

# Industrial emissions and health hazards among selected factory workers at Eleme, Nigeria

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## Abstract

The objective of this study was to measure the levels of selected atmospheric contaminants and assess their possible association with the prevalence of several self-reported respiratory and dermal symptoms among workers in the refinery and petrochemical complexes at Eleme.

PM<sub>10</sub>, lead (Pb) and polycyclic aromatic hydrocarbons (PAH) were determined in the atmosphere at Port Harcourt Refining Company (PHRC) and Eleme Petrochemical Complex Ltd (EPCL) and the pollution levels were related with the health hazards to the workers. The study was preliminary, descriptive and laboratory based. A high volume sampler with PM10 inlet was used to collect six air samples from three locations in each industry. Questionnaires were administered to 400 randomly selected subjects from the industries. Five year hospital data were obtained. The data were analysed for logistic regression using SPSS software.

At PHRC, the highest PM<sub>10</sub> level of  $130.3 \pm 3.32 \mu\text{g}/\text{m}^3$  was recorded at a location within the environment department. The highest Pb level ( $0.20 \pm 0.03 \text{ mg}/\text{m}^3$ ) was recorded at the safety unit and the highest concentration of benzo (a) pyrene ( $1.63 \times 10^2 \text{ ng}/\text{m}^3$ ) was recorded at the maintenance section. At EPCL, the highest Pb level ( $0.16 \pm 0.09 \text{ mg}/\text{m}^3$ ) was recorded at the polypropylene plant while the highest concentration of benzo (a) pyrene ( $1.61 \times 10^2 \text{ ng}/\text{m}^3$ ) was recorded at the production unit. All the PAH levels observed in these locations were higher than the WHO limit of  $1.0 \times 10^2 \text{ ng}/\text{m}^3$ . Exposure to dust and smoke was found to be significantly associated with respiratory symptoms among 65 (65.7%) of PHRC and 52 (57.1%) of EPCL workers ( $P < 0.05$ ). Also eye and skin conditions were reported. Exposure to industrial emissions containing mixtures of compounds could present potent risk factors for the onset of dermal and respiratory disorders among the workers.

**Key words:** Air pollutants; Environmental Health; Health hazards; Industrial workers; Nigeria; PM<sub>10</sub>; Workplaces.

## Introduction

Each year, industrial facilities discharge into the environment large amounts of chemicals leading to respiratory, neurological, developmental and reproductive disorders, and cancers. Yet, communities living within and around such industrial facilities, especially in developing

countries, seldom know the extent to which these discharges may be affecting their health.

Industries such as petroleum refineries are a major source of hazardous and toxic air pollutants including benzene, toluene, ethylbenzene, and xylene (BTEX compounds), particulate matter (PM), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), hydrogen sulphide (H<sub>2</sub>S), and sulphur dioxide (SO<sub>2</sub>). Refineries also release less toxic hydrocarbons such as natural gas (methane) and other light volatile fuels and oils. Some of the chemicals released are known or suspected cancer-causing agents, responsible for developmental and reproductive problems. They may also aggravate certain respiratory conditions such as childhood asthma and can result in worry and fear among residents of surrounding communities (US DOE, 1998).

Air emissions can come from a number of sources within a petroleum refinery including: equipment leaks (from valves or other devices); high-temperature combustion processes in the actual burning of fuels for electricity generation; the heating of steam and process fluids; and the transfer of products. Many thousands of kilograms of these pollutants are typically emitted into the environment over the course of a year through normal emissions, fugitive releases, accidental releases, or plant upsets. The combination of volatile hydrocarbons and oxides of nitrogen also contribute to ozone formation, one of the most important air pollution problems globally (US DOE, 1998).

In the Republic of China, nine serious air pollution events occurred in petrochemical municipalities between 1971 and 1990, making scientists consider the petrochemical industry as the main source of industrial air pollution (EPA, China, 1992). The pollutants released by the petrochemical industries include vinyl chloride monomer and polycyclic aromatic hydrocarbons (PAHs), both of which have been recognised as environmental carcinogens (Vainio and Wilbourn, 1992). Subsequent to these events, public concern has been elevated regarding possible increased cancer risks for residents in petrochemical municipalities.

Studies carried out by Abbey *et al.*, (1993) on long-term ambient concentrations of Total Suspended Particulates (TSP), ozone, sulphur dioxide and respiratory symptoms in a non-smoking population indicated that there were statistically significant relationships between ambient concentrations of TSP and ozone, but not sulphur dioxide, with several respiratory outcomes. In a related study, TSP

was significantly associated with increased daily mortality in Poisson regression analyses controlled for season and temperature and that an increase in particulates of 100ug/m<sup>3</sup> was associated with a 4% increase in mortality (Schwartz and Dockery, 1995). Exposure to particulate matter (PM) was strongly associated with morbidity (Dockery *et al.*, 1982) while acute exposure to airborne particles was associated with increased mortality (Schwartz and Marcus, 1990). Exposure to different heavy metals is associated with different health outcomes. For instance, some of the most important health effects associated with low-level lead exposure are the complex of neurological deficits particularly in children, modest elevations in blood pressure in adults, and developmental problems (Schwartz and Dockery, 1992). High blood lead (PbB) concentrations cause frank brain damage and slowing of nerve conduction (Seppalainen *et al.*, 1983). Intelligence quotient (IQ) deficits in children have been associated with PbB levels as low as 10-15ug/l (US EPA, 1986). Elevated PbB levels are also associated with developmental abnormalities including foetal neurological damage (Bornshein *et al.*, 1985), reduced birth weight (Bornshein *et al.*, 1989), reduced stature (Schwartz *et al.*, 1986) and reduced attainment of developmental milestones (Schwartz and Otto, 1987).

In Nigeria, the petroleum refinery and petrochemical industries are expected to expand in the coming years with the potential for environmental pollution to increase with corresponding effects on the health of the communities within, and those residing near the industrial plants. The objective of this study was to measure the levels of selected atmospheric contaminants including lead and PAHs and assess their possible association with the prevalence of several self-reported respiratory and dermal symptoms among workers in the refinery and petrochemical complexes at Eleme.

## Methodology

### Description of study area

Eleme Local Government Area, the most industrialised in the Niger Delta, is where the refinery and petrochemical industries are found and is located about 20km away from Port Harcourt city, Rivers State, in Southern Nigeria.

The Port Harcourt Refining Company (PHRC) has a refining capacity of 210,000 barrels per day. It is located on a parcel of land jointly owned by Eleme/Okrika Local Government Areas of Rivers State. The refinery uses crude oil transferred through a 55km pipeline from

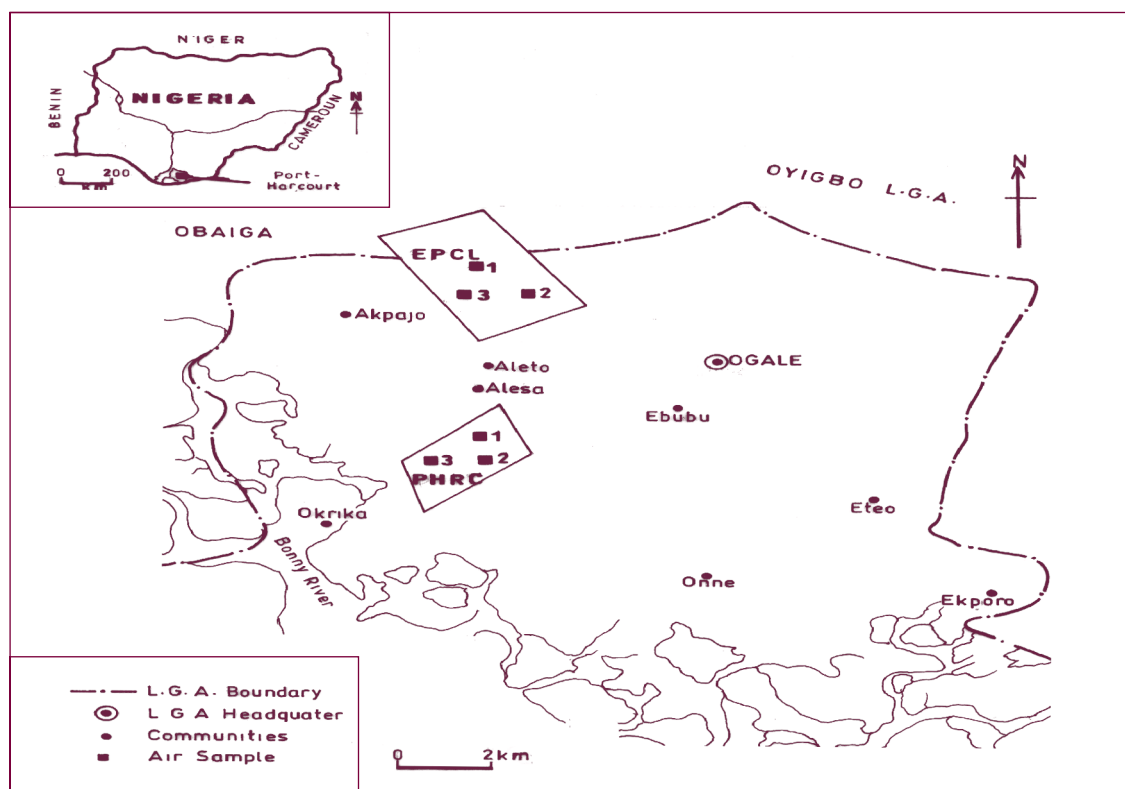
Bonny terminal. The major products obtained from the crude distillation and catalytic processes are liquefied petroleum gas (LPG) as cooking gas, dual-purpose kerosene (DPK) for aviation/household uses, premium motor spirit (PMS), petrol and automotive gas oil (AGO) and diesel and fuel oil.

The refinery has staff of about 2,000 who facilitate diverse industrial processes located in various units of the plant complex. These units include crude distillation (CD) unit; catalytic reforming (CR) unit; fluid catalytic cracking (FCC) unit (this unit was not operational during the period of investigation); hydrofluoric alkylation (HA) unit and complete refining plant. The various processes mentioned produce wastes, which include particulates from combustion of fossil fuels in heaters, flares and incinerators; hydrocarbon vapour from oil spills, evaporation from tank hatches etc, gaseous products of various combination from fossil fuels and from crude oil refining process such as volatile hydrocarbons, H<sub>2</sub>S, NO<sub>x</sub>, SO<sub>x</sub>, phenol and its derivatives.

The petrochemical complex is located on a parcel of land jointly owned by Akpajo/Agbanjia/Aleto communities in Eleme Local Government Area. It occupies an area of about 900 hectares and is approximately 15km from Port Harcourt City. The plant complex is made up of units such as olefin, polypropylene, polyethylene and butene-1 plants, as well as the utilities and offsite facilities. Others include the retention pond, administrative building, auditorium, operations and technology building, laboratory, maintenance workshops, spare parts warehouse, chemicals/catalysts warehouse, laundry, industrial clinic, communication facilities, fuel depot, fire station, and pipelines to and from Port Harcourt refining company.

The major feedstock for the complex is natural gas liquids (NGL), supplied by pipeline from the Nigeria National Petroleum Corporation (NNPC)/AGIP/PHILIPS joint venture NGL extraction plant located at Obiafu/Obrikom about 80km from the complex. The NGL provides 100% and 45% of the ethylene and propylene requirements, respectively. The fuel requirements of the complex for power generation and heating are carried by a separate pipeline from the Obiafu/Obrikom NGL plant. The olefin plant cracks the NGL to produce ethylene (300,000 tons/annum) and propylene (126,000 tons/annum) while the polypropylene plant (with a capacity of 80,000 tons/annum) produces 40 different grades of polypropylene resins. The polyethylene plant on the other hand, with a capacity of 270,000 tons/annum, produces 140 different grades of polythene

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**Figure 1.0**  
Location map showing sampling points at EPCL and PHRC

resins (both linear low and high density types). The butene-1 plant, with a capacity of 22,000 tons/annum, produces the butene-1 co-monomer.

The products of the utilities and off site facilities include 250 metric tonnes per hour of steam generation, 130 megawatts of electric power generation, 2,000 cubic metres per hour raw water treatment, 34,500 cubic meters per hour of cooling water circulation system, plant and instrument air system, 4,400 normal cubic meters per hour nitrogen plant, storage tanks, effluent treatment facilities, flare system and solid waste incinerator.

The complex has a total staff establishment of more than 2,000 workers.

## Air sampling

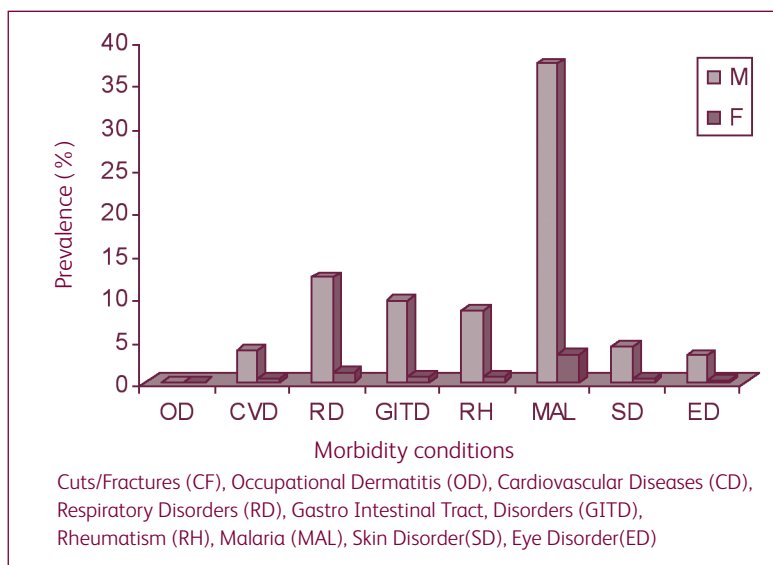
A total of six particulate air samples were collected purposively and cross sectionally for four hours from three locations (see Figure 1.0), each from the refinery and petrochemical complexes using an Anderson Model

High volume sampler with PM10 inlet. At the refinery, samples were collected near the air stack of the old and smaller refinery from a location designated as area 5 close to the environment department (PHRC 1), a location near the air stack of the new and larger refinery designated as area 3 close to the safety unit (PHRC 2) and a location close to the wastewater treatment plant by maintenance department (PHRC 3). At the petrochemical complex, samples were collected from a location by effluent treatment point (EPCL 1), a location close to the off-site area (EPCL 2) and a location within the polypropylene plant (EPCL 3). At the time of sampling within the PHRC complex, one of the major air pollutants in the facility, the FCC unit, was down. The emissions from this unit would probably have added to the particulate load in the ambient air.

## Determination of TSP in ambient air

From the samples of air collected, the concentration of total suspended particles (TSP) was determined gravimetrically after proper equilibration and

**Figure 2.0**  
Prevalence of dominantly occurring morbidity conditions at PHRC



conditioning of the 20.3 x 25.4cm (8x10in) glass-fibre filter paper cat No: 1882 866 EPM 2000. Prior to the commencement of the analysis, the equipment was calibrated and standardised.

#### Determination of heavy metals in ambient air

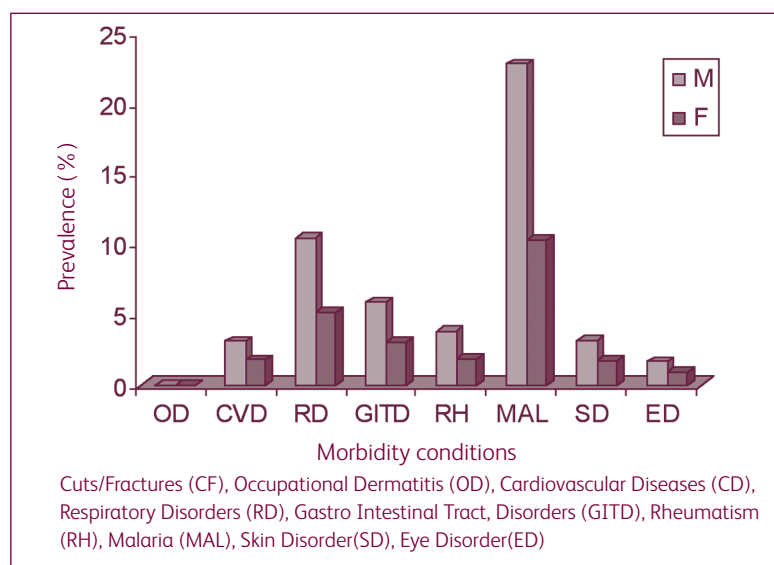
The concentration of heavy metals in the air was determined using standard methods (Dorn *et al.*, 1975) but with modifications to suit laboratory conditions at R&D, Nigeria National Petroleum Corporation (NNPC). A proportion of the exposed filter paper was split into tiny fragments to increase its surface area after which a twenty cubic centimetre mixture of concentrated hydrochloric acid and nitric acid (in a ratio 3:1) was added for digestion to take place. The digest was recovered and made up to 100ml. The concentration of heavy metals such as Ni, Cd, and Pb was determined using an atomic absorption spectrophotometer (AAS) model 929 made in Cambridge, London. The equipment was calibrated and equilibrated accordingly using one to five standards. Appropriate hollow cathode lamps (HCL), specific for the different metals, were used and nitrous oxide/acetylene flame (3,000°C) was utilised. The concentration of heavy metals in air is expressed in mg/m<sup>3</sup>.

#### Determination of PAHs in ambient air

This involved extraction using methanol, purification/solvent exchange and concentration stages. After

sampling, the particle-impregnated filter paper was properly stored under dark and cool temperature conditions prior to further processing. Before solvent extraction, the filter paper was reduced to tiny fractions to increase its surface area. This product was introduced as chips into a thimble for extraction using Soxhlet extractor based on a modified standard method (Lee *et al.*, 1979). According to this method, 150ml of methanol was used for the extraction process, which lasted 1 hour. This was repeated and the combined extract recovered for the purification and concentration stages. The extract was purified, and concentrated and analysed using HPLC.

The HPLC used is made up of an auto sampler of model Waters 717, a pump of model Waters 610 for both the fluid unit and valve station and Waters 6.00E for the pump system controller; a photodiode detector of model Waters IM 996, a fluorescence detector of model Waters 470, all made by Millipore. The software Millennium 32 was used and the method of operation was of the isocratic/gradient type with a combination of acetonitrile and deionised filtered water as the mobile phase and a stationary phase made up of silica gel loaded in 5µm HPLC column, SUPELCO SİLTM LC-PAH col: 12435-007 of dimensions 15cm x 4.6mm. The samples were run against a previously calibrated set of standards particularly for benzo (a) pyrene and indeno(1,2,3-cd)pyrene. The concentration of the PAH components is expressed in ng/m<sup>3</sup>.



**Figure 3.0**  
Prevalence of dominantly occurring morbidity conditions at EPCL

## Health survey

Information regarding the health of the plant workers was collected through a questionnaire survey and from health records. A 75-item semi-structured, validated and pre-tested questionnaire divided into five sections including occupational history, perceived environmental characteristics and health conditions were self administered to 200 plant workers each at EPCL and PHRC respectively.

Data from clinics within the industrial premises were collected from prepared records forms for morbidity and mortality cases within the period 1995-1999. Information concerning common morbidity cases including respiratory, skin, eye, and GIT disorders, rheumatism, poisoning and cancer were documented. Records comprising both male and female subjects aged at least 30 years were obtained from these facilities.

## Data analysis

Data obtained from laboratory analysis were processed statistically using mean and standard deviation, range as well as Mann-Whitney test for quantitative variables. Data from the questionnaire and hospital records were analysed using descriptive statistics, Chi Square test and logistic regression.

## Results

### Ambient PM<sub>10</sub> levels within PHRC and EPCL plants at Eleme

At the refinery, the highest PM<sub>10</sub> level ( $130.3 \pm 3.32 \mu\text{g}/\text{m}^3$ ) was recorded at PHRC1 (Area 5 close to the environmental department). The other locations viz PHRC 2 (Area 3, close to the safety unit) and PHRC3 (close to the maintenance department) recorded  $36.5 \pm 1.27 \mu\text{g}/\text{m}^3$  and  $27.9 \pm 2.33 \mu\text{g}/\text{m}^3$ , respectively. At the petrochemical complex the highest PM<sub>10</sub> level ( $81.3 \pm 4.31 \mu\text{g}/\text{m}^3$ ) was recorded at EPCL1 (close to effluent treatment plant) while locations EPCL2 (offsite area) and EPCL3 (within the polypropylene plant) recorded  $50.3 \pm 3.32 \mu\text{g}/\text{m}^3$  and  $28.9 \pm 2.05 \mu\text{g}/\text{m}^3$  respectively. The average PM<sub>10</sub> levels at PHRC were higher than that recorded at EPCL.

### Lead and other heavy metals in air within PHRC and EPCL plants at Eleme

The results indicated that the highest Pb level of  $0.20 \pm 0.03 \text{ mg}/\text{m}^3$  was recorded at the PHRC2, while the highest Ni level ( $0.86 \pm 0.34 \text{ mg}/\text{m}^3$ ) was recorded at PHRC3 (see Table 1.0). At the petrochemical complex, the highest Pb level ( $0.16 \pm 0.09 \text{ mg}/\text{m}^3$ ) was recorded at EPCL3 while the highest Ni level ( $0.05 \pm 0.02 \text{ mg}/\text{m}^3$ ) was recorded at EPCL1 (Table 2.0). Overall, the average heavy metal concentrations were higher at PHRC.

**Table 1.0**  
Levels of  
atmospheric  
emissions at  
PHRC Eleme

Parameter	PHRC1 (Mean ± SD)	PHRC2 (Mean ± SD)	PHRC3 (Mean ± SD)	Average/ Location	Guideline Limits
PM <sub>10</sub> (µg/m <sup>3</sup> )	130 ± 3.32	36.5 ± 1.27	27.9 ± 2.33	64.8	100(FMENV)
Pb (mg/m <sup>3</sup> )	0.16 ± 0.12	0.20 ± 0.03	0.11 ± 0.10	0.16	–
Cd (mg/m <sup>3</sup> )	0.008 ± 0.002	0.003 ± 0.001	0.009 ± 0.006	0.007	–
Ni (mg/m <sup>3</sup> )	0.004 ± 0.002	0.009 ± 0.004	0.86 ± 0.34	0.291	–
Benzo (a) pyrene ng/m <sup>3</sup>	–	–	1.63 x 10 <sup>2</sup>	54.3	<0.1–100ng/m <sup>3</sup> (WHO, 1997)
Indeno (1,2,3-cd) pyrene ng/m <sup>3</sup>	1.53 x 10 <sup>-3</sup>	2.53 x 10 <sup>-3</sup>	–	0.0014	<0.1–100ng/m <sup>3</sup> (WHO, 1997)
<sup>†</sup> PAH*(ng/m <sup>3</sup> )	1.53 x 10 <sup>-3</sup>	2.53 x 10 <sup>-3</sup>	1.63 x 10 <sup>2</sup>	54.3	<0.1–100ng/m <sup>3</sup> (WHO, 1997)

\* Total PAH {sum of benzo(a)pyrene + indeno(123-cd)pyrene}

#### Ambient PAH concentrations within PHRC and EPCL plants at Eleme

The highest concentration of benzo (a) pyrene (1.63x10<sup>2</sup>ng/m<sup>3</sup>) was recorded at PHRC 3 (Table 2.0) while the highest concentration of benzo (a) pyrene (1.61x10<sup>2</sup> ng/m<sup>3</sup>) was recorded at EPCL 3, which is in the production unit of the industrial complex. However, the total PAH concentration taken as the sum of benzo(a)pyrene and indeno(123)-cd pyrene was found to be higher at EPCL when compared with PHRC.

#### Reported health conditions at PHRC and EPCL based on survey findings

Based on the questionnaire findings 70.8% workers at PHRC as compared to 67.2% at EPCL reported poor air quality conditions. In both cases, the major cause was attributed to gas flaring. In both locations, symptoms associated with exposure to fumes and sprays such as respiratory disorder were widely reported among 40.8% respondents at PHRC and 27.6% at EPCL. There were reports of respiratory symptoms associated with exposure to dust and smoke, which causes irritation among 65.7% PHRC and 57.1% EPCL workers. Both the eyes and the skin were among other parts of the body also affected by the irritation. Cancer incidences were generally low with cases reported among 10.5% PHRC and 5.3% EPCL family members.

The results of the Chi Square analyses indicate that the duration of stay of PHRC workers in their residential communities was significantly associated with respiratory health problem (p=0.000), with cancers (p=0.000). Exposure to hazards within the industrial facility was significantly associated with painful body outgrowth (p=0.000) with miscarriages (p=0.000) and with cancer (p= 0.03). The result of the logistic regression indicated that at PHRC, smoking habits were significantly associated with painful body outgrowth (p=0.054, β= 0.402, OR = 1.49).

At EPCL, the duration of residence in the community was significantly associated with miscarriages (p=0.000), with deformed children (p=0.000), with symptoms related to health effects from air contaminants (p= 0.000) and with cancers (p = 0.000). Also, inadequate use of safety apparels was significantly associated with respiratory problems (p =0.03). Exposure to industrial hazards was significantly associated with respiratory problems (p= 0.03) and with painful body outgrowth (p = 0.000). The logistic regression analysis indicated that consumption of common aquatic food was found to have significant relationship with parts of the body affected by cancer (p= 0.026, β= 0.522, OR = 1.69).

Although the questionnaire outcome did not indicate which sex was more vulnerable to the health effects, this was strongly elucidated by the outcome of the hospital records. The latter did not only show a higher reporting

Parameter	EPCL 1 (Mean ± SD)	EPCL 2 (Mean ± SD)	EPCL 3 (Mean ± SD)	Average/ Location	Guideline Limits
PM <sub>10</sub> (µg/m <sup>3</sup> )	81.3 ± 4.31	50.3 ± 3.32	28.9 ± 2.05	53.5	100(FMENV)
Pb (mg/m <sup>3</sup> )	0.11 ± 0.08	0.14 ± 0.04	0.16 ± 0.09	0.14	-
Cd (mg/m <sup>3</sup> )	0.008 ± 0.004	0.007 ± 0.005	0.002 ± 0.003	0.006	-
Ni (mg/m <sup>3</sup> )	0.05 ± 0.02	0.02 ± 0.01	0.02 ± 0.01	0.03	-
Benzo (a) pyrene ng/m <sup>3</sup>	1.41 × 10 <sup>1</sup>	-	1.61 × 10 <sup>2</sup>	58.4	<0.1–100ng/m <sup>3</sup> (WHO, 1997)
Indeno (1,2,3-cd) pyrene ng/m <sup>3</sup>	-	1.10 × 10 <sup>1</sup>	-	3.67	<0.1–100ng/m <sup>3</sup> (WHO, 1997)
<sup>†</sup> PAH*(ng/m <sup>3</sup> )	1.41 × 10 <sup>1</sup>	1.10 × 10 <sup>1</sup>	1.61 × 10 <sup>2</sup>	62.03	<0.1–100ng/m <sup>3</sup> (WHO, 1997)

**Table 2.0**  
Levels of atmospheric emissions at EPCL Eleme

\* Total PAH (sum of benzo(a)pyrene + indeno(123-cd)pyrene)

rate of morbidity for males in both factories but an increased prevalence in most of the reported ailments including respiratory and skin disorders.

### Morbidity conditions at PHRC and EPCL based on clinic records

A total of 80,958 cases were studied at PHRC industrial location during the period 1995-1999 of which 73,877(91.3%) were males and 7081(8.75%) females. The distribution of morbidity conditions at PHRC indicates that cuts/scalds, respiratory conditions and other industrial accidents were among the most prevalent occupationally related health effects. Apart from malaria, which recorded the highest proportion, morbidities with fairly high proportions among males (M) and females (F) were respiratory disorders M: 123/1000 and F: 10.9/1000; GIT disorder M: 96.5/1000 and F: 7.6/1000; rheumatism M: 84.3/1000 and F: 6.50/1000; cardiovascular disorder M: 38.2/1000 and F: 4.10/1000 and skin conditions M: 42.1/1000 and F: 4.50/1000. In all these cases, the highest proportion was recorded among the males, who constituted the major work force in the industry. The records from PHRC indicated that there were more mortality cases among the male workers. The most reported causes of death were attributed to Road traffic accidents (RTA) and carcinoma.

At the petrochemical industrial complex, a total of 48,896 cases were studied during the period 1995-1999

of which 32,241 (65.9%) were males and 16,655 (34.1%) females. A distribution of the morbidity pattern indicated, as at PHRC, malaria recorded the highest proportion. Other reported health conditions such as cuts/fractures, occupational dermatitis and respiratory conditions also recorded high proportions. High proportions were recorded for morbidities such as GIT conditions M: 59.1/1000 and F: 30.8/1000; respiratory disorder M: 105/1000 and F: 30.4/1000; rheumatism M: 38.1/1000 and F: 18.6/1000 and skin infections M: 31.7/1000 and F: 17.4/1000. The mortality rate was higher among the male workers than the females both at EPCL and PHRC. The most reported causes of death were attributed to cardiac disorders, hepatitis and other factors whose etiologies were not established.

### Discussion

The outcome of this investigation is preliminary in nature. The results of the air quality assessment showed that average PM<sub>10</sub> levels within the PHRC were higher than the values recorded at EPCL but lower than the guideline limits stipulated by the Federal Environmental Protection Agency (FEPA, 1991), which is the national guideline. Although guideline values for heavy metals in air in Nigeria were not readily available, all the heavy metals determined including lead were relatively low. The low level of these substances notwithstanding may have health implications depending on the duration of exposure.

Of all the 16 PAH components measured, only two: benzo (a) pyrene and indeno (1,2,3-cd pyrene) were eluted and found to occur in the air within the PHRC and EPCL industrial premises. The benzo(a)pyrene concentrations at PHRC3 and EPCL3 were both higher than the WHO guideline limit. Incidentally, the average total PAH levels recorded at EPCL were higher than the values obtained at PHRC even though more PM<sub>10</sub> concentration was observed for the latter. This may have been associated with the breakdown of the highly polluting FCC unit in PHRC which was not operating during the study. However, both average total PAH levels recorded at PHRC and EPCL were lower than the WHO guideline limits of 0.1-100 ng/m<sup>3</sup> (WHO, 1997)

Studies carried out by Ana *et al.*, (In Press) revealed that TSP and PAH levels observed in the communities that surround these industrial complexes were higher than the values reported in this particular study and most of these values were higher than the stipulated guideline limits. This suggests that the burden of these toxicants is higher in the residential community areas than within the industrial premises.

The outcome of the survey had indicated that some of the staff in these industries occupy quarters located within these adjoining communities to PHRC and EPCL. It is therefore logical to find adverse health outcomes reported among the plant workers, even though their prevalence would be expectedly lower than the general population (Michael *et al.*, 1974)

This was corroborated by the outcome of the clinic data, which indicated respiratory morbidity as the most prevalent ailment (after malaria) among both PHRC and EPCL workers. This revelation is further supported by a report from other studies (Abbey *et al.*, 1993). The low level of smoking in the two populations also reduces the confounding factors. This perhaps also explains the reportedly high prevalence of respiratory morbidity and skin disorders among the plant workers from clinic data.

Overall, the trend in health outcomes indicates that male workers in PHRC and EPCL recorded the highest prevalence for all categories of morbidity cases documented throughout the five-year study period. This phenomenon could be explained by the fact that both industries have more male than female workers, and that the male workforce are involved in more risky and hazardous job specifications in the plants than their female counterparts. Similar studies by Ana *et al.*, (2005) also support this assertion.

## Conclusions

The burden of atmospheric emissions for PM<sub>10</sub>, heavy metals and PAH indicated that their average concentrations per the industrial locations were within permissible limits stipulated by regulatory bodies like FMEnv and WHO.

Chronic exposure to life time and low doses of atmospheric pollutants coupled with inadequate utilisation of personal protective equipments (PPE) may aggravate diverse deleterious health outcomes particularly pulmonary and dermal disorders as reported in this study.

In view of the outcome of this study it would be imperative to:

- Carry out a comprehensive environmental audit (EA) of the PHRC and EPCL facilities;
- Ensure that the EA involves an in-depth assessment of all other forms of atmospheric toxicants and a human exposure assessment employing appropriate checklists and biomarkers;
- Establish causality between the exposure factors and the identified health outcomes so as to reveal some of the unknown etiologies;
- Intensify regular environmental and health education and awareness programmes among the plant workers to enlighten them on the dangers inherent in exposure to hazards and their health consequences;
- Direct environmental education messages mostly at the male workers, the most vulnerable group in the industry.

## Acknowledgements

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