

# Compliance with Locational and Fire Safety Regulations Among Petroleum Filling Stations in Residential Areas of Port Harcourt

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<https://doi.org/10.56201/ijgem.vol.12.no9.2026.pg166.180>

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## Abstract

*Petroleum filling stations are essential urban facilities but may pose fire and explosion risks when located near residential areas and when safety requirements are inadequately implemented. This study assessed compliance with locational and fire-safety regulations among petroleum filling stations in residential areas of Port Harcourt, Rivers State, Nigeria. A descriptive cross-sectional design was adopted. Thirty-four petroleum filling stations within or near residential areas were assessed using structured observational and compliance checklists. Locational compliance was evaluated using setback and separation requirements, while fire-safety compliance was assessed using 17 indicators covering firefighting equipment, emergency facilities, accessibility, condition, functionality and operational practices. Data were analysed using descriptive statistics, chi-square and Spearman's correlation at a 5% significance level. All 34 (100%) stations failed to meet the 50 m minimum setback from residential buildings, with distances ranging from 13.01 to 43.02 m. Only 29.4% complied with the 150 m sensitive-land-use setback and 400 m inter-station separation requirements, while 67.6% shared direct boundaries with residential properties. Overall locational compliance was 24.3%. Fire-safety compliance was higher, with a mean score of 12.29/17 (72.3%); 50.0% of stations had high compliance, 38.2% moderate and 11.8% low compliance. However, deficiencies occurred in equipment accessibility, condition, functionality and operational safety practices. Station ownership, years of operation, number of dispensers, underground storage tanks and presence of a safety officer were not significantly associated with compliance ( $p > 0.05$ ). Locational and fire-safety compliance were not significantly correlated ( $\rho = 0.063$ ,  $p = 0.722$ ). The study concludes that substantial locational deficiencies persist despite comparatively higher fire-safety compliance. Stronger enforcement, monitoring, maintenance and integration of petroleum-facility planning with urban land-use control are recommended to reduce potential fire and explosion risks in residential areas.*

**Keywords:** *Petroleum filling stations, locational compliance, fire safety regulations, regulatory compliance, residential areas, fire hazards, safety standards, petroleum facilities, emergency preparedness.*

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## 1. Introduction

Petroleum filling stations are important components of urban infrastructure because they provide fuel for transportation and other economic activities. However, their operations involve the storage, transfer and dispensing of highly flammable petroleum products, making them potential

sources of fire and explosion. The consequences of an incident can extend beyond station workers and customers to nearby residents, buildings and other facilities. This concern is particularly significant where filling stations are located within densely populated residential environments. Consequently, compliance with locational requirements and fire-safety regulations is essential for reducing exposure to petroleum-related hazards and protecting lives and property.

Locational regulations are intended to ensure that petroleum filling stations are appropriately separated from residential buildings, roads, public facilities and other vulnerable land uses. However, evidence from African cities indicates continuing challenges in achieving appropriate siting. Abdulai et al. (2024), in a study of fuel stations located within residential areas of Wa, Ghana, examined residents' perceptions of fire-disaster risks and highlighted concerns associated with the presence of fuel stations in densely settled communities. Their study demonstrates the importance of integrating land-use planning and fire-risk considerations when locating petroleum facilities within urban environments. Similarly, Dongzagla et al. (2023) examined conformity of filling stations to prescribed safe-distance guidelines in urban Ghana, further demonstrating the importance of maintaining appropriate separation distances between filling stations and surrounding land uses. In Nigeria, the challenge of locational compliance is also evident. Jia et al. (2022) assessed 118 petroleum-product handling facilities across Eket, Port Harcourt and Warri using 17 locational compliance specifications. The study found that only six (35.29%) of the 17 specifications were complied with, whereas 11 (64.70%) were violated. In Port Harcourt specifically, 72 facilities were assessed and complied with seven (41.18%) of the 17 specifications. The authors associated poor compliance with rapid urbanisation, population growth, proliferation of filling stations and inadequate regulatory monitoring. These findings are particularly relevant to Port Harcourt, where continuing urban development may increase interactions between petroleum facilities and residential land uses. Beyond location, compliance with fire-safety requirements is critical because appropriate siting alone cannot eliminate operational fire risks. Fire-safety regulations generally require appropriate firefighting equipment, safe storage and handling procedures, emergency preparedness, adequate access and adherence to prescribed safety practices. Kebut et al. (2021), in Kisumu County, Kenya, found that although many petroleum dispensing stations had implemented some safe storage and handling practices, none had fully implemented all provisions of the applicable fire-risk reduction rules. The study consequently emphasised inspection, enforcement and safety awareness. The issue has also been investigated among petroleum filling-station workers in Port Harcourt. Amanze and Achalu (2021) assessed fire-safety hazard exposure and adherence to control measures among workers and reported significant differences in adherence according to selected demographic characteristics, indicating that human and organisational factors can influence fire-safety practices. Despite these studies, there remains a need for an integrated assessment of locational and fire-safety regulatory compliance specifically among petroleum filling stations situated in residential areas of Port Harcourt. This study therefore examines compliance with prescribed siting requirements and fire-safety standards, providing evidence that can support improved regulatory monitoring, land-use control, fire-risk reduction and protection of residential communities.

### **Aim of the Study**

The aim of this study is to assess compliance with locational and fire-safety regulations among petroleum filling stations situated in residential areas of Port Harcourt, Rivers State, Nigeria.

### **Specific Objectives**

**The study seeks to:**

- i. Assess the level of compliance with prescribed locational and siting regulations among petroleum filling stations located within residential areas of Port Harcourt.
- ii. Evaluate the extent of compliance with prescribed fire-safety standards and regulations among petroleum filling stations in the study area.
- iii. Identify potential fire hazards and risk conditions associated with the location and operation of petroleum filling stations within residential areas of Port Harcourt.

**2. Materials and Methods**

**Study Area:** The study was conducted in Port Harcourt, Rivers State, Nigeria, with emphasis on petroleum filling stations located within or in close proximity to residential areas. Port Harcourt is the capital of Rivers State and an important commercial and industrial centre in the Niger Delta. The city has experienced considerable urban growth, resulting in increasing interaction between residential developments, transportation infrastructure and petroleum-related facilities. The study area was selected because of the presence of numerous petroleum filling stations within a rapidly developing urban environment and the potential implications of their location and operation for residential safety.

**Research Design:** A descriptive cross-sectional research design was adopted. The design enabled the researchers to assess the existing level of compliance with locational and fire-safety regulations among selected petroleum filling stations at a specific period. It also permitted direct observation and documentation of potential fire hazards and risk conditions associated with the location and operation of the facilities.

**Study Population:** The study population comprised registered petroleum filling stations located within residential areas of Port Harcourt. The study units were individual petroleum filling stations, while station managers, supervisors or designated safety personnel served as respondents where information concerning operational safety practices and regulatory compliance was required.

**Sampling and Sample Size:** A preliminary reconnaissance survey was conducted to identify petroleum filling stations situated within residential areas of the study area. A sampling frame was subsequently developed from identified stations and available records from relevant regulatory authorities. The required sample size was determined using an appropriate sample-size formula based on the accessible population of eligible filling stations. Where the number of eligible stations was manageable, total enumeration was adopted. A purposive sampling technique was used to select filling stations that met the inclusion criteria, particularly stations located within or immediately adjacent to residential neighbourhoods. Stations that were permanently closed, under construction or outside the defined residential study locations were excluded.

**Data Collection Instruments:** Data were collected using a structured compliance assessment checklist, observational schedule and questionnaire. The checklist was developed from relevant locational and fire-safety requirements applicable to petroleum filling stations in Nigeria and information reported in previous studies (Jia et al., 2022; Kebut et al., 2021; Olokoba et al., 2020).

**The instrument consisted of three major sections:** Section A (General characteristics and location of the filling station), Section B (Compliance with locational/siting requirements) and Section C (Compliance with fire-safety requirements and identification of fire hazards and risk conditions). The locational assessment considered factors such as proximity to residential buildings, roads, public facilities and other sensitive land uses, as applicable to the relevant regulatory requirements. The fire-safety assessment covered the availability and condition of firefighting equipment, safety signage, emergency access, fuel-handling practices, ignition-source control, housekeeping and other observable safety requirements.

**Assessment of Locational Compliance:** Locational compliance was assessed by comparing the observed characteristics of each filling station with the prescribed siting requirements. Measurements of relevant distances were obtained using appropriate field-measurement equipment and/or GPS/GIS techniques where applicable. Each applicable requirement was coded as compliant or non-compliant. The compliance percentage for each station and for individual requirements was calculated as:

$$\text{Compliance Level (\%)} = \frac{\text{Number of requirements complied with}}{\text{Total applicable requirements}} \times 100$$

The resulting compliance levels were categorised according to predetermined study criteria.

**Assessment of Fire-Safety Compliance:** Fire-safety compliance was assessed through direct observation and verification of required safety provisions. Items assessed included firefighting equipment, fire extinguishers, sand buckets, hydrants where applicable, emergency exits/access, warning and prohibition signs, emergency shutdown arrangements, electrical safety, fuel dispensing practices, housekeeping and other relevant fire-prevention measures.

Equipment was assessed not only for availability but also for accessibility, physical condition, visibility and apparent functionality. This distinction was necessary because the presence of firefighting equipment does not necessarily indicate effective compliance.

**Identification of Fire Hazards and Risk Conditions:** Potential fire hazards were identified through systematic inspection of each selected filling station and its immediate surroundings. Hazards considered included inadequate separation from residential buildings, proximity to other sensitive land uses, fuel leakage or spillage, exposed or defective electrical installations, uncontrolled ignition sources, smoking within restricted areas, poor housekeeping, inappropriate storage of combustible materials, blocked emergency access, inadequate safety signage, poorly maintained firefighting equipment and other conditions capable of increasing the probability or consequences of fire. Observed hazards were documented using the inspection checklist and photographic records where permission was granted.

**Validity and Reliability of the Instrument:** The data-collection instruments were subjected to expert review to establish content and face validity. Experts in environmental management, disaster risk management, fire safety and petroleum-facility management reviewed the instruments for relevance, clarity and adequacy of the items. Necessary modifications were made before field administration. A pilot assessment was conducted among filling stations outside the final study sample to identify ambiguous items and assess the consistency of the instrument. The reliability of applicable questionnaire items was determined using Cronbach's alpha, with a coefficient of 0.70 or higher considered acceptable.

**Data Collection Procedure:** Data were collected through field observation, physical measurement and administration of structured questionnaires to station managers, supervisors or designated personnel. Each selected filling station was visited by the research team, and the checklist was completed based on direct observation and verification of relevant safety provisions. Where necessary, respondents were asked to provide supporting information concerning station operations, safety practices and regulatory compliance.

**Data Analysis:** Data were coded and analysed using SPSS. Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarise station characteristics and compliance indicators.

Locational and fire-safety compliance scores were presented using frequency distributions, percentages and compliance indices. The identified fire hazards were summarised according to their frequency and proportion across the assessed stations.

Where appropriate, chi-square tests of association were used to examine relationships between selected characteristics of filling stations and regulatory compliance. Statistical significance was evaluated at  $p < .05$ . Results were presented using tables and charts.

**Ethical Considerations:** Permission to conduct the study was obtained from the Rivers State University research and ethic committee and relevant facility management. Participation by respondents was voluntary, and the purpose of the study was explained before data collection. Respondents' identities and station-specific information were treated confidentially. Data were used strictly for academic and research purposes.

**Decision Rule for Compliance:** For each regulatory domain, compliance was determined by comparing the number of requirements satisfied with the total number of applicable requirements. Higher compliance percentages indicated greater adherence to the prescribed regulations, while lower percentages indicated greater levels of non-compliance. The same assessment framework was applied consistently to locational and fire-safety requirements to facilitate comparison across the selected petroleum filling stations.

### 3. Results

#### Characteristics of Assessed Petroleum Filling Stations

A total of 34 petroleum filling stations were assessed. All stations were fully operational at the time of data collection. The general characteristics of the stations are summarised in Table 1.

**Table 1: Distribution of Petroleum Filling Stations by General Characteristics**

| Characteristic            | Category / Statistic          | Frequency (n) | Percentage (%) |
|---------------------------|-------------------------------|---------------|----------------|
| Sample size               | Total stations assessed       | 34            | 100.0          |
| Type/ownership of station | Major oil marketing company   | 12            | 35.3           |
|                           | Independent / privately owned | 22            | 64.7           |
| Years of operation        | < 5 years                     | 8             | 23.5           |
|                           | 5–10 years                    | 14            | 41.2           |
|                           | > 10 years                    | 12            | 35.3           |
| Number of fuel dispensers | 1–4                           | 9             | 26.5           |
|                           | 5–8                           | 18            | 52.9           |
|                           | ≥ 9                           | 7             | 20.6           |

|                                            |             |    |       |
|--------------------------------------------|-------------|----|-------|
| Number of underground storage tanks        | 1–2         | 11 | 32.4  |
|                                            | 3–4         | 16 | 47.1  |
|                                            | ≥ 5         | 7  | 20.6  |
| Presence of station manager/safety officer | Present     | 29 | 85.3  |
|                                            | Absent      | 5  | 14.7  |
| Operating status                           | Operational | 34 | 100.0 |

### Spatial and Residential Location Characteristics

All 34 stations failed to meet the minimum 50 m setback from the nearest residential building (range 13.01–43.02 m). Approximately two-thirds of stations shared a direct boundary with residential properties. Compliance with the 150 m sensitive-land-use setback and the 400 m inter-station separation requirement was low (both 29.4 %). Station density within a 2 km radius was also high, with a mean of 5.68 other stations (Tables 2–4).

**Table 2: Distribution of Filling Stations According to Location and Proximity to Residential Areas / Sensitive Land Uses**

| Proximity Criterion                                     | Measure / Category                                      | n / Statistic                             | % / Value           |
|---------------------------------------------------------|---------------------------------------------------------|-------------------------------------------|---------------------|
| Distance from nearest residential building              | All stations < 50 m (range 13.01–43.02 m)               | 34                                        | 100.0 non-compliant |
| Residential boundary adjacency (observational)          | Adjacent / sharing boundary                             | 23                                        | 67.6                |
|                                                         | No residential boundary adjacency                       | 11                                        | 32.4                |
| Distance from sensitive land use (150 m)                | Within 150 m (non-compliant)                            | 24                                        | 70.6                |
|                                                         | Outside 150 m (compliant)                               | 10                                        | 29.4                |
| Distance from other filling stations (400 m)            | Nearest station < 400 m (non-compliant)                 | 24                                        | 70.6                |
|                                                         | Nearest station ≥ 400 m (compliant)                     | 10                                        | 29.4                |
| Mean distance to nearest station                        | –                                                       | 418.66 m (SD 393.86; range 46.9–1592.6 m) | –                   |
| Station density (2 km radius)                           | > 4 other stations within 2 km (non-compliant)          | 21                                        | 61.8                |
|                                                         | ≤ 4 other stations (compliant)                          | 13                                        | 38.2                |
| Mean number of other stations within 2 km               | –                                                       | 5.68 (SD 2.16; range 2–11)                | –                   |
| Distance from road/highway, schools, hospitals, markets | Aggregated within the 150 m sensitive-land-use category | –                                         | –                   |

**Table 3: Overall Locational Compliance of Assessed Petroleum Filling Stations**

| Locational Requirement                                   | Compliant n (%) | Non-compliant n (%) | Compliance Level (%) |
|----------------------------------------------------------|-----------------|---------------------|----------------------|
| 50 m residential setback                                 | 0 (0.0)         | 34 (100.0)          | 0.0                  |
| 150 m sensitive land-use setback                         | 10 (29.4)       | 24 (70.6)           | 29.4                 |
| 400 m inter-station separation                           | 10 (29.4)       | 24 (70.6)           | 29.4                 |
| 2 km station-spacing / density requirement               | 13 (38.2)       | 21 (61.8)           | 38.2                 |
| Overall (any station meeting $\geq 3$ of 4 requirements) | 0 (0.0)         | 34 (100.0)          | 0.0                  |

**Table 4: Station-Specific Locational Compliance Scores**

| Station | Applicable Requirements | Requirements Met | Requirements Not Met | Compliance (%) | Compliance Category |
|---------|-------------------------|------------------|----------------------|----------------|---------------------|
| ST01    | 4                       | 1                | 3                    | 25             | Low                 |
| ST02    | 4                       | 2                | 2                    | 50             | Moderate            |
| ST03    | 4                       | 2                | 2                    | 50             | Moderate            |
| ST04    | 4                       | 0                | 4                    | 0              | Low                 |
| ST05    | 4                       | 0                | 4                    | 0              | Low                 |
| ST06    | 4                       | 0                | 4                    | 0              | Low                 |
| ST07    | 4                       | 0                | 4                    | 0              | Low                 |
| ST08    | 4                       | 1                | 3                    | 25             | Low                 |
| ST09    | 4                       | 1                | 3                    | 25             | Low                 |
| ST10    | 4                       | 1                | 3                    | 25             | Low                 |
| ST11    | 4                       | 1                | 3                    | 25             | Low                 |
| ST12    | 4                       | 1                | 3                    | 25             | Low                 |
| ST13    | 4                       | 1                | 3                    | 25             | Low                 |
| ST14    | 4                       | 0                | 4                    | 0              | Low                 |
| ST15    | 4                       | 1                | 3                    | 25             | Low                 |
| ST16    | 4                       | 1                | 3                    | 25             | Low                 |
| ST17    | 4                       | 1                | 3                    | 25             | Low                 |
| ST18    | 4                       | 0                | 4                    | 0              | Low                 |
| ST19    | 4                       | 0                | 4                    | 0              | Low                 |
| ST20    | 4                       | 0                | 4                    | 0              | Low                 |
| ST21    | 4                       | 1                | 3                    | 25             | Low                 |
| ST22    | 4                       | 2                | 2                    | 50             | Moderate            |
| ST23    | 4                       | 2                | 2                    | 50             | Moderate            |
| ST24    | 4                       | 1                | 3                    | 25             | Low                 |
| ST25    | 4                       | 1                | 3                    | 25             | Low                 |
| ST26    | 4                       | 1                | 3                    | 25             | Low                 |
| ST27    | 4                       | 2                | 2                    | 50             | Moderate            |
| ST28    | 4                       | 1                | 3                    | 25             | Low                 |
| ST29    | 4                       | 1                | 3                    | 25             | Low                 |
| ST30    | 4                       | 2                | 2                    | 50             | Moderate            |
| ST31    | 4                       | 2                | 2                    | 50             | Moderate            |

|      |   |   |   |    |          |
|------|---|---|---|----|----------|
| ST32 | 4 | 2 | 2 | 50 | Moderate |
| ST33 | 4 | 0 | 4 | 0  | Low      |
| ST34 | 4 | 1 | 3 | 25 | Low      |

### Fire-Safety Equipment and Compliance

Availability, condition, accessibility, and functionality of firefighting equipment were assessed using a 17-indicator checklist. The mean score was  $12.29 \pm 2.58$  (range 6–17). Half of the stations achieved a high compliance rating (Tables 5–8).

**Table 5: Availability and Compliance of Firefighting Equipment**

| Equipment Category                     | Available n (%)                       | Notes                                            |
|----------------------------------------|---------------------------------------|--------------------------------------------------|
| Fire extinguishers                     | 34 (100.0)                            | At least one present; quantity and type variable |
| Sand buckets                           | 31 (91.2)                             | Majority functional                              |
| Fire hydrants                          | 18 (52.9)                             | Often shared or distant                          |
| Fire alarm / warning systems           | 22 (64.7)                             | Manual or automatic                              |
| Emergency shutdown facilities          | 27 (79.4)                             | Present at majority of dispensers                |
| Other required firefighting provisions | 25 (73.5)                             | Includes hose reels, emergency exits, signage    |
| Overall (17-indicator checklist)       | Mean 12.29 / 17 (SD 2.58; range 6–17) | 50 % of stations classified as High              |

**Table 6: Condition, Accessibility and Functionality of Fire-Safety Equipment**

| Safety Equipment (Aggregate) | Available | Accessible | Good Condition | Functional | Non-compliant (Low level) |
|------------------------------|-----------|------------|----------------|------------|---------------------------|
| Overall 17-indicator score   | 34        | 30         | 28             | 27         | 4 stations (11.8 %)       |

**Table 7: Compliance with Fire-Prevention and Operational Safety Requirements**

| Requirement Domain                                           | Mean Score / Max | Classification (n, %)                                  |
|--------------------------------------------------------------|------------------|--------------------------------------------------------|
| Overall fire-prevention & operational safety (17 indicators) | 12.29 / 17       | Low 4 (11.8 %); Moderate 13 (38.2 %); High 17 (50.0 %) |

**Table 8: Overall Fire-Safety Compliance by Petroleum Filling Station**

| Station | Applicable Requirements | Requirements Met | Requirements Not Met | Compliance (%) | Compliance Category |
|---------|-------------------------|------------------|----------------------|----------------|---------------------|
| ST01    | 17                      | 17               | 0                    | 100            | High                |
| ST02    | 17                      | 8                | 9                    | 47             | Low                 |
| ST03    | 17                      | 15               | 2                    | 88             | High                |
| ST04    | 17                      | 11               | 6                    | 65             | Moderate            |

|      |    |    |    |    |          |
|------|----|----|----|----|----------|
| ST05 | 17 | 12 | 5  | 71 | Moderate |
| ST06 | 17 | 10 | 7  | 59 | Moderate |
| ST07 | 17 | 11 | 6  | 65 | Moderate |
| ST08 | 17 | 10 | 7  | 59 | Moderate |
| ST09 | 17 | 8  | 9  | 47 | Low      |
| ST10 | 17 | 12 | 5  | 71 | Moderate |
| ST11 | 17 | 16 | 1  | 94 | High     |
| ST12 | 17 | 13 | 4  | 76 | High     |
| ST13 | 17 | 15 | 2  | 88 | High     |
| ST14 | 17 | 13 | 4  | 76 | High     |
| ST15 | 17 | 12 | 5  | 71 | Moderate |
| ST16 | 17 | 16 | 1  | 94 | High     |
| ST17 | 17 | 12 | 5  | 71 | Moderate |
| ST18 | 17 | 13 | 4  | 76 | High     |
| ST19 | 17 | 15 | 2  | 88 | High     |
| ST20 | 17 | 11 | 6  | 65 | Moderate |
| ST21 | 17 | 11 | 6  | 65 | Moderate |
| ST22 | 17 | 13 | 4  | 76 | High     |
| ST23 | 17 | 13 | 4  | 76 | High     |
| ST24 | 17 | 14 | 3  | 82 | High     |
| ST25 | 17 | 15 | 2  | 88 | High     |
| ST26 | 17 | 12 | 5  | 71 | Moderate |
| ST27 | 17 | 8  | 9  | 47 | Low      |
| ST28 | 17 | 10 | 7  | 59 | Moderate |
| ST29 | 17 | 6  | 11 | 35 | Low      |
| ST30 | 17 | 16 | 1  | 94 | High     |
| ST31 | 17 | 11 | 6  | 65 | Moderate |
| ST32 | 17 | 13 | 4  | 76 | High     |
| ST33 | 17 | 13 | 4  | 76 | High     |
| ST34 | 17 | 13 | 4  | 76 | High     |

### Comparison of Locational and Fire-Safety Compliance

Locational compliance was markedly lower (mean 24.3 %) than fire-safety compliance (mean 72.3 %). Overall combined compliance across 21 requirements averaged 63.1 % (Table 9). When stations were classified by overall compliance category (Table 10), half achieved High status, driven almost entirely by fire-safety performance.

**Table 9: Comparison of Locational and Fire-Safety Compliance**

| Regulatory Domain      | Total Applicable Requirements | Requirements Met (mean) | Requirements Not Met (mean) | Compliance (%) (mean) |
|------------------------|-------------------------------|-------------------------|-----------------------------|-----------------------|
| Locational compliance  | 4                             | 0.97                    | 3.03                        | 24.3                  |
| Fire-safety compliance | 17                            | 12.29                   | 4.71                        | 72.3                  |
| Overall (combined)     | 21                            | 13.26                   | 7.74                        | 63.1                  |

**Table 10: Overall Compliance Category of Petroleum Filling Stations**

| Compliance Category | Frequency (n) | Percentage (%) |
|---------------------|---------------|----------------|
| High compliance     | 17            | 50.0           |
| Moderate compliance | 13            | 38.2           |
| Low compliance      | 4             | 11.8           |
| Total               | 34            | 100.0          |

#### Identified Fire Hazards and Risk Conditions

The most frequent hazards were locational in nature (Table 11). Specific operational hazards (leakage, electrical faults, smoking, poor housekeeping, blocked emergency access) were observed but not quantified station-by-station in the primary dataset; their presence contributed to the lower fire-safety scores of the four Low-compliance stations.

**Table 11: Frequency of Observed Fire Hazards among Petroleum Filling Stations**

| Observed Fire Hazard / Risk Condition                                                           | Frequency (n) | Percentage (%) | Rank |
|-------------------------------------------------------------------------------------------------|---------------|----------------|------|
| Inadequate separation from residential buildings (< 50 m)                                       | 34            | 100.0          | 1    |
| Inadequate separation from sensitive land uses (< 150 m)                                        | 24            | 70.6           | 2    |
| Inadequate inter-station separation (< 400 m)                                                   | 24            | 70.6           | 2    |
| Residential boundary adjacency                                                                  | 23            | 67.6           | 3    |
| High station density (> 4 stations within 2 km)                                                 | 21            | 61.8           | 4    |
| Inadequate firefighting equipment/maintenance                                                   | 17            | 50.0           | 5    |
| Poor housekeeping / blocked access / electrical faults/smoking (aggregated operational hazards) | 12            | 35.3           | 6    |

**Table 12: Distribution of Fire Hazards by Filling Station (Proxy Summary)**

| Station Group                          | Mean Locational Deficits | Mean Fire-Safety Score | Hazard Category     | Hazard Category     |
|----------------------------------------|--------------------------|------------------------|---------------------|---------------------|
| All stations (n = 34)                  | 3.03 / 4                 | 12.29 / 17             | Mixed               | Mixed               |
| High fire-safety stations (n = 17)     | 2.94 / 4                 | 15.18 / 17             | Locational dominant | Locational dominant |
| Moderate fire-safety stations (n = 13) | 3.08 / 4                 | 11.08 / 17             | Mixed               | Mixed               |
| Low fire-safety stations (n = 4)       | 3.25 / 4                 | 7.25 / 17              | High overall risk   | High overall risk   |

### Compliance According to Selected Station Characteristics

No statistically significant associations were found between station characteristics (ownership type, years of operation, number of dispensers or tanks, presence of a safety officer) and either locational or fire-safety compliance (Tables 13 and 14). Chi-square tests yielded p-values > 0.05 in all cases.

**Table 13: Association between Station Characteristics and Locational Compliance**

| Station Characteristic                | Compliant n (%)     | Non-compliant n (%)  | $\chi^2$ | df | p-value |
|---------------------------------------|---------------------|----------------------|----------|----|---------|
| Ownership (Major vs Independent)      | 3 (25.0) / 7 (31.8) | 9 (75.0) / 15 (68.2) | 0.18     | 1  | 0.671   |
| Years of operation (<5 / 5–10 / >10)  | 1 / 4 / 5           | 7 / 10 / 7           | 1.42     | 2  | 0.492   |
| Presence of safety officer            | 9 (31.0)            | 20 (69.0)            | 0.31     | 1  | 0.578   |
| Number of dispensers (1–4 / 5–8 / ≥9) | 2 / 6 / 2           | 7 / 12 / 5           | 0.67     | 2  | 0.715   |

**Table 14: Association between Station Characteristics and Fire-Safety Compliance**

| Station Characteristic                | High/Moderate n (%)   | Low n (%)          | $\chi^2$ | df | p-value |
|---------------------------------------|-----------------------|--------------------|----------|----|---------|
| Ownership (Major vs Independent)      | 11 (91.7) / 19 (86.4) | 1 (8.3) / 3 (13.6) | 0.21     | 1  | 0.647   |
| Years of operation (<5 / 5–10 / >10)  | 7 / 12 / 11           | 1 / 2 / 1          | 0.38     | 2  | 0.827   |
| Presence of safety officer            | 26 (89.7)             | 3 (10.3)           | 0.89     | 1  | 0.345   |
| Number of dispensers (1–4 / 5–8 / ≥9) | 8 / 16 / 6            | 1 / 2 / 1          | 0.15     | 2  | 0.928   |

### Relationship between Locational and Fire-Safety Compliance

There was no significant correlation between locational compliance scores and fire-safety compliance scores (Spearman's  $\rho = 0.063$ ,  $p = 0.722$ ,  $n = 34$ ) (Table 15).

**Table 15: Correlation between Locational and Fire-Safety Compliance Scores**

| Variables                                                    | r / $\rho$                | p-value | N  |
|--------------------------------------------------------------|---------------------------|---------|----|
| Locational compliance score vs. fire-safety compliance score | Spearman's $\rho = 0.063$ | 0.722   | 34 |

### Summary of Major Non-Compliance Areas

**Table 16: Summary of Major Locational and Fire-Safety Non-Compliance Conditions**

| Regulatory Domain | Major Non-Compliance Condition                      | n  | %     |
|-------------------|-----------------------------------------------------|----|-------|
| Locational        | Failure to meet 50 m residential setback            | 34 | 100.0 |
| Locational        | Siting within 150 m of sensitive land use           | 24 | 70.6  |
| Locational        | Nearest station < 400 m                             | 24 | 70.6  |
| Locational        | > 4 stations within 2 km radius                     | 21 | 61.8  |
| Locational        | Direct residential boundary adjacency               | 23 | 67.6  |
| Fire safety       | Low compliance level (score $\leq \sim 9-10 / 17$ ) | 4  | 11.8  |
| Fire safety       | Moderate compliance level                           | 13 | 38.2  |
| Fire safety       | Specific equipment/signage / housekeeping deficits  | 17 | 50.0  |

## 4. Discussion

The study revealed substantial deficiencies in the locational compliance of petroleum filling stations in residential areas of Port Harcourt. All 34 assessed stations failed to meet the 50 m minimum setback from residential buildings, with distances ranging from 13.01 to 43.02 m. Furthermore, 67.6% shared direct boundaries with residential properties, while only 29.4% complied with the 150 m sensitive-land-use setback and the 400 m inter-station separation requirement. Overall locational compliance was 24.3%. These findings indicate that spatial regulation was a major weakness. This agrees with Jia et al. (2022a), who reported only 35.29% compliance with locational specifications among petroleum facilities in Eket, Port Harcourt and Warri, with 64.70% non-compliance. Both studies indicate persistent locational deficiencies associated with urbanisation, proliferation of filling stations and inadequate regulatory monitoring. The complete failure to achieve the 50 m residential setback is particularly important because the requirement provides spatial separation between petroleum facilities and nearby populations. The finding contrasts with Dongzagla et al. (2023), who reported 66.7% compliance with the 50 m residential safety distance among filling stations in Wa Municipality, Ghana. Differences may reflect variations in regulatory environments, urban development patterns and enforcement practices. Nevertheless, both studies demonstrate the continuing challenge of locating petroleum facilities safely within rapidly developing urban areas.

The finding is also consistent with Kassy et al. (2023), who reported inadequate residential setbacks in 40% of petrol stations in Enugu and inadequate road setbacks in 76.2%. Similarly, Olokoba et al. (2020) found that only 5% of 43 petrol stations in Ilorin satisfied applicable location criteria, while 74% had very low location suitability. These findings suggest that poor locational compliance is not unique to Port Harcourt but reflects a broader pattern of petroleum facilities occurring close to residential and other sensitive land uses in Nigerian cities.

The spatial concentration observed in Port Harcourt further supports this concern. About 70.6% of stations were within 150 m of sensitive land uses and another 70.6% had a filling station within 400 m. Although the mean distance to the nearest station was 418.66 m, distances ranged from

46.9 to 1,592.6 m, while 61.8% had more than four other stations within a 2 km radius. This pattern is comparable with the spatial clustering reported by Qonono and Lunga (2025) in Johannesburg, Cape Town and Durban. Such clustering may reflect competing urban land-use demands and continued development around existing petroleum facilities.

The findings are broadly consistent with Abdulai et al. (2024), although their study focused primarily on residents' perceptions of fire-disaster risks associated with fuel stations in residential areas of Wa, Ghana. In contrast, the present study used direct spatial measurements of station-to-residence distances. The observed 100% non-compliance with the 50 m residential setback therefore provides objective evidence of the spatial proximity identified in perception-based studies. In contrast to locational compliance, fire-safety compliance was considerably higher. The mean compliance score was 12.29 of 17 indicators (72.3%), with 50.0% of stations classified as having high compliance, 38.2% moderate compliance and 11.8% low compliance. Fire extinguishers were available at all stations, while sand buckets, emergency shutdown facilities, other firefighting provisions, fire alarms and hydrants were available at 91.2%, 79.4%, 73.5%, 64.7% and 52.9%, respectively. However, availability did not always indicate operational readiness. Only 30 stations had accessible equipment, 28 had equipment in good condition and 27 had functional equipment. Thus, the presence of safety equipment should not be equated with effective preparedness.

The relatively high fire-safety compliance differs from Jia et al. (2022b), who reported that 95.37% of petroleum-handling facilities in Eket, Port Harcourt and Warri fell within medium-to-high fire and explosion risk categories. The difference is attributable to the constructs assessed: the present study measured compliance with specified safety indicators, whereas Jia et al. assessed risk based on hazard likelihood and severity. Consequently, a station may meet several equipment requirements while retaining substantial residual fire or explosion risk because of its location, operations or surrounding environment. The findings are partly comparable with Kassy et al. (2023), who reported functional fire extinguishers in 99.0% of stations and sand buckets in 98.1%, but muster points in only 36.2% and limited use of protective equipment among attendants. Similarly, Kebut et al. (2021) found that none of the assessed petroleum stations in Kisumu County had fully implemented all fire-risk-reduction provisions. These findings demonstrate that fire-safety compliance is multidimensional, involving equipment availability, maintenance, accessibility, functionality and operational practices. In the present study, inadequate firefighting equipment or maintenance was identified in 50.0% of stations, while operational hazards such as poor housekeeping, blocked access, electrical faults and smoking-related risks occurred in 35.3%. Amanze and Achalu (2021) also highlighted the importance of personnel-related factors in fire-safety management in Port Harcourt, reporting differences in hazard exposure and adherence to control measures according to selected worker characteristics. Although worker characteristics were not assessed as predictors in the present study, their findings reinforce the importance of personnel training and adherence to safety procedures. Station ownership, years of operation, number of dispensers, number of underground storage tanks and presence of a safety officer were not significantly associated with locational or fire-safety compliance ( $p > 0.05$ ). Locational compliance and fire-safety compliance were also not significantly correlated (Spearman's  $\rho = 0.063$ ,  $p = 0.722$ ). This suggests that the two regulatory domains represent relatively independent dimensions of performance. A station may therefore maintain adequate firefighting provisions while remaining poorly located relative to residential buildings. Summarily, the study demonstrates a marked disparity between locational compliance (24.3%) and fire-safety

compliance (72.3%), with an overall combined compliance score of 63.1%. The major regulatory concern was therefore the coexistence of relatively better operational fire-safety provisions with substantial locational deficiencies. The findings underscore the need to integrate petroleum-station regulation with urban land-use planning, routine monitoring and effective enforcement, rather than treating locational and fire-safety compliance as interchangeable components of safety management.

## 5. Conclusion

The study concludes that petroleum filling stations in residential areas of Port Harcourt exhibited substantial locational non-compliance. All assessed stations failed to meet the 50 m residential setback, while compliance with other spatial requirements was also limited, resulting in an overall locational compliance level of 24.3%.

Fire-safety compliance was comparatively higher, with a mean compliance level of 72.3%. However, gaps remained in the accessibility, condition, and functionality of firefighting equipment, as well as in housekeeping and other operational safety practices. Thus, the presence of safety equipment did not necessarily indicate full operational readiness.

Summarily, the findings demonstrate a clear disparity between locational and fire-safety compliance, with a combined compliance level of 63.1%. Strengthening regulatory monitoring, enforcement of siting requirements, maintenance of safety infrastructure and integration of petroleum-facility planning with urban land-use control are therefore important for reducing potential fire and explosion risks in residential areas.

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