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Article

Liquefied Petroleum Gas Stations Disaster Risk Preparedness Assessment of Port Harcourt City, Nigeria

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Abstract: This study assessed the risk management or preparedness measures in Liquefied Petroleum Gas (LPG) stations in Port Harcourt metropolis. The sample size of this study comprised of 79 licensed Liquefied Petroleum Gas Stations located within the metropolis obtained from the regulatory agency. The data were collected, administered analyzed using Kobocollect App, Spearman Rank Correlation and percentages. The findings reveal that 96.2% of gas stations were stand-alone while 3.8% are with petrol stations, the storage tanks are cylindrical and were placed above-ground. Majority (88.61%) of the staff have been trained in safety and firefighting with 65.82% possessing automated Gas detector, 21.52% having mechanical gas detector, 8.68% having both mechanical and automated gas detectors while 5.06% have no leak detection devices. Also, 88.61% of gas stations have emergency plans, 3.8% have no emergency plans while on how often drills were conducted; 50.63% of respondents indicated that drills were conducted once, 22.78% twice and 3.8% thrice a year. Finally, it was found that 86.7% of the vulnerability to LPG station risk is determined by the type of station. There is therefore the need for regular assessment and monitoring of facilities by the regulatory agency to mitigate potential disasters due to LPG stations for sustainable development in the metropolis.

Keywords: Hazardous Chemicals; Liquefied Petroleum Gas; Liquefied Petroleum Gas Stations Explosion; Preparedness and Risk Management Measures; Kobotoolbox

1. Introduction

Liquefied Petroleum Gas station explosions have become recurring events posing serious societal and economic risks, raising questions about public safety. These disasters due to LPG stations is exacerbated by increased population density, urbanization, the drive for cleaner energy and indiscriminate location or proliferation of hazardous chemicals or poor urban planning [1]. According to [2], urban hazards are potentially damaging phenomenon that threatens a city, its population and socioeconomic activities. The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of disaster risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed in broad terms at least. In his book theory

of modernity, Risk Society: Towards a new modernity, Beck [3] opiates that the industrial era had led to new society called the "modern society" with technological changes. These technological changes produce new forms of risks which we need to constantly prepare for and respond to. He further argues that before the industrial era hazards were mainly natural but risks in the modern society are handiworks of our own social development of science and technology giving birth to a risk society.

Industrial hazards pose one of most prevalent risks in urban areas exacerbated by underlying disaster risk drivers. Industrial risks in urban areas such as Liquefied Petroleum Gas could be in the form of chemical Spill, Collapse, Explosion, Fire, Gas leak, Poisoning and Radiation from processing, transportation and storage plants or facilities. But the scope of this research is limited to the risks of LPG Storage facilities (gas stations). LPG station hazards pose serious health issues to man when it's inhaled, absorbed through the skin, or ingested resulting in acute (immediate) or chronic (prolonged) health issues. Acute effects include nausea, vomiting, burns, and asphyxiation while chronic cases may develop into dermatitis, asthma, liver damage and cancer. LPG produces heat on combustion, stored in industries and stations to produce heat energy. It is one of the highly hazardous and volatile substances in nature. It is a widely used chemical in industries and has the potential of causing major catastrophe and requires risk management measures to store and use safely [4].

The transformation of industrial areas into residential areas due to disaster risk drivers such as increasing population density and urbanization coupled with the building of many industrial sites near highly populated residential areas for proximity to customers to gain competitive market advantage while ignoring the risks of the LPG Stations leading to disasters and increasing the severity of impact is now the norm in most countries globally. As the global population grows more and more people are settling in urban areas worldwide. Urban growth is a complex process that is a result of a combination of manifold factors which include geographical location, natural population growth, rural-to-urban migration, infrastructural development, national policies, corporate strategies, and other major political, social and economic forces, including globalization [5]. In 1960, only one city – Shanghai had a population of more than one million people. In 2000, 450 cities had a population of more than one million; of these 50 cities had population of over 3.5 million with 25 cities having a population of over 8 million people. According to report from the United Nations (UN) the global population in 2018 was 7.6 billion. It is projected that by 2050, the global population is expected to rise to 9.7 billion with 68% of the population (6.59 billion) living urban areas [6]. While stating that the current degree of urbanization by continents in 2020; Szmigeira [7] indicated that global urbanization stands at 56%; North America with 82% has the highest percentage of urban population in total population, followed by Latin America and the Caribbean 79%, Europe 75%, Oceania 68%, Asia 51% and Africa 43% respectively. In Africa, urbanization recently has gained additional momentum due to climate change and armed riot in rural areas. Africa in particular displays the highest urban growth rates in the whole world, growing by 3.4% each year. The UN forecasted that African's population will double over the next 40 years and attain a total population of 2 billion persons in 2050. This figure is expected to be centered within the urban areas resulting to a projection of 720 million cities dwellers during this period [5]. This situation is expected to be more pronounced in Nigeria as the most populated nation in Africa with a land area of 923,000 Km^2 and 193,392,517 million people as at 2016 [8]. The landuse and vegetation map of the study area drawn from satellite imagery in 1976 shows that the total anthropogenic altered/built-up area/space of the city and its environment was only 16.25 Km^2 by 1995, an updated edition of same map showed that the

anthropogenic/built-up area of the region had increased to 282.25 Km^2, indicating that the size of the city has increased by seventeen times in two decades [4, 9]. Although accidents from Liquefied Petroleum Gas stations happen occasionally, they are unpredictable and very catastrophic once it happens. The Feyzin 1966, Mexico City 1984, Siberia 1989, Warsaw Poland, Illinois USA are well known cases of this phenomenon globally [10-11], while in Nigeria this had resulted in disaster situations in Warri, Agbor, Delta State; Magodo, Lagos State; Lafia, Nassarawa state, Osogbo, Osun State; Owerri, Imo State; Nnewi, Anambra State and Rumuodomaya, Obirikwere in Rivers State [12-15].

Disaster risk assessment which is a core strategy and an intrinsic part of disaster risk management is; a qualitative or quantitative approach to determine the nature and extent of disaster risk by analyzing potential hazards and evaluating existing conditions of exposure and vulnerability that could harm people, property, services, livelihoods and the environment on which they depend. Disaster risk assessments include: the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative disaster risk management measures with respect to likely risk scenarios [15].

Disaster risk management or preparedness measures aim to reduce residual risks to levels acceptable by society are selected based on the outputs of risk assessment [16]. The major disaster risk management or preparedness measures are; identification and knowledge of the hazardous chemical, knowledge of the characteristics of the station, safety and firefighting training, formulation and implementation of emergency preparedness and response plans/drills, possession of devices for leak detection, possession of emergency devices for risk mitigation and Personal Protective Equipment (PPE). Beck [3] summed up his theory of modern society by stating that risk management and preparedness planning is the ultimate or prime feature of the global order for sustainable development. It is based on this backdrop that this study assessed the risk management/preparedness measures in place in Liquefied Petroleum Gas stations in Port Harcourt City, Nigeria.

2. Materials and Methods

2.1. Study Area

The study was carried out in River's state, Nigeria while major interest was placed on Liquefied Petroleum Gas stations in Port Harcourt metropolis. Spatially, the study covers five Local Governments Areas (Obio-Akpor, Eleme, Oyigbo, Ikwerre, and Port Harcourt City Council) (Figure 1 & 2). The metropolis is positioned from Latitude 40 45'N through Latitude 40 55' N, and Longitude 60 55' E through Longitude 70 05' E. The Atlantic Ocean is found at an approximate distance of 25 km from it. Port Harcourt, one of Nigeria 's major cities and has been experiencing rapid urbanization since its inception in 1913. The city has grown from 5,000 persons in 1915 to 79,634 in 1953 and to 179,563 in 1963 [17]. The 1991 census gave the city 's population as 440,399 and in the 2006 census National Population Commission fixed it at 1,005,904. There is a considerable population growth that has led to spatial expansion, engulfing once distant communities on the urban periphery, to the extent that they can no longer be seen as distinct communities but have become part of the urban fabric extending into Local Government Areas [5, 18, 19] and as the time of the study (2023), Port Harcourt's

population is now estimated at 3,480,101 with an increase of 175,586 in the last year, which represents a 3.33% annual change [20]. In addition to rising urban population, there are worsening environmental problems such as poor urban planning, poor solid waste management, flooding, traffic congestion, poor state of the urban physical environment and rising crime rates have been documented [21-22]. More recently, [12, 14, 15] have noted LPG station explosions while [23] noted inadequate space in the city. This situation triggered the desire to assess the level of preparedness in to Liquefied Petroleum Gas station hazard in the city.

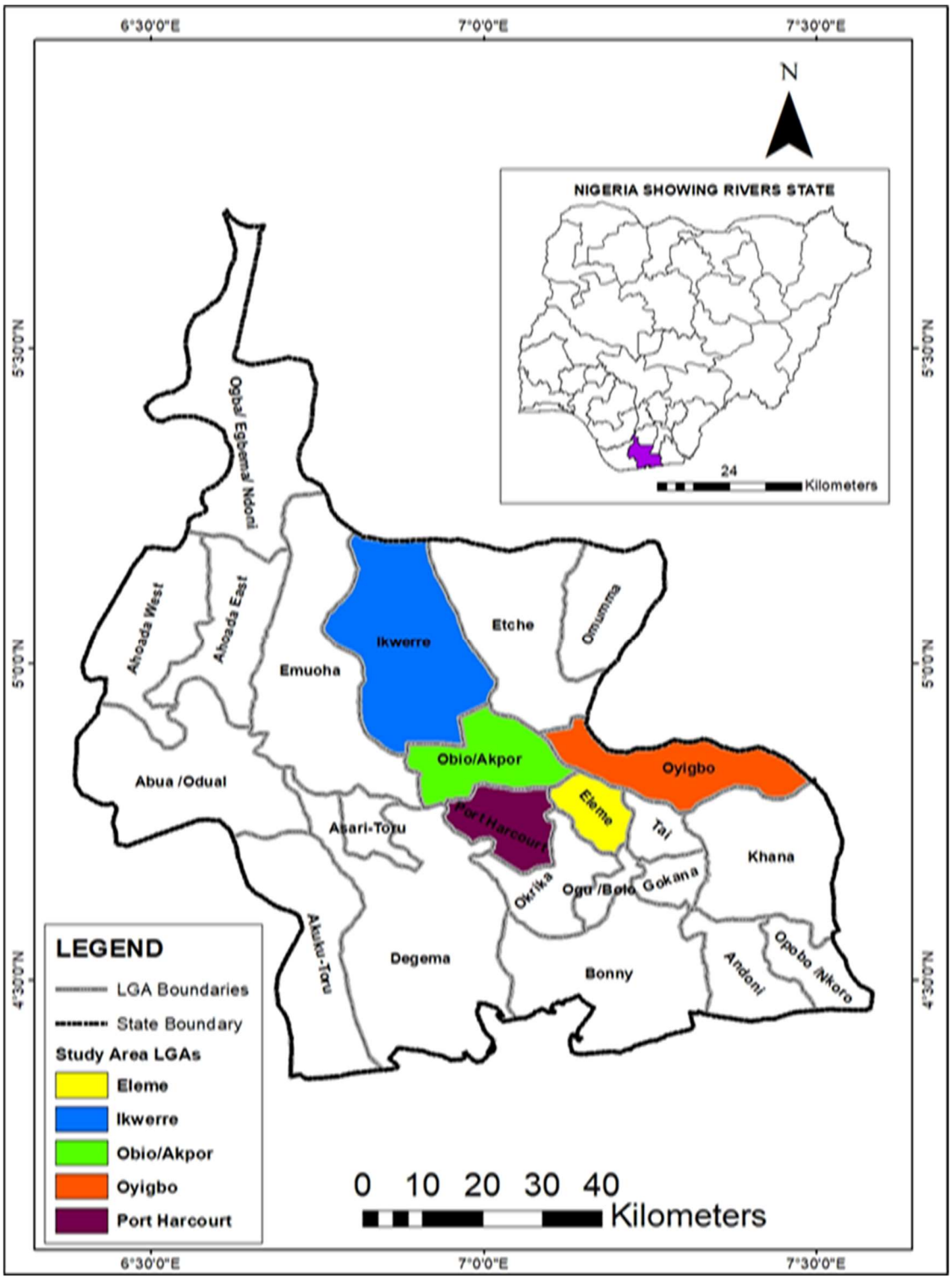
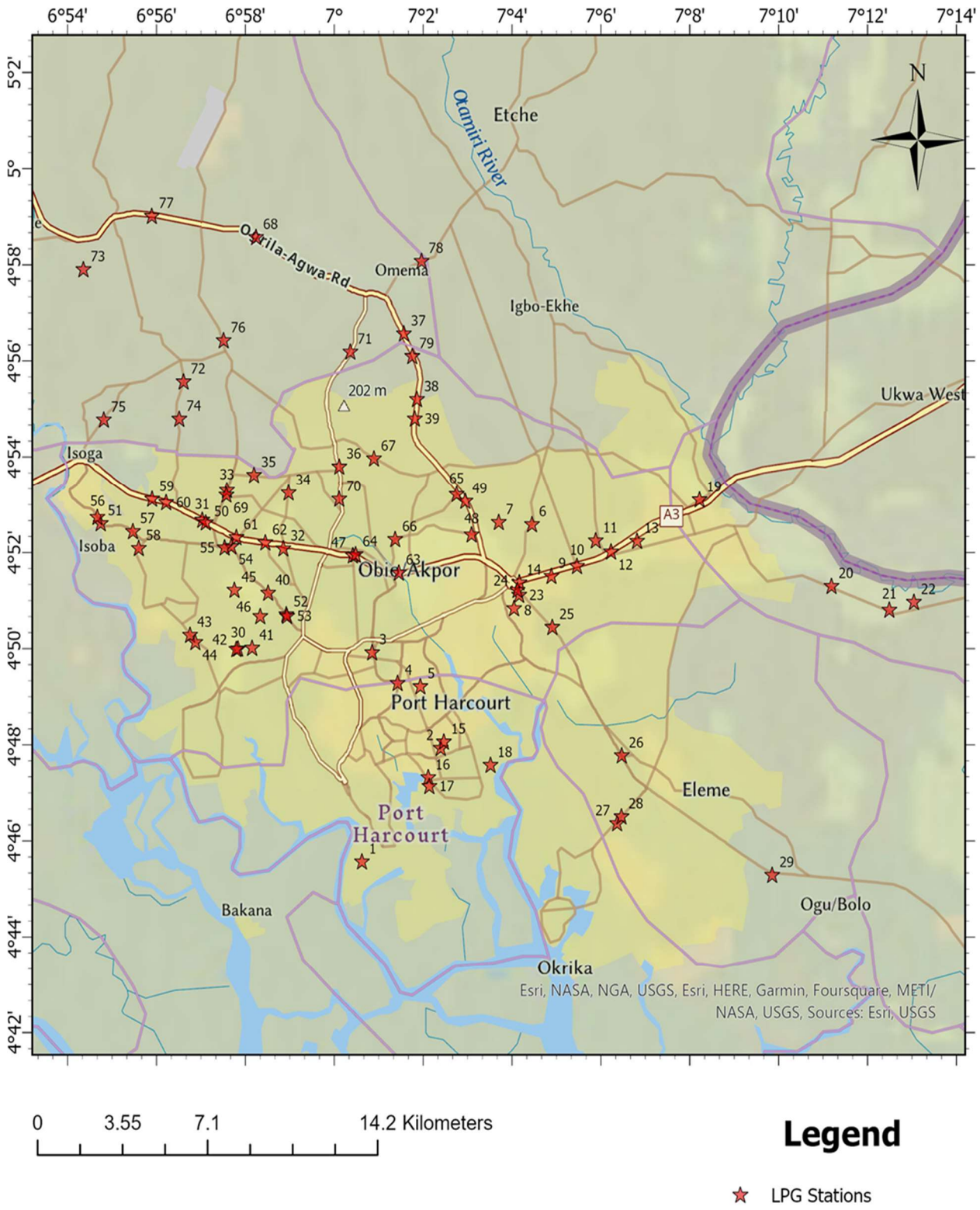


Figure 1. Map of Study Area.



(**Source:** Researchers fieldwork 2023)

Figure 2. Map of the distribution liquefied petroleum gas stations in the study area.

2.2. Study Design and Sample Size

The study design consisted of a cross-sectional observational method. This design method was adopted because it is suitable and efficient in studies collecting data on the entire population under study providing a snapshot of the population of study at a specific time. The sample size of this study

comprises of all (79) licensed Liquefied Petroleum Gas Stations located within the metropolis obtained from the regulatory agency. The data were collected and administered using Kobocollect by the one of the authors and one research assistant. The questionnaire was divided into two sections;

• Section A: contains station Characteristic information such as; nature of station, nature of tank, names and staff strength and placement of tank (6 questions).

• Section B: contains the Risk management or preparedness information such staff training, devices available for leak detection, possession of emergency plan, how often drills are conducted, available emergency devices, possession of Personal Protective Equipment (PPE) (6 questions).

2.2.1. The Kobotoolbox Software

The Kobotoolbox software is a free and open-sourced software initially developed by the Harvard Humanitarian Initiative School of Public Health and the Brigham and Women's Hospital and it's currently widely used in Africa by researchers [24]. Prior to the survey the questionnaire was expertly tested and a one-day training was administered on the research assistant on the use of Kobocollect for reliability and validity. Two (2) Android smart phones were used with Kobocollect (v2023.1.2) and a power bank each in the event of smartphone battery depletion. Each smartphone had a Google and Kobo account which allowed the use for getting, filling, saving, editing, viewing, sending of blank, saved and finalized forms. The blank form was downloaded from Kobotoolbox server to the smartphones and survey was conducted based on the questions in the form while completed and saved forms data was sent from the smartphone to the server. A key security feature of the software is the inability of even the data collector to access aggregated data from the server if permission is not granted by the administrator.

2.3. Data Analysis

Once data collection was finalized, the electronic form is created on Microsoft Excel in xlsx standard format. The opinions of the respondents to the questionnaires were extracted and processed into raw data, and presented in figures, frequency distributions and percentage statistic. Effort was made to tabulate the collected raw data into a form of computation of tables with a view to presenting a vivid picture of the variables under investigation while the hypothesis was tested using the Spearman Rank Correlation Analysis.

H0: There is no statistically significant relationship between the type of station and gas station risk in the study area.

H1: There is statistically significant relationship between the type of station and gas station risk in the study area.

3. Results

3.1. Disaster Risk Preparedness Assessment of Liquefied Petroleum Gas Stations

Table 1 presents the characteristics of the Liquefied Petroleum Gas Stations across Port Harcourt City. The study reveals that there are 76 (76.2%) stand-alone Liquefied Petroleum Gas stations while 3 (3.8%) are with petrol stations, with all the stations having cylindrical tanks and tanks placed above ground.

Table 1. Characteristics of Liquefied Petroleum Gas (LPG) Stations.

S/N	Station Type	Frequency	Percentage
1	Stand-alone	76	96.2
2	With petrol station	3	3.8
Total	--	79	100
S/N	**Nature of Tank**	**Frequency**	**Percentage**
1	Cylindrical	79	100
2	Spherical	0	0
Total	--	79	100
S/N	**Placement of Tank**	**Frequency**	**Percentage**
1	Aboveground level	79	100
2	Belowground level	0	0
Total	--	79	100

The analysis of table 2 reveals; that 70 (95.9%) had safety and firefighting training, 3 (4.1%) had no training while 6 (7.6) were unresponsive with 52 (65%) having automated gas leak detectors, 17 (21.25%) having mechanical leak detectors, 7 (8.75) having both automated and mechanical detectors while 4 (5%) had none. Furthermore, 70 (88.6%) of the stations possess Emergency/Response Plan while 3 (3.8%) had none and 6 (7.6) unresponsive with 40 (65.6%) of the gas stations testing the plan or conducting drills once a year, 18 (29.6%) of the stations conducted drills twice, 3 (4.9%) thrice while 18 (29.6%) had no response. On devices available for emergency, it was found that; 72 (46.5%) had fire extinguishers, 40 (25.8%) had sprinklers, 37 (23.8%) had alarm systems while 6 (3.9%) having no response with 71 (89.9 %) stations having personal Protective Equipment (PPE) while 1 (1.3%) had none with 7 (8.9%) having no response.

Furthermore, the Spearman Rank Correlation analysis revealed that:

Rho = 0.932.

Coefficient of Determination = (r2 x 100) = (0.932)2 x 100 = 86.7.

t = 8.20 and t critical = 1.665.

4. Discussion

The finding reveals that 96.2% of gas stations are stand-alone while 3.8% are with petrol stations, all tanks are cylindrical and placed above-ground. This is in line with the findings of [25], that installation of storage tank could be aboveground or underground and studies of [26], which stated that storage tanks installed aboveground could cause Unconfined Vapour Cloud Explosion and Boiling Liquid Expanding Vapour Explosion by a gas leak while buried underground type tanks are extremely vulnerable to corrosion which degrades safety and economic efficiency. Therefore, storage tank should not be on the ground and buried underground. This indicates that whether the tanks are aboveground or below ground the society is exposed to som upe level of vulnerability from the presence of Liquefied Petroleum Gas stations especially people working and living around gas stations. According to [27], prolonged exposure to petroleum hazardous substances results in risks of asphyxiation, sleeping disorders, memory loss, cancer, with lots of uncertainty for the attendants. Also, [28-29] add that Liquefied Petroleum Gas tend to evaporate and form a vapor cloud that may result in a cascading accident or domino effect thus with the presence of other volatile hazardous

chemical installations such as petrol stations as revealed from the study would increase the extent of area, population at risk and severity of impact, escalating the intensity of the initial accident to a catastrophic level if not contained and controlled immediately.

Table 2. Preparedness and Risk Management Measures in Liquefied Petroleum Gas Stations.

S/N	Had Safety and Fire Training	Frequency	Percentage
1	Yes	70	88.6
2	No	3	3.9
3	Unresponsive	6	7.6
Total	--	79	100
S/N	**Devices for Gas leak detection**	**Frequency**	**Percentage**
1	Automated Gas detector	52	65
2	Mechanical Leak detector	17	21.25
3	Both	7	8.75
4	None	4	5
Total	--	80	100
S/N	**Possess Emergency/Response Plan**	**Frequency**	**Percentage**
1	Yes	70	88.6
2	No	3	3.8
3	No Response	6	7.6
Total	--	79	100
S/N	**How Often are Emergency Drills Carried out yearly**	**Frequency**	**Percentage**
1	Once	40	65.6
2	Twice	18	29.5
3	Thrice	3	4.9
4	No response	18	29.5
Total	--	79	100
S/N	**Devices Available for Emergency**	**Frequency**	**Percentage**
1	Fire Extinguishers	72	46.5
2	Sprinklers	40	25.8
3	Fire Alarm Systems	37	23.8
4	No response	6	3.9
Total	--	155	100
S/N	**Possession of Personal Protective Equipment**	**Frequency**	**Percentage**
1	Yes	71	89.9
2	No	1	1.3
3	No response	7	8.9
Total	--	79	100

On preparedness and risk Management measures in Liquefied Petroleum Gas Stations the study reveals that majority (88.61%) of the staff had been trained in safety and firefighting and with trained and 3.8% not trained which conforms with findings of [29] of 86.7% of the respondents receiving safety training and studies of [30] in Ghana where 52% received training before starting work. As training improves the personnel's perspective of risk and compels employees to adhere to Standard

Operating Procedures (SOPs) and safe systems of work thereby building the preparedness and capacity of the personnel.

Furthermore, the finings reveal that LPG stations in the study area possess automated Gas detector (65.82%), mechanical gas detector (21.52%), 8.68% have both mechanical and automated gas detectors while 5.06% have no leak detection device. Automated gas detector systems set up alarm systems when the concentration of gas exceeds a certain level in the air prompting users to set up necessary response while routine checks or inspections could also be done on devices to ascertain leakage of LPG gas from storage tanks to have prior information or early warning for response [31].

The study further revealed that 88.61% of gas stations have emergency plan, 3.8% had no emergency plan or the attendants or supervisors have no knowledge of their presence while on how often drills were conducted; 50.63% of respondents indicated that drills were conducted once, 22.78% twice and 3.8% thrice a year. A well thought out plan is needed during an emergency by all organizations by legislation to ensure the safety of staff, contractors, bystanders and other stakeholder in a bid to respond quicker, and reduce loss, damage and severity of impact and the testing of this plan builds confidence among personnel and gives direction and responsibility to each staff on what to do during an emergency [32]. The more frequent the drills the lesser the livelihood of errors and most likely the lesser the severity of impact. Finally, for devices available in an emergency and protective equipment in the gas stations; it was found that 91.14% of gas stations have fire extinguishers, 54.43% have sprinklers and 46.84% have fire alarm systems. This conforms with findings of [30] of other observed safety measures being; policy document, sand bucket, functional fire extinguisher, first aid, protective canopy and safety signs while on Person Protective Equipment, 89.87% of stations have Personal Protective Equipment (PPE) with 1.27% without PPE this aligns with findings of [30, 33] in the possession of PPE in Gas stations but differ from the referenced studies in not considering usage of PPE. As most of respondents in the referenced studies never used gloves, mask, colored vest and safety glasses while only less than half, 40% and 38.6%, of respondents always use overall and boots respectively. The analysis finally revealed that 86.7% of the vulnerability to LPG station risk is determined by the type of station and since the calculated t value 8.20 is more than the critical t value 1.66 at 77 degrees of freedom and 95% confidence level; we accept the alternate hypothesis which states that "there is statistically significant relationship between the type of station and gas station risk in the study area".

5. Conclusions

The study assessed the risk management or preparedness measures associated with Liquefied Petroleum Gas stations in Port Harcourt City, a major metropolis and the fifth largest city in Nigeria. This was achieved with a cross-sectional observational design and the use of the Kobotoolbox and Kobocollect software. Knowledge of the preparedness levels of Liquefied Petroleum Gas stations have become paramount considering the recent spate of explosions of gas stations in the country to ascertain if stations can cope with an incident before aid or outside help comes. The study found that the presence of Liquefied Petroleum Gas stations predisposes the city to the effects of LPG risk but the preparedness measures in place (safety and firefighting training, formulation and implementation of emergency preparedness and response plans/drills, possession of devices for leak detection, possession of emergency devices for risk mitigation and Personal Protective Equipment (PPE) should be able to quell incidents until external help arrives. There is the need for regular

monitoring of facilities by the regulatory agency Nigerian Midstream and Downstream Regulatory Agency, Collaboratory refresher trainings conducted between station owners and the regulatory agency and map the area at risk and refrain from locating gas stations close to each other to avert the domino tendency of Liquefied Petroleum Gas Stations. Also, the government should create general awareness on the dangers of living too close gas stations while station owners should always wear and in script the importance of wearing PPE in pay slips and food vouchers to create a culture and avert the adverse health consequences that may arise from prolong exposure of Liquefied Petroleum Gas on personnel.

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