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Assessment of Soil Contamination with Monocyclic Aromatic Hydrocarbons and Heavy Metals in Residential Areas Sited Close to Fuel Filling Stations in Ibadan Metropolis

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Abstract The study aimed to assess soil contamination with mono-cyclic aromatic hydrocarbons and heavy metals in residential areas situated close to (1-20m range) fuel filling stations in Ibadan metropolis, Nigeria. The study involved a laboratory based analysis of soil samples collected in the neighbourhood of five fuel filling stations systematically selected during the study. Two local government areas were randomly selected for the study, they were split into five natural clusters and soil samples were purposively collected from the neighbourhood of one fueling station per cluster. Topsoil (0 – 15cm deep) and subsoil (15 – 30cm deep) samples were collected at 5m, 10m, and 20m intervals away from the fuel filling stations. Samples were analyzed for benzene, toluene, ethyl-benzene, xylene, lead, and chromium using standard methods. Results were compared with Canadian and United Kingdom standards. Results were analyzed using descriptive statistics and were compared with the Canadian (monocyclic aromatic hydrocarbon) soil quality guideline limit for human health and the UK heavy metal guideline limit for soil in residential areas. Apart from xylene, the mean concentration of benzene, toluene, and ethyl-benzene were approximately 600 times higher than the Canadian limit both for topsoil and subsoil. Fortunately, mean concentrations of lead and chromium in all soil samples were insignificant compared with the UK limit. The study showed that there is contamination of the soil in the study area with some monocyclic aromatic hydrocarbons namely benzene, toluene, and ethyl-benzene while there are no potential threats with regards to heavy metal contamination.

Keywords: *soil contamination, fueling station, hydrocarbons, heavy metals, guideline limit*

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1. Introduction

Sustainable development does not come cheap, our attitude and practice of today with respect to our environment, especially the soil which forms a major component of the vital environment can impact generations not yet born [3]. Most urban areas in developing countries are characterized by chemical wastes from non-point source and that includes oil spillage from filling stations. The nature of these spills is such that it contains a wide spectrum of heavy metals which constitute a major threat to plant life and human health [1]. A specific example of heavy metal that can result from such spill is Lead, and plants have the capacity to take up lead from contaminated soil. Lead can also find its way into the food chain when it is picked up by plants from contaminated water [17]. Children are most at risk and can have their blood lead levels elevated when they ingest lead-contaminated soil [15].

According to Plaza et al., 2006, BTEX compounds (Benzene, Toluene, Ethyl-benzene, and Xylene) are implicated as chief environmental pollutants majorly because of enormous leakages and accidental spills obtainable from various petroleum storage tanks and distribution stations [5]. These hydrocarbons are toxic and can bio-accumulate via the food chain and hence, they constitute a major public health and ecological concern. Other ways by which heavy metals in urban soils can bio-accumulate in human body includes direct inhalation, ingestion, and body-surface contact absorption [2].

Nigeria is seen as the giant of Africa, and this is not without her all surpassing operational activities in her oil and gas exploration. However, these activities have gruesome environmental implication which has been a major concern to the various stake holders and the host communities [16]. Resultant soil and water pollution from the various activities of the oil and gas industry in Nigeria has made life unbearable for local farmers [6]. Likewise, the location of petroleum product substation or filling station can also have serious implications for plant and animal life. That is why the Oyo state government stipulated some set back specifications (Table 1) with the aim of ensuring that petrol filling stations maintain a reasonably safe distance from specific landmarks, establishments, and dwellings to ensure safety of lives and properties, in most cases however, these specifications are only obtainable on papers.

Table 1. URBAN AND REGIONAL PLANNING BOARD, OYO STATE, NIGERIA (2008)

S/No.	Parameters	Land mark	Specifications
1	Setback of pumps *(Pumps to the centre)*	Express road	30m
		Trunk 'A' road	30m
		Other roads	25m
2	Setback of Service stations *(Station to the centre of the road)*	Express road	50m
		Trunk 'A' road	40m
		Other roads	35m
3	Setback to dwelling house	From the wall of service station	7m
4	Setback to an existing service station	Along the same direction	300 – 500m

Various researches across the country of Nigeria are pointing to the fact that indiscriminate siting of petrol stations in residential areas is a major problem faced by the masses [7,10,14]. When standard requirements for buildings of petrol filling stations are not adhered to, a serious threat on the health of filling station workers and the populace living close to the petrol filling stations is implied [14]. The potential impact that setting up a fuel filling station poses to the environment are enormous, the various activities done in the petrol station and the outcome of such activities can impact negatively on the air quality, soil and water, and consequently on human health. This study is therefore aimed at assessing the extent to which soil of residential areas sharing close proximity with fuel filling stations has been contaminated by comparing results of analysis with known guideline limits from various quarters.

2. Methodology

2.1. Study Area

The study was carried out in Ibadan, Nigeria. Ibadan was created in 1829 as a war camp for warriors coming from Oyo, Ife, and Ijebu. Ibadan thus began as a military state and remained so until the last decade of the 19th century [8]. At independence, Ibadan was the largest and the most populous city in Nigeria and the third in Africa after Cairo and Johannesburg. It is located in the South-western Nigeria, 78 miles inland from Lagos and it's a prominent transit point between the coastal region and the areas to the north. Its population is 5,580,894 according to 2006 census results, with eleven (11) local government areas [11]. Ibadan Southeast and Southwest local government areas were chosen at random for this study from those in core Ibadan metropolis.

2.2. Study Design

The study involved a laboratory-based analysis of groundwater samples collected from the vicinity of five fuel filling stations in the two local government areas selected for the study.

2.3. Soil Sampling

The fuel filling stations were grouped into five natural clusters and soil samples were purposively collected from the vicinity of one fuelling station per cluster. Thirty soil samples from surface (0 – 15cm deep) and subsurface (15 – 30cm deep) were collected at a radius of 5m, 10m, and 20m intervals away from each fuel filling station. All samples were stored in black polythene bags, labelled properly and safely transported to the laboratory for analysis. Samples were analyzed for benzene, toluene, ethyl-benzene, xylene, lead, and chromium using standard methods

3. Laboratory Analysis

3.1. Determination of Aromatic Hydrocarbon Using Spectrophotometric Method

Aromatic hydrocarbons in samples were determined using method by Osuji and Nwoye, in 2007 [12]. 5g of soil samples was put into 250ml of volumetric flask. Into this was added 50ml of xylene. The mixture of xylene and soil was shaken vigorously on a mechanical shaker (orbit shaker) for 30minutes. The mixture was then filtered using a Whatman (No. 1) filter paper. The solid remains was rinsed using 50ml xylene and filtered. The filtrate was left at room temperature to evaporate the xylene. The extract was placed in cuvette wells and its absorbance was determined using spectrophotometer at 410nm. Standards of 10ppm were prepared for each of the analytes from their various reagents.

1ml reagent (e.g. Toluene reagent) was measured into a 100ml volumetric flask. 70ml of xylene was added to this and was made up to 100ml with water. 10ml was taken from this into a 100ml volumetric flask and was made up with water, thus, giving 10ppm. A calibration curve was obtained by measuring the absorbance of the dilute solution of standards at varying volumes of 2.5, 5.0, 10.0, 20.0, 25.0, and 30.0mls.The standards were prepared for each analytes namely Benzene, Toluene, Ethyl-benzene, and Xylene (BTEX). The absorbance of the extract was measured with spectrophotometer (Spectronic 21D model) at a wavelength of 410nm.

3.2. Determination of Heavy Metal Contaminants Using Atomic Absorption Spectrophotometer

5ml of the samples was weighed into a digestion tube. One tablet of selenium catalyst was placed inside the tube. 10mls of concentrated perchloric acid and 10mls of concentrated Nitric acid (ratio 1:1) was measured into the digestion tube. The tube was placed inside a digestion block and slowly digested. The digest was washed into 100mls volumetric flask and made up with distilled water. This was centrifuged at 3000rpm for 30 minutes to get the supernatant. Meter reading was done using the Atomic Absorption Spectrophotometer (AAS) at wavelength of 283.3nm for Lead (Pb) and 357.9nm for Chromium. The data obtained were summarized using descriptive statistics, the mean values were obtained and compared with guideline limits.

4. Results

The laboratory results for the analysis of BTEX and heavy metals in topsoil and subsoil samples are presented in Table 2 and Table 3 below. The mean concentrations of BTEX in the topsoil were 6.18±1.4, 6.42±1.5, 6.14±1.5, and 6.82±1.6 mg/kg respectively. These were compared with the Canadian soil quality guideline for human health as shown in Figure 1. The chart clearly shows that the mean concentrations of Benzene, Toluene, and Ethyl-benzene in the topsoil were about 600 times higher than the guideline limit, this is an indication that soil is contaminated and that there is the possibility of a high impact level on human beings. The mean concentration of Xylene was however below the guideline limit. In Figure 2, the mean concentrations of Benzene, Toluene, and Ethyl-benzene in subsoil were 6.39±1.5, 6.53±1.5, 6.29±1.4, and 6.94±1.6mg/kg respectively. The values were also about 600 times higher than the Canadian guideline limits while Xylene was also below the guideline limit. The potential impact levels of heavy metals were low when their mean concentrations were compared with the United Kingdom guideline limits for soil in residential areas as indicated in Figure 3 and Figure 4.

Table 2. RESULTS OF BTEX AND HEAVY METALS ANALYSIS IN TOPSOIL SAMPLES

Sample Code	Benzene mean±std (mg/kg)	Toluene mean±std (mg/kg)	Ethyl-benzene mean±std (mg/kg)	Xylene mean±std (mg/kg)	Lead mean±std (mg/kg)	Chromium mean±std (mg/kg)
5A1	5.814±0.01	5.929±0.00	5.076±0.00	6.299±0.00	0.142±0.00	0.010±0.00
5B1	5.935±0.00	6.055±0.00	5.829±0.00	6.434±0.00	0.063±0.00	0.003±0.00
5C1	3.694±0.00	3.761±0.00	3.629±0.00	4.005±0.00	0.123±0.00	0.005±0.00
5D1	6.247±0.03	6.348±0.00	6.114±0.00	6.752±0.01	0.133±0.00	0.011±0.00
5E1	6.433±0.00	6.564±0.00	6.322±0.01	6.974±0.00	0.121±0.00	0.007±0.00
10A1	6.638±0.00	6.775±0.00	6.523±0.00	7.199±0.00	0.070±0.00	0.003±0.00
10B1	3.651±0.00	3.728±0.00	3.587±0.00	3.960±0.00	0.131±0.00	0.011±0.00
10C1	3.859±0.00	3.939±0.00	3.793±0.00	4.185±0.00	0.126±0.00	0.006±0.00
10D1	7.469±0.00	7.621±0.00	7.389±0.08	8.149±0.07	0.140±0.00	0.002±0.00
10E1	6.088±0.00	7.027±0.00	6.766±0.00	7.471±0.00	0.138±0.00	0.004±0.00
20A1	7.469±0.00	7.621±0.00	7.338±0.00	8.131±0.05	0.144±0.00	0.006±0.00
20B1	7.016±0.01	7.156±0.00	6.888±0.00	7.608±0.01	0.149±0.00	0.010±0.00
20C1	7.884±0.00	8.045±0.00	7.744±0.00	8.574±0.04	0.115±0.00	0.012±0.00
20D1	7.178±0.00	7.836±0.01	7.540±0.00	8.321±0.00	0.118±0.00	0.011±0.00
20E1	7.812±0.19	7.831±0.00	7.541±0.00	8.322±0.00	0.124±0.00	0.007±0.00

Key in sample code: 5, 10, and 20 are distances (in metres) away from the fuel filling station where soil samples were collected; A, B, C, D, and E are the five filling stations where samples were collected and 1 indicates topsoil samples.

Table 3. RESULTS OF BTEX AND HEAVY METALS ANALYSIS IN SUBSOIL SAMPLES

Sample Code	Benzene mean±std (mg/kg)	Toluene mean±std (mg/kg)	Ethyl-benzene mean±std (mg/kg)	Xylene mean±std (mg/kg)	Lead mean±std (mg/kg)	Chromium mean±std (mg/kg)
5A2	5.395±0.00	5.509±0.01	5.346±0.07	5.921±0.11	0.144±0.00	0.008±0.00
5B2	6.311±0.01	6.433±0.00	6.196±0.00	6.844±0.01	0.063±0.00	0.005±0.00
5C2	4.149±0.00	4.234±0.00	4.076±0.00	4.500±0.00	0.131±0.00	0.011±0.00
5D2	6.683±0.00	6.821±0.00	6.562±0.00	7.245±0.00	0.120±0.00	0.011±0.00
5E2	6.399±0.02	6.520±0.00	6.277±0.00	6.929±0.00	0.123±0.00	0.006±0.00
10A2	6.764±0.00	6.900±0.00	6.645±0.00	7.348±0.02	0.071±0.00	0.005±0.00
10B2	3.669±0.00	3.640±0.00	3.506±0.00	3.869±0.00	0.134±0.00	0.010±0.00
10C2	3.944±0.00	4.022±0.00	3.827±0.00	4.277±0.00	0.123±0.00	0.007±0.00
10D2	7.179±0.00	7.324±0.00	7.055±0.01	7.784±0.00	0.143±0.00	0.002±0.00
10E2	7.015±0.00	7.158±0.00	6.886±0.00	7.613±0.01	0.140±0.00	0.005±0.00
20A2	7.594±0.00	7.748±0.00	7.456±0.00	8.234±0.00	0.142±0.00	0.008±0.00
20B2	7.262±0.00	7.410±0.00	7.134±0.00	7.874±0.00	0.153±0.00	0.011±0.00
20C2	8.258±0.00	8.428±0.00	8.110±0.00	8.951±0.00	0.116±0.00	0.013±0.00
20D2	7.750±0.01	7.919±0.00	7.623±0.00	8.411±0.00	0.120±0.00	0.009±0.00
20E2	7.576±0.14	7.832±0.00	7.540±0.00	8.311±0.02	0.122±0.00	0.008±0.00

Key in sample code: 5, 10, and 20 are distances (in metres) away from the fuel filling stations where soil samples were collected; A, B, C, D, and E are the five filling stations where samples were collected and 2 indicates subsoil samples.

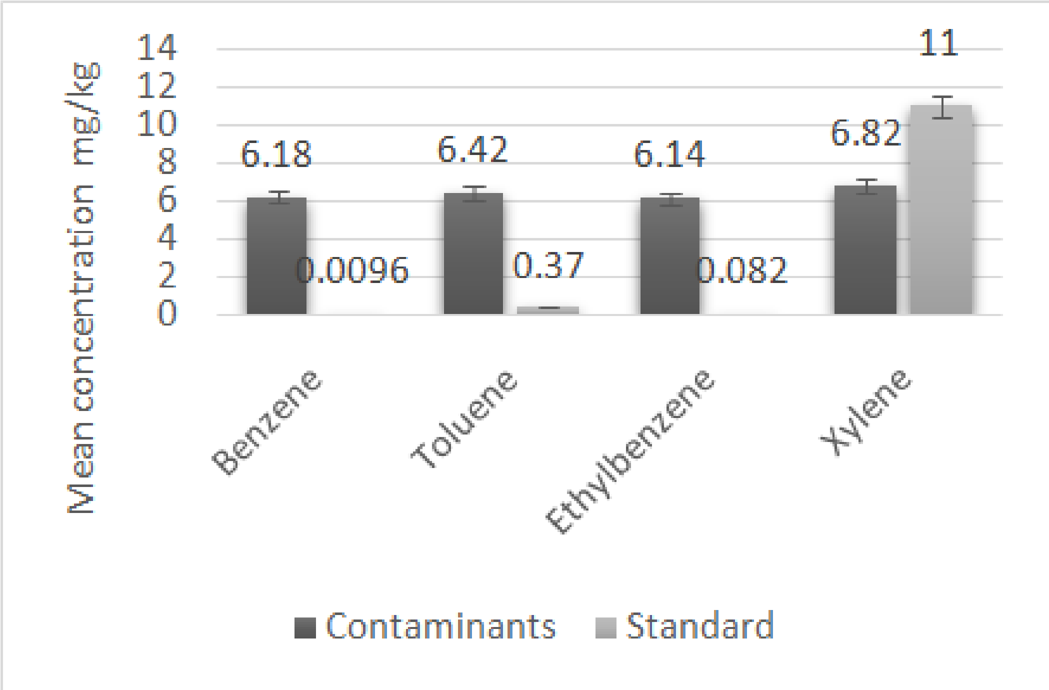

Figure 1. Mean concentrations of BTEX in Topsoil compared with the Canadian soil quality guideline for human health

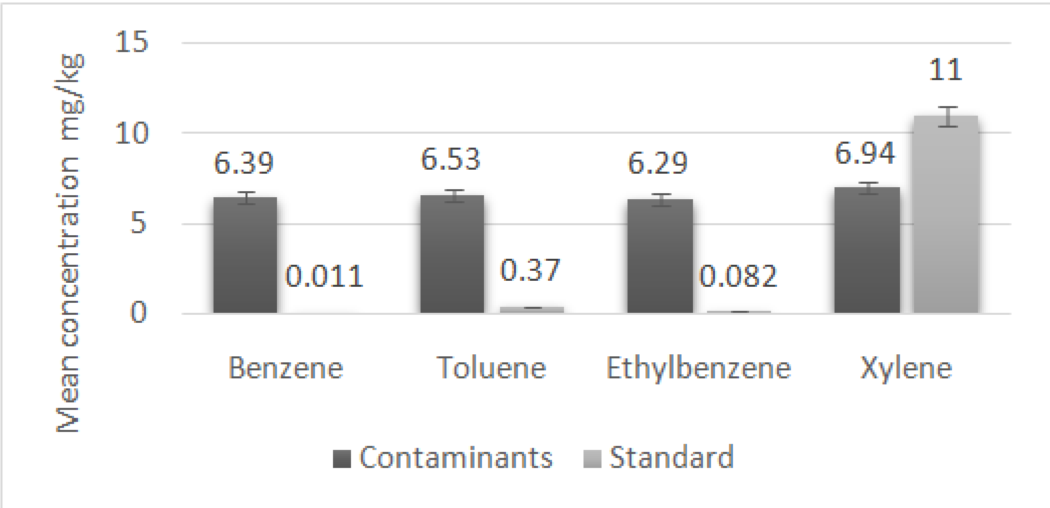

Figure 2. Mean concentrations of BTEX in Subsoil compared with the Canadian soil quality guideline for human health.

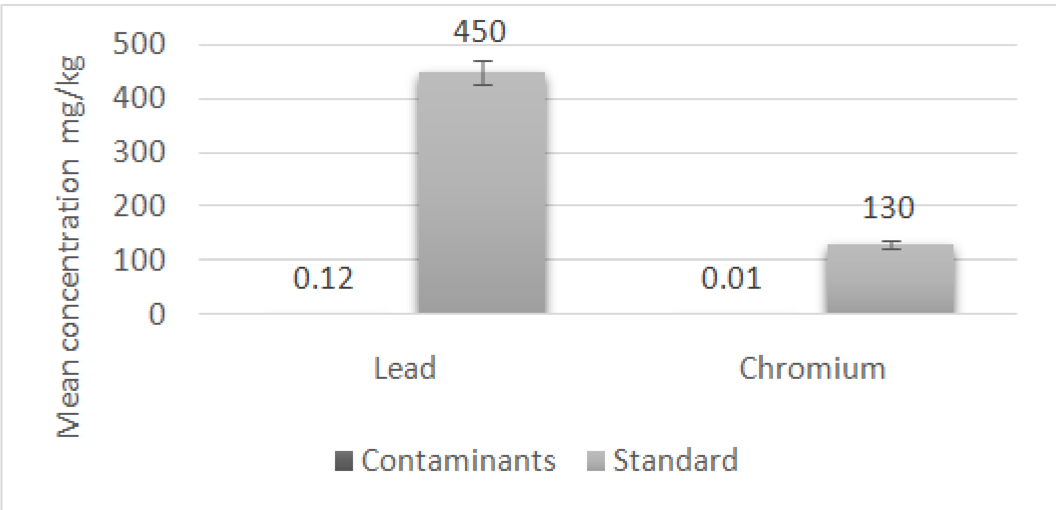

Figure 3. Mean concentrations of heavy metals in Topsoil compared with the UK soil quality guideline for soil in residential areas

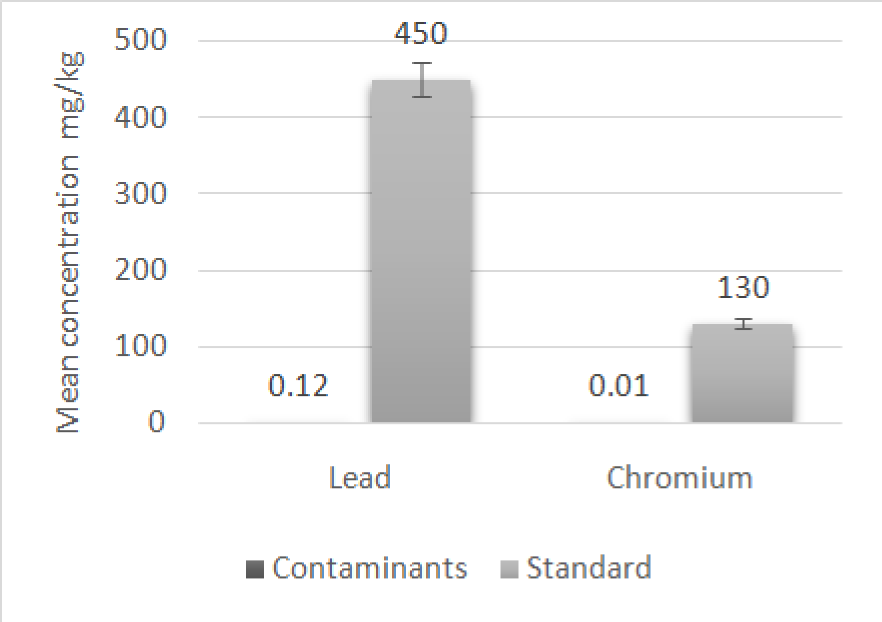

Figure 4. Mean concentrations of heavy metals in Subsoil compared with the UK soil quality guideline for soil in residential areas.

5. Discussion

Virtually all researches in Nigeria and some West African countries that considered the environmental and health consequences of siting petrol filling stations in close proximity with residential areas have reported one form of anomaly or the other, they have all pointed to the possibility of environmental contamination and of negative health impact on individuals [1,4,9,10,14]. Most of them have given special consideration to the assessment of heavy metals in soil having close proximity with fuel filling stations, while only a few have considered assessing hydrocarbon contamination in such vicinity.

As presented in the result (Table 2 and Table 3), the mean concentration of benzene, toluene, and ethyl-benzene in topsoil and subsoil samples were beyond the Canadian guideline limit employed for comparison. This is not unexpected because direct spills of petroleum products onto soil and drainage was observed in some of the filling stations while conducting the research. This could eventually impact the various environmental media in the neighbourhood of such service station and it is all the more serious because these three compounds have been classified as environmental priority pollutants [5]. According to Pedersen *et al.* 2003, the most hazardous substance among the BTEX compound is benzene and the risk of developing cancer is increased when it is taken in from drinking water sources over a long period of time [13].

Soil contamination can have significant deleterious consequences for ecosystems. At low concentrations, the presence of many of these hazardous chemicals can trigger radical changes in the chemical constituents or composition of soil which can ultimately and negatively alter plant's metabolism and reduce crop yield [18].

Fortunately, the mean concentrations of heavy metals (lead and chromium) in soils were insignificant compared with the guideline limit. This is in contrast with most similar work done where there were high degree of soil contamination with heavy metals, particularly Lead, Chromium and Cadmium [1,3,4,9]. A logical explanation for this is that the petroleum products may not contain heavy metals and most especially, Lead in lieu of the regulation restricting the use of leaded fuel in automobiles.

6. Conclusion

This study has shown that soil in the study area were contaminated with monocyclic aromatic hydrocarbons, particularly, benzene, ethyl-benzene, and toluene. Also, the study revealed in contrast to similar studies that heavy metal contamination in soil of the study area is insignificant compared with the guideline limits.

Competing Interest

The authors hereby declare that there is no competing interest with regards to the publication of this paper.

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