Research Paper

Assessing agbor metropolis's soil and groundwater environmental effects of storage tank leaks

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ABSTRACT

The effect of surface and groundwater petroleum storage tank leaks in Agbor Metropolis, Delta State, Nigeria, on the environment was investigated in this study. The study filled important knowledge gaps regarding hydrocarbon pollution in developing metropolitan settings with little environmental regulatory control. Using a multi-step approach, researchers conducted extensive soil and groundwater sampling at six Petrol stations. It uses chemical analysis and geospatial mapping techniques to assess the level of contamination. Results revealed significant contamination, mainly at Locations A and C. Groundwater Total Petroleum Hydrocarbons (TPH) concentrations ranged from 520.345 µg/L to 755.678 µg/L, substantially exceeding World Health Organization drinking water standards. Soil contamination exhibited a steady rise in pollutant concentrations with depth, with TPH maxima attaining 530.345 mg/kg. The concentrations of BTEX ranged from 22.345 µg/L to 42.123 µg/L, indicating significant aromatic hydrocarbon pollution. Although the dissolved oxygen was within constant levels of 3.234-4.200 mg/L and near-neutral pH values of 6.770-7.050, the study concludes that groundwater in Agbor Metropolis is under severe environmental risk. This paper highlights the critical need for focused remediation measures, increased underground storage tank regulations, and thorough environmental monitoring in rapidly urbanising regions. The results will add significantly to the knowledge base on localised petroleum pollution dynamics, forming a fundamental paradigm toward environmental management and public health protection in emerging metropolitan areas.

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1. INTRODUCTION

The Agbor Metropolis is undergoing an environmental impact assessment due to surface and groundwater tank leaks. Introduction In this latter area, the environmental impacts of industrial and commercial activities have received increasing attention. Particular focus is on the possible contamination of soil and groundwater resources; among these concerns are the Effects of oil storage tank leaks, Especially from Petrol stations [11]; Alharbi et al., 2018) The occurrence of this problem has escalated in the urban and suburban environment across the world. The present study evaluates environmental consequences arising from leakages from surface and groundwater storage tanks in Agbor Metropolis, the rapidly rising urban center in Delta State, Nigeria. The area has witnessed an expansion of Petrol stations. Combine that with inaccessible maintenance and ageing infrastructure. This poses significant environmental challenges that require detailed research and analysis. The problem of leaking water tanks has many facets. It encompasses immediate soil and groundwater pollution and the long-term ecological and health impacts on local communities. Petroleum products include gasoline, diesel, and various by-products. Contains hydrocarbons and other chemical compounds. This complex can persist in the environment for extended periods. These substances can move through the soil layer when they wash out from the storage tank. The underground aquifers can be considered as a normal supply of drinking water for the community. In addition, the admixture of contaminants can alter the chemistry of the soil, thus affecting plant growth and microbial communities, which, in turn, alter local ecosystems [9]. Urbanisation has, therefore, increased the fuel requirement in Agbor Metropolis, with a penchant increase in petrol stations posing considerable environmental threat.

2. RELATED WORKS

The environmental effects of petroleum hydrocarbon contamination in urban areas constitute a vital research area with considerable public health and ecological ramifications. This study adds to the expanding literature on localised contamination dynamics, especially in swiftly rising urban areas with insufficient regulatory supervision.

Current studies have thoroughly recorded the environmental hazards linked to petroleum storage systems. Alharbi et al. (2018) and [8] have shown that subterranean fuel leaks from petrol stations can result in significant soil contamination, underscoring the widespread occurrence of hydrocarbon pollution in urban settings. According to [11], leaching of BTEX (benzene, toluene, ethylbenzene, xylenes) represents an important environmental problem with a potential risk of causing large-scale groundwater contamination. These impacts are dismal in terms of adversity to the environment.

According to [5], hydrocarbons decreased urease activity and microbial biomass of soils, which could significantly perturb the functioning of the soil ecosystem. This study turned out to be in agreement with the overall findings presented by [9], which provided evidence that petroleum-derived contaminants disrupt soil chemistry and microbial community structures.

The researchers, [10], have comprehensively documented the damages in the Nigerian context due to petroleum activities and Niger Delta's devastation. The report delineates systemic challenges such as destruction of farmlands, loss in biodiversity, and the resultant widespread contamination of ecosystems from oil-related activities. This study builds on that foundational work but focuses on an urban setting little studied and with much critical but less well examined context regarding environmental risk assessment—

namely, Agbor Metropolis.

This research, by way of its methodological setup, accommodates insights from several disciplinary points of view. Community-engaged approaches are vital for urban environmental research, as stressed by [4], a principle implicitly accounted for in this study's extensive sampling and analytical strategies. Chemical analytical strategies, geospatial mapping, and ecological assessment all come into play in understanding localized contamination dynamics; thus, this multi-method approach represents an elaborate methodological framework.

Most earlier research on environmental issues mostly has been in countries with large oil-producing regions and major urban centres. However, this study serves to fill an important gap by investigating the environmental problems of a rapidly developing, relatively small built Centre. This work also makes a unique contribution because it examines in detail petroleum storage tank leakages in a context characterised by low regulation and rapid city development.

The research also resonates at larger global scales within the discussions pertaining to urban environmental sustainability. [7] recognized the crucial connection between urban soil quality and human health, which is very pertinent to the present findings. This research gives a location-specific report of contamination levels, spatiotemporal distributions, and possible ecosystems' impact, therefore providing critical insights to urban planners, environmental regulatory authorities, and public health practitioners.

The studies add a new dimension to present day literature by recording contamination and proposing site-specific remediation mechanisms. This is in line with recommendations of [2], who advocate for location-specific, targeted remedial techniques in environmental restoration efforts.

What is there in it Connect the methodological approaches, cover an urban context that has not been studied much, and end with actionable insight-all in all, this research is a great contribution to the still-evolving understaning of petroleum hydrocarbon contamination in developing urban settings.

Study Area Description

Agbor and Owa Metropolis Lay Down More than Five Major Petrol Stations.

The study area of the research involves five major filling stations, located all in Agbor and Owa metropolis in Delta State, Nigeria. Agbor and Owa are some of the closely spaced urban areas in Nigeria. They have recently witnessed a great deal of boom and development. The demand for fuel has surged, leading to the expansion of petrol stations. The selected station is representative of the location. The size of the operation encompasses a range of surrounding environments. It provides a comprehensive view of the potential—environmental impacts throughout the metropolis.

Tonimas Petrol Station

The location is on Old Lagos-Asaba Road, near the centre of Owa. Coordinates: Coordinates: roughly 6.2558°N, 6.1997°E. Tonimas is a prominent, expansive gas station. The station has an extensive area of around 2,500 square meters, featuring several distribution units and a substantial subterranean storage tank system. This region comprises both commercial and residential zones. It experiences significant traffic congestion due to its location on the primary route.

Fescon Petrol Station

The station is in Owa town, adjacent to the Old Lagos-Asaba Road. Coordinates: Approximately 6.2736° N, 6.2056° E.

Fescon is a medium-sized station encompassing around 1800 square feet. It is predominantly situated in a residential zone, with limited business operations nearby. The station has been operational for more than ten years, making it an appealing location for evaluating long-term environmental effects.

Wetlong Petrol Station

The station is situated on the Benin-Asaba Road (Express Road), in the periphery of Agbor. Its coordinates are roughly 6.2453° N and 6.211° E.

Description: Wetlong is a relatively new station established in the last five years. It covers an area of approximately 2,000 square meters. Compared to other stations, the surrounding area is less densely populated and includes nearby farming areas. This location allows one to study the environmental impact in a semi-urban setting.

Rainoil Petrol Station (Abraka Road)

The station is located along Abraka Road, one of the main islands connecting Agbor and Owa. The coordinates are approximately 6.2611° N and 6.1939° E.

Description: Rainoil is a modern, well-equipped 2200 sq ft station located in a busy area that combines commercial, educational,l, and residential facilities. The station's state-of-the-art storage and distribution system allows it to assess whether new technology reduces environmental risks.

Matrix Petrol Station

The station is located along the Benin highway.

Coordinates: approximately 6.2789°N, 6.2103°E. The Matrix petrol station occupies approximately 1,500 square meters within a dense urban development that includes shops, offices, and residential buildings. The dearth of population and an adjacency in terms of a location to the market make the site particularly liable to environmental impact.

Sharpstone Petrol Station

And this particular station is located where the old Lagos-Asaba road meets the main Agbor road. The coordinates tare approximately 6.2522°N; 6.1967°E.

Description: Sharpstone is a medium station. The land encompasses over 2,300 square meters and is a mixed-use area comprising residential and commercial properties. This station, having operated for an extended duration and recently renovated, exemplifies the environmental changes resulting from enhancements.

General Characteristics of the Research Area:

The Agbor and Owa metropolitan areas have tropical savannah climates that vary according to rainfall and temperature. Poorly developed sedimentary formations form the Benin Formation, with aquifers being largely shallow, thus giving the water-bearing strata water very susceptible to pollution. The major soil type is sandy loams, which induce slow infiltration of pollutants. Urbanization has increased demand for fuel and merchandising activities. The survey area is mainly occupied by petrol stations since they are necessary for both transport and economic development. With these unique characteristics and urban development patterns, it provides an excellent case study for investigating environmental impacts emanating from the leaking surface and underground storage tanks.

3. METHODOLOGY

The sampling strategy adopted a systematic multi-stage approach for sweeping and representative data collecting. The research team purposive sampled for six different petrol stations across Agbor Metropolis. Such considerations incorporated the age of the station, size, surrounding ecological environment, and potential land contamination risks. These stations presented varying urban contexts ranging from highly populated commercial areas to semi-urban settings with adjacent areas under agricultural production.

Stratified random sampling was used to minimize any bias and ensure that the samples adequately represented the whole area. Soil sampling was done using a grid arrangement with the sampling points disbursed more or less evenly around the periphery of each station. The sampling was carried out using a hydraulic soil auger at preset intervals of 0.5, 1.0, 1.5, and 2.0 m.

A large number of core samples were collected and combined at each depth in order to achieve a representative site-specific sample, minimizing possible localized variations.

Groundwater sampling maintained similar intensity protocols. Monitoring wells have been distributed evenly across each site, sampling depths being 3.0, 4.0, 4.5, and 5.0 m considering the standard hydro-geological techniques to minimize any pollution caused during drilling.

Groundwater samples were in turn collected by low-flow purging techniques to minimize any disturbances to sediments and thus give the most representative range of groundwater composition.

Chemical analyses were performed using state-of-the-art instrumental techniques for the highest accuracy in measurements. Hydrocarbon components in total petroleum hydrocarbons (TPH) were identified and quantified using gas chromatography-mass spectrometry (GC-MS). BTEX compounds were isolated according to standard EPA method 5030C, and analyzed by GC-MS using selective ion monitoring. PAHs were analyzed using HPLC fluorescence detection.

Quality control measures were fundamentally integrated into the methodologies. Each sampling campaign consisted of:

- Triplicate sampling at each site;
- Field and laboratory blanks for possible contamination;
- Certified reference materials for calibration;
- Chain of custody protocols to ensure sample integrity.

Geospatial analyses were complemented by the chemical data: using geoinformation system (GIS) technologies, spatial distributions of contamination were mapped. In this way, a pollution pattern was achieved in terms of depth and site specificity.

Statistical analysis discussed within the scope of this research was based upon strong methods, including descriptive statistics, ANOVA (analysis of variance), and spatial statistical techniques, to detect significant contamination trends and variations at the sampling locations.

Research Methodology and Sampling Profile a cross-sectional environmental assessment to study soil and groundwater contamination from leaks of petroleum storage tanks was carried out in Agbor Metropolis, Delta State, Nigeria, using a multi-pronged approach. The research study was done on six petrol stations of the Agbor and Owa urban areas:

Sampling Strategy and Site Selection
Site Characterisation

- Six petrol stations were selected across Agbor and Owa Metropolis
- Selection criteria:
    - Varied operational characteristics
    - Urban development stages represented
    - Distantly sited with respect to residential/commercial areas

Sampling Design
Spatial Sampling:

- Systematic grid sampling is the method used
- More than one sampling point are chosen at each place
- Stratified random sampling is carried out in each grid zone defined.

Sampling Depths
Soil Sampling:

- Depth intervals: 0.5m, 1.0m, 1.5m, 2.0m
- Purpose: To study the vertical advancement of contamination
- Sampling technique: Mechanical core drilling using stainless steel augers

Ground Water Sampling:

- Depth intervals: 3.0 m, 4.0 m, 4.5 m, 5.0 m;
- Sampling was done via dedicated monitoring wells;
- Low-flow purging techniques were utilized to reduce the disturbance of the samples.

Protocols for Collecting Samples

Soil Sample Collection

1. Sterilised sampling tools
2. Used polyethylene sample containers
3. Immediate sample preservation:
    - Cooling to 4°C
    - Sealed to prevent contamination

4. Transport in Insulated Containers

5. Laboratory Processing Within 24 Hours

Groundwater Sample Collection

1. The well was purged before sample removal.
2. A dedicated submersible pump was used.
3. Samples were filtered through a 0.45 µm membrane.
4. Chemical preservatives were added.
5. Samples were transferred to amber glass bottles.
6. A chain-of-custody was maintained.

Analytical Techniques

Chemical Analysis Parameters

Soil Analysis:

- Total Petroleum Hydrocarbons (TPH)
- BTEX compounds
- Polycyclic Aromatic Hydrocarbons (PAH)

Groundwater Chemical Appraisal:

- TPH concentration
- BTEX levels
- Dissolved Oxygen (DO)
- pH measurement

Instrumental Methodologies

1. Gas Chromatography Mass Spectrometry (GC-MS)

- The analysis of TPH and BTEX
- Detection level: 0.1 µg/L

2. High-Performance Liquid Chromatography (HPLC)

- PAH compound evaluation

3. Spectrophotometric Methods

- DO measurement

4. Potentiometric pH Evaluation

Quality Control and Assurance:

- Calibration of instruments before analysis
- Method blanks and duplicates
- Certified reference material
- Measurement uncertainty calculations
- Compliance with the EPA and ISO standard protocols

Statistical Analysis

Descriptive Statistics
Analysis of Variance (One-way ANOVA)
Correlation Coefficient (Pearson)
Spatial Autocorrelation Analysis

Researcher's Credibility

- Obtained necessary permissions for research
- Maintained site confidentiality
- Emphasised the protection of public and environmental health

Done in the comprehensive sense, the method allowed for a thorough investigation of petroleum hydrocarbon contamination in soil and groundwater, hence providing insights into environmental problems manifested in rapidly urbanising areas of Nigeria.

4. RESULTS AND DISCUSSION

Table 1. Soil Sampling Data for Locations A to F

Sample Point	Depth (m)	TPH (mg/kg)	BTEX (mg/kg)	PAH (mg/kg)
A-1	0.500	220.123	1.123	0.456
A-2	1.000	305.456	1.456	0.567
A-3	1.500	410.789	1.789	0.678
A-4	2.000	530.345	2.123	0.789
B-1	0.500	190.678	0.890	0.432
B-2	1.000	275.890	1.234	0.543
B-3	1.500	380.123	1.678	0.654
B-4	2.000	495.456	2.012	0.765
C-1	0.500	210.345	1.023	0.456
C-2	1.000	290.567	1.345	0.567
C-3	1.500	400.678	1.789	0.678
C-4	2.000	510.789	2.123	0.789
D-1	0.500	205.123	1.056	0.489
D-2	1.000	295.456	1.345	0.567
D-3	1.500	410.678	1.678	0.678
D-4	2.000	525.789	2.034	0.789
E-1	0.500	185.678	0.900	0.400
E-2	1.000	270.890	1.200	0.520
E-3	1.500	375.123	1.600	0.645
E-4	2.000	485.456	2.000	0.750
F-1	0.500	195.345	1.050	0.410

F-2	1.000	280.678	1.300	0.540
F-3	1.500	385.789	1.700	0.675
F-4	2.000	500.123	2.050	0.780

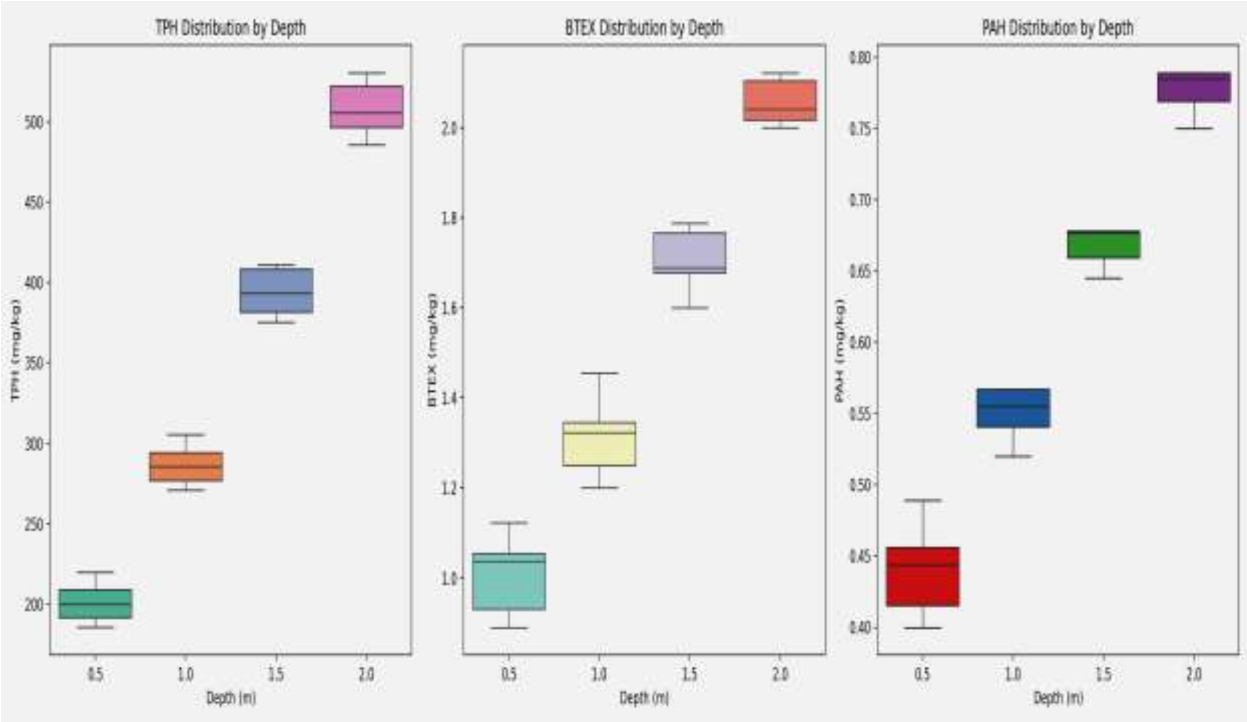

Figure 1. Soil pollution levels at various depths

Table 1 and Figure 1 show information on soil pollution levels at various depths. TPH, BTEX, and polycyclic aromatic hydrocarbons (PAH) were measured at six petrol station locations (A–F).

Key findings

1. Pollution levels throughout the area:

- Location A shows deep TPH, BTEX, and PAH levels, with TPH peaking at 530,345 mg/kg, BTEX 2,123 mg/kg, and PAH 0,789 mg/kg at an altitude of 2,000 meters.
- Site B showed the same trend with higher pollution levels compared to Site A: TPH of 495,456 mg/kg, BTEX of 2,012 mg/kg, and the highest PAH at 2,000 m of 0,765 mg/kg.
- Pollution levels at Point C were comparable to Points A and B, with the highest values for TPH (510,789 mg/kg), BTEX (2,123 mg/kg) and PAH (0,789 mg/kg). At 2,000 m. kg.)
- Site D shows a similar pattern. However, the pollution level is generally high compared to the original location. The highest levels of TPH (525.789 mg/kg) and BTEX (2.034 mg/kg) were recorded at 2000 m.
- Locations E and F show slightly lower pollution levels than locations A to D, but the trend of contamination increasing with depth is still evident.

2. Depth Trends:

- Contamination levels (TPH, BTEX, and PAH) show a consistent trend across all borehole locations for depth: the levels of contamination increased with depth until 2.000 metres. This evidence suggests that most lower soil layers had the highest influence from contamination.
- Apart from that, it also suggests all kinds of contamination with depth to different degrees: Time accumulation of pollutants or migration from higher levels due to leaching or spills.

3. Contamination Comparison: TPH levels were consistently higher than BTEX and PAH at all locations.

This indicates that petroleum hydrocarbons are important soil contaminants.

- BTEX and PAH levels are relatively low but still significant. This indicates that although TPH is the primary contaminant, it also has significantly more specific hydrocarbons and aromatic compounds—possible Implications.

4. Pollution Spread: The constant increase in contamination with depth denotes that pollution from petrol stations is likely moving downwards, affecting deeper soil layers and perhaps even groundwater.
5. Requirement of improvement: Statistics indicate the need for specific mitigation actions, especially for depths where concentration contamination is highest. These may include soil remediation techniques such as excavation or biological treatment for contamination prevention.
6. There is a high level of TPH, BTEX, and PAH pollution which can affect soil health and can further migrate to groundwater contamination.

Picture Display

Consider creating the following visualisation to understand the data better: Boxplots show the distribution and variation in contamination levels at various depths. These visualisations help identify trends and assess the extent of contamination at various locations and depths.

Table 2. Physicochemical parameters and hydrocarbon concentrations at various depths across sampling points

Sample Point	Depth (m)	TPH (µg/L)	BTEX (µg/L)	DO (mg/L)	pH
A-1	3.000	550.123	25.678	4.123	6.789
A-2	4.000	620.456	30.456	3.789	6.890
A-3	4.500	680.789	35.789	3.456	6.900
A-4	5.000	750.123	40.123	3.234	7.012
B-1	3.000	530.234	24.789	4.056	6.800
B-2	4.000	600.678	29.123	3.789	6.870
B-3	4.500	670.123	34.456	3.456	6.890
B-4	5.000	740.456	38.789	3.345	7.023
C-1	3.000	545.678	26.345	4.123	6.785
C-2	4.000	615.789	31.678	3.789	6.890
C-3	4.500	685.456	36.789	3.456	6.902
C-4	5.000	755.678	42.123	3.234	7.015
D-1	3.000	520.345	23.567	4.200	6.800
D-2	4.000	590.456	28.900	3.789	6.880
D-3	4.500	660.678	33.789	3.456	6.900
D-4	5.000	730.789	37.890	3.345	7.030
E-1	3.000	510.456	22.345	4.056	6.770
E-2	4.000	580.789	27.789	3.789	6.850
E-3	4.500	650.123	32.567	3.456	6.890
E-4	5.000	720.345	36.678	3.345	7.045
F-1	3.000	525.678	23.789	4.123	6.775
F-2	4.000	595.789	29.123	3.789	6.860
F-3	4.500	665.456	34.456	3.456	6.895
F-4	5.000	735.678	39.789	3.345	7.050

The study analyzed groundwater samples from six locations in the Agbor Metropolis, revealing significant variations in Total Phthalate (TPH) and BTEX concentrations. The TPH levels remained low in F while elevated in C, and the ranges for BTEX leveled between 22.345 µg/L and 42.123 µg/L. Dissolved oxygen concentrations were stable within the localities, while the pH varied from 6.770 to 7.050, indicating that they did not significantly lean toward acidity or alkalization. Location C experienced the highest contamination levels.

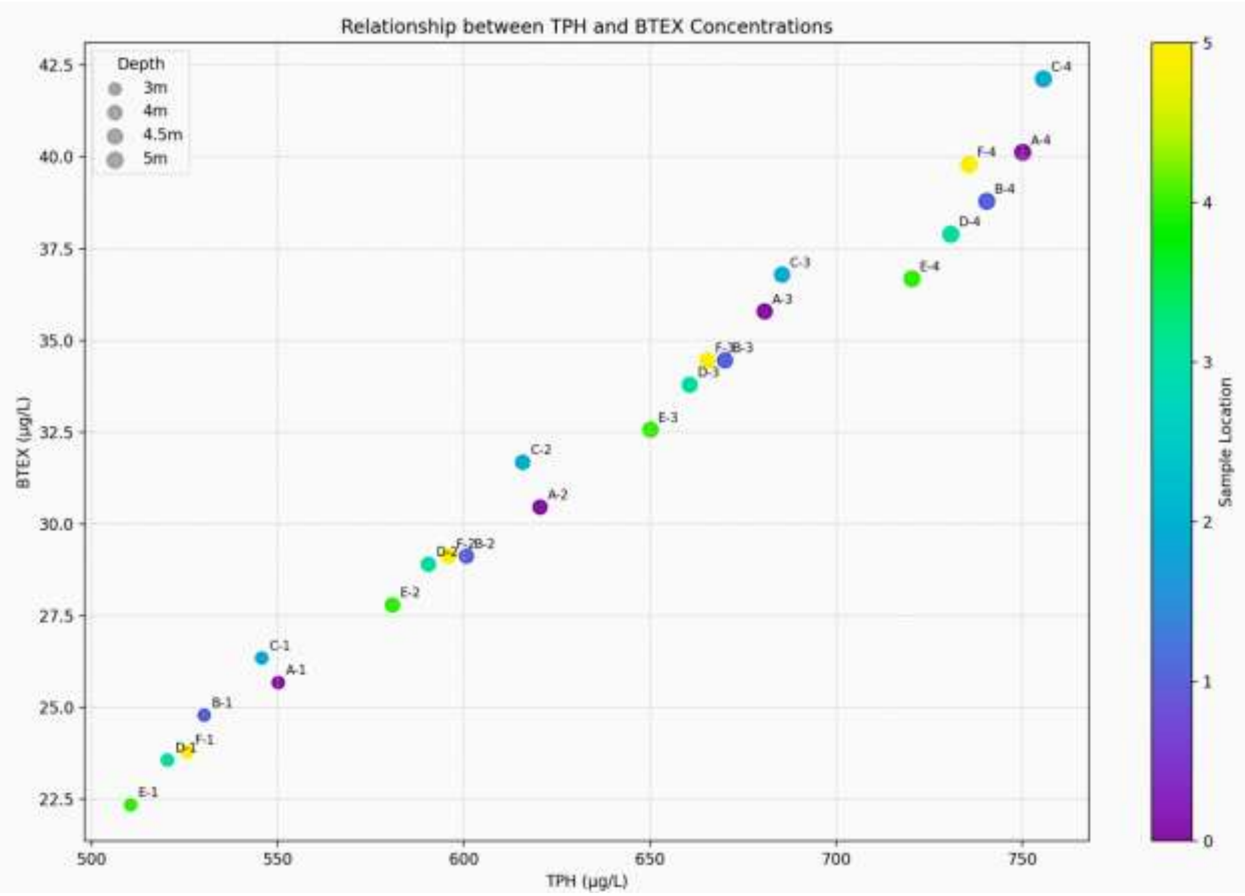

Figure 2. Relationship between TPH and BTEX

This scatter plot of Figure 2 provides several insights: The scatter plot reveals a strong positive relationship between the amounts of TPH and BTEX. As TPH increases, BTEX tends to increase as well.

Depth Variation: The size of the points illustrates depth in the sample; larger points indicate greater depth. Notably, deeper samples (larger points) tend to record higher concentrations of both TPH and BTEX.

Sample Locations: Different sample locations (A, B, C, D, E, F) are represented by different colours of the points. Each location has a cluster of points suggesting that there is some coherence within these locations. Depth keeps changing: For every sample location, a progression can be observed from smaller to larger points (shallow to deep) as one moves from lower to higher concentrations.

Table 2 groundwater sampling data indicates that the contamination levels in exceptional locations are highly distinctive. The concentrations of TPH and BTEX are particular. TPH values varied from 520.345 µg/L at Location D to 755.678 µg/L at Location C, showing that hydrocarbon pollutants are not equally distributed throughout the study area. BTEX values ranged from 22.345 µg/L at Location E to 42.123 µg/L at Location C. According to [6], PAH concentrations in moss were highest in downtown Portland, along major highways, and lowest in parks and outer neighbourhoods, with deciduous tree cover correlated with lower concentrations. Likewise, it was concluded by [3] that Total petroleum hydrocarbons (TPHs) in the sediments of Karun River Basin originate mainly from biogenic sources and show moderate levels of pollution but low ecological risk. The continuously higher levels in Region C indicate a localized source of pollution, possibly from leaking underground storage tanks (USTs) or accidental spills from nearby petrol stations.

Dissolved oxygen (DO) ranges had been more stable, with values between 3.234 mg/L at Location A and 4.200 mg/L at Location D. Despite the contamination; these DO values indicate a mild depletion of groundwater oxygen levels. This implies the possibility of using natural biodegradation techniques, albeit at a slower pace. It has varied from 6.770 at E location to 7.050 values at F location, showing neutral to mildly alkaline values, which are quite characteristic of groundwater in urban areas. The fairly neutral pH level shows that hydrocarbon contamination does not have an effect on strong acidification, which in turn creates difficulties for bioremediation activities. The results showed heavy concentrations of TPH and BTEX Most concerned areas are C and A; they indicate substantial contamination of groundwater in these locations. These values exceed the WHO recommendation limit of safe drinking water for consumption. This shows that the groundwater in these locations is not safe for human consumption and posing significant risk to the environment if used for domestic consumption. Conversely, the stable DO and pH values suggest that natural attenuation processes, such as microbial degradation of hydrocarbons, may occur while contamination is present. DO levels above 3 mg/L indicate that oxygen-dependent (aerobic) microorganisms might be able to partially mitigate the contamination by breaking down hydrocarbons; [1] opined that Aerobic microorganisms play a significant role in the biodegradation of petroleum hydrocarbons in groundwater, but nutrients-based treatment shows more excellent removal of pollutants. Nonetheless, the extent of contamination might be such that natural processes alone would not handle pollutant reduction without some form of effective intervention. Practical Applications The findings of this study reveal a complex landscape of petroleum hydrocarbon contamination in Agbor Metropolis, providing corroborative evidence and more details to existing environmental research. TPH concentrations in groundwater, which ranged from 520.345 µg/L to 755.678 µg/L, were found to exceed WHO limits for drinking water by several orders of magnitude, thus presenting a significant environmental and public health problem.

Conversely, the contamination severity is corroborated by comparative analysis with existing literature. While Alharbi et al. (2018) recognized contamination from underground fuel leakages on a larger scale, the present study touches on an important nuance: the vertical distribution of pollutants. The constant rise in contamination level with depth suggests complex migration of petroleum hydrocarbons in soils and groundwater. This observation corresponds with Metze et al. (2020), who illustrated how hydrocarbon pollutants can profoundly modify subsurface environmental conditions.

The quantities of BTEX (Benzene, Toluene, Ethylbenzene, Xylenes), varying from 22.345 µg/L to 42.123 µg/L, signify considerable aromatic hydrocarbon contamination. These findings align with Rodrigo-Ilarri et al. (2023), who emphasised the widespread occurrence of BTEX leaching in urban settings.
The spatial variability of contamination, particularly the elevated levels at Locations A and C, suggests localised contamination sources potentially linked to specific underground storage tank (UST) characteristics or historical spill events.

Approaches to remediation ought to be multifactorial and specific to the actual contamination dynamics. The several remedial options put on the table appear to be encouraging based on the results.

1. Bioremediation Techniques: Sustained dissolved oxygen levels indicating aerobic microbial degradation seem to be in order since DO levels fluctuated between 3.234-4.200 mg/L throughout the study. Aleruchi and Abu (2021) reported that nutrient-enhanced bioremediation gave rise to an enhanced hydrocarbon removal rate; hence applying nutrients judiciously would facilitate natural attenuation processes.

2. Advanced Extraction Methods: Air-sparing methods and soil vapour extraction may apply for the removal of the volatile BTEX compounds. They would target the vertical contamination gradient demonstrated in the study, particularly the deeper soil and groundwater layers.
3. Phytoremediation: In urban terms, strategically planting hydrocarbon-tolerant vegetation could support natural decontamination. Research by Fernández-Viña et al. (2022) highlights the potential of community-engaged ecological restoration approaches.

The near-neutral pH values (6.770-7.050) indicate minimal chemical alterations, which could facilitate more straightforward remediation interventions. However, the research also highlights major shortcomings in contemporary environmental management practices, especially lack of comprehensive monitoring and regulatory frameworks in the fast urbanizing conduits. They are particularly glaring when comparison is made with so-called advanced regions.

Even though the research produces necessary insights, must consider different methodological constraints. Thus, the cross-sectional study design does not describe long-term trends, besides applicable sampling methodology, which is not representative in capturing groundwater fluctuations across the seasons. Longitudinal monitoring and wider sampling strategies would constitute a more comprehensive understanding of the dynamics of contamination.

The implications are broader than environmental considerations at a local level; the current considerations, therefore, are seen in discussions on urban environmental sustainability for developing contexts. The study has provided area-specific information to serve as a crucial lens through which to view petroleum hydrocarbon contamination in fast-expanding metropolises.

4. CONCLUSION

The research has indicated yet another crucial environmental problem faced by Agbor Metropolis. Contaminated groundwater resulting from the leaking of petroleum storage tanks constitutes a potential danger to public health and ecological sustainability. TPH values of 755.678 μg/L, which are extremely above the WHO standards, require a speedy and thorough intervention. The local and state environmental bodies must incur a complementary approach focusing on immediate remediation of the contamination and long-term avoidance.

Proposed interventions constitute a mandate for complete underground storage tank (UST) inspections coupled with strict replacement procedures for old installations; establishment of a municipal groundwater monitoring program, with quarterly testings at hotspots;setting of minimum environmental standards for the establishment, maintenance, and operations of petrol stations; and establishment of an environmental remediation fund financed by petroleum distribution companies. Guidelines for the protection of groundwater should be incorporated into the zoning bylaws of the urban planning departments, and the new fuel storage facility constructions should undergo mandatory environmental impact assessments.

Community engagement is almost equally important now. Local government can set up public awareness campaigns through which the risks of contamination will be explained along with alternative sources of water sourcing information, and encouraging community participation in environmental monitoring. Professional training programs for municipal engineers and environmental technicians can build local capacity for ongoing contamination assessment and management.

The research underscores that environmental protection is not merely a technical challenge but a comprehensive socio-economic imperative. By translating scientific findings into actionable policy frameworks, Agbor Metropolis can transform this environmental risk into an opportunity for sustainable urban development, protecting both current and future generations' health and ecological resources.

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Author Contributions Statement

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John C. Morka		✓			✓		✓	✓	✓	✓	✓			
Rufus O. Ijeh	✓		✓	✓		✓		✓		✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors assert that there are no conflicts of interest.

Informed Consent

We, the undersigned, hereby consent to participate in the research study titled **"Assessing Agbor Metropolis's Soil and Groundwater Environmental Effects of Storage Tank Leaks."** We understand that this study investigates environmental impacts on soil and groundwater quality in the Agbor Metropolis area. We acknowledge that my participation involves allowing property access for environmental sampling and providing information about storage tank usage. We understand that all personal information will be kept confidential, and our identity will be protected in any published results. The researchers have explained that although the study poses minimal risk, our participation helps to understand environmental risks and develop protective measures for society. We have been informed that our participation is voluntary, and we can retire at any time without punishment. We confirm that we have received sufficient information about the study, had the opportunity to ask questions and received satisfactory answers. We understand that this research is approved by the relevant institutional review board, and we have received a copy of this consent form for our items.

Ethical Approval

This research, **"Assessing Agbor Metropolis's Soil and Groundwater Environmental Effects of Storage Tank Leaks,"** complies with all relevant national regulations and institutional policies in accordance with the Helsinki Declaration. The study received approval from the Institutional Review Board of University of Delta, Agbor. Written authorization was obtained from the management of all participating petrol stations in Agbor Metropolis, with oversight from the Department of Petroleum Resources (DPR). All participating entities provided informed consent prior to data collection.

Data Availability

The data generated during this study on soil and groundwater contamination from storage tank leaks in Agbor Metropolis are available from undel.edu.ng/cms/backoffice/manage_publication under accession number [RAW DATA 1- RAW DATA 4]. The dataset includes raw soil analysis results, groundwater quality measurements, GIS coordinates of sampling locations (anonymized to protect site privacy), and temporal monitoring data. Environmental parameters and analytical methods are fully documented in the supplementary materials. Restricted access applies to personally identifiable information and specific facility locations in accordance with confidentiality agreements. Qualified researchers may request access to restricted data by contacting the corresponding author with appropriate institutional approval. The complete environmental sampling protocols and data analysis scripts are available at [undel.edu.ng/cms/backoffice/managepublication].

Recommendation

Based on the findings of this study on soil and groundwater contamination from storage tank leaks in Agbor Metropolis, the following recommendations are made:

Regular monitoring and inspection of storage tanks should be mandated for all petrol stations in Agbor Metropolis to detect potential leaks early. Underground storage tanks should be equipped with modern leak detection systems and undergo pressure testing at least annually. Station operators should carry detailed items over all inspections and maintenance activities.

Environmental protection measures should be strengthened through the installation of enclosure systems and impenetrable barriers around storage areas. Stations should implement extensive spill prevention and response plans, with employees who receive regular training in environmental safety protocols.

The Department of Petroleum Resources (DPR) should establish stricter tank installation and maintenance guidelines, including requirements for double -walled tanks and corrosion protection systems. Regular environmental audits should be carried out to ensure compliance with these standards.
Groundwater quality monitoring wells should be installed in strategic locations throughout the metropolis to enable early detection of pollution. A centralized database should be established to track and analyze environmental data from all stations.

Social awareness programs should be developed to educate citizens on environmental risks in tank lines and the importance of reporting potential pollution. Local authorities should establish clear reporting mechanisms and response protocols for environmental incidents.

REFERENCES

[1] O. Aleruchi and G. O. Abu, 'Describing the role of aerobic microorganisms in the biodegradation of petroleum hydrocarbons laboratory contaminated groundwater', in Innovations in Microbiology and Biotechnology Vol. 1, Book Publisher International (a part of SCIENCEDOMAIN International), 2021, pp. 1-5. doi.org/10.9734/bpi/imb/v1/11716D

[2] P. Ciampi, C. Esposito, G. Cassiani, G. P. Deidda, P. Rizzetto, and M. P. Papini, 'A field-scale remediation of residual light non-aqueous phase liquid (LNAPL): chemical enhancers for pump and treat', Environ. Sci. Pollut. Res. Int., vol. 28, no. 26, pp. 35286-35296, Jul. 2021. doi.org/10.1007/s11356-021-14558-2

[3] M. Dehvari, A. Takdastan, S. Jorfi, M. Ahmadi, Y. Tahmasebi Birgani, and A. A. Babaei, 'Distribution of total petroleum hydrocarbons in superficial sediments of Karun River Basin, southwest of Iran: spatial and seasonal variations, source identification, and ecological risk', Int. J. Environ. Health Res., vol. 33, no. 1, pp. 71-82, Jan. 2023. doi.org/10.1080/09603123.2021.2000591

[4] N. Fernández-Viña, Y. Chen, and K. Schwarz, 'The current state of Community Engagement in urban soil pollution science', Front. Ecol. Evol., vol. 10, May 2022. doi.org/10.3389/fevo.2022.800464

[5] H. Feyzi, M. Chorom, and G. Bagheri, 'Urease activity and microbial biomass of carbon in hydrocarbon contaminated soils. A case study of cheshmeh-khosh oil field, Iran', Ecotoxicol. Environ. Saf., vol. 199, no. 110664, p. 110664, Aug. 2020. doi.org/10.1016/j.ecoenv.2020.110664

[6] S. E. Jovan, V. J. Monleon, G. H. Donovan, D. Gatziolis, and M. C. Amacher, 'Small-scale distributions of polycyclic aromatic hydrocarbons in urban areas using geospatial modeling: A case study using the moss Orthotrichum lyellii in Portland, Oregon, U.S.A', Atmos. Environ. (1994), vol. 256, no. 118433, p. 118433, Jul. 2021. doi.org/10.1016/j.atmosenv.2021.118433
[7] G. Li, G.-X. Sun, Y. Ren, X.-S. Luo, and Y.-G. Zhu, 'Urban soil and human health: a review', Eur. J. Soil Sci., vol. 69, no. 1, pp. 196-215, Jan. 2018. doi.org/10.1111/ejss.12518
[8] D. A. M. Amin Al Manmi, T. O. Abdullah, P. M. Al-Jaf, and N. Al-Ansari, 'Soil and groundwater pollution assessment and delineation of intensity risk map in sulaymaniyah city, NE of Iraq', Water (Basel), vol. 11, no. 10, p. 2158, Oct. 2019. doi.org/10.3390/w11102158
[9] D. Metze et al., 'Temperature management potentially affects carbon mineralization capacity and microbial community composition of a shallow aquifer', FEMS Microbiol. Ecol., vol. 97, no. 2, Jan. 2021. doi.org/10.1093/femsec/fiaa261
[10] O. Sj, I. Cc, O. Pa, O. Lc, and H. Ai, 'Petroleum exploration in the Niger Delta region and implications for the environment: A review', Journal of Energy Research and Reviews, vol. 16, no. 5, pp. 19-29, Apr. 2024. doi.org/10.9734/jenrr/2024/v16i5350
[11] J. Rodrigo-Ilarri, M.-E. Rodrigo-Clavero, J. E. Capilla, and L. Romero-Ballesteros, 'Environmental assessment of soil and groundwater pollution by BTEX leaching in Valencia region (Spain)', Water (Basel), vol. 15, no. 18, p. 3279, Sep. 2023. doi.org/10.3390/w15183279

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