boiler use, flushing sanitary/sewage use and general cleaning. Very large amount of water is required for these activities.

Within a given industrial sector, water use correlates with the size of the industry, and also for predicting the rate of generation of wastewater. Water supply requirements of an industry vary from one sector to another. While some industries may only require smaller volumes for cooling and cleaning (as in metal fabrication, cement bagging, etc), some others due to the nature of their processes may require very large volumes of water. Among such industries are breweries, distilleries and soft drinks manufacturing industries where water forms the bulk of the products themselves as a solution. Total consumption is about 205,000 m^3/day, with major users being Breweries, 22%; Textile, 18%; and Industrial chemicals, 16.6% (M.A.N., 2003). Industries utilize a vast array of input in the process of production of goods and services, and generate different forms of waste to varying degrees, which depends on the types and quantity of raw materials inputs, and the process technology employed (Ogungbuyi and Osho, 2005).

This study estimated pollution loads of some industries among the top most polluting sectors in Lagos (i.e., chemical, basic metal, plastics and textile). The selection of the industries was based on data availability and level of cooperation by industries studied. The industries selected are paint manufacturing, industrial gas manufacturing and lubricating oil production under the chemical and pharmaceutical sector while aluminium extrusion, steel manufacturing and glass bottle cap production industries were selected under the basic metal sector. Tyre manufacturing, foam and plastic production; and textile fabric and yarn production industries were selected under the domestic and industrial plastics and textile and wearing apparel sectors, respectively. IPPS pollution loads were estimated with respect to employment and total output, and the results of effluent pollution loads were compared statistically with IPPS pollution loads.

2. Experimental

2.1 Description of the study area

Lagos state has the largest population density of the four most industrialized states in Nigeria (Lagos, Rivers, Kano and Kaduna). It is also the state with the greatest concentration of industries, with well over seven thousand medium and large-scale industrial establishments. It is claimed that about 70-80% of the manufacturing facilities operating within the medium and large-scale industries are located there in. The major industrial estates in Lagos are: Ikeja, Agidingbi, Amuwo Odofin (industrial), Apapa, Gbagada, Iganmu, Ijora, Ilupeju, Matori, Ogba, Oregun, Oshodi/Isolo/Ilasamaja, Surulere (light industrial) and Yaba (Arikawe, 2002; Akinsanya, 2003; Ogungbuyi and Osho, 2005) as shown in Fig. 1.

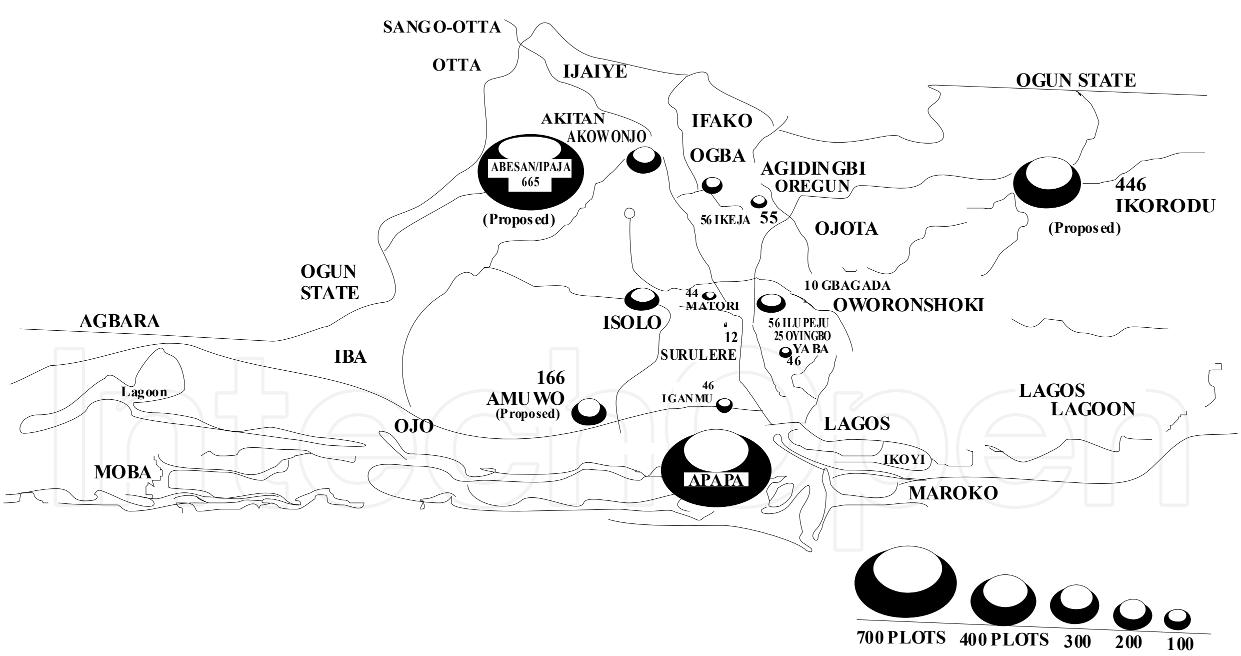

Fig. 1. Map of Industrial Estates in Lagos

2.2 Pollution data estimation methodology

Economic considerations and lack of cooperation from the industries limited the selection of number of industries considered in this study and the number of samples analysed. Hence, two paint manufacturing industries represented as CAP and BGR, domestic insecticides and aerosol production (DIA), and basic industrial gas manufacturing (IGM) were considered under the chemical and pharmaceutical sector; steel manufacturing (UST), aluminium extrusion (AET), aluminium windows and doors production (AWD) and glass bottle cap production (CCP) were selected under the basic metal sector. Industries selected under the domestic and industrial plastics and textile and wearing apparels were tyre, foam and plastic manufacturing industries; and textile and yarn manufacturing industries, respectively.

The total number of employees and average total output in CAP, BGR, LOP, UST, CCM, AWD, AET, FMI, TTP, CLP, WSY, RLT and APT were 225 and 3, 900 ton/yr; 250 and 8,000 ton/yr; 200 and 16.1 ton/yr; 120 and 1,170 ton/yr; 1,025 and 63,200 ton/yr; 370 while total output data was not available; 36 and 222 ton/yr; 200 and 1,800 ton/yr; 710 and 6,650 ton/yr; 1,000 and 9,560 ton/yr; 200 and 960,000 ton/yr; 350 and 12,000 ton/yr; 800 and 3,600 ton/yr; and 375 and 3,750 ton/yr, respectively. Lower Bound (LB) pollution intensities by medium with respect to total value of output and employment were obtained from the literature (Hettige, et al., 1994). The pollution intensities were used to estimate the pollution loads of these manufacturing industries based on the International Standard Industrial Classification (ISIC) code as found in the literature using the formulae:

With respect to total output;

$$\text{Pollution load} = \frac{\text{Pollution intensity factor x Unit of Output}}{2204.6} \tag{1}$$

With respect to employment;

$$PL = \frac{PI \text{ X } TEM}{1000 \times 2204.6} \tag{2}$$

Where,

PL	=	Pollution load of a sector in ton/year
PI	=	Pollution intensity per thousand employees per year
TEM	=	Total number of employees in that sector
2204.6	=	Conversion factor from pounds to tonnes

2.3 Effluent sample analysis

Treated and untreated effluent samples were collected from the industries at the point of discharge to the environment and production line, respectively. Effluent samples were analyzed for physico-chemical parameters and heavy metals using standard methods (APHA, 1992; Miroslav and Viadimir, 1999; Taras, 1950). The parameters determined were: temperature, pH, turbidity, conductivity, total suspended solids (TSS), total hardness, acidity, alkalinity, chloride, sulphate, nitrate, chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO), sodium chloride, calcium, magnesium, and heavy metals (e.g., Fe, Pb, Zn, Cd, Cr, Mn, Ni, Cu, and Co).

2.4 Statistical analysis

The data were validated statistically using t - test at 95% confidence interval (2- tailed) and analysis of variance (ANOVA) to ascertain if there is any significant difference between IPPS pollution loads with respect to employment and total output; and pollution loads from conventional effluent analysis at $p > 0.05$.

Industrial Sector	Four ISIC Code	Product Produced	Major Raw Materials	Types of Waste Generated	Mode of Disposal	Effluent Treatment Plant (ETP)/Constrain	General Remarks
CPH	3521 (CAP)	Paints	Pigment, resin, solvent and additives	Effluent Waste solvent	Discharge in drain By contractor off-site	Operational	Discharge treated effluent into the environment
	3521 (BGR)	Paints, wood preservatives, allied products	Dyes, pigment, solvent, extender	Effluent Sludge	Discharge in drain By contractor off-site	Operational	Discharge treated effluent into the environment
	3511 (IGM)	Industrial gases e.g. O_2, CO_2, acetylene	Caustic soda, soda ash, calcium carbide, ammonium nitrate.	Effluent, Sludge	Discharge in drain, Sludge is disposed by contractor off-site	Not available, installing ETP	Discharge effluent to the environment
	3540 (LOP)	Lubricants, aerosol insecticide etc	Petroleum products	Effluent Solid waste Sludge	Used oil generated is discharged to cement kiln and solid/sludge by contractor off site	Operational	Treat effluent before discharge
DIP	3551 (TTP)	Tyres for cars, trucks and light trucks	Natural and synthetic rubber, ZnO, cobalt stearate, carbon black, mineral oil	Effluent Solid waste	Discharge in drain, By contractor off-site	Not available	Uses effluent as cooling water
	3513 (FMI)	Flexible and rigid foams, adhesives	Polyol, toluene-di-isocyanate (IDI), silicone oil, methylene chloride	Solid waste	Recycled	Not available	Emitting volatile organic compounds into the atmosphere
	3560(CLP)	Plastics	Pigments and mastic batches	Solid waste	Waste oil discharged by contractor off-site	Not Applicable	Do not generate effluent at the production line
TWA	3211 (RLT)	Grey fabrics e.g. suiting, ankara	Yarn, chemicals and dyes	Effluent Solid waste	In drain after treatment By contractor off-site	Operational	Discharge treated effluent into the environment
	3211 (WSY)	Textiles	Dyes, pigment, caustic soda, acetic acid	Effluent Solid waste	Discharge in drain, by contractor off-site	Operational	Discharge treated effluent into the environment
	3219 (APT)	Yarn	Cotton	Solid waste	By contractor off-site	Not applicable	Do not generate effluent.
BML	3720 (AET)	Aluminium profiles	Aluminium billets, H_2SO_4, NaOH,Tin (II) Sulphate, Chromic acid	Effluent, solid and sludge	Effluent discharged in drain after treatment and sludge by contractor off-site.	ETP operational	Do not discharge effluent that contains hazardous substances into the environment.
	3720 (AWD)	Aluminium windows	Aluminium profile from	Solid waste	Recycle waste	Not applicable	Do not generate effluent at all.

		and doors	aluminium ingot				
	3710 (UST)	Steel bars, refractory bricks and enamelware	Steel scrap, ferrous alloys (Fe-Mn, Fe-Si), NaOH, clay, silica.	Effluent, Slag and Sludge	Discharge in drain By contractor off-site	Not available, installing ETP	Reuse effluent as cooling water
	3720 (CCM)	Paint cans, crown caps and beverage cans	Tin plate, copper wire etc	Solid waste	Molded together and sold off	Not available	Do not generate effluent during production

Table 1. Major raw materials and types of waste generated by the selected industries in Lagos

3. Results and discussion

Emission to air was determined based on emission of total suspended particulate (TSP), fine particulate (FP, PM10), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and volatile organic compounds (VOCs). Emission to water was estimated in terms of biological oxygen demand (BOD) and total suspended solid (TSS) while emission of toxic pollutants was estimated in terms of toxic chemicals and metals released into air, water and land, whose pollution intensities were available in the literature (Hettige, et al., 1994). The major raw materials and the type of waste generated by the selected industries are presented in Table 1 while the total number of employees and total value of output as well as the pollution loads are shown in Tables 2 and 3, respectively. UST have the highest number of employees and second highest total value of output while AWD have the lowest number of employees and LOP the lowest value of output.

3.1 IPPS pollution load assessment

3.1.1 Air pollution load

Air pollution loads for all the selected industries are shown in Tables 2 and 3, respectively for pollution load estimated with respect to employment and total value of output. UST with 1025 employees and 63, 200 ton/yr of total output have the highest emission of all pollutants into environmental media (i.e., air, water, and land). The air pollution load with respect to employment and total value of output are 4,810 tons/yr and 1,860,000 tons/yr, respectively. This was followed by FMI,CCM, LOP, AET, TTP, IGM, RLT, APT, AWD, WSY, BGR, CAP, and CLP, respectively in decreasing order.

In most cases, the higher the number of employees and total output, the higher the air pollution loads. Basic metal, and domestic and industrial plastic (DIP) sectors are the most polluting sector in terms of air pollutant emission. UST ranked first while FMI and CCM ranked second and third, respectively. Total air pollution loads with respect to employment are 2,660 tons/yr and 2050 tons/yr in FMI and CCM, respectively. With respect to total output, air pollution loads are 94,500 ton/yr in FMI. Output data from CCM was not available thus; air pollution load with respect to total output cannot be estimated. Emission of CO and NO_2 was the highest in UST and FMI when pollution load was estimated with respect to the two variables (i.e., employment and total output) while SO_2 emission was the highest in CCM when pollution load was estimated with respect to employment. The trend in air pollution load by pollutant types in these industries are

$$\text{UST: } CO > SO_2 > NO_2 > FP > TSP > VOC$$

FMI: NO_2 > VOC > SO_2 > CO > TSP > FP
CCM: SO_2 > CO > TSP > VOC > NO_2 > FP

Pollution loads estimated with respect to employment and total output revealed that the most emitted air pollutant from UST was CO. This could be attributed to the fact that in steel making, oxygen reacts with several components in the bath, including Al, Si, Mn, P, C, and Fe, to produce metallic oxides which end up in the slag. It also generates carbon monoxide boil, a phenomenon common to all steel making processes and very important for mixing of the slag. Mixing enhances chemical reaction, purges hydrogen and nitrogen, and improves heat transfer. The CO supplies a less expensive form of energy to the bath, and performs several important refining reactions (Jeremy, 2003; and Bruce and Joseph, 2003). It is also important for foaming and help to bury the arc.

INDUSTRIAL SECTOR/ SECTOR CODE	**CHEMICAL & PHARMACEUTICALS (CPH)**				**BASIC METALS (BML)**			
ISIC CODE	3521 (CAP)	3521 (BGR)	3540 (LOP)	3511 (IGM)	3710 (UST)	3720 (CCM)	3720 (AWD)	3720 (AET)
EFFLUENT VOL. (L/day)	1,500	2,000	NA	NA	1MILLON	NA*	NA	10
EFFLUENT TREATMENT PLANT (ETP)	Operational	Operational	Operational	NA	NA	NA*	NA	Operational
NO OF EMPLOYEE	225 (M)	250 (M)	200 (M)	120 (M)	1025 (L)	370 (M)	36 (M)	200 (M)
AIR POLLUTANTS								
SO_2	5.88	6.53	565	200	1320	1,260	122	680
NO_2	5.19	5.77	352	148	575	41.0	3.99	22.2
CO	0.73	0.81	266	115	2060	586	57.0	317
VOC	43.5	48.4	88.3	116	177	45.8	4.46	24.8
FP	1.78	1.98	17.4	6.77	366	11.6	1.13	6.25
TSP	3.49	3.88	217	32.1	307	106	10.3	57.2
TOTAL	60.6	67.3	1,510	617	4810	2,050	199	1,110
WATER POLLUTANTS								
BOD	0.01	0.07	0.59	68.3	0.89	96.5	9.39	52.2
TSS	0.03	0.03	0.73	105.6	14,400	1,400	136	754
TOTAL	0.04	0.10	1.32	174	14,400	1,490	145	806
TOXIC CHEMICALS								
TO AIR	38.8	43.1	10.8	101	73.0	97.3	9.47	52.6
TO LAND	93.1	103	3.17	353	418	258	25.1	140
TO WATER	0.10	0.11	0.32	51.3	25.9	3.78	0.38	2.04
TOTAL	132	147	14.7	505	517	359	35.0	194
TOXIC METALS								
TO AIR	0.33	0.37	0.02	0.50	12.5	6.73	0.66	3.64
TO LAND	2.54	2.82	0.30	15.9	276	223	21.7	121
TO WATER	0.002	0.002	0.01	0.47	1.89	0.13	0.01	0.07
TOTAL	2.89	3.18	0.33	16.9	291	230	22.4	124

NOTE: L = large scale, M = medium scale, S = small scale, NA = not available, NA* = not applicable

Table 2. Pollution loads (ton/yr) with respect to employment

INDUSTRIAL SECTOR/SECTOR CODE	DOMESTIC AND INDUSTRIAL PLASTICS (DIP)			TEXTILE, WEARING APPAREL (TWA)		
ISIC CODE	3560 (CLP)	3513 (FMI)	3551 (TTP)		3219 (APT)	3211 (RLT)
EFFLUENT VOL. (L/day)	NA*	NA*	484,000	160	NA*	720
EFFLUENT TREATMENT PLANT (ETP)	NA	NA	NA	Operational	NA	Operational
NO OF EMPLOYEE	200 (M)	710 (L)	1,000 (L)	350 (M)	375 (M)	800 (L)
AIR POLLUTANTS						
SO2	0.54	441	275	36.0	21.0	82.3
NO2	0.12	1,150	95.1	49.7	8.67	114
CO	0.04	169	11.7	6.67	1.58	15.3
VOC	6.48	838	278	13.6	166	31.2
FP	0.11	0.36	3.93	0.96	0.00	2.20
TSP	0.16	67.3	30.4	6.45	12.5	14.7
TOTAL	7.45	2,660	695	113	210	259
WATER POLLUTANTS						
BOD	4.97	1.89	0.002	1.46	0.00	3.34
TSS	0.11	58.2	0.68	2.27	0.09	5.18
TOTAL	5.08	60.0	0.68	3.73	0.09	8.52
TOXIC CHEMICALS						
TO AIR	18.2	484	9.98	5.22	147	11.9
TO LAND	5.38	401	17.2	4.85	33.2	11.1
TO WATER	0.04	35.4	0.21	2.66	0.01	6.08
TOTAL	23.6	920	27.4	12.7	180	29.1
TOXIC METALS						
TO AIR	0.004	0.13	0.39	0.04	0.03	0.10
TO LAND	0.16	20.9	15.1	0.09	0.01	0.20
TO WATER	0.01	0.44	0.02	0.003	-	0.01
TOTAL	0.18	21.5	15.5	0.13	0.04	0.31

NOTE: L = large scale, M = medium scale, S = small scale, NA = not available, NA* = not applicable

Table 2. Contd. Pollution loads (ton/yr) with respect to employment

INDUSTRIAL SECTOR/ SECTOR CODE	CHEMICAL & PHARMACEUTICALS (CPH)				BASIC METALS (BML)			
ISIC CODE	3521 (CAP)	3521 (BGR)	3540 (LOP)	3511 (IGM)	3710 (UST)	3720(CCM)	3720 (AWD)	3720 (AET)
EFFLUENT VOL. (L/day)	1,500	2,000	NA	NA	1MILLION	NA*	NA	10
EFFLUENT TREATMENT PLANT (ETP)	Operational	Operational	Operational	NA	NA	NA*	NA	Operational
TOTAL VALUE OF OUTPUT (ton/yr)	3,900	8,000	16.1	1,170	63,200	NA	222	1,800
AIR POLLUTANTS								
SO_2	435	893	152	6,180	512,000	NA	3,890	31,600
NO_2	384	787	94.7	4,590	222,000	NA	127	1,030
CO	54.8	112	71.7	3,550	798,000	NA	1,800	14,700
VOC	3,220	6,600	23.8	3,590	68,600	NA	141	1,150
FP	131	269	4.68	210	142,000	NA	35.7	290
TSP	258	530	58.4	994	119,000	NA	326	2,650
TOTAL	4,480	9,190	405	19,100	1,860,000	NA	6,320	51,300
WATER POLLUTANTS								
BOD	0.46	0.94	0.16	2,120	379	NA	298	2,410
TSS	1.91	0.26	0.20	3,270	5,580,000	NA	4,300	35,000
TOTAL	2.37	1.20	0.36	5,390	5,580,000	NA	4,600	37,400
TOXIC CHEMICALS						NA		
TO AIR	2,870	5,880	2.90	3,140	28,000	NA	300	2,440
TO LAND	6,880	14,100	0.85	10,900	162,000	NA	796	6,470
TO WATER	7.47	15.3	0.09	1,590	10,000	NA	11.7	94.8
TOTAL	9,760	20,000	3.84	15,600	200,000	NA	1,110	9,000
TOXIC METALS								
TO AIR	24.3	49.9	0.01	15.6	4,850	NA	20.8	169
TO LAND	187	385	0.17	493	107,000	NA	689	5,590
TO WATER	0.15	0.32	0.002	14.5	732	NA	0.41	3.36
TOTAL	212	435	0.18	523	112,000	NA	710	5,760

NOTE: NA = not available, NA* = not applicable

Table 3. Pollution loads (ton/yr) with respect to total value of output

INDUSTRIAL SECTOR/ SECTOR CODE	DOMESTIC AND INDUSTRIAL PLASTICS (DIP)			TEXTILE, WEARING APPAREL (TWA)		
ISIC CODE	3560 (CLP)	3513 (FMI)	3551 (TTP)	3211 (WSY)	3211 (RLT)	3219 (APT)
EFFLUENT VOL. (L/day)	NA*	NA*	484,000	160	720	NA*
EFFLUENT TREATMENT PLANT (ETP)	NA	NA	NA	Operational	Operational	NA
TOTAL VALUE OF OUTPUT (ton/yr)	960,000	6,650	9,560	12,000	3,600	3,750
AIR POLLUTANTS						
SO_2	24,400	15,600	16,500	13,200	3,950	1,270
NO_2	5,230	40,600	5,690	18,300	5,460	526
CO	0.001	6,010	698	2,450	731	95.3
VOC	294,00	30,000	16,700	5,010	1,500	10,100
FP	5,230	12.1	234	355	106	0.00
TSP	7,400	2,390	1,820	2,360	707	757
TOTAL	337,000	94,400	41,600	41,700	12,400	12,800
WATER POLLUTANTS						
BOD	226,000	638	0.09	536	160	0.00
TSS	4,880	2,060	40.9	833	249	5.44
TOTAL	231,000	2,700	41.0	1,370	409	5.44
TOXIC CHEMICALS						
TO AIR	826,000	17.2	598	1,920	573	8,940
TO LAND	245,000	14.2	1,030	1,780	532	2,010
TO WATER	2,020	1.25	12.4	977	292	0.08
TOTAL	1,070,000	32.6	1,640	4,670	1,400	10,900
TOXIC METALS						
TO AIR	192	4.76	23.2	15.8	4.72	1.83
TO LAND	7,400	741.1	903	320	95.5	37.7
TO WATER	416	15.5	1.16	1.07	0.32	0.35
TOTAL	8,010	761	928	336	100.6	39.9

NOTE: NA = not available, NA* = not applicable

Table 3. Contd. Pollution loads (ton/yr) with respect to total value of output

3.1.2 Water pollution load

Of all the industries, UST ranked first in terms of total water pollution load while CCM and AET ranked second and third, respectively. This was due to the fact that emission of TSS from the two industries was more than BOD. Estimated TSS pollution load from these industries are 14,400 and 1,400 ton/yr, respectively while BOD pollution load are 0.89 and 96.5 ton/yr, respectively. The steel industry with the highest number of employees generated the highest water pollution load. Thus, the higher the number of employees, the higher the water pollution loads. Pollution load estimated with respect to total output showed that 5.6 million ton/yr of TSS was generated by UST. Water pollution load estimated with respect to employment and total output revealed that emission of TSS was more than BOD in all the manufacturing facilities under the basic metal sector with UST having the highest water pollution load with respect to the two variables (i.e., employment and total output). This is shown in Tables 2 and 3, respectively. APT and CAP have the lowest water pollution load thus, their contribution to water pollution is insignificant.

3.1.3 Toxic pollution load

Toxic chemical and metal pollution load with respect to employment and total output are presented in Tables 2 and 3, respectively. Total chemical pollution load with respect to employment and total output is more than total metal pollution load in all the facilities. This may be attributed to the nature of the raw materials used by these facilities. Thus, raw material characteristics and product grades are some of the factors affecting pollution load (Oketola and Osibanjo, 2009b).

3.2 Pollution load assessment by effluent analysis

The results of the composite untreated effluent samples collected from the production line of the facilities are presented in Tables 4 and 5, respectively. The result of effluents analysis showed varying concentration of some of the parameters such as heavy metals, COD etc., which are above the permissible limits of Federal Ministry of Environment, (FEPA, 1998) for effluent discharge thus indicating gross pollution. The values of some of the parameters obtained could be attributed to the production processes, raw material characteristics etc.

Industrial Code /Parameters	**BGR**	**CAP**	**UST[1]**	**TTP[1]**	**WSY**	**LOP**	**IGM**	**AET**
Sampling time (n)	**4**	**5**	**2**	**2**	**3**	**2**	**2**	**5**
Parameters								
Temp0C	30.3±1.7	29.2±1.8	45	33±1.4	46.3±7.8	36±1.4	29.5±0.7	30.5±0.7
pH	7.62±0.5	6.32±0.5	6.75±0.1	5.75±0.1	9.6±1.0	6.85±0.6	11.3±0.0	10.8±0.9
Turbidity (NTU)	4.15±0.3	3.53±0.5	ND	ND	**0.31**±0.04	1,230±360	ND	0.72±0.1
Conductivity (μs/cm)	2210±410	810±85	104±5.7	260±14	0.31±0.04	305±78	2,700±280	3550±780
TSS (mg/L)*	9.65±2.8	1.40±0.8	0.28±0.3	0.05±0.01	0.14±0.1	301±66	1.55±1.3	2.33±1.4

Oil & Grease (mg/L)	3.42±8.8	6.30±1.5	104±5.7	260±14	2,400±400	91.2±30	0.34±0.4	34.3±30
Total Alkalinity (pH 4.3) (mg/L)	863±570	650±270	0.37±0.4	ND	1.0±0.4	32.6±46	505±710	3,730±2,400
Total Acidity (pH 8.3) (mg/L)	813±97	602±120	41.1±6.7	**67.9**±10	7931.0±61	40.5±31	ND	2,070±1,300
Methyl Orange Acidity (pH 3.7) (mg/L)	293±590	ND	34.9±32	ND	147±120	ND	ND	-
Total Hardness (mg/L)	78.7±28	58.8±20	222.6±300	6.27±1.0	376±530	80.5±63	35.9±43	246±350
Cl^- (mg/L)	82.2±38	33.6±10	8.57±4.1	1.79±0.1	36.7±18	9.06±0.5	2.44±1.0	21.1±38
SO_4^{2}- (mg/L)	106±53	855±780	46.1±2.7	1.19±0.1	1,180±680	37.4±49	199±120	717±520
PO_4^{3}- (mg/L)	94.5±20	46.2±17	ND	ND	7 7.0±6.1	10.5±9.6	12.0±17	47.5±14
NO_3^- (mg/L)	2.12±1.4	ND	ND	ND	0.8±0.7	0.11±0.1	ND	ND
DO (mg/L)	ND	ND	7.50±1.4	6.80±0.1	ND	ND	ND	80±1.8
COD (mg/L)	1700±630	642±390	130±6.4	621±43	783±86	22,160±95	897±7.1	159±130
BOD_5 (mg/L) *	23.4±2.9	20.3±7.7	10.5±3.0	0.48±0.04	4.56±0.4	54.5±18	ND	3.95±1.9
Ca (mg/L)	15.3±5.9	15.6±15	0.34±0.2	1.04±0.02	14.6±15	53.8±65	38.2±19	0.02±0.04
Mg (mg/L)	9.85±9.2	5.77±7.1	53.8±73	0.78±0.1	82.3±140	14.6±15	0.73±1.0	60.0±85
Pb (mg/L)	2.01±4.0	12.4±15	3.07±4.3	ND	**9.07**±16	0.22±0.3	ND	19.0±23
Ni (mg/L)	0.73±0.5	0.52±0.8	0.10±0.1	0.35±0.1	ND	0.1±0.1	0.6±0.8	0.48±0.8
Cd (mg/L)	0.78±1.1	1.77±1.3	0.11±0.2	ND	0.09±0.2	ND	ND	0.44±0.6
Cr (mg/L)	0.53±0.4	0.41±0.3	0.18±0.2	0.05±0.01	0.18±0.1	ND	0.2±0.3	0.19±0.3
Fe (mg/L)	8.80±6.4	4.56±6.4	7.3±10	ND	8.27±7.2	1.40±2.0	4.9±6.9	8.96±12
Mn (mg/L)	2.71±2.2	1.02±0.9	ND	0.23±0.3	ND	0.06±0.1	0.27±0.4	0.98±1.5
Zn (mg/L)	0.15±0.1	0.02±0.04	1.00±1.4	ND	0.01±0.02	0.01±0.01	ND	0.06±0.1
Cu (mg/L)	20.7±14	8.48±7.0	2.70±2.2	0.30±0.1	2.54±0.6	7.8±7.8	4.98±7.0	14.3±6.5
Co (mg/L)	0.29±0.1	0.14±0.1	0.04±0.1	0.02±0.01	0.23±0.2	ND	0.14±0.2	0.25±0.1
TOTAL (mg/L) *	36.7	20.8	14.5	0.95	20.4	9.59	11.1	44.6

Note: * Parameters compared with IPPS pollution load
[1] cooling water

Table 4. Mean concentration and standard deviation of physico-chemical parameters of untreated effluent from the selected industries

Industrial Code/Parameters	BGR (n = 2)	CAP (n = 2)	WSY (n = 2)	LOP (n = 2)	IGM (n = 3)	AET (n = 2)	FMENV LIMIT
Parameters							
Temp^{0}C	30±2.8	28.8±3.2	47.8±1.8	30.8±0.4	35±2	29.5±0.7	
pH	7.3±0.3	8.2±0.0	9.85±0.2	8.45±1.1	9.03±0.3	10.3±0.9	6.5 – 9.0
Turbidity (NTU)	0.05±0.01	0.06±0.01	0.44±0.2	137±52	ND	0.41±0.03	
Conductivity (µs/cm)	545±92	2,300±140	4,500±710	289±150	5,670±610	3,400±570	
TSS (mg/L) *	0.23±0.02	0.32±0.1	0.37±0.2	32.0±9.9	0.44±0.1	1.91±1.3	
Oil & Grease (mg/L)	0.30±0.03	0.03±0.01	19.2±3.8	4.79±1.0	9.19±6.8	3.16±0.4	
Total Alkalinity (pH 4.3) (mg/L)	293±57	572±97	1,350±440	131±56	2,880±170	1,720±1,100	
Total Acidity (pH 8.3) (mg/L)	136±130	60±85	220±75	9.16±1.8	76.1±16	ND	
Total Hardness (mg/L)	118±67	44.5±20	32.1±25	22.0±8.5	207±330	1.57±2.2	
Cl^- (mg/L)	31.9±0.2	7.62±8.8	46.4±66	9.34±6.4	127±31	55.1±68	600
SO_4^{2-} (mg/L)	103±16	471±83	303±84	36.4±36	111±32	1,100±890	
PO_4^{3-} (mg/L)	8. 85±5.2	ND	25.5±21	3.14±1.0	8.93±7.7	43.5±30	
DO (mg/L)	3.75±3.5	ND	ND	0.75±1.5	6.5±1.3	1.75±2.5	
COD (mg/L)	1450±92	1,030±250	1,140±510	97.4±6.6	363±260	909±9.9	80.0
BOD_5 (mg/L) *	27.0±1.1	16.1±2.7	60.1±11	21.8±8.5	10.2±11	6.55±1.0	30.0
Ca (mg/L)	16.3±16	2.34±0.1	5.31±6.5	10.9±13	2.4±0.4	ND	
Mg (mg/L)	18.7±6.6	9.38±4.8	4.55±2.1	5.38±3.7	48.8±79	0.38±0.5	
Pb (mg/L)	3.27±4.6	4.7±6.7	6.35±9.0	7.0±9.9	0.28±0.4	ND	< 1.0
Ni (mg/L)	2.8±0.6	1.20±0.3	0.90±0.1	ND	0.67±1.2	0.8±1.1	< 1.0
Cd (mg/L)	0.47±0.7	ND	0.97±1.4	ND	1.64±1.6	0.15±0.1	< 1.0

Cr (mg/L)	0.23±0.3	0.14±0.1	0.46±0.1	0.23±0.3	0.1±0.2	0.29±0.4	< 1.0
Fe (mg/L)	10.9±3.3	0.6±0.9	6.5±9.2	4.18±5.7	60.5±66	61.1±61	20.0
Mn (mg/L)	ND	ND	0.08±0.1	0.06±0.1	13±6.7	ND	5.0
Zn (mg/L)	0.11±0.6	0.20±0.3	0.01±0.01	0.12±0.2	0.1±0.1	0.07±0.1	< 1.0
Cu (mg/L)	9.21±7.4	8.03±4.6	3.18±4.5	1.81±2.4	11.5±10	6.85±2.0	< 1.0
Co (mg/L)	0.32±0.4	0.15±0.2	0.16±0.1	ND	0.11±0.2	0.14±0.03	< 1.0
TOTAL (mg/L)*	**28.7**	**16.7**	**19.3**	**6.68**	**87.6**	**72.7**	

Note: * Parameters compared with IPPS pollution load

Table 5. Mean concentration and standard deviation of physico-chemical parameters of effluent discharged to the environment in the selected industries in Lagos

3.3 Results of statistical analysis

IPPS estimated pollution loads with respect to employment and total output in these industries were statistically analysed to ascertain the level of agreement between them. There is no significant difference between the pollution load estimated with respect to the two variables (i.e. employment and total output) at $p > 0.05$ in all the industries except in IGM, WSY, RLT, AWD, and AET. At the 0.05 level, the means are significantly different. IPPS pollution load was also compared with pollution load from conventional effluent analysis. There is no significant difference between them at $p > 0.05$ in CAP, BGR, UST, TTP and AET while there is significant different between IPPS pollution load and pollution load from conventional effluent analysis in WSY**.** Hence, IPPS compared favourably with effluent analysis in most of the industries.

4. Conclusion

This study estimated pollution loads of some industries in Lagos using IPPS pollution intensities with respect to employment and total output. In most cases, the higher the total number of employees and total output, the higher the estimated pollution loads. There is no significant difference between the pollution loads estimated with respect to the two variables in all the industries except IGM where the two means are significantly different. IPPS pollution loads were also compared with pollution loads from conventional effluent analysis at $p > 0.05$. The two pollution loads compared favourably at this limit.

Application of IPPS in Lagos and most developing countries will no doubt enable the regulatory and monitoring agencies in such countries to focus on the most polluting industries. This will on the long run increase the level of enforcement since more time can be spent on the few polluting industries. This will also enable the policy makers in the developing countries to tackle industrial pollution since IPPS is a cheap means of assessing industrial pollution when compared to running scientific monitoring data gathering, analysis and assessment which is time consuming, expensive and resource intensive.

Detailed information on employment and total output obtained from the fourteen industries studied revealed that in most cases, the higher the total number of employees and output, the higher the pollution loads by pollutant types except in TTP where the higher the total number of employees and total output, the lower the estimated pollution loads. This variation can be attributed to other factors which affect pollution loads. These are types and quantity of raw materials, process technology, product grade, efficacy of facility, and source type etc. Also, pollution load of the fourteen industries estimated with respect to employment and total output were compared statistically using t-test at 95% confidence interval and analysis of variance (ANOVA). At this level, the two means are not significantly different in CAP, BGR, TTP, FMI, UST, LOP, CLP, and APT while there was significant different in AWD, WSY, RLT, IGM, and AET. These can be attributed to the information and data supplied by these industries including process efficiency and efficacy of installed pollution control technology if any. For example, IGM with only 120 employees produced 1,170 ton/yr of total output while LOP with 200 employees have a total production capacity of 16.1 tons/yr which is significantly less than that of IGM.

The results of untreated effluent samples collected from these industries also revealed that most of the industries discharged untreated or partially treated effluent into the environment. Out of the 14 industries which data were available for this study, only 29% have effluent treatment plant which is operational, 36% have no effluent treatment plant while the remaining 36% operate dry process in which Effluent Treatment Plant (ETP) is not applicable. Unavailability of ETP in these industries could be attributed to the high cost of installing and maintaining an ETP, air pollution control devices, and weak enforcement of extant environmental regulations in Lagos.

Pollution load from conventional effluent analysis were compared with IPPS pollution load in these industries. There is no significant difference between them at $p > 0.05$. IPPS pollution load of the selected industries compared favourably with pollution load from conventional effluent analysis in CAP, BGR, UST, TTP and AET. Enough data was not available from IGM and LOP. The exception was in WSY where there is significant difference between IPPS pollution load with respect to output and pollution load from conventional effluent analysis from effluent collected at the production line. Consequently, there was an agreement between effluent analysis or scientific monitoring and assessment and IPPS. Since IPPS compares favourably with scientific monitoring and analysis in these industries, IPPS therefore offers a cheap management tool for pollution load assessment in these industries; and directional basis for rapid policy intervention by government regulatory agencies in Lagos and other developing countries where pollution abatement technology is absent and level of enforcement is very low. It will enhance industrial pollution control in the developing countries where funding for environmental protection is lacking or grossly inadequate. The effectiveness of the intervening measures would significantly reduce the overall industrial pollution.

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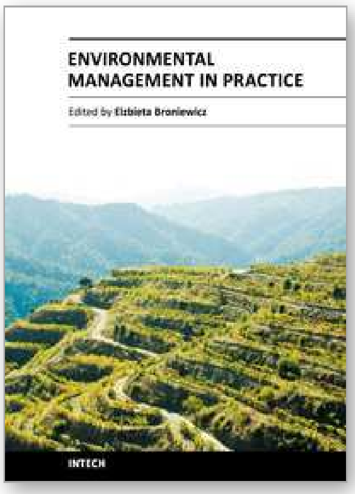

Environmental Management in Practice

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In recent years the topic of environmental management has become very common. In sustainable development conditions, central and local governments much more often notice the need of acting in ways that diminish negative impact on environment. Environmental management may take place on many different levels - starting from global level, e.g. climate changes, through national and regional level (environmental policy) and ending on micro level. This publication shows many examples of environmental management. The diversity of presented aspects within environmental management and approaching the subject from the perspective of various countries contributes greatly to the development of environmental management field of research.