Journal of Scientific Research & Reports
7(6): 400-412, 2015; Article no.JSRR.2015.222
ISSN: 2320-0227

SCIENCEDOMAIN *international*
www.sciencedomain.org

Environmental Quality in Communities around Warri Refining and Petrochemical Company (WRPC), Niger Delta Region, Nigeria

G. O. Igile[1*], F. E. Uboh[1], U. O. Luke[1], S. U. Ufot[1], A. E. Robert[1] and P. E. Ebong[1]

[1]Department of Biochemistry, College of Medical Sciences, University of Calabar, P.M.B. 1115, Calabar, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author GOI designed the research, coordinated and interpreted the data. Author FEU carried out experimentation, field sampling, analysis and interpretation of data. Author UOL managed the literature searches and prepared draft manuscript and analyses of the study performed. Author SUU prepared micrographs, graphics and preparation of final manuscript. Author AER performed Atomic Absorption spectrometry and Flame Photometry and author PEE managed the experimentation process and interpretation of data. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2015/13627
Editor(s):
(1) Shunpu Zhang, Department of Statistics, University of Nebraska – Lincoln, USA.
(2) Kan Chi-wai, Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hong Kong.
Reviewers:
(1) Anonymous, Metropolitan Autonomous University, México.
(2) Anonymous, University of Misurata, Libya.
(3) Anonymous, Hamdard University, Karachi, Pakistan.
(4) Anonymous, University of Benin, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1130&id=22&aid=9458

Original Research Article

Received 26th August 2014
Accepted 11th May 2015
Published 28th May 2015

ABSTRACT

Petroleum refining is accompanied by the release of toxicants into the environment, including suspended particulate matter (SPM), poisonous gaseous oxides of carbon (COx), nitrogen (NOx), and sulphur (SOx) and hydrogen sulphide (H_2S), ammonia (NH_3), volatile organic compounds (VOCs) and heavy metals such as Pb, As, Hg, Cd, Cr and Fe. These atmospheric acid rain precursor emissions contribute significantly ($p<0.05$) to environmental degradation and toxicity to humans, aquatic and terrestrial life forms. The aim of this study was to assess the environmental

**Corresponding author: Email: goitech2000@yahoo.com;*

quality in communities around the Warri Refining and Petrochemical Company (WRPC). The study design involved choosing a circumference of 10 km around the WRPC and dividing into distances of 10 km (control), 3.55 km (Ubeji), 2 km (Ijala), 500 m (Ifie-Kporo and Aja-Etan), and 0 km (Gas flaring tower base) from the refinery plant. Air quality parameters were measured in these locations in the wet and dry seasons using standard air quality measuring kits, at wind speed of 2.60±1.22 m/s; wind direction NE, temperature 30±2.50°C, and relative humidity of 68±1.20%. Negligible concentrations of oxides of NO_2, SO_2 and CO, and H_2S, NH_3, VOC and SPM were detected in the air at the control location (10 km) from the refinery. Significant levels ($p<0.05$) of emissions were detected in the air as the distances got closer to the refinery. At Ubeji (3.55 km) from the refinery, mean levels detected were CO (2.60±0.22 ppm), NO_2 (10±2.1 ppm), SO_2 (24±1.5 ppm), H_2S (0.40±0.01 ppm), NH_3 (0.11±0.01 ppm), VOC (63±1.25 ppm), and SPM (184±2.5 ppm) respectively. Significant ($p<0.05$) levels of SPM were detected at between 2 km and 500 m from the refinery. The mean SPM levels recorded in the communities around the WRPC were Ifie-kporo and Ajala (194±4.12 ppm), Aja-Etan (188±3.0 ppm) and the base of the gas flaring tower (186±2.5 ppm). Ifie-kporo and Ajala communities (2 km) recorded significantly ($p<0.05$) highest values of toxic substances, including CO (3±0.42 ppm), NO_2 (23.40±0.50 ppm), SO_2 (83±1.4 ppm), H_2S (0.60±0.11 ppm), VOC (116.80±5.4 ppm) and SPM (194±3.9) respectively. Mean noise levels of 60.75±0.50 dbA and 61.25±2.70 dbA were recorded for the wet and dry seasons respectively. Hg and Cr exceeded EPA limits, while Cd and Pb fell within EPA limits. It was concluded that some of the parameters in the gaseous emissions exceeded EPA limits and may therefore be classified as hazardous to the ecosystem and populations living around the refinery and may elicit endocrine disruption in humans and animals.

Keywords: Petroleum refining; emissions; pollutants; toxicants; endocrine disruption.

1. INTRODUCTION

Petroleum refining in the Warri Refining and Petrochemical Company (WRPC) Limited has generated persistent and constant agitation from neighbouring communities with respect to environmental air pollution and black carbon deposits on soil. Indigenous inhabitants in this area insist on proper environmental controls and Best Practices to minimize air pollution, precipitation chemistry (or acid rains) and Carbon Black (CB) emissions from the crude oil refining operations.

There is a perception in these communities that the refining operation emit toxic wastes into the environment and that these toxicants are detrimental to their environment including human health, livestock and food crops, on both short and long term basis. These claims have not actually been scientifically substantiated, but the agitations persists.

Air pollution has become a major public and political concern in Nigeria, including the petroleum refining sites. In a similar study, [1] had reported that environmental pollution cause global warming and deplete the ozone layer, and that the impact of ozone and nitric oxide on the health and performance of plants and animals has not been properly estimated, and appears to be used as a political instrument. In contrast, the combination of SO_2 with soot and asbestos particles may represent an underestimated toxic potential associated with air pollution caused by petroleum refining.

The present study aim to verify the qualitative and quantitative composition of environmental pollution including air and soil pollution from the WRPC oil refining operation into the immediate environment comprising Ubeji, Ifie-Kporo, Aja-Etan and Ijala communities compared to the control community of Efurun (10 km away from the Warri refinery).

The composition of petroleum refining emissions generally consists of suspended particulate matter (SPM), poisonous gaseous oxides of carbon (COx), nitrogen (NOx) and sulphur (SOx), as well as hydrogen sulphide (H_2S), ammonia (NH_3) and volatile organic compounds (VOCs) [2,3]. Some of these compounds are themselves persistent organic pollutants (POPs) or precursors of POPs. The compounds are also major contributors to acid rain precipitation, especially during wet seasons. Acid rain is not only harmful to humans and livestock, but also to plants and buildings [4]. The composition of SPM may also include heavy metals of global concern, including cadmium, mercury, arsenic and lead. All of these hazardous compounds and carbon

deposits from petroleum refining are known to be implicated in soil pollution [5,6,7].

Fossil fuel combustion gives off soot, sometimes known as black smoke. Soot consists of heavy metals, acidic and toxic compounds, and extremely fine carbon-containing particles that, in addition to being a health hazard, are responsible for the blackening of buildings and other outdoor structures with an attendant hazardous effect on human and animal health and food crops [6].

The consequences of these substances in the environment include, their direct contact with humans and livestock as well as their direct entry into the food chain [4]. Persistent organic pollutants (POPs) and chemical residues produce all kinds of toxicities in man, including cardiovascular and respiratory tract diseases, endocrine disruption, hemolyses and immunosuppression. They cause testicular and cervical cancers, hepatotoxicities, nephrotoxicities, cardiotoxicities, lymphomas and leukemia and may potentially induce diabetes and spontaneous aging [8,9,10].

The primary sources of atmospheric emissions and other environmental pollution from petroleum refining, vehicular movement and construction operations include:

- Airborne particulates from soil disturbance during construction activities.
- Airborne particulates from heavy traffic and vehicular movement.
- Combustion processes such as petroleum distillation, catalytic cracking and gas flaring.
- Fugitive particulates, emissions and smoke
- Black carbon deposits on soil, which bring with it heavy metals and toxic chemical compounds.

The advent of crude oil exploration and petroleun refining, and the attendant oil spills and environmental pollution necessitated the ratification of environmentally related multilateral International agreements (MEAs) by the Nigerian Government. The aim being majorly to compel oil companies operating in Nigeria to comply with these MEAs, EPA and National Standards on environment. Some of these UN and UNEP multilaterally binding environmental instruments include the Basel, Stockholm and Rotterdam Conventions. These agreements mean that all member countries must regulate their environmental practices and enforce Cleaner Chemistry, to minimize detrimental effects of environmental pollution and releases in humans and the environment [11].

The Nigerian Ambient Air Quality Standards is shown in Table 1. The standard was established to regulate environmental air quality especially in cities and industrial locations, and to enforce regulatorycompliance.

2. MATERIALS AND METHODS

2.1 Materials

Air quality parameters were measured in these locations using standard air quality measuring kits (V-RA Instruments, IR MultiRAE, AEROTRACK Particle Counter and EXTECK 407730-China PROC, Envirotech Instruments, Pvt. Ltd, India), after the determination of the prevailing meteorological parameters including temperature, relative humidity, wind speed and wind direction.

2.2 Experimental Design

A circumference of 10 km was chosen around the WRPC and divided into six (6) distances. Ugbori (10 km) served as control, while Ubeji (3.50 km), Ijala (2km), Aja-Etan (500 m), Ifie-Kporo (400 m), and Gas flaring tower base (0 km) were the test and sampling areas. The gas flaring tower and the catalytic plant were the major sources of emissions, with a mean stack vertical emission mixing height of approximately 60 m.

2.3 Method

2.3.1 Determination of meteorological parameters

Mean values of relative humidity (%), temperature (ºC) and wind speed and wind direction were determined for the wet and dry seasons throughout this study before air quality parameters were measured. Humidity and temperature were measured using Omega Humidity/temperature transmitter (HX400 Series, USA), while wind speed and wind direction were measured using Handheld HHF 81 Omega digital Instr (USA).

Table 1. Nigerian ambient air quality standard

Pollutants	Time of average	Limits
Particulates as SPM	Daily average of hourly values	250 μg/m^3 -600 μg/m^3
SO_x as SO_2	Daily average of hourly values	0.01 - 0.1 ppm
NO_x as NO_2	Daily average of hourly values (range)	0.04 – 0.06 ppm
COx as CO	Daily average of hourly values 8 - hourly range	10 – 20 ppm
Petrochemical oxidants	Hourly value	0.66 ppm max
Non-Methane hydrocarbon	Daily average of 3-hourly values	160 μg/m^3

**Note: Concentration not to be exceeded for more than once a year*

2.3.2 Determination of noise levels

The noise levels at various distances were measured using a pre-calibrated Envirotech sound level meter (Model WM 271, SI No162-DTC-2011). The sensor of the noise meter was directed towards the source of the noise and the noise levels at the various distances were read from the digital meter in decibels (dBA).

2.3.3 Determination of air quality parameters

Air quality parameters including concentrations of NO_2, SO_2, CO, Volatile organic compounds (VOCs), and concentrations of NH_3 and H_2S gases were determined using outdoor direct Air Quality reading instruments (V-RA Instruments, IR MultiRAE, AEROTRACK Particle Counter and EXTECK 407730-China PROC, Envirotech Instruments, Pvt. Ltd, India). For each parameter, the specific meter was switched on at each sampling point for about 30 minutes to record three readings. Mean values were calculated and recorded in ppm.

2.3.4 Determination of suspended particulate matter (SPM)

Suspended particulate matter (SPM) was determined in the communities around the WRPC, using a direct reading AEROTRACK Particle Counter 9306-V2 (China). Three determinations were read per location for the dry and rainy (wet) seasons respectively, and values expressed in ppm.

2.3.5 Determination of heavy metals

Heavy metals including lead (Pb), mercury (Hg), cadmium (Cd), Iron (Fe), arsenic (As) and chromium (Cr) were analyzed in air samples according to the method described by [12].

2.4 Statistical Analysis

All data were expressed as Mean±SEM of number of replicates (n = 3). Results of test locations were compared using Analysis of Variance (ANOVA) in the SPSS version 16 software. Values of $p<0.05$ were considered to indicate a significant difference between locations.

3. RESULTS AND DISCUSSION

Tables 2 and 3 shows the meteorological parameters determined for the wet and dry seasons. Temperatures were found to be lower (approx 24°C) during the wet season, and higher (approx 30°C) during the dry season. These temperature values, humidity, wind speed and direction, are characteristic of the two seasons in the south of Nigeria. Air quality parameters determined in the dry and wet seasons are presented in Tables 4 and 5. The mean wind speed of 1.50±0.02 m/s SW; temperature 24.5±0.20°C, and relative humidity of 79±1.50% were measured for the wet season (Table 2). Wind speed of 2.60±1.22 m/s NE; temperature 30±2.50°C and relative humidity of 68±1.20% were obtained for the dry Season study (Table 3). The mean values for humidity and temperature were consistent of tropical climatic conditions. The wind direction (SW) for the wet season, and and (NE) for the dry season is consistent with the prevailing wind conditions in Nigeria at both seasons respectively. Mean noise levels of 60.75±0.50 dbA and 61.25±2.70 dbA were recorded for the wet and dry seasons respectively.

The results of mean air quality parameters determined during the rainy (wet) and dry seasons are presented in Tables 4 and 5 respectively. Ugbori Community (10km from WRPC), in Effurun area served as the control location.

Relative humidity was higher (80±0.25%) in the rainy season with lower temperatures (28±0.01°C) compared to lower humidity values (65.60±0.60%) and higher temperatures (30±0.50°C) during the dry season with accompanying dry North East (NE) trade winds.

Three key parameters (CO, VOCs and SPM) measured during the wet and dry seasons gave values that were considered significant ($p<0.05$), but fell below EPA standard set by the Federal Ministry of Environment (Tables 4 & 5). CO levels were: Ugbori (3 ppm), Ubeji (55 ppm), Ijala (42 ppm), Aja-Etan (50 ppm), Ifie-Kporo (58 ppm) and the base of the Gas Flaring Tower (59 ppm) (Figs. 2&3). These values fell below EPA standards, and were not considered harzardous to the environment. VOC levels were, Ugbori (0.05 ppm), Ubeji (65 ppm), Ijala (117 ppm), Aja-Etan (25 ppm), Ifie-Kporo (64 ppm) and the base of the Gas Flaring Tower (65 ppm). Mean SPM values were, Ugbori (22 ppm), Ubeji (189 ppm), Ijala (195 ppm), Aja-Etan (182 ppm), Ifie-Kporo (185 ppm) and the base of the Gas Flaring Tower (190 ppm) (Tables 4 & 5). SPM levels were found to be higher in Ubeji, Ijala, Aja-Etan and Ifie-Kporo when compared to the control location (Igbori (Effurun). However these values were significantly ($p<0.05$) lower than specified EPA standard.

The values of NO_2, SO_2, H_2S and NH_3 for the two seasons (Wet and Dry) were low and insignificant ($p>0.05$) in all the communities studied as well as the base of the Gas Flaring Tower of the WRPC (Tables 4&5). The control location (Ugbori) gave even lower values compared to the test location.

Table 2. Mean results of meteorological parameters of communities around the WRPC (Wet Season)

Location	Noise dB(A)	Tempt (ºC)	Wind speed (ms^{-1})	Rel. Hum (%)	Wind Dir	Dist (km) from WRPC
Ugbori Comm	61.50±0.87	24±0.05	2.0±0.01	78±1.50	SW	10.75
Ubeji Comm	60.50±0.25	25±0.50	1.5±0.03	79±1.50	SW	3.50
Ijala	60.50±0.20	24±0.00	1.5±0.01	78±1.55	SW	2.00
Aja-Etan	60.00±0.45	25±0.20	2.0±0.05	80±0.25	SW	0.50
Ifie-Kporo	60.00±0.40	25±0.20	1.5±0.02	80±0.55	SW	0.50
Gas Tower	63.00±1.25	26±0.25	2.0±0.05	82±0.50	SW	0.00

Values are mean±SEM, and n=3

Table 3. Mean results of meteorological parameters of communities around the WRPC (Dry Season)

Location	Noise db(A)	Tempt ºC	Rel. Hum (%)	Wind speed (ms^{-1})	Wind Dir	Dist (km) from WRPC
Ugbori Comm	62.50±0.25	30±0.20	64.70±0.15	2.5±0.02	NE	10.75
Ubeji Comm	65.50±2.20	30±0.20	65.00±0.05	2.0±0.01	NE	3.50
Ijala	60.50±0.50	30±0.25	64.60±0.50	2.0±0.01	NE	2.00
Aja-Etan	60.00±1.20	30±0.50	65.60±0.60	3.0±0.32	NE	0.50
Ifie-Kporo	60.00±1.25	30±0.55	65.60±0.65	2.5±0.10	NE	0.50
Gas Tower	59.00±1.50	32±0.05	67.6±0.55	3.0±0.20	NE	0.00

Values are mean±SEM, and n=3

Table 4. Mean concentrations of air quality pollutants in Ubeji, Ijala, Aja-Etan, Ifie-Kporo communities and the gas flaring tower base (Wet Season)

Sampling points	CO	NO_2	SO_2	H_2S	NH_3	SPM	VOC
Unit of measure	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Ugbori (Control)	3.0±0.22	10.0±1.51	24±2.0	0.00±0.00	0.00±0.00	45±2.50	0.00±0.00
Ubeji	55±0.22	22±1.51	24±2.44	0.40±0.01	0.00±0.00	184±3.17	63±2.45
Ijala	42±0.27	23±1.20	83±1.67	0.60±0.10	0.03±0.01	194±3.50	109±5.20
Aja-Etan	58±0.54	13.6±0.12	85.5±0.31	0.87±0.11	0.02±0.01	178±3.62	17±1.04
Ifie-Kporo	58±1.70	13.2±0.02	84.0±0.08	0.08±0.03	0.01±0.00	178±2.50	63±1.24
Gas Tower base	59±0.50	80±0.32	30±0.11	0.06±0.01	0.20±0.03	186±3.26	63±1.75
FMEnv STD	22.8 max	113 max	260 max	10 max	25 max	600 max	160 max

Values are mean±SEM, and n=3

Table 5. Mean concentrations of air quality pollutants in Ubeji, Ijala, Aja-Etan, Ifie-Kporo communities and the gas flaring tower base (Dry Season)

Sampling points	CO	NO_2	SO_2	H_2S	NH_3	SPM	VOC
Unit of measure	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Ugbori (Control)	10±0.03	12±0.50	26±0.72	0.05±0.01	0.02±0.01	52±1.40	0.05±0.01
Ubeji	58±0.57	26±0.11	24±0.60	0.62±0.03	0.06±0.02	189±2.31	65±1.21
Ijala	52±0.25	25±1.05	81±0.45	0.80±0.05	0.07±0.01	195±2.50	117±2.34
Aja-Etan	58±2.70	11±0.50	15±0.30	0.92±0.07	0.05±0.01	182±2.33	25±1.22
Ifie-Kporo	58±.2.55	12±0.34	12±0.40	0.55±0.02	0.07±0.02	185±2.26	64±0.50
Gas tower base	59±1.50	56±0.02	47±0.50	0.41±0.01	0.25±0.03	190±2.25	65±0.75
FMEnv STD	22.8 max	113 max	260 max	10 max	25 max	600 max	160 max

Values are mean±SEM, and n=3

Concentrations of NO_2, SO_2, CO and (H_2S), (NH_3), VOC and SPM were not detected in the air at a distance of 10km (Control location) from the Refinery. As distances were closer to the refinery, significant levels ($p<0.05$) of these emissions were detected in the air. At Ubeji (3.55 km) from the refinery, levels detected were CO (2.60±0.22 ppm), NO_2 (10±2.1 ppm), SO_2 (24±1.5 ppm), H_2S (0.40±0.01 ppm), NH_3 (0.11±0.01 ppm), VOC (63±1.25 ppm), and SPM (184±2.5 ppm) respectively (Tables 4&5). Significant ($p<0.05$) levels of SPM was detected at between 2 km and 500 m from the refinery. Ifie-kporo and Ijala communities recorded SPM levels (194±4.12 ppm), Aja-Etan (188±3.0 ppm), and the base of the gas flaring tower (186±2.5 ppm). Ifie-kporo and Ijala communities (2km) recorded significantly ($p<0.05$) highest values of toxic substances, including CO (3±0.42 ppm), NO_2 (23.40±0.50 ppm), SO_2 (83±1.4 ppm), H_2S (0.60±0.11 ppm), VOC (116.80±5.4 ppm) and SPM (194±3.9 ppm) respectively.

The range of CO (42-59 ppm) in the study area far exceeded the Nigerian EPA specified limit (22.8 ppm max) for carbon monoxide in the air. Highest values were obtained in Ubeji, Aja-Etan and Ifie-Kporo communities. If CO is absorbed by the lungs, it reduces the oxygen carrying capacity of blood, impairs mental function and aggravates cardiovascular diseases. Prolonged low level exposure to CO diminishes visual perception and ability to perform intellectual tasks [13,9,10]. The main anthropogenic source of CO in the atmosphere is incomplete combustion of carbonaceous materials [14].

Significant ($p<0.05$) levels of NO_2 were obtained around the base of the gas flaring tower in the wet season (80 ppm) and the dry season (56 ppm), when compared to the control location at Ugbori (10-12 ppm), 10 km away from the source of pollution. The gas flaring tower is located in an area with reasonable daily human activity. At high concentrations, NO_2 causes lung injury and hepatotoxicities. Toxicological studies have shown that it reduces the efficacy of lung defense mechanisms against infection [9]. Short–term exposure may exacerbate asthma [13]. NO_2 may also cause serious damage to vegetation, including defoliation of food crops and ornamental plants. The release of NO_2 into the atmosphere and its subsequent conversion to HNO_3 is responsible for the acidity of rain water. NO_2 is instrumental to troposphere layer ozone production and stratospheric ozone depletion [2].

Sulphur dioxide (SO_2) levels were found in significant ($p<0.05$) concentrations during the wet season at Ijala (83±1.67 ppm), Aja-Etan (85.5±0.31 ppm) and Ifie-Kporo (84.0±0.08 ppm) communities respectively (Table 4). The dry season recorded high SO_2 value (81±0.45 ppm) only at Ijala community. Variations in SO_x distribution at other communities in the study area during the dry season were statistically insignificant ($P > 0.05$) (Table 5). SO_2 is an irritant gas that affects the upper respiratory tract, causing physical discomfort and even death. SO_2 is known to reduce atmospheric visibility and damages agricultural crops, and may be corrosive to metallic materials as clearly observed on the roof tops of the communities studied. [15] have reported that when SO_2 is either oxidized or hydrolyzed, it produces acid rains, which have adverse effects on terrestrial and aquatic flora and fauna as well as infrastructure as observed in the environment under investigation.

Significant ($p<0.05$) concentrations of VOCs were detected at Ijala in the wet season (109±5.20 ppm) (Fig. 7), and the dry season (117±2.34 ppm) (Fig. 5), compared to the control location of Ugbori (0.05±0.01 ppm) (Figs. 6 & 7). Other locations tested gave values that were

insignificant ($p>0.05$) and below regulatory limits. However, VOC's are generally known to be carcinogenic, causing hepatotoxicities, nephrotoxicities and inductive Type 1 diabetes [16,17].

Various anthropogenic sources appear to contribute to the elevated SPM levels around the Warri refinery, including over 500 trucks that park at the loading bay for PPMS products, and over 200 WRPC operational and staff cars. There is also a nearby dump-site that is continuously burned, some construction sites, as well as increasing urbanization activities, all of which contribute to increasing the concentration of suspended particulate matter (SPM) in the air (Figs. 4 & 5). The major discharge of air pollutants including SPM, comes from the Gas Flaring Tower (Fig 1), providing a mixing height of approximately 500m. The discharge from the Gas flaring tower spread particulate matter over a distance of 5 km (Fig. 1). Constituents of particulate matter are known to cause cardiovascular diseases such as myocardiac infarction and hypertension, and also cause respiratory infections including cough, catarrh and asthma [18].

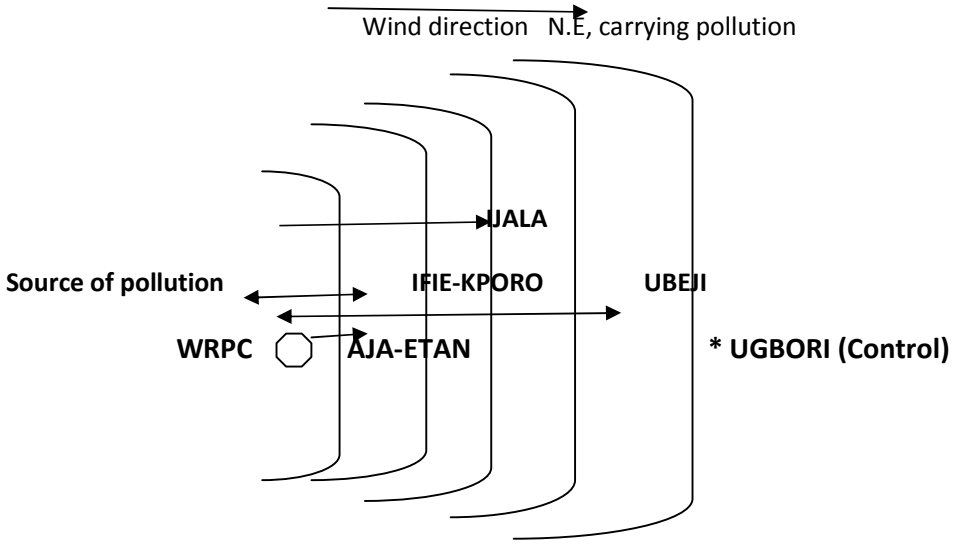

Fig. 1. Schematic illustration of study design

**Distances for Ijala, Ubeji and Ugbori were in kilometers while that of Ifie-kporo and Aja-etan were in meters.*

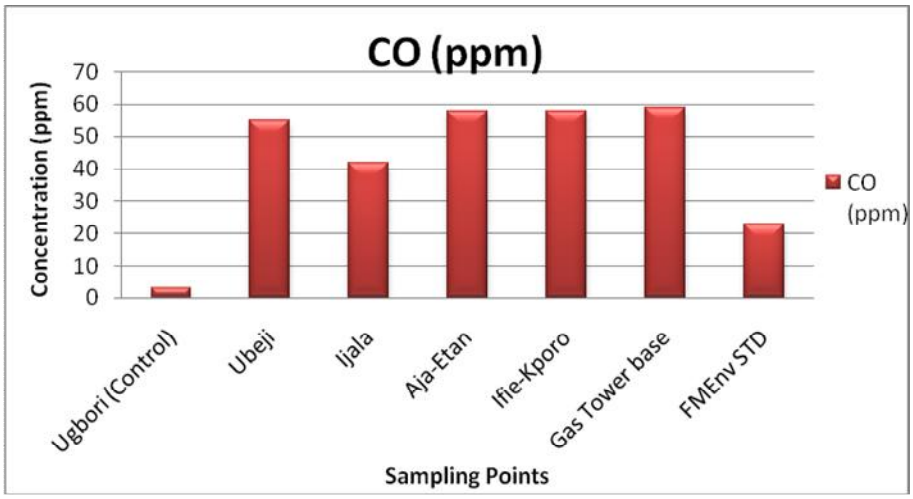

Fig. 2. CO concentration during the dry season

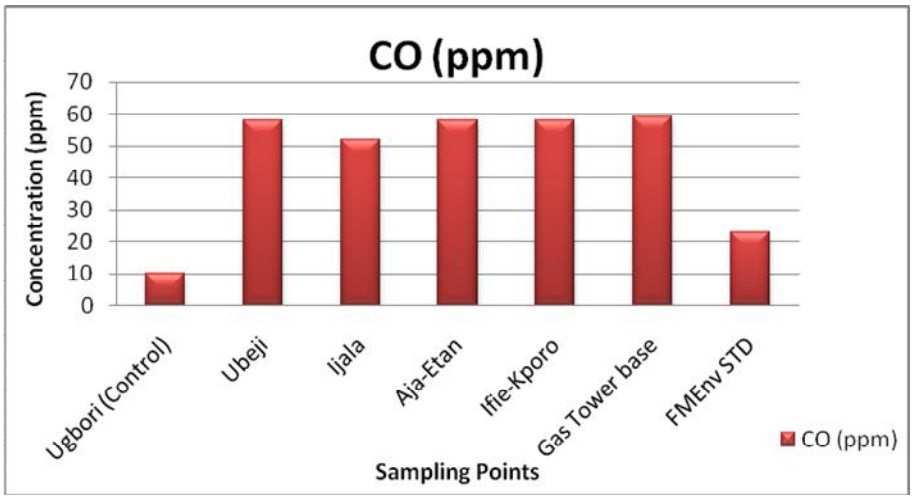

Fig. 3. CO concentration during the wet season

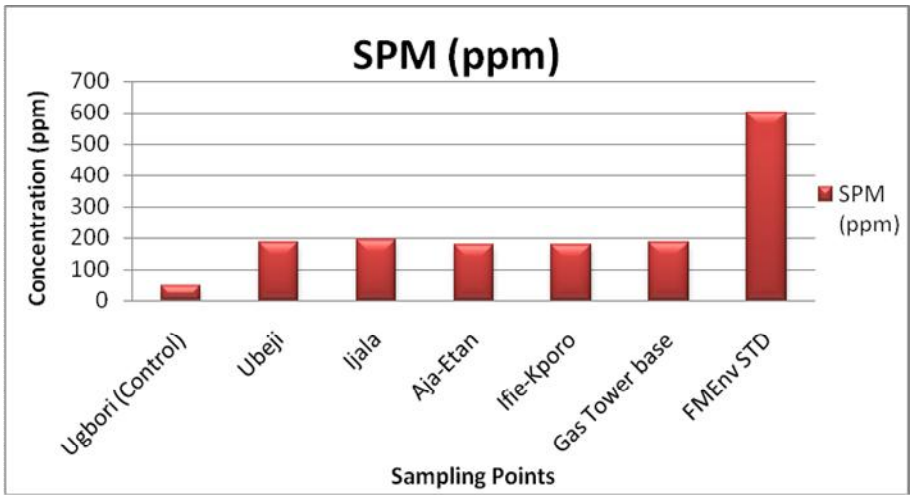

Fig. 4. SPM concentration during the dry season

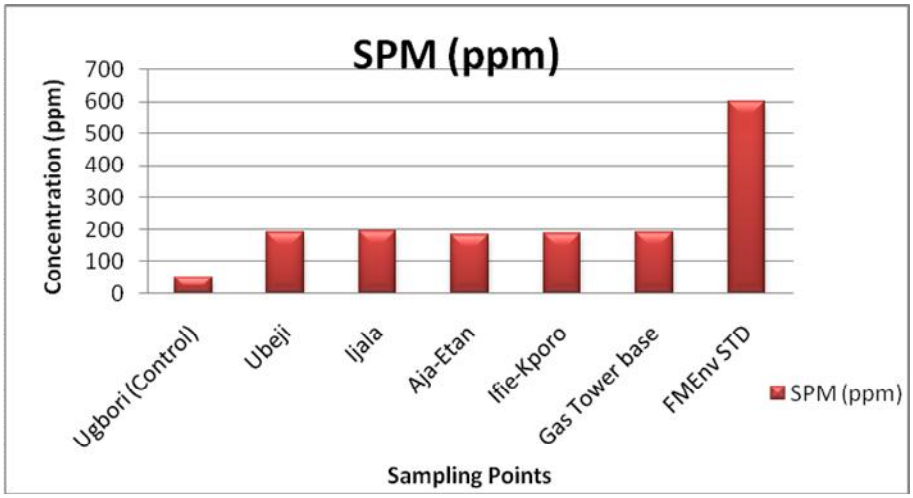

Fig. 5. SPM concentration during the wet season

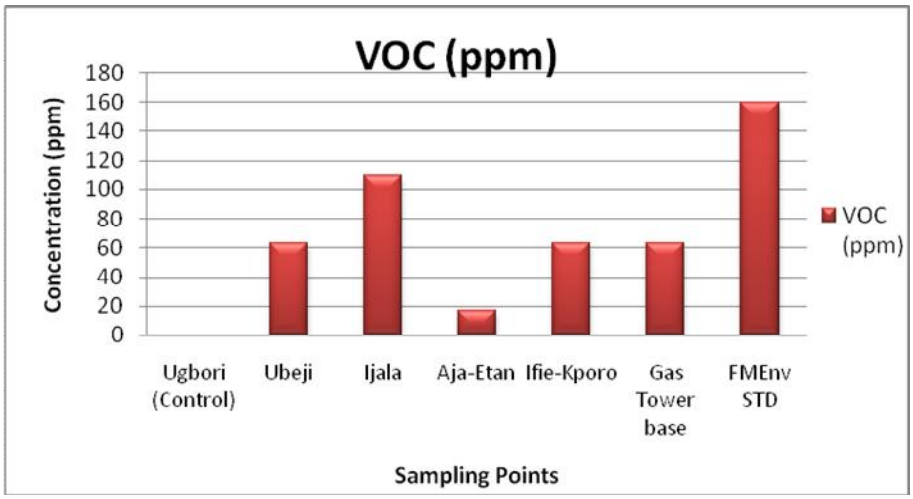

Fig. 6. VOCs concentration during the dry season

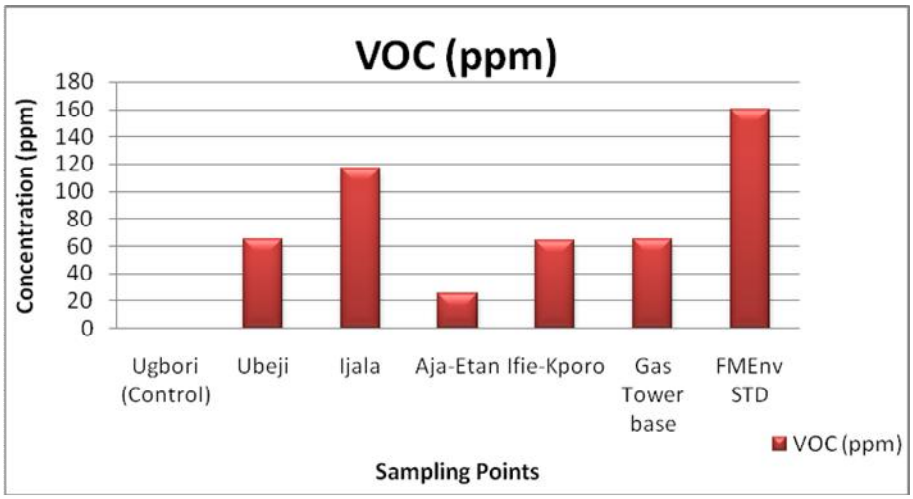

Fig. 7. VOCs concentration during the wet season

Although the VOCs concentrations obtained in this study were low (180-195 ppm) for the wet (Table 4) and dry (Table 5) seasons, the values were significant ($p<0.05$) enough to cause harm to the ecosystem.

There was significant ($p<0.05$) emission of unpleasant hydrocarbon odour at Ijala, Aja-etan, Ifie-Kporo, and some parts of Ubeji community near the Gas flaring Tower with a mixing height of approximately 500 m, when compared to the control location of Ugbori community. The constant and persistent inhalation of petroleum odours and fumes may lead to various endocrine related disorders, including cardiotoxicities, hepatotoxicities, hemoglobinopathies, gonadal dysfunctions, diabetes and spontaneous ageing.

Air quality values for H_2S and NH_3 in all the locations studied were found to be statistically insignificant ($p>0.05$) in this study and below regulatory limits.

The noise levels at the base of the Gas Flaring Tower and the adjoining communities were found to be relatively low (Table 2). The values were <65dbA and below the 90 dB(A) regulatory standard set by FMEnv [11]. However, there were significant spatial variations ($P < 0.05$) in the noise levels (Table 2), with the highest mean noise load of 65 dB(A) recorded at Ubeji Community in the dry season. The noise range of 60-65 dB(A) recorded in the communities of the study area is typical of unperturbed remote sites, as earlier reported [19].

The level of metallic pollutants in this study (Table 6), may be attributed to the differential derivations of these inorganic pollutants from the environment and differential discharge of gaseous pollutants originating from the gas flaring tower of the refinery (Figs. 8 & 9). Heavy metals are potentially harmful to humans and animals. Some metals including Hg, Cd and Cr have received attention as both environmental and potential toxicological hazards and have been categorized as "Metals of Global Concern" by UN bodies. Mean heavy metal concentrations higher than specified by the FMEnv, were detected in some of the communities studied [11].

Mean concentration of cadmium at 0.07 ppm and 0.08 ppm were detected at Aja-etan and Ifie Kporo in the wet and dry seasons respectively. This could be attributed to atmospheric precipitation from the refinery, and leachate from the refinery sludge lagoon containing Nickel – Cadmium batteries and Cadmium plate.

The presence of cadmium in the study area could be attributable to industrial discharges resulting from oil refining operations which support earlier findings [20-22].

Table 6. Mean concentrations of heavy metals in wet depositions of Ubeji, Ijala, Aja-Etan and Ifie-Kporo communities

	Rainy (Wet) Season				Dry Season			
Sampling points	**Cd**	**Hg**	**Pb**	**Cr**	**Cd**	**Hg**	**Pb**	**Cr**
Unit of measure	**(ppm)**	**(ppm)**	**(ppm)**	**(ppm)**	**(ppm)**	**(ppm)**	**(ppm)**	**(ppm)**
Ugbori (Control)	0.03±0.01	0.01±0.00	0.03±0.02	0.05±0.01	0.03±0.01	0.02±0.00	0.04±0.02	0.06±0.01
Ubeji	0.04±0.01	0.02±0.01	0.04±0.01	0.06±0.02	0.05±0.01	0.03±0.01	0.06±0.01	0.07±0.02
Ijala	0.06±0.02	0.04±0.02	0.05±0.01	0.08±0.02	0.07±0.02	0.05±0.02	0.07±0.02	0.09±0.03
Aja-Etan	0.07±0.02	0.05±0.01	0.06±0.02	0.09±0.03	0.08±0.02	0.06±0.01	0.08±0.02	0.11±0.04
Ifie-Kporo	0.07±.0.01	0.05±0.02	0.06±0.01	0.09±0.02	0.08±.0.01	0.05±0.02	0.08±0.03	0.10±0.04
Gas tower base	0.05±0.02	0.02±0.01	0.05±0.01	0.08±0.01	0.06±0.02	0.03±0.01	0.07±0.01	0.08±0.02
EPA STD	<1	<0.05	<1	<0.05	<1	<0.05	<1	<0.05
WHO STD	0.003	0.001	0.001	0.001	0.003	0.001	0.001	0.001

Values are mean±SEM, and n=3

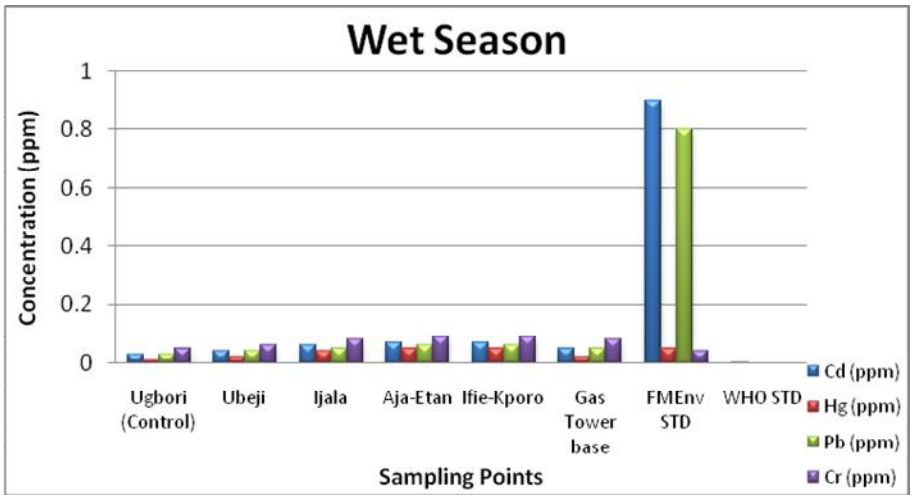

Fig. 8. Heavy metals concentration during the wet season

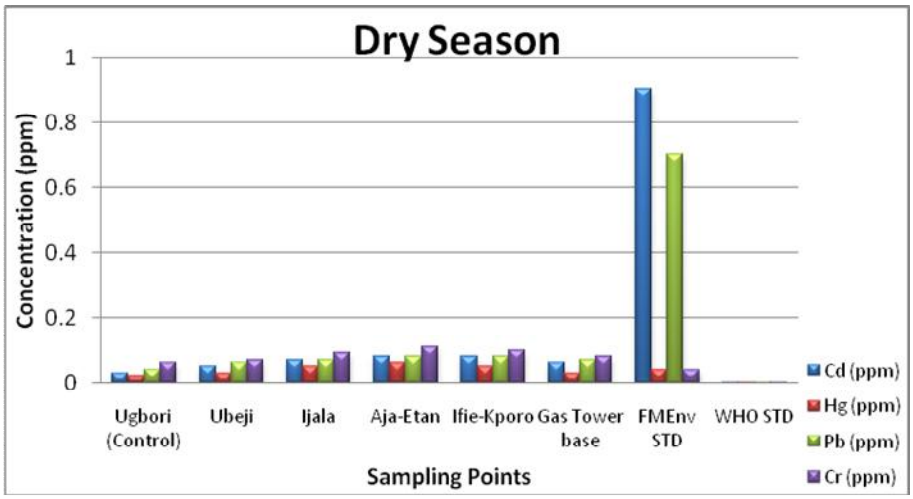

Fig. 9. Heavy metals concentration during the dry season

Studies have shown that cadmium could cause adverse health effect to humans and toxicity to fish and other aquatic organisms [5,23,24,21]. In this study, the levels of cadmium, mercury, lead and chromium exceeded the threshold limits (0.01, 0.003, 0.4 and 0.05 mg/l respectively) set by the WHO health-based guideline for drinking water and the environment, and this could portend environmental hazards. The levels of lead found in this study agree with earlier studies on lead contents in soil and ground water from Warri, Niger Delta [25].

The concentrations of lead in the soil sample were high (0.03±0.02-0.08±0.02 ppm), and may leach into both surface and underground water at significant concentrations. Lead exposure has been associated with hepatotoxicities, nephrotoxicities, microcytic and hypochromic anemia with basophilic stippling of erythrocytes, hyperactivity, anorexia, decreased play activity, low intelligence quotient and poor school performance in children [9,10]. It has been reported that the ability of Pb^{2+} to undergo metathesis reactions with Zn^{2+} and Ca^{2+} metalloproteins resulting in loss of metabolic function continues to be a primary hypothesis underlying the detrimental effects of lead exposure [26]. Cadmium is highly toxic, accumulating in the body and eventually causing effects such as tubular dysfunction, disturbances in calcium homeostasis and metabolism [16]. Cadmium is capable of inducing renal, hepatic and testicular injury [27]. It was reported that some chromium compounds are carcinogenic, and long exposure may cause kidney, liver and nerve tissue damage [1,28].

4. CONCLUSION

This study showed that there is an unhealthy environment around the WRPC and the adjoining communities which may affect the health of the populations around the refinery. The results of the study suggest that a large number of people may be exposed to hazardous and toxic emissions around the WRPC, and these may contribute to some biochemical responses, including, endocrine disruption, cerebrovascular, cardiovascular and respiratory tract infections and even diabetes mellitus and spontaneous aging resulting from air pollution exposure.

5. RECOMMENDATIONS

Greater awareness and more extensive research on air pollution in Warri, Port Harcourt and Kaduna refineries is required to determine the extent of carbon black emissions from these refineries, and to develop air quality management plans and policies to improve public health in petroleum refining cities in Nigeria.

6. FUTURE RESEARCH

Research is on-going on the Air pollution component in the WRPC that may be considered carbon black, and a soot that darkens buildings, as well as properties of the soil, and their impact on the health man and animals, and environmental degradation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hippeli S, Elstner EF. Biological and biochemical effects of air pollutants: Synergistic effects of sulphites. Biochem. Soc. Symp. 1995;61:153-61.
2. Elsom DM. Atmospheric pollution. A Global Problem. 2nd edition. Blackwell Publ; 1992.
3. US EPA. Guidelines for water reuse, EPA/625/R-04/108. 2004;1-445.
4. Nduka JK, Orisekwe DE. Assessment of environmental distribution of lead in some municipalities of South-Eastern Nigeria. Int. J. Environ. Res. Public Health. 2010; 7(6):2501-2513.
5. Davidson CL, Cartwright LG, Landis LR, Lindberg SE, Schmidt JA. Dry deposition of sulphate onto surrogate surfaces. Journal of Geophysical Research. 1985; 90.
   DOI: 1-.1029/JD090iD01p02123.
6. Fang W, Fang G, Shi P, Huang Q, Xie Q. Seasonal structures of upper layer circulation in the southern South China Sea from *in situ* observations. Journal of Geophysical Research. 2002;107.
   DOI: 10.1029/2002JC001343.
7. Mason CF. Biology of freshwater pollution. 2nd Edition; Longman New York. 1991;351.
8. Pope CA, Schwartz J, Ransom MR. Daily mortality and PM_{10} pollution in Utah Valley. Arch. Environ. Health. 1992;47:211–217.
9. Needleman HL, Bellinger D. The health effects of low level exposure to lead. Annu Rev Publ. 1991;12:111-140.
10. Emory E, Pattilo R, Archiobold E, Bayorn M, Sung F. Neurobehavioral effects of low level exposure in human neonates. Am J Obstet Gynecol. 1999;181:S2-S11.
11. FEPA. Federal Ministry of Environment Act No. 58; Nigerian Federal Environmental policy and Laws; 1988.
12. Okuda T, Kato J, Mori J, Tenmoku M, Suda Y, Tanaka S, He K, Ma Y, Yang F, Yu X, Duan F, Lei Y. Daily concentrations of trace metals in aerosols in Beijing, China. Determined by Using Inductively Coupled Plasma Mass Spectrometry Equipped with Laser Ablation Analysis and Source Identification of Aerosols. Sci. Total Environ. 2004;330:145–158.
13. Pope SB. Turbulence combustion modelling: Fluctuations and Chemistry: In, Advanced Computation and Analyses of Combustion. Eds, Roy GD, Frolov SM, Givi P. Moscow, Russia, ENAS Publ. 1997;310 –320.
14. Egborge ABM. Water pollution in Nigeria (I) Biodiversity and Chemistry of Warri River. Ben Miller Publisher, Warri; 1994.
15. Strauss W. Air pollution control, Parts 1 and 11. Wiley Interscience, New York, USA. 3rd Edition; 1971.
16. WHO. Environmental Health Criteria Cd. General: World Health Organisation. 1992; 134.
17. D'Souza JC. Ethnicity, housing and personal factors as determinants of VOC exposures. Atmospheric Environment. 2009;43(18):2884-2892.
18. Sun Q, Hong X, Wold LE. Cardiovascular effects of ambient particulate air pollution exposure. Circulation. 2010;121:2755–2765.
19. Offermann FJ. Ventilation and indoor air quality in new homes, in PIER Energy-Related Environmental Research Program Collaborative Report CEC-500-2009-0852009, California Air Resources Board and California Energy Commission: Sacramento, CA; 2009.
20. Stoeppler M. Cadmium In: Metals and their compounds in the environment: Occurrence, analyses and biological Relevance. Merian E. (Ed.) VCH, New York. 1991;803-851.
21. DWAF. South African Water Quality Guidelines, Aquatic System, 1st Edition. 1996;7:17-88.
22. Merian E. Metals and their compounds in the environment. Occurrence, Analysis and Biological Relevance, UCH, Weintrein – New York; 1991.
23. Friberg L, Elinder CG, Kjellstroem T, Nordberg GF (Eds). Cadmium and health. A toxicological and Epidemiological Appraisal Vol. II. Effects and Response. CRC Press. Boca Raton. Florida; 1986.
24. Kjellstroem T. Itai-Itai disease In: Cadmium and heath: A Toxicological and Epidemiological Appraisal by Friberg L, Elinder CG, Kjellstroem T, Nordberg GF (Eds). Vol. II. Effects of Response. CRC Press Boca Raton, Florida. 1986;257-290.
25. Emoyan OO, Ogban FE, Akarah E. Evaluation of Heavy metals loading of River Ijana, Nigeria. J Appl Sci Environ Manag. 2005;10(2):121-7.

26. Lewis JA, Cohen SM. Addressing lead toxicity: Complexation of lead II with thiopyrone and hydroxypridine O, S mixed chelators. Inorg Chem. 2004;43:6534-6.
27. Suzuki Y, Morital J, Yamane Y, et al. Cadmium stimulates postage land in E2 production and bone resorption in cultured fetal mouse Calvarias. Biochem Biosphys Res Commum. 1989;158:503-18.
28. Praydot P. Comprehensive guide to the hazardous properties of chemical substances. 2nd ed. John Wiley and Sons: Inc. Canada. 1999;614-24.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=1130&id=22&aid=9458