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# Occurrence and Distribution of Polycyclic Aromatic Hydrocarbons (Pahs) in Soils Around Flyover Road Construction Sites

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## ABSTRACT

Soil samples were collected from the vicinity of two flyover road construction sites in Port Harcourt. The the collected samples were stored in aluminium foil and transported to the laboratory in ice coolers. The samples were later subjected to gas chromatographic analysis for polycyclic aromatic hydrocarbon (PAH), after pre-ectraction with 30 ml of dichloromethane. Results showed a distribution of measurable concentration of high molecular weight (HMW) PAHS. Of the sixteen priority PAHs detected, Fluoranthene, Pyrene and Benzo(a)anthracene were found to be present in concentration of 0.47 mg/kg, 0.07mg/kg and 0,01 mg/kg respectively. The absence of low molecular weight (LMW) PAHs such as Naphthalene and Phenanthrene suggests that environmental weathering processes, including volatilization and degradation, have likely removed these more labile compounds over time. Although most contaminant levels remained within international regulatory limits, the observed increases in concentration, particularly for PAHs in the second stage, indicates a gradual decline in soil quality. This suggests that reliance on regulatory thresholds alone may not be sufficient to capture early-stage environmental degradation. Instead, continuous monitoring and trend analysis are essential for identifying emerging risks before they reach critical levels. This is important because of the tendency of PAHs to bioaccumulate.

**Keywords:** Polycyclic aromatic hydrocarbons (PAHs); Flyover road construction; Soil; Asphalt; Contaminant

## Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds that are colourless or pale-yellow solids. PAHs are produced primarily by the incomplete combustion of organic materials (coal, oil, wood, garbage) and released into the atmosphere, from where they travel and deposit into all other media[1,2]. PAHs are ubiquitous, that is, it widespread and exists virtually everywhere. They can be found in all the environmental media - air, water, soil and sediment. The compounds are known to travel long distances through the atmosphere once released. They are persistent (cannot be broken down easily) anywhere they are found and because of this tendency of not degrading, they can impact toxicity on the environment.

PAHs can come from industrial, residential and natural sources. One of the source areas not often mentioned is the road construction site. Road construction utilizes asphalt, a highly viscous liquid or semi-solid form of petroleum, used mainly as a binder for concrete construction. They are hydrocarbons, often produced as a residue from petroleum refining. The complex hydrocarbons in asphalt can release harmful polycyclic aromatic hydrocarbons (PAHs) during production and application. These emissions contribute to air pollution and environmental concerns, necessitating sustainable practices and controls to mitigate their impact on air quality[3,4].

Bitumen, a primary component of asphalt, is a complex mixture of hydrocarbons. During construction, bitumen is heated to high temperatures, releasing volatile organic carbons into the atmosphere. These compounds also include polycyclic aromatic hydrocarbons (PAHs) and benzene, toluene, ethylbenzene and xylene (BTEX) molecules[5]. Roofing materials like asphalt shingles and built-up roofing systems contain bitumen, which can harbor PAHs. As these materials degrade over time due to weathering and wear or when buried in landfills as a result of demolition works, they may similarly release PAHs into the environment[6].

In an effort to reduce road traffics, road constructions, especially dual carriages and flyover bridges are embarked on as major infrastructural projects. These construction activities often do present a huge menace to the ecological stability of the surrounding area. Apart from asphalt-induced PAHs, the environments surrounding construction sites may also experience soil contamination from inappropriate handling or disposal of hazardous items[7,8]. In the overall, urban roads are often contaminated with polycyclic aromatic hydrocarbons (PAHs) from road dust and a variety of other sources, including worn-out road surface materials, vehicle exhaust, lubricating oils, petrol, diesel fuel, tyre fragments and deposited particulates from construction activities.

Regular monitoring of construction sites for persistent organic compounds like PAHs can help identify and prevent pollution before it becomes a problem. If contamination is detected, prompt investigation, clean-up and remediation efforts are necessary to minimize risks. It is for this reason that this work sought to investigate the occurrence and distribution of PAHs in soils near flyover construction sites in Port Harcourt and the probable health implications of their levels in the study areas.

## Materials and Methods

### Study area

The areas of focus for the study **(Figure 1)** were some flyover sites in Port Harcourt metropolis in Rivers State Nigeria. The geographical coordinates for the location of Port Harcourt city are within latitude 40 47' 30" N and 40 54' 30" N and longitude 60 54' 00" E and 70 04' 30" E. Port Harcourt consists of two Local Government Areas which are the Port Harcourt Local Government Area (PHALGA) and Obio-Akpor Local Government Area. Our specific sampling locations were distributed between both local government areas.

For the first stage of the research, field samples were collected from two flyover construction sites - the Ada George Location (AGL1) Flyover and the Rumuokwuta (RUA1) Flyover. A control sample was also collected from Ozuoba area (CTL1). For the second stage of comparative analysis, A reference water sample was collected from the Julius Berger waste dump site (JB@) at Eastern bypass Port Harcourt. Samples from two recently ongoing flyover project were also collected from Rumuekini (RUK2) and Rumuosi-Ozuoba (ROA2) Area. One composite sample each was also collected from the initial flyover sampling sites at Ada George Location (AGL2) and Rumuokwuta (RUA2) after 2 seasons. The specific coordinates of the sampled sites are given in the area of study map **(Figure 1)**.

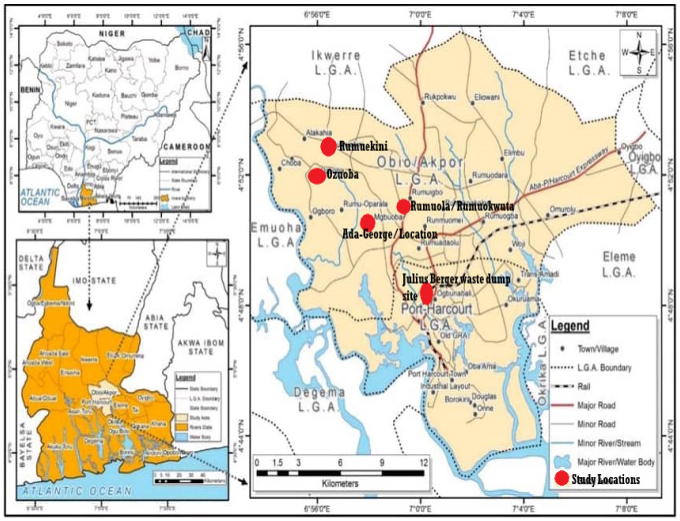


**Figure 1:** Map of the Study Area showing locations from where samples were collected.

### Research design

The research was quantitative in nature. The Analysis involved both field and laboratory components. In the field study, Soil samples were obtained from the study sites of interest according to standard procedures. The Laboratory analysis involved the testing of PAHs in the soils.

### Sample and sampling technique

For the first stage of Analysis, three (3) soil samples each were randomly collected from three sample points at AGL1 and RUA2. The samples were collected at depths of 0-15cm and wrapped in aluninium foil, stored in ice coolers and then transported to the laboratory for analysis. A control soil sample was also collected from soil around the Ozuoba residential area of Port Harcourt city where there was no ongoing construction activity at the time.

For the second stage analysis which took place after 2 seasons, one water sample was collected from JS2. One composite sample each of soil was also collected from the initial sample sites at Ada George Location (AGL2) and Rumuokuta (RUA2) for re-evaluation. One composite soil sample each was also collected from two ongoing flyover construction projects at RUK2 and ROA2. In all sampling instances, the collected samples were stored in aluminium foil and transported to the laboratory in ice coolers.

### Extraction

The soil samples were subjected to the following extraction procedure:

Thirty grams (30g) of the wet soil sample was homogenized using a spatula, after which the homogenized sample was dried using NaSO4. Thirty millilitres (30 ml) of dichloromethane was then added to the dry sample. The sample was agitated for 30 mins, filtered and concentrated to 1ml. thereafter, the filtrate samples were then analyzed using the GC-FID.

### Validity of instrument

To ensure the integrity of all samples collected, data for the samples were recorded on a field datasheet during sampling. Additionally, a standard chain of custody form was completed once sampling was finished to ensure proper storage, identification and processing for instrumentation. Before running the samples, procedural blanks were used to ensure the validity of the instruments results from processing the samples in the GC-FID. Analyses of procedural blanks were performed to ensure that the reagents were pure and free of interference and possible laboratory contamination. To do this, the analytical process was carried out on the reagents in the absence of the samples. The procedure blank samples were found to contain none of the identified PAH compounds being determined. Known concentrations (standards) of PAHs were added (spiked) to selected samples prior to extraction and all analytical procedure was repeated. The percentage recoveries were then calculated.

### Human health risk assessment: Toxic equivalent factor (TEF) and toxic equivalence (TEQ)

The toxic equivalency factor (TEF) method was used to compute the BaP equivalence (BaPeq) of PAHs which is a value used in evaluating the carcinogenicity of PAHs compared to BaP[9]. BaP has been assigned a value of 1 in the TEF calculation for PAHs and is considered a reference chemical due to its high carcinogenic potential. This allows the carcinogenicity of each PAH to be evaluated in relation to BaP. Even though according to Nisbet and LaGoy and some other frameworks, the he reported TEF for Nap, Acy, Ace, FI, Phe, Ant, Flu, Pyr, BaA, Chr, BbF, BkF, BaP, DBA (DahA), BghiP and IND (Icdp) were 0.001, 0.001, 0.001, 0.001, 0.001, 0.01, 0.001, 0.001, 0.1, 0.01, 0.1, 0.1, 1, 1, 0.01 and 0.1, only the TEFs for BaA, Chr, BbF, BkF, BaP, DBA and Icdp are computed in the calculation of the TEQ equivalents for this work. This is because according to the EPA, the 16 Priority PAHs include 7 carcinogenic PAHs (with TEFs) and 9 non-carcinogenic or weakly carcinogenic PAHs (no generally agreed TEFs). Therefore, only the 7 carcinogenic PAHs are calculated.

In this work, the toxic equivalent quotient (TEQ) of each site was determined using the following equations:

$BaPeq_i$ = (PAH$_i$ x $TEF_i$)..... (1)

TEQ = $\sum_{i=1}^{n}$ PAH$_i$ $x$ $C_i$ ……(2)

Also, only the priority PAHS with carcinogenic tendencies were utilized in the evaluation. Where PAHi is the concentration of each PAH and TEFi stands for toxic equivalency factor. For the purpose of the analysis, the TEF values utilized for the calculation for BaA, Chr, BbF, BkF, BaP, Icdp and DahA were 0.1, 0.001, 0.1, 0.01, 1, 0.1 and 1 respectively (Nisbet and LaGoy, 1992). Concentration values were converted from ppm to ng/g (i.e mg/kg to ng/g by multiplying by 1000) before calculation. All non detected PAH concentrations were computed as zero (0).

## Results and Discussion

## Results of Analysis

The results of the chromatographic analysis for PAHs are contained in **(Tables 1-3)** while **(Figures 2,3)** show the distributive chromatograms for Ada George Location (AGL) and Rumuokwuta (RUA) respectively.

**Table 1:** Distribution of sixteen priority PAHs in analysed soil samples.

| PAHs | JB2 | ROA2 | RUK2 | AGL2 | RUA2 |
|---|---|---|---|---|---|
| Nap | <0.001 | 0.02 | 0.09 | 0.13 | 0.38 |
| Acy | 0.0013 | 0.05 | 0.03 | 0.05 | 0.04 |
| Ace | 0.0017 | 0.12 | 0.05 | 0.11 | 0.05 |
| Flu | 0.0008 | 0.14 | 0.03 | 0.04 | 0.05 |
| Phen | 0.0012 | 0.05 | 0.01 | 0.02 | <0.001 |
| Anth | 0.0009 | 0.03 | 0.01 | 0.02 | 0.01 |
| Flth | 0.1001 | 0.08 | 0.07 | 0.48 | 0.47 |
| Pyr | 0.0110 | 0.08 | 0.07 | 0.07 | 0.07 |
| B(a)A | 0.0159 | 0.01 | 0.01 | 0.02 | 0.01 |
| Chr | 0.0077 | 0.01 | 0.01 | 0.02 | 0.01 |
| B(b)F | 0.0059 | 0.02 | 0.01 | 0.08 | 0.01 |
| B(k)F | 0.0208 | 0.03 | 0.18 | 0.26 | 0.21 |
| B(a)P | 0.0331 | 0.04 | 0.05 | 0.03 | 0.04 |
| IcdP | 0.0077 | 0.02 | 0.02 | 0.07 | 0.02 |
| D(ah)A | 0.0112 | 0.21 | 0.05 | 0.78 | 0.13 |
| B(ghi)P | <0.001 | 0.04 | 0.03 | 0.13 | 0.02 |
| Total (∑ 16 PAHs) | 0.2193 | 0.95 | 0.72 | 2.31 | 1.52 |

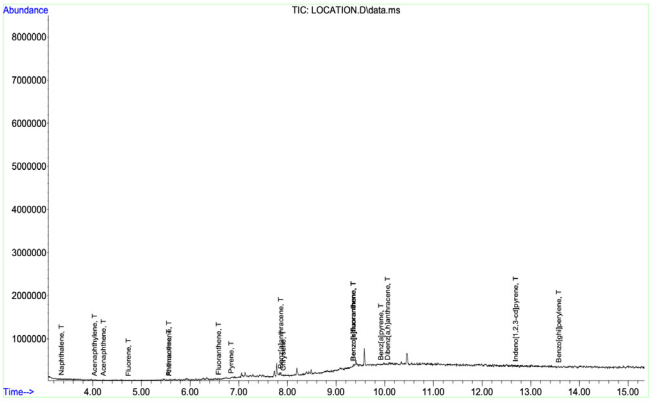


**Figure 2:** AGL2 (Ada George Location) PAH Sample Chromatogram

**Table 2:** Summary of PAH Results from all stages

| PAHs | AGL1 AVRG | RUA1 AVRG | CTL1 | JB2 | ROA2 | RUK2 | AGL2 | RUA2 |
|---|---|---|---|---|---|---|---|---|
| Nap | <0.001 | <0.001 | <0.001 | <0.001 | 0.02 | 0.09 | 0.13 | 0.38 |
| Acy | <0.001 | <0.001 | <0.001 | 0.0013 | 0.05 | 0.03 | 0.05 | 0.04 |
| Ace | <0.001 | <0.001 | <0.001 | 0.0017 | 0.12 | 0.05 | 0.11 | 0.05 |
| Flu | <0.001 | <0.001 | <0.001 | 0.0008 | 0.14 | 0.03 | 0.04 | 0.05 |
| Phen | <0.001 | <0.001 | <0.001 | 0.0012 | 0.05 | 0.01 | 0.02 | <0.001 |
| Anth | <0.001 | <0.001 | <0.001 | 0.0009 | 0.03 | 0.01 | 0.02 | 0.01 |
| Flth | 0.557 | 0.078 | <0.001 | 0.1001 | 0.08 | 0.07 | 0.48 | 0.47 |
| Pyr | 0.046 | 0.062 | <0.001 | 0.0110 | 0.08 | 0.07 | 0.07 | 0.07 |
| B(a)A | 0.433 | <0.001 | <0.001 | 0.0159 | 0.01 | 0.01 | 0.02 | 0.01 |
| Chr | <0.001 | <0.001 | <0.001 | 0.0077 | 0.01 | 0.01 | 0.02 | 0.01 |
| B(b)F | <0.001 | <0.001 | <0.001 | 0.0059 | 0.02 | 0.01 | 0.08 | 0.01 |
| B(k)F | <0.001 | <0.001 | <0.001 | 0.0208 | 0.03 | 0.18 | 0.26 | 0.21 |
| B(a)P | <0.001 | <0.001 | <0.001 | 0.0331 | 0.04 | 0.05 | 0.03 | 0.04 |
| IcdP | <0.001 | <0.001 | <0.001 | 0.0077 | 0.02 | 0.02 | 0.07 | 0.02 |
| D(ah)A | <0.001 | <0.001 | <0.001 | 0.0112 | 0.21 | 0.05 | 0.78 | 0.13 |
| B(ghi)P | <0.001 | <0.001 | <0.001 | <0.001 | 0.04 | 0.03 | 0.13 | 0.02 |
| Total (∑ 16 PAHs) | 1.034 | 0.138 | <0.001 | 0.2193 | 0.95 | 0.72 | 2.31 | 1.52 |

**Table 3:** PAH TEQ values from AGL1, RUA1 and CTL1(ngTEQ/g).

| PAH TEQ | AGL 1 | | | | RUA 1 | | | | CTL1 |
|---|---|---|---|---|---|---|---|---|---|
| | **Sp 1** | **Sp 2** | **Sp 3** | **Avrg** | **Sp 1** | **Sp 2** | **Sp 3** | **Avrg** | |
| $BaPeq_{BaA} x\ C_{BaA}$ | 129.9 | 0 | 0 | 43.3 | 0 | 0 | 0 | 0 | 0.00 |
| $BaPeq_{Chr}\ x\ C_{Chr}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $BaPeq_{BbF} x\ C_{BbF}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $BaPeq_{BkF} x\ C_{BkF}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $BaPeq_{BaP} x\ C_{BaP}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $BaPeq_{IND} x\ C_{IND}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $BaPeq_{DBA} x\ C_{DBA}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TEQ | 129.9 | 0 | 0 | 43.3 | 0 | 0 | 0 | 0 | 0.00 |
| Cs | 1.30E-01 | 0 | 0 | 4.33E-02 | 0 | 0 | 0 | 0 | 0 |

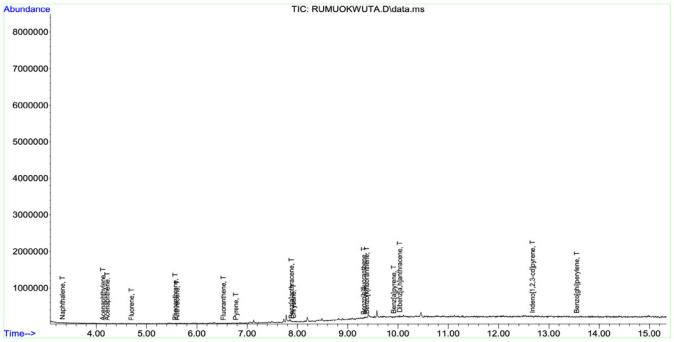


**Figure 3:** RUA2 (Rumuokwuta) PAH Sample Chromatogram.

### Distribution of PAHs and concentrations

The characterization of polycyclic aromatic hydrocarbons (PAHs) across the AGL1 and RUA1 flyover construction sites revealed a highly selective contamination profile, with only three out of the sixteen priority PAHs detected at measurable concentrations (cf: **Table 1**). These included Fluoranthene, Pyrene and Benzo(a)anthracene. The absence of low molecular weight (LMW) PAHs such as Naphthalene and Phenanthrene suggests that environmental weathering processes, including volatilization and degradation, have likely removed these more labile compounds over time[10].

At the AGL1 site, significant spatial variability in PAH distribution was observed. Sample 1 was characterized by the exclusive presence of Benzo(a)anthracene at a concentration of 1.299 mg/kg, indicating a localized hotspot of carcinogenic PAH contamination. Sample 2 exhibited measurable concentrations of Fluoranthene (0.163 mg/kg) and Pyrene (0.137 mg/kg), while Sample 3 was dominated solely by Fluoranthene at 1.504 mg/kg, the highest concentration recorded across all samples. The total PAH concentration at AGL1 ranged from 0.3 to 1.504 mg/kg, with an average of 1.034 mg/kg, reflecting elevated contamination driven by localized peaks.

In contrast, the RUA1 site displayed a more uniform but significantly lower contamination pattern. Across all three samples, only Fluoranthene and Pyrene were detected, with concentrations ranging from 0.055 to 0.104 mg/kg (Fluoranthene) and 0.053 to 0.079 mg/kg (Pyrene). The total PAH concentration ranged from 0.108 to 0.158 mg/kg, with an average of approximately 0.138 mg/kg, indicating moderate but consistent contamination. No detectable PAHs were recorded at the control site (CTL1), confirming that the contamination observed at AGL1 and RUA1 is anthropogenic rather than naturally occurring.

The dominance of Fluoranthene, Pyrene and Benzo(a) anthracene - classified as high molecular weight (HMW) PAHs - strongly indicates a pyrogenic origin, typically associated with incomplete combustion processes such as vehicular emissions, fossil fuel combustion and asphalt-related activities[11]. The presence of Benzo(a)anthracene, in particular, is consistent with emissions from diesel exhaust, coal combustion and construction-related materials[9]. Importantly, Benzo(a)pyrene, widely regarded as the most toxic PAH and a key indicator of carcinogenic risk, was not detected across any of the samples. While this may suggest a reduced overall carcinogenic burden, it does not eliminate potential health risks associated with other carcinogenic PAHs such as Benzo(a)anthracene.

AGL1 showed the highest PAH concentration and the greatest toxic equivalence, identifying it as a localized hotspot. RUA1 showed lower and more uniform PAH contamination, while the control site recorded no detectable PAHs. The PAH risk assessment for Stage 1 showed that AGL1 had measurable carcinogenic potential, with ILCR values around the lower acceptable risk boundary. Dermal exposure was the dominant pathway, followed by ingestion, while inhalation was negligible. The absence of Benzo(a)pyrene in Stage 1 reduced the overall carcinogenic burden, but the presence of Benzo(a)anthracene still indicated that health concerns could not be completely dismissed.

In the second stage, PAH contamination increased substantially in both concentration and compound diversity. Nearly all 16 priority PAHs were detected across the sampled sites, including low molecular weight compounds such as Naphthalene, Acenaphthene and Fluorene. Their presence suggests fresh or ongoing contamination inputs, likely from petroleum products, fuel leaks, construction machinery and active site operations. The detection of Benzo(a)pyrene across all Stage 2 sites marked a major increase in toxicological concern compared with Stage 1. AGL2 recorded the highest total PAH concentration and the highest TEQ and ILCR values, making it the most impacted site in the second stage. RUA2 also showed a major increase compared with its first-stage result, indicating that contamination intensified over time. Diagnostic ratios confirmed that combustion remained the dominant PAH source, but the reappearance of low molecular weight PAHs showed that petrogenic inputs were also present. This means that Stage 2 contamination was not only residual or aged but was being actively replenished. Comparison with guideline values showed that Stage 2 PAH concentrations at AGL2 and RUA2 exceeded the EGASPIN and Dutch target value of about 1 mg/kg, indicating moderate contamination and a decline in soil quality. Although the concentrations were still far below intervention values requiring immediate remediation, the consistent detection of carcinogenic PAHs, especially Benzo(a)pyrene, shows that the sites require closer environmental attention.

In summary, the findings show that contamination at the flyover construction sites is dynamic, site-specific and influenced by both seasonal conditions and construction activities. PCB risks were controlled mainly by congener toxicity, while PAH risks were strongly linked to the presence of carcinogenic compounds such as Benzo(a)pyrene and Benzo(a)anthracene. The study therefore demonstrates that total contaminant concentration alone is not enough to assess environmental or health risk. Congener-specific and compound-specific assessments, supported by TEQ, ILCR and diagnostic ratio analyses, provide a more reliable understanding of contamination severity. Overall, while most contaminant levels did not exceed major international intervention limits, the increasing concentrations, toxicological significance and evidence of ongoing inputs justify continuous monitoring, improved construction-site waste management, proper fuel handling, dust control and periodic human health risk assessment around the study areas.

## Conclusion

Soil contamination in construction-impacted urban environments is dynamic, multi-source and strongly influenced by both chemical composition and environmental processes. The detection of varying concentration of PAHs in soils within the vicinity of flyover construction sites in Port Harcourt. underscores the importance of integrating concentration data with toxicity-based metrics and temporal analysis to achieve a more accurate understanding of environmental risks. The reappearance of low molecular weight PAHs alongside the detection of highly carcinogenic compounds such as Benzo(a)pyrene indicates that contamination is being continuously replenished. This suggests that construction environments do not merely accumulate legacy pollutants but can function as active sources of environmental contamination over time.

Although most contaminant levels remained within international regulatory limits, the observed increases in concentration, particularly for PAHs in the second stage, indicates a gradual decline in soil quality. This suggests that reliance on regulatory thresholds alone may not be sufficient to capture early-stage environmental degradation. Instead, continuous monitoring and trend analysis are essential for identifying emerging risks before they reach critical levels.

## References


1. Sam KS, Onyena AP, Zabbey N, et al. Prospects of emerging PAH sources and remediation technologies: insights from Africa. Environ. Sci Pollut Res 2023;30(14):39451-39473.
2. Waka AT, Osuji LC, Onojake MC. Ecological risk assessment of soils contaminated with polycyclic aromatic hydrocarbons and polychlorinated biphenyls in industrial sites of Rivers State, Nigeria. As J Curr Res 2025;10:140-152.
3. Zhang J, Guo Z, Cao Y. Environmental hazards and restraining methods of pavement asphalt. In E3S Web of Conferences. EDP Sci 2021;260:1007.
4. Ashworth C. Asphalt a concern for air pollution. Nature Reviews Earth & Environ 2020;1(10):497-497.
5. Kalagaeva K. Bitumen fumes, impacts on human health and natural environment: Reduction, prevention and control of bitumen fumes in road construction industry 2014.
6. De Buyck PJ, Matviichuk O, Dumoulin A, et al. Roof runoff contamination: establishing material-pollutant relationships and material benchmarking based on laboratory leaching tests. Chemosphere 2021;283:131112.
7. Edo M ortuño N, Persson PE, Conesa JA, Jansson S. Emissions of toxic pollutants from co-combustion of demolition and construction wood and household waste fuel blends. Chemosphere 2018;203:506-513.
8. Butera S, Christensen TH, Astrup TF. Composition and leaching of construction and demolition waste: inorganic elements and organic compounds. J hazardous materials 2014;276:302-311.

9. Nisbet IC, Lagoy PK. Toxic equivalency factors (TEFs) for polycyclic aromatic hydrocarbons (PAHs). Regulatory toxicology Pharma 1992;16(3):290-300.

10. Abdel-Shafy HI, Mansour MS. A review on polycyclic aromatic hydrocarbons: source, environmental impact, effect on human health and remediation. Egyptian J Petro 2016;25(1):107-123.

11. Yunker MB, Macdonald RW, Vingarzan R, et al. PAHs in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH source and composition. Organic geochemistry 2002;33(4):489-515.