Scientia Africana, Vol. 21 (No. 2), August, 2022. Pp 13-22 https://dx.doi.org/10.4314/sa.v21i2.2

ISSN 1118 – 1931

HEALTH HAZARDS AND RISK ASSESSMENT OF THE USE OF FOSSIL FUEL ELECTRICITY GENERATORS IN SUBURB OF PORT HARCOURT, NIGERIA

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Received: 08-02-2022
Accepted: 16-05-2022

ABSTRACT

*Study on the health hazards and risk assessment of the use of fossil fuel electricity generators in suburb of Port Harcourt, Nigeria was carried out. The results showed that the concentrations of the metals varied greatly among the vegetable species and locations. It was observed that the vegetables (**Telfairia occidentalis** and **Talinum triangulare**) cultivated less than 15m away from fossil fuel generator after analysis showed some level of trace metals concentration. The variation in metal concentrations in the vegetables can be attributed to the metal concentrations in soils. The concentration of the metals in the edible vegetables studied ranged from 0.90 ± 0.01 to 3.20 ± 0.001, Pb; 0.08 ± 0.001 to 0.11 ± 0.01, Cd; 53.10 ± 0.002 to 106.30 ± 0.02, Fe; and 0.40 ± 0.002 to 1.60 ± 0.02, Zn. The difference in the concentration of the metals in the various vegetable can be attributed to the different concentration of the metals in the soils and also the direction at which the vegetation was located. The CDI values of iron for adult and children were all above oral reference dose (RfD) (0.007mg/kg/day). The hazard quotient (HQ) values of the metals in all the stations were greater than 1 except Zn and Cu for children. Lead, Iron, Cadmium and Chromium exceeded 1 for both adult and children while in In all the stations, HQ values were generally high for children, thereby making people living around the area more vulnerable. The high HQ values recorded in this study were as result of high CDI values of the metals involved. These metals pose long term health risk to the land users. All the hazard index (HI) values recorded in this study were well above 1. The long-term health risk is high and the non-carcinogenic adverse effect is not negligible. Health risk assessment for all the sites considered showed that cumulative effect of some of the heavy metal studied, as indicated by the hazard index (HI), calls for concern.*

Keywords: Hazard quotient, health, edible vegetable, pollution

INTRODUCTION

Fossil fuels contain high percentages of carbon including petroleum, coal, and natural gas. Fossil fuels range from low carbon-to-hydrogen ratios (like methane) volatile materials, to liquids (like petroleum), and nonvolatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields alone, in the form of methane clathrates. (Schmidt-Rohr, 2015). *C*ountless research findings have clearly established and proven beyond all reasonable doubts that the combustion of fossil fuel in electricity generators have grave consequences on the natural environment, human health and several aspects of our psychological & socio-economic lives etc. The use of fossil fuel generators increases carbon dioxide released into the atmosphere and consequently causing depletion of ozone layer and has remained a major concern to the modern world. Fossil fuel generators are used to meet up with the high demand of electricity due to the lack or inconsistent supply of electricity in Nigeria, as many homes and businesses use fossil fuel generator as a source of generating electricity. The burning of hydrocarbon fossil fuel (by generators) results in the emission of poisonous gases and particulate matter into the environment and contaminates the environment and this is harmful to human health. The concern for generator emissions in urban areas has been expressed due to the recognition of numerous adverse effects of these particulate emissions on man and the environment. The generators emit hydrocarbons, carbon monoxide, nitrogen dioxide, lead, particulate matter and in strong sunlight, some of these hydrocarbons and oxides of nitrogen may be converted into "photochemical pollutants" of oxidizing nature (Horsfall and Spiff, 1998).

This study is also necessitated by the lack of awareness of potential dangers posed to residence and the populace by the continuous exposure to the harmful fumes released during generator usage. Uncontrolled exposure to these fumes can cause breathing challenges, sore throat, sore eyes, nausea, vomiting, light headedness, unconsciousness and in extremely high levels, death to undiscerning users and the general populace (Ubong *et al*., 2008; CDC, 2011). Literature sources have shown and established that exhaust fumes, arising from the burning of fuels in automobiles, homes and industries are a major source of air pollution (Gobo *et al*., 2008). Example is nitrous acid which is capable of causing deamination of guanine, adenine, cytosine, and cross-linking of the DNA. Another product from the atmosphere is nitrosamines, known for its carcinogenicity in laboratory animals (Zhang *et al*., 2018). In addition, health conditions and symptoms such as headache, nausea and unconsciousness have been linked to less than ten (< 10) hours human exposure. This study investigates the implication of the use of fossil fuel generators in suburb of Port Harcourt.

MATERIALS AND METHODS

Collection of samples

A random sampling technique was employed in selecting the samples. Soil samples were collected from 2 locations (sampling site in Choba campus and sampling site in Abuja campus) randomly around the generator plants. Vegetable samples (***Telfairia occidentalis*** and ***Talinum triangulare***) were collected from 2 different gardens 50 to 150 meters away from the locations where some of the soil samples were also drawn. Soil samples were collected to a depth of 0 -10 cm, 10- 20 cm, and 20 – 30 cm using soil auger and immediately packed in self-zip plastic bags and taken to the laboratory for analysis. Samples were labeled CHS1, CHS2, CHS3, ADS1, ADS2, ADS3, CHP, ADAP, CHW, and ADAW, where CH and AD represent the sampling site Choba and Abuja campuses respectively, SI, S2 and S3 represent different soil depths 0 -10 cm, 10- 20 cm and 20 – 30 cm respectively; CHP and ADAP represents ***Telfairia occidentalis*** from Choba and Abuja respectively and CHW and ADAW represent ***Talinum triangulare*** from Choba and Abuja respectively. Samples and control were treated in triplicate and analysis was carried out following standard methods (APHA, 1998).

Analytical Methods

The soil samples were air dried at room temperature in the laboratory and then homogenized and passed through a 2 mm sieve (preparation for determining the soil properties) after drying to a constant weight.

Scientia Africana, Vol. 21 (No. 2), August, 2022. Pp 13-22 https://dx.doi.org/10.4314/sa.v21i2.2
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Finally, the soil samples were ground in an agate mortar and passed through a 0.14 mm sieve for heavy metal analysis. The vegetables samples were dried in an air-blowing thermostatic oven after washing with deionized water. The plant samples for metal content determination were digested with 4 mL of concentrated nitric acid (HNO_3) and 1 mL of hydrogen peroxide (H_2O_2) using a microwave digestion system. The total content of the studied metals in plant samples were determined using an atomic absorption spectrometer (UNICAM SOLAAR 32).

Determination of heavy metals in soil

Digestion is done in order to dissolve the heavy metals from the soil samples. In this process, 1 g dry weight of each soil sample was accurately measured and mixed with 3 mL of nitric acid and 9 mL of hydrochloric acid in a rotor vessel. 1 mL of hydrogen peroxide was also added to the mixture. The mixture was then digested at a temperature of 120 ^{o}C for about 25 min and then allowed to cool down for about 15 min. After this, the digested samples were transferred into 100 mL volumetric flasks with 2% HNO_3. Deionised water was then used to top up to this volume. The digested samples were then allowed to sediment overnight and there after filtered with No. 40 Whatman filter paper in readiness for the concentration of the metals which were then determined using Atomic Adsorption Spectrophotometer machine.

Determination of heavy metal in vegetables

Edible parts of each vegetable were weighed after washing with de-ionized water and blotting dry with tissue paper. The samples were then dried in an oven at 70^{o}C for 72 hours, weighted and ground. A 0.5g sub-sample was digested in a crucible with 4ml concentrated nitric acid (HNO_3). The sample and solution suspension was left at room temperature for two hours before the sealed vessel was fitted into a high-pressure metal cylinder. Metal cylinders were heated in an oven at 100^{o}c for 1 hour followed by 170^{o}c for 5 hours. After digestion, vessels (open at this stage) were put on a hot plate at 105^{o}C to evaporate excessive acid until near dry. The residences were then diluted with de-ionized water to 50ml into volumetric flasks, and stored in fridge at 4^{o}c prior to analysis. Soil samples were air dried at room temperature (approximately 30^{o}C) and ground to pass a 0.15mm mesh. A 0.1g subsample was digested in a polyvinyl-fluoride crucible with 3ml of "aqua-regia" (HNO_3/HCl = 1:3). The sample acid solution suspension was left at room temperature overnight, and then heated in sealed tanks, as for vegetables, at 100^{o}C for 1 hour and then 170^{o}C for 6 hour. The "aqua-regia" was evaporated on a hot plate at 105^{o}C. The mineral residues were diluted with de-ionized water to 50ml in a volumetric flask and stored in a fridge at 4^{o}C until analysis. Concentrations of metals in the edible vegetables and soil samples were determined by atomic adsorption spectrophotometer (AAS).

Human Health Risk Assessment

The human health risk assessment method used in this study was for Non-carcinogenic as described by Muhammed *et al* (2011). The Chronic Daily Intake (CDI) of heavy metals in studied samples was evaluated by the equation (USEPA, 2011):

$$CDI = \frac{\text{CW x IR x EF x ED}}{\text{BW x AT}} \qquad (1)$$

Where, CDI is the daily dose of heavy metals (mg/l) to which consumers might be exposed. CW (mg/l) is the concentration of heavy metals in the soil, IR is the Ingestion rate, EF is the Exposure frequency, ED is the Exposure duration, BW is the Body weight, AT is the Averaging time.

Hazard Quotient (HQ)

The HQ for non-carcinogenic risk was calculated using the equation by USEPA (1999):

$$HQ = \frac{CDI}{RFD} \qquad (2)$$

Where, CDI is the daily dose of heavy metals (mg/l) to which consumers might be exposed and RfD is the reference dose which is the daily dosage that enable individual to sustain this level of exposure over a long period of time without experiencing any harmful effects.

If, HQ>1, it represents adverse non-carcinogenic effects of concern while HQ<1 represents acceptable level (no concern).

Hazard Index

The HQs are summed to arrive at the overall toxic risk, the Hazard Index (Kolluru *et al.*, 1996; Paustenbach, 2002; Zheng *et al.*, 2010).

$$HI = \sum_{i=1}^{n} (HQ)i \qquad (3)$$

Where, HI is the hazard index for the overall toxic risk and n is the total number of metals under consideration.

If, HI<1.0, the non-carcinogenic adverse effect due to this exposure pathway or chemical is assumed to be negligible.

Accumulation factor

The accumulation factors (AFs) of the studied heavy metals in vegetables were determined.

AFs were calculated using equation (4):

$$A.F = \frac{C_{vegetables}}{C_{soil}} \qquad (4)$$

Where $C_{vegetables}$ is the heavy metal content in vegetables (dry weight), and C_{Soil} is the heavy metal contentin the soil.

Here, If AF < 1, suggests that the specific element does not accumulate in vegetables;

1 < AF < 2 reflects low accumulation; and AF > 2 reflects high accumulation (Liu *et.al.*,2008).

RESULTS AND DISCUSSIONS

Table 1. Concentration of trace metals in Soil from fossil fuel generator suburb area of Port Harcourt.

M (Mg/kg)	CHS1	CHS2	CHS3	ADS1	ADS2	ADS3	CONTROL
Pb	14.30± 0.03	4.00± 0.001	1.10± 0.03	11.40± 0.04	3.140± 0.04	1.36± 0.002	0.90± 0.002
Cd	9.14± 0.03	2.40± 0.01	0.90± 0.001	5.30± 0.02	1.02± 0.03	0.60± 0.02	0.20± 0.002
Cu	14.20± 0.05	5.30± 0.02	2.10± 0.003	16.40± 0.10	4.90± 0.02	1.80± 0.02	1.30± 0.003
Fe	262.10± 1.50	196.40± 0.9	21.20± 0.70	121.60	108.7± 0.03	66.40±0.03	1320.60± 2.0
Zn	198.40± 2.20	141.60± 0.2	17.40± 0.04	222.60± 2.6	116.8± 0.05	34.60± 0.03	123.40± 0.80
Cr	7.30± 1.10	2.06± 0.10	0.90± 0.001	4.20± 0.001	3.30± 0.05	1.20± 0.01	0.040± 0.001

Scientia Africana, Vol. 21 (No. 2), August, 2022. Pp 13-22 *https://dx.doi.org/10.4314/sa.v21i2.2*
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Table 2 Concentration of trace metals in selected vegetables.

Heavy metals (Mg/kg)	PUMPKIN		WATER LEAVE	
	CHP	ADAP	CHW	ADAW
Pb	3.20± 0.001	1.60± 0.001	1.80± 0.002	0.90± 0.01
Cd	0.10± 0.001	0.09± 0.001	0.08± 0.001	0.11± 0.01
Fe	106.30± 0.01	60.90± 0.03	53.10± 0.002	68.30± 1.20
Zn	0.90± 0.01	1.60± 0.02	0.40± 0.002	0.9± 0.01
Cr	ND	ND	ND	ND
Cu	7.50± 0.70	4.80± 0.20	3.20± 0.20	1.20± 0.01

Table 3. Bioaccumulation factor in plant around generator plants.

Heavy metals (Mg/kg)	PUMPKIN		WATER LEAVE	
	CH	ADA	CH	ADA
Pb	0.224	0.146	0.140	0.079
Cd	0.011	0.009	0.017	0.021
Fe	0.406	0.501	0.202	0.562
Zn	0.005	0.002	0.007	0.004
Cr	0.00	0.00	0.00	0.00
Cu	0.528	0.225	0.293	0.245

Table 4: The chronic daily intakes of the heavy metals for children

Metal	CHS1	CHS2	CHS3	ADS1	ADS2	ADS3
Pb	0.091416	0.025571	0.007032	0.072877	0.020073	0.008694
Cd	0.058429	0.015342	0.005753	0.033881	0.006521	0.003836
Cu	0.090776	0.033881	0.012785	0.10484	0.031324	0.011507
Fe	1.675525	1.255525	0.135525	0.777352	0.694886	0.424475
Zn	1.268311	0.905205	0.111233	1.423014	0.746667	0.221187
Cr	0.046667	0.013169	0.005753	0.026849	0.021096	0.007671

Table 5: The chronic daily intakes of the heavy metals for adult

Metal	CHS1	CHS2	CHS3	ADS1	ADS2	ADS3
Pb	0.391781	0.109589	0.030137	0.312329	0.086027	0.03726
Cd	0.250411	0.065753	0.024658	0.145205	0.027945	0.016438
Cu	0.389041	0.145205	0.054795	0.449315	0.134247	0.049315
Fe	7.180822	5.380822	0.580822	3.331507	2.978082	1.819178
Zn	5.435616	3.879452	0.476712	6.09863	3.2	0.947945
Cr	0.2	0.056438	0.024658	0.115068	0.090411	0.032877

Table 6: Hazard quotients and total hazard index of the heavy metals for children

Metal	CHS1	CHS2	CHS3	ADS1	ADS2	ADS3
Pb	26.11872	7.305936	2.009132	20.82192	5.73516	2.484018
Cd	116.8584	30.68493	11.50685	67.76256	13.0411	7.671233
Cu	2.269406	0.847032	0.319635	2.621005	0.783105	0.287671
Fe	239.3607	179.3607	19.36073	111.0502	99.26941	60.63927
Zn	4.227702	3.017352	0.370776	0.481583	2.488889	0.737291
Cr	155.5556	43.8965	19.17808	89.49772	70.31963	25.57078
HI	**544.39053**	**265.1125**	**52.7452**	**292.23499**	**191.63729**	**97.390263**

Table 7: Hazard quotients and total hazard index of the heavy metals for adult

Metal	CHS1	CHS2	CHS3	ADS1	ADS2	ADS3
Pb	111.9374	31.31115	8.610568	89.23679	24.57926	10.64579
Cd	500.8219	131.5068	49.31507	290.411	55.89041	32.87671
Cu	9.726027	3.630137	1.369863	11.23288	3.356164	1.232877
Fe	1025.832	768.6888	82.97456	475.9295	425.4403	259.8826
Zn	14.09234	10.05784	1.235921	1.605277	8.296296	2.457636
Cr	666.6667	188.1279	82.19178	383.5616	301.3699	109.589
HI	**2329.0764**	**1133.323**	**225.6978**	**1251.977**	**818.93233**	**416.68461**

The results of the total concentration for some trace elements in the bulk soil sample determined after extraction using AAS is shown in Table 1. The table shows the result of analysis of trace metals of different depths of soil from fossil fuel generator suburb from two (2) sites (CH & AD).

From the Table 1, it can be seen that the highest concentration for the trace metals was observed in soil collected from 0-10cm depth, which ranges from 1.10 ± 0.003 to 14.30 ± 0.04, Pb; 0.60 ± 0.02 to 9.14 ± 0.03, Cd; 2.10 ± 0.003 to 14.20 ± 0.05, Cu; 21.20 ± 0.70 to 262.10 ± 1.50, Fe; 17.40 ± 0.04 to 198.40 ± 2.20,Zn and 0.90 ± 0.001 to 7.30 ± 1.10, Cr. As the soil depth increases, the concentration of the heavy metals decreases. The decrease in the concentration of the metals as the soil depth increases can be attributed to absorption or leaching of the heavy metals into the ground water (Osu and Okereke, 2010). The source of these metals into the soil is likely to be from the exhaust fume.

The concentrations of trace metals in vegetables (***Telfairia occidentalis*** and ***Talinum triangulare*** leaves) were presented in Table 2. The concentrations of the metals varied greatly among the vegetable species and locations. It can be observed that the vegetables (pumpkin and water leaves) cultivated less than 15m away from fossil fuel generator after analysis showed some level of trace metals concentration. The variation in metal concentrations in the vegetables can be

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attributed to the metal concentrations in soils. The concentration of the metals in the edible vegetables studied ranged from 0.90 ± 0.01 to 3.20 ± 0.001, Pb; 0.08 ± 0.001 to 0.11 ± 0.01, Cd; 53.10 ± 0.002 to 106.30 ± 0.02, Fe; and 0.40 ± 0.002 to 1.60 ± 0.02, Zn. The average concentration of trace metals in all vegetable samples were in the descending order: Fe > Cu > Pb >Zn > Cd > Cr . Chromium however wasn't detected in the vegetables.

Among the studied vegetables in both sites, pumpkin accumulation of trace metal is in much higher amounts in site CH as compared to site AD. While in site AD, water leaves accumulated more of Fe, Zn and Cd than in site CH. This difference in the concentration of the metals in the various vegetable can be attributed to the different concentration of the metals in the soils and also the direction at which the vegetation is located. In both sites, it was observed that the air quality within the generator suburb was partially affected via the emission of the combustion product of the fossil fuel generator and also the droplet on the hot part of the generator which vaporises into the atmosphere surrounding.

The BCF or bioaccumulation factor can be defined as the ratio of chemical concentration in the plant tissue to the spiked (or nominal) concentration in the growth medium (Wu et al., 2013; Zheng et al., 2014). The bio-accumulation factor is used to evaluate the effectiveness of a plant in metal accumulation and translocation. The uptake of contaminants into plants is influenced by many factors, such as diffusion through cell membranes (Briggs et al., 1982), hydrophobicity (Pilon-Smits 2005), and molecular ionization (Trapp 2004). The bio-accumulated factor for the metals studied ranges (Table 3) from 0.079 to 0.224, 0.009 to 0.021, 0.202 to 0.562, 0.002 to 0.007 and 0.225 to 0.528 for Pb, Cd, Fe, Cu and Zn respectively. The bioaccumulation factor for chromium was found to be zero this showed there was no contamination.

The Chronic Daily Intake (CDI) of the assessed heavy metals of soil is presented in Table 4 and 5. The CDI values for children and adult respectively were recorded for Pb and ranged from 0.0077032 to 0.025571 mg/kg/day and 0.030137 to 0.391781mg/kg/day respectively; values obtained for Cd ranged from 0.003836 to 0.058429 mg/kg/day and 0.016438 to 0.250411mg/kg/day respectively, values obtained for Cu ranged 0.010507 to 0.10484 mg/kg/day and 0.49315 to 0.448315 mg/kg/day respectively, values recorded for Fe ranged from 0.135525 to 1.675525 mg/kg/day and 0.580822 to 7.180822 mg/kg//day respectively. Values obtained for Zn ranged from 0.111233 to 1.423014mg/kg/day and 0.476712 to 6.09863 mg/kg/day respectively. Finally, results obtained for chromium ranged from 0.005753 to 0.04667 mg/kg/day and 0.024658 to 0.200 mg/kg/day respectively mg/kg/day. The lead CDI values for adult and children were above oral reference dose (RfD) for lead (0.0035 mg/kg/day) in the sampling sites.. Maigari *et al* (2016) equally recorded low lead CDI values while Ayantobo *et al* (2014) and Ekere *et al (*2014) recorded high lead CDI values.

The CDI values of iron for adult and children were all above oral reference dose (RfD) (0.007mg/kg/day). Ekere *et al* (2014) and Maigari *et al* (2016) equally recorded high iron CDI values. Thus, high iron CDI values recorded could be attributed to natural cause, leaching and fossil fuel spill. In high concentration, iron may produce neurological effects. Long-term iron toxicity may involve iron-mediated oxidative damage to the mitochondrial genome leading to progressive dysfunction. CDI values of cadmium for adult and children were above oral reference dose (RfD) (0.0005mg/kg/day). Ayantobo *et al* (2014), Ekere *et al* (2014) and Maigari *et al* (2016) recorded similar higher cadmium CDI values. The high cadmium CDI values could be as a result of petroleum products spill on the soil. Thus, cadmium pose health risk for those exposed to drinking water and vegetables through food chain. At high concentrations, cadmium affects the liver, placenta, kidneys, lungs, brain, and bones. Experimental data in humans and animals showed that cadmium may cause cancer in humans (Jarup *et al.*, 2000; Nordberg *et al*., 2002).

CDI values of chromium for adult and children were above oral reference dose (RfD) (0.0003 mg/kg/day). Ayantobo *et al* (2014) and Ekere *et al* (2014) equally recorded high chromium CDI values. The high cadmium CDI values could be as a result of petroleum products spill on the soil (Wong 2013). Chromium levels in soil could be as a result of oil spill, emission from the generator and due to their different primary exposure pathways for arable soil. Chromium poses health risk for those exposed to soil and through food chain.. High concentrations of chromium may cause liver and kidney toxicity and genotoxic carcinogen (Strachan, 2010).

The hazard quotient (HQ) values of the metals in all the stations were greater than 1 except Zn and Cu for children. Lead, Iron, Cadmium and Chromium exceeded 1 for both adult and children while in In all the stations, HQ values were generally high for children thereby making people living around the area to be more vulnerable. The high HQ values recorded in this study were as result of high CDI values of the metals involved. These metals pose long term health risk to the land users. All the hazard index (HI) values recorded in this study were well above 1. It is in line with the findings of Ayantobo *et al* (2014), Ekere *et al* (2014) and Maigari *et al* (2016). The long-term health risk is high and the non-carcinogenic adverse effect is not negligible.

CONCLUSIONS AND RECOMMENDATIONS

This study illustrated the effect of power generator for generation of electricity. The extent of heavy metal contaminations varied with metal species and vegetable types. The concentration of the heavy metals studied was significantly higher in soils at depths 0-10. The pattern of distribution of heavy metals is uniform. However, all the heavy metals concentrations were higher at the surface horizons and it decreased sharply with depth. Some of the heavy metals considered exceeded the standards set by Nigerian Standard for soil Quality and World Health Organisation. Health risk assessment for all the sites indicated that some of the heavy metals considered exceeded the standards set by Nigerian Standard for soil Quality and World Health Organisation. Health risk assessment for all the sites indicated that cumulative effect of some of the heavy metal studied as indicated by the hazard index (HI), calls for concern.. Hazard Index (HI) for all the stations highly exceeded threshold value (1). This calls for concern for both adults and children exposed to the site. Analysis of the air quality parameter within the generator suburb showed the presence of many air contaminants.

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Scientia Africana, Vol. 21 (No. 2), August, 2022. Pp 13-22 https://dx.doi.org/10.4314/sa.v21i2.2
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