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Vulnerability Assessment: A Geospatial Bio-accessibility Approach Using Polycyclic Aromatic Hydrocarbons Concentration of Soils in Lagos, Nigeria.

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Abstract

Cancer is on the increase globally. Cancer could be associated with hazards from anthropogenic activities. This study attempted to determine the site-specific potential human risks from polycyclic aromatic hydrocarbons (PAHs) in sites of different socio-economic human activities from soils across Lagos metropolis in Nigeria by including a geographic information system (GIS) approach. A Human Simulation Test method was used to determine bio-accessibility for 16 priority PAHs. This was then spatially modelled using a GIS. The spatial vulnerability index for cancer developed show some variation within the study area from 0.2 – 0.0002 all falling below the normal exposure risk level of 1.0. The vulnerability to cancer based on different anthropogenic activities assessed were within the acceptable risk levels. However, it is important to reduce human exposure to even low concentrations of bio-accessible PAHs due to their tendency to bio-accumulate in plants, humans and other organisms.

Keywords: Geographic information system (GIS), spatial vulnerability index, Bio-accessibility, Polycyclic Aromatic Hydrocarbons.

1.0 Introduction

Geographic information system is an integration of software, hardware, personnel to collect, store, analyze and interpret geographic and associated descriptive data to support planning and decision making. Its use has increasingly gained prominence in environmental studies where the earth and associated phenomena of interest are modelled. This helps to understand such environmental challenges as it presents itself in reality in order to make appropriate decisions in such regards. Its application has been used in several disciplines such as soil studies to air quality, surface and ground water assessments, biodiversity studies, and pollution control among others (Wieczorek and Delmerico, 2009). Specifically environmental pollutants (such as PAHs), have been assessed in the past using GIS (Yu, et al., 2015).

Many PAHs are carcinogens, mutagens and teratogens. Sources of PAHs include oil spills, cracking of crude oil, burning of fuels and open burning of wastes. The amount of PAH(s) in an environment is a measure of its quality with resultant effects on human health (Igwe and Ukaogo, 2015). The US environmental protection agency has stated humans ingest at least 0.1g of soil involuntarily daily. This amount is more in children and people with pica behaviour (USEPA, 2011). Hence, the concern of contaminants in soils to regulatory bodies of countries around the world.

Bio-availability refers to the concentration of a chemical or pollutant that is absorbed by the skin, pulmonary and/or gastro-intestinal tract systems and becomes available for internal absorption via blood stream while the bio-accessibility refers to amount of a chemical present in water, soil/sediment or food, -that can be released during the digestion process after ingestion. When plants or organisms are exposed to contaminants, bio-availability and bio-accessibility determines the effect(s) expected (Harris et al., 2013). These factors are usually used as main indicators of plausible risk posed by pollutants in the environment or to public health. The Fed Organic Estimation Human Simulation Test (FOREShT) is a laboratory simulated bio-accessibility assessment which has been standardized for assessing organic pollutants in soils (Cui et al., 2016).

The need to merge environmental models like Geographic Information System (GIS) with toxicological models in environmental risk assessments has been suggested (Hursthouse and Kowalczyk, 2008). Geographic Information System (GIS) has been used to map vulnerable communities to environmental disasters and diseases (Morrow, 1999).

Past works on PAHs bio-accessibility and cancer risk did not fully exploit the capacities of GIS (Siciliano et al., 2010, Juhasz et al., 2016, Adetunde et al., 2018). To fill this gap knowledge gap, the site-specific potential health risks from PAHs associated with different anthropogenic activities form soils across Lagos metropolis in Nigeria were assessed by including a geographic information system (GIS) approach. This follow-on assessment was to exploit GIS in spatial modelling of cancer risk in the population based on PAH bio-accessibility.

2.0 Materials And Method

2.1 Sampling

Lagos is Nigeria's megacity with over 10 million residents (Ilesanmi, 2015). Built-up urban development is concentrated in a vertical pattern as one move up north spilling over to neighbouring Ogun State (Opoko and Oluwatayo, 2014). Composite purposively sampled surface soils from eight locations at depths ranging from 0 to 10 cm were gathered. Two sites were dumpsites, two were depots for motor spirit/kerosene, the last four sites were depot for black oil, a trailer park/mechanic workshop, a mechanic workshop for small vehicles and the last a random roadside in Lagos (Figure 1).

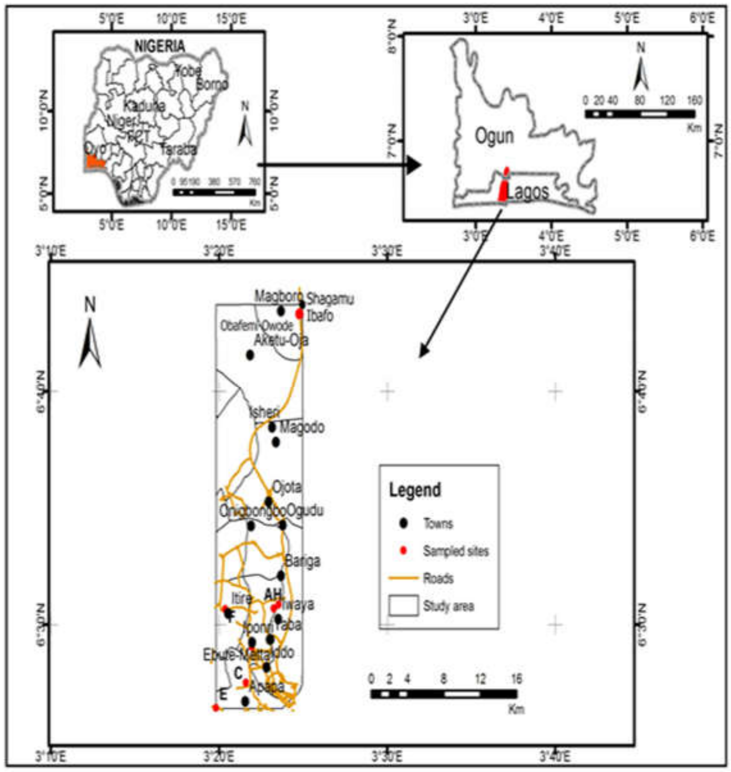

Figure 1: Study area in Lagos mega city (Author, 2018).

2.2 Analysis of total PAHs

Sample(s) extraction and cleanup were using a procedure described in Adetunde et al., (2018). Briefly, acetone:n-hexane (1:1 v/v, 10 mL) was used to extract the 16 USEPA PAHs from 0.5 g to 5 g of soils and certified reference material (CRM) sequentially, thrice. The extracts were concentrated to 1 mL, loaded onto a C18 solid Phase extraction cartridge (Bond Elute), eluted at a flow rate of 1 mL /min with 5 mL of DCM:n-hexane and concentrated to near dryness using a gentle stream of nitrogen. The final extracts were reconstituted in 1 mL of n-hexane. Extracts of n-hexane (1 µL) were analysed with an initial temperature of 290 °C on an Agilent gas chromatograph-mass spectrometer (6890N) (GC) and a mass selective detector (Agilent 5975)(MS) with split/splitless injector in selective ion monitoring (SIM) mode. A HP-5MS UI capillary column of 30 m, 0.25 mm i.d. x 0.25 mm film thickness was used with helium as the mobile phase at a 1 mL/min constant flow rate. The column oven was held at 50 °C (3.2 mins) and at 30 °C/min, it was ramped to 150 °C. From 150 °C it was raised to 238 °C at 2 °C/min. The temperature increased to 272 °C at 3 °C/min and finally to 300 °C at 70 °C/min and maintained for 2.73 mins. A 70 eV was used to acquire the mass spectra. The analytical series was made up of a blank, CRM, recovery standard and six calibration standards. Internal standard calibration method was used for the quantification of PAHs.

2.3 Determination of Bio-accessible PAHs and Geospatial analysis
FOREhST was used to measure the bio-accessible PAHs present in sampled soils (Adetunde et al., 2018). The results from laboratory analysis were then interpolated using the inverse distance weighting (IDW) technique for the whole study area to first generate the PAHs pollution concentration in soils map (Figure 3) then generate bio-accessibility map (Figure 4). ESRI ArcGIS 10.1 was used to run IDW and all other spatial analysis. The IDW technique is a spatial interpolation method that uses cross-validation to get optimum parameters from which optimal interpolation is made after which uncertainty of each of these estimates are calculated through jacknife procedure (Tomczak, 1998). In the mapping of soil properties, IDW has been regarded to be the best spatial interpolation technique (Cojocaru and Breabăn, 2014, Gozdowski et al., 2015).

2.4 Risk Analysis
The risk analysis of exposure to the priority PAHs were based on bio-accessibility results from the FOREShT method and not the total PAHs since not all the PAHs present were bio-accessible. The risk was calculated as earlier discussed in Adetunde et al., (2018).

The work flow diagram for the GIS based analysis is as shown in Figure 2. After PAHs soil pollution was modelled using IDW (Figure 3), the concentration of bio-accessible PAHs derived from the FOREShT method was spatially interpolated for the study area also using IDW technique (Figure 4). The official projected population for the study area for the period of sampling (2011/2012) (NBS, 2012) was linked to centroids of the Local Government Areas and spatially interpolated for using IDW. Population age bracket of 15 years and above were used for the analysis as that is the minimum official age for labour force calculation and available data was group according to this classification. The calculated theoretical cancer risk (ER) was also spatially interpolated for the study area using IDW (Figure 5). The ER with normal exposure level of 1 x 10-6 was used to standardize the spatial cancer risk index based on PAH bio-accessibility for the study area. The spatial data in raster form had the same pixel/cell size of 0.0049239619 x 0.0049239619. The local ER and population data were then multiplied with each other and the product multiplied by 10-6. This was to standardize the result relative to the normal exposure risk level of 1 person per 100,000 people. In this paper the standardized spatial theoretical cancer risk is referred to as the cancer spatial vulnerability index as shown in Figure 6. This produced a scale of 0 to 1 with zero having no risk, and increasing cancer risk as values approach one and above.

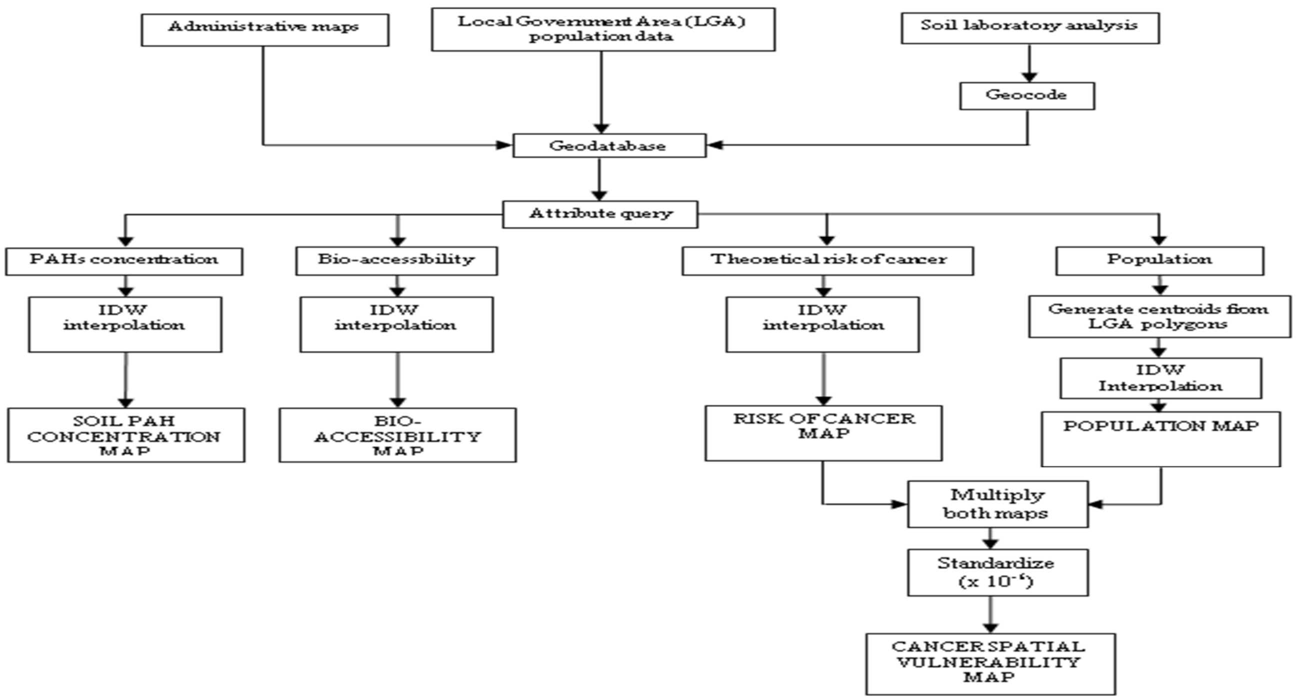

Figure 2: Workflow diagram for GIS analysis (Author, 2018)

3.0 Results and Discussion

The sum concentration of 16 USEPA's priority PAHs in the different soils had a range of 689 to 253,922 ng/g, as shown in Figure 3 and these can be classified as contaminated soils to extremely contaminated soils. Soil PAH concentration greater than 1,000 ng/g has been classified as heavily contaminated soils, while 600-1,000 ng/g as contaminated soils, 200-600 ng/g as lightly contaminated soils and as 200 ng/g as non-contaminated soils (Maliszewska-Kordybach, 2005). Extremely contaminated soils are soils with PAHs concentration greater than 100,000 ng/g. The PAH contamination concentration in soils increased diagonally as one moved from the north-east to the south-west region of the study area. The observed pattern could be due to the production activities in the area. The southern tip plays host to most of Nigeria's depots for refined petroleum products as well as parking bays for heavy duty trailers carrying imported products from the ports on the Atlantic coast to all parts of the country. The northern edge still has some Tropical Forest cover even though urban expansion is rapidly fazing these out. The trailer park/mechanic workshop along the Ibafo end up north is an example of urban expansion's negative impact on the environment. Trailers from all parts of Nigeria heading for Lagos ports break journey there when waiting for their turn to load at the ports or refuelling their provisions before going the last mile of the supply chain.

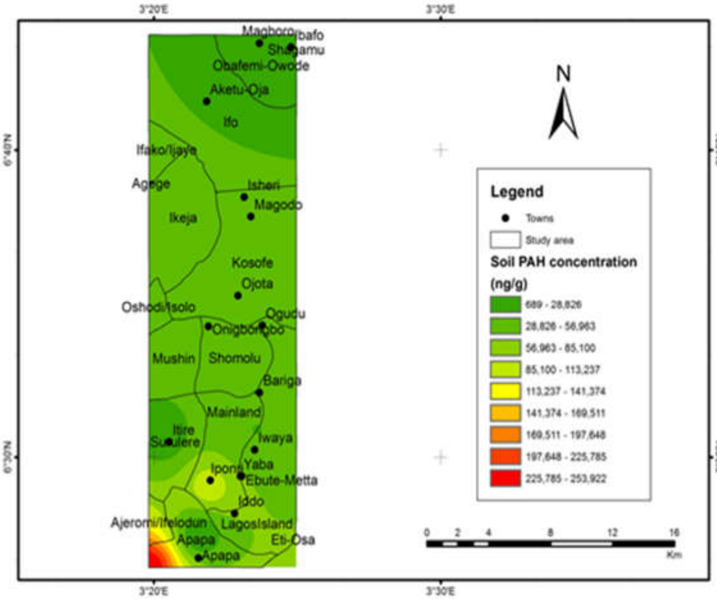

Figure 3: PAHs concentration in soil (Author, 2018)

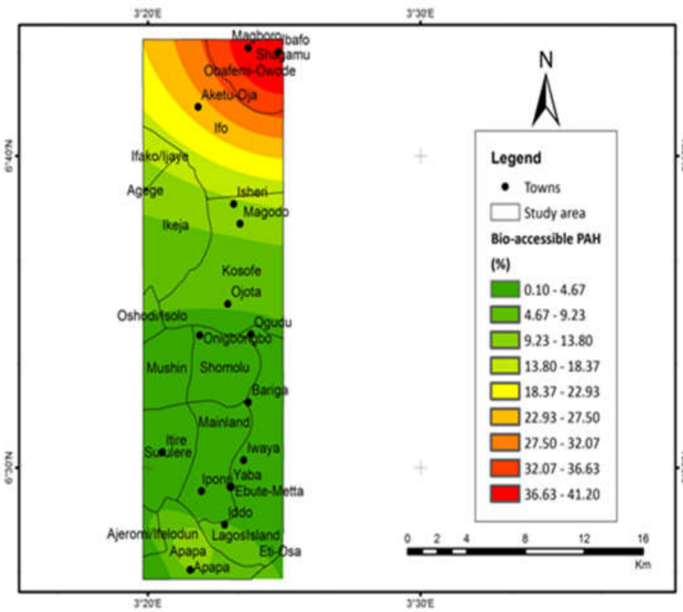

Figure 4: Bio-accessibility of PAHs in the study area (Author, 2018).

The bio-accessible fraction was expressed as a percentage of the total observed concentration (Figure 4). Total bio-accessible USEPA's priority PAHs for the soil samples in this study had a range of 0.1 % to 41.2 %. While according to a review by Cui et al., (2010), it ranges between 12 and 61 % in other studies. Our study corroborated the findings of Cui et al., (2010) that bio-accessible PAHs present in soil make up a small percent of the total PAHs. The observed spatial pattern reflects the temporal dimension of soil contamination in the area. Areas with lower percentage bio-accessible PAHs such have had long period of contamination over decades of years like the industrial zones in Iponri, the train terminus and associated factories, trailers and car parks at Iddo, etc which have existed since Nigeria's independence in 1960. Higher areas of bio-accessibility are the more recent urban expansion sites as found in Ibafo, Magboro to the north of the study area. This may be due to aging effect of PAHs on the organics in soils.

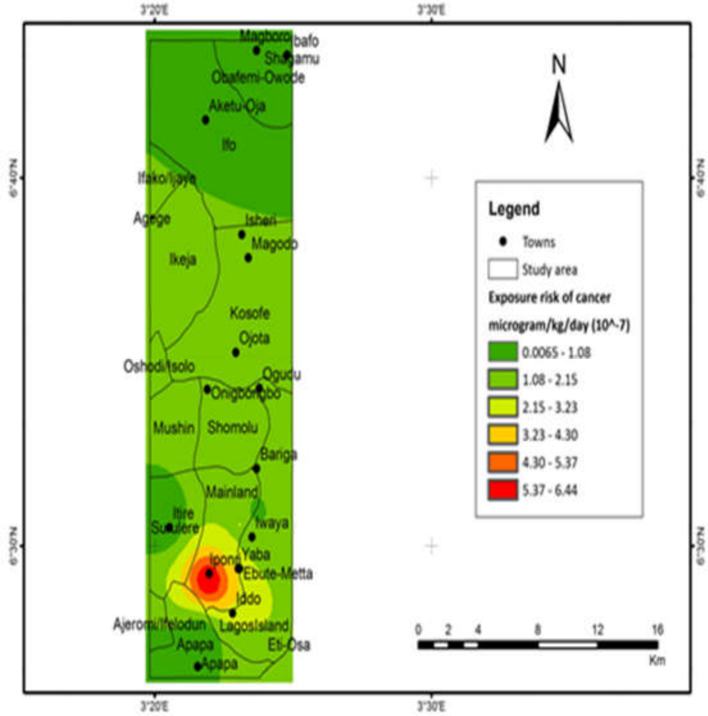

Figure 5: Theoretical risk of cancer in the study area (Author, 2018).

The estimated theoretical cancer risks (ER) for soil in these environments based on bio accessible PAHs were low. Based on bio-accessible oral ingestion were all less than both the 1 x 10-4 for extreme exposure and the target risk of 1 x 10-6 for normal exposure in these studied sites (Peng et al., 2011). However, in this study, the ER values for an adult was found to be between 7.3 x 10-7 and 1.2 x 10-4 (Figure 5).

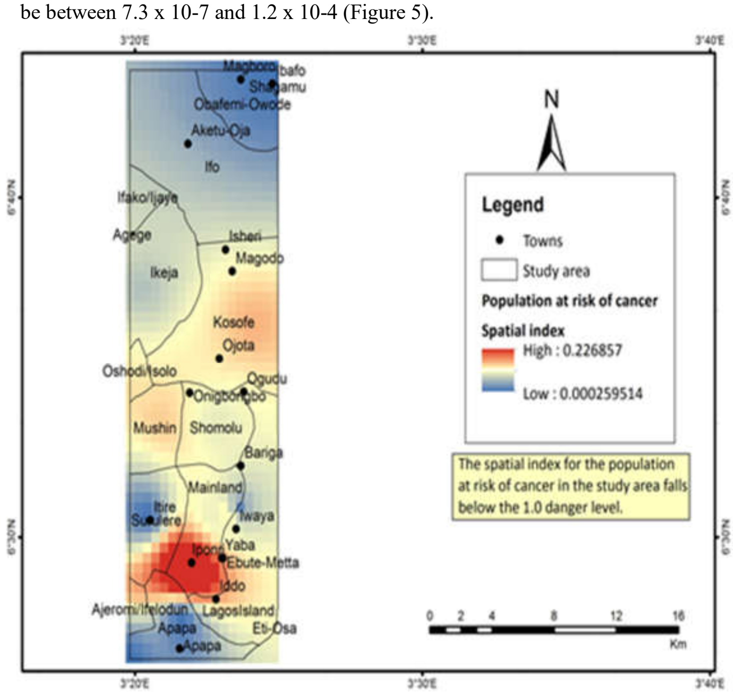

Figure 6: Spatial vulnerability to cancer in the study area (Author, 2018).

Figure 6 showed the spatial vulnerability to cancer in the study area overall from being exposed to soil surface through oral ingestion. These were all below the acceptable level of 1 person per 100,000 people for normal exposures (Peng et al., 2011). Iponri area to the south with 0.226 in 100,000 people was the most vulnerable area to cancer while the least vulnerable area to cancer was around Magboro/Ibafo axis to the north with 0.002 per 100,000 people. The ER from this model were all below the acceptable level of 1 per 100,000 people as shown in Figure 6. The highest, being 0.2 person per 100, 000 people. Relative to the whole study area Iponri, Kosofe and Mushin areas had higher vulnerability to cancer due to bio-accessible PAH in soil surface. These areas are highly industrialized zones of Lagos metropolis with a lot of manufacturing and hydrocarbon related industrial activities going on here.

4.0 Conclusion

This study evaluated the potential health risks, based on a site-specific assessment of bio-accessibility, of PAHs in soils across diverse socio-economic activities within Lagos, Nigeria. GIS can be used to spatially model soil surface-based bio-accessibility of PAHs and also model cancer spatial vulnerability based on theoretical risk of cancer. Locational components in analysis using GIS have been used to model spatial vulnerability to cancer using the theoretical cancer risk model.

Conflicts of Interest

The authors state that we do not have any conflict of interest to declare.

Authors Contribution

AOA Conception: KOO; Design: KOO and OTF; Execution: OTF and OTA; Interpretation: OTF and OTF; Writing the paper: OTA, OTF and KOO

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