PLASU Journal of Environment Sciences, E-ISSN 2360-9222, Vol.1, No. 2, June 2025, Published by the Faculty of Environmental Sciences, Plateau State University, Bokkos. https://www.pjes.ng
DOI: 10.5281/zenodo.15516555

ASSESSMENT OF THE SPATIAL LOCATION OF LIQUEFIED PETROLEUM GAS REFILL POINTS IN CHIKUN LOCAL GOVERNMENT AREA: A QUEST FOR ENVIRONMENTAL SAFETY

***[1 and 2]Azi Musa Bulus [1]Mohammed Tela [1]Muhammed Bala Adamu [1]Haruna Bala Dandara**

[1]*Department of Geography, Aminu Saleh College of Education Azare, Bauchi State.*
[2]*Geography Department, Nigerian Defence Academy, Kaduna.*

**Corresponding Author's email:* mbulusazi@gmail.com
https://orcid.org/0000-0001-8128-4161

ABSTRACT

The increasing demand for Liquefied Petroleum Gas (LPG) as a cleaner alternative to conventional fossil fuels has led to the proliferation of refill points lacking iota of planning, consequently exposing residents of the study area to risk. This study addresses the need to balance energy accessibility with environmental safety by evaluating safety measures and risk prevention in retail facilities. Using accidental and snowball sampling techniques, data were collected via GPS devices and checklists and analyzed through frequencies and percentages. The findings reveal high compliance with access restrictions, safety protocol promotion, and the consideration of hazards and risks during planning. Strong adherence to emergency planning and response procedures was noted; however, many facilities failed to comply with requirements to build away from sensitive populations. Most facilities maintained the recommended 100-meter distance from each other, implemented perimeter fencing, and integrated safety considerations into their layouts. Clear signage indicating hazards and internal emergency plans were prevalent, and most had measures to mitigate accident consequences. While LPG refill points are essential for meeting community energy needs, their distribution and management can pose risks to environmental and public health if not properly regulated. The study recommends enhancing regulatory enforcement, increasing public education and awareness, conducting detailed Environmental Impact Assessments (EIAs), providing training and capacity building, and using Geographic Information Systems (GIS) to identify high-risk areas for effective safety planning and implementation.

Keywords: *Environmental Safety, Liquefied, Petroleum Gas, Quest, Refills Point, Spatial Location.*

1. INTRODUCTION

The deleterious impact of the use of unsustainable energy sources on the environment has attracted global attention, this is adjudged why Sustainable Development Goal (SDG) 7 was fashioned basically to provide clean and affordable energy that is environmentally sustainable and universally accessible. Liquefied Petroleum Gas (LPG) stands tall as clean energy and has led to an astronomical increase in LPG retail outlets (Monney *et al.* 2015; Gatawa and Abdullahi, 2017; Azi *et al.,* 2023). Despite this, Sexton (2024) expressed that 2.4 billion people globally still lack access to clean cooking fuel and the situation is dire in sub-Saharan Africa (SSA), where only 17% of the population currently uses clean energy (Khavar *et al.*, 2023). Azi *et al.* (2023) enumerated environmentally unsustainable energy sources used as fuel wood, charcoal, coal, agricultural residue, animal dung, kerosene, used tires, polythene bags, plastic rubbers and bottles. Continuous usage of these energy sources hinder will hinder the attainment of SDG 7. Also, these energy sources contribute to indoor air pollution levels that exceed World Health Organization (WHO) 2018 recommended limits. Consequently, they exacerbate poverty, poor health, gender inequality, environmental degradation, air pollution, climate change, and cause up to 4 million premature deaths annually worldwide (WHO, 2018).

Chikun local government area of Kaduna state, has experienced the proliferation of LPG retail outlets. However, their operations can impact humans, their properties, and the environment when the spatial distribution of these outlets is not guided by a framework of environmental safety. Paliwal *et al.* (2014); Kapi *et al.* (2017); Jin *et al.* (2018) corroborated that LPG retail and use are not without hazards, the potential hazards are explosion and fire which may cause various clinical manifestations after inhalation, depending on the duration, the quantity of substance inhaled, and its concentration (Rocha *et al.*, 2014; World LPG Association (WLPGA), 2018; Seven *et al.*, 2017). Jin *et al.* (2018) held that the incidence of LPG-related hazards has increased recently leading to a great feeling of insecurity, this is a reason to seek environmental safety and sustainability in LPG retail outlets (Ihemtuge and Aimikhe, 2020).

Understanding the spatial distribution of these LPG retail outlets is essential to minimize its impacts and enhance existing safety measures. Highlighting the significance of spatial analysis in determining the optimal locations for LPG retail outlets to mitigate risks and environmental hazards associated with their operations is vital. Ma and Huang (2019); Kusumaningrum *et al.* (2020); Almadiana and Tualeka (2020) emphasize the need for proper spatial planning to safeguard the health and manage harmful exposures of people and properties to potential impacts of siting LPG facilities. Wang *et al.* (2019) in recognition of the need for environmental safety in the retailing and establishment of LPG in neighbourhoods highlighted the importance of spatial planning to mitigate fire hazards effectively. This is because LPG is potentially hazardous if mishandled or misused and that the risks associated therein must be controlled and managed duly (Marfo *et al.*, 2016). Thus, the planned spatial distribution of LPG retail outlets is a vital aspect of environmental safety and risk management. By incorporating spatial analysis and strategic planning, stakeholders can enhance safety protocols, minimize environmental impacts, and ensure the sustainable operation of LPG retail outlets to ensure access to all.

2. STATEMENT OF THE PROBLEM

The increasing incidences of LPG disasters are challenging environmental safety related to non-consideration of human and environmental safety in siting LPG retail outlets. Mohammad (2020); Calister *et al.* (2021) revealed that LPG is highly combustible,

flammable, and inflammable which can burn even at some distance from the source of leakage. The leaked gases may cause an explosion resulting in material loss, human deaths and injuries. Ogbette *et al.* (2018) report that Nigeria has continued to experience countless gas explosions and it has become a recurring decimal across the country. There is no state yet to experience these nasty incidents in homes, public places and retail outlets killing thousands of people and rendering several million miserable and homeless in the last decades (Calister *et al.,* 2021). This is attributed to negligence in safety considerations in siting and management of LPG retail outlets, thus, raising questions about public safety despite the economic benefits. It is based on this premise that this study aimed to assess the spatial distribution of LPG retail points in Chikun LGA in a quest for environmental safety and its sustainability. This aim will be achieved through the assessment of safety measures in LPG refill outlets aimed at protecting humans and properties, and examining whether the siting of the LPG retail outlets is guided by a potential risk assessment in Chikun LGA.

3. LITERATURE REVIEW

3.1 Safety measures in LPG refill outlets and facilities

Badro (2022) defined LPG as a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. Hammeed *et al*. (2016) opined that LPG is a product of the hydrocarbon refining process. It is a versatile fuel source mostly used for cooking and heating, but recently, with increased environmental consciousness and the desire to power vehicles and generators with a clean fuel, LPG is used for vehicular and power in homes. Lagos LPG Initiative (2014) states that it is possibly the cleanest and most efficient fuel available today. It is portable and convenient to use, with significant health, safety and environmental benefits compared to traditional fuels, i.e. wood, coal, coconut husk, corn husk and charcoal. Gürsan and de Gooyert (2021) expressed that though it is a fossil fuel, it has been identified as a transitional fuel in the bid to utilize cleaner and net-zero carbon energy sources, which are expected to bridge the gap between zero-carbon technology fuels and fossil fuels such as oil and coal. Despite these notable advantages of the energy source, it is highly inflammable and its retailing cannot be without hazard.

It is critical to aspire for safety in LPG retail stations and retail outlets as hazards related to fire and explosions have become recurring decimals, posing serious health, societal, and economic risks. This has led to loss of life and properties arising from explosions and fires, thereby raising questions about public safety. Additionally, it is reported to cause air, groundwater, and surface water pollution and contamination through the emission of Volatile Organic Compounds (VOCs) (Matori and Aulia, 2010; Morales *et al.,* 2010; Sehgal *et al.,* 2012; Akpi *et al.,* 2023). This is the reason why most countries of the world have outlined safety measures for the operation of these LPG retail outlets among whom are Bhutan: Standard Operating Procedure for Storage and Handling of Liquefied Petroleum Gas At LPG Retail Outlets (2024); Republic of Rwanda: Provisional Technical Guidelines for LPG Operations (2010); Philippines: safety code Practices (2016); Zambian Guidelines for Siting of Petroleum Infrastructure (2022); Nigeria: Guidelines for the Establishment and Operations of Downstream Gas Facilities (2020). At the international level, the United Nations Environment Programme (UNEP) (2018). Guidelines for Good Safety Practices in the LP Gas Industry. All these guidelines are aimed at reducing the incidences of LPG fire, pollution, and explosion that have affected man, his properties and the environment.

In Nigeria, several fire incidents were experienced, resulting in explosions that translated into a disaster situation. The Leadership (2018) expresses that gas plant explosions have become recurring events across the country raising questions about public safety because a lot of

incidences have been recorded lately among which are Magodo and Badagry in Lagos State, Warri and Agbor in Delta State, Osogbo in Osun State, Owerri in Imo State, Nnewi in Anambra State, Lafia in Nassarawa state, and Rumuodomaya and Obirikwere in Rivers State among others (Nadi, 2018; Egufe, 2021; Chinedu, 2022).

The desire for safety is a result of chemical spills, explosions, fires, gas leaks, poisoning, and radiation from processing, transportation, storage plants, and retailing in LPG facilities (Akpi *et al.*, 2023). LPG station hazards pose serious health issues to people when it is inhaled, absorbed through the skin, or ingested resulting in acute (immediate) or chronic (prolonged) health issues with effects including nausea, vomiting, burns, and asphyxiation while chronic cases may develop into dermatitis, asthma, liver damage, and cancer and can be described as one of the highly hazardous and volatile substances in nature, and has the potential of causing a major catastrophe and requires risk management measures (Kumar and Rajasekaran, 2016; Akpi *et al.*, 2023).

Several measures are in place to reduce the risk related to LPG disasters. For safety purposes, LPG contains a sulphur-based odorizing agent with a distinctive, persistent and unpleasant smell to allow leaks to be more easily detected (Sirdah *et al.*, 2013; Seven *et al*., 2017). Apeh *et al.* (2014) reveal that the desire for safety has given rise to the development of LPG leak detection devices to reduce the occurrence of fire outbreaks during leakages through the use of proprietary devices designed to use sudden pressure drops and rise in gas concentration to set off an alarm system and enable a manual or automatic shutdown of the gas supply.

Gas leak detection devices have also been designed to shut down the supply of gas in the event of a leakage, thereby preventing the explosion and a reason why all retail outlets must have effective emergency management systems to respond to accidents and mitigate environmental effects (UNEP, 2018). Canadian Centre for Occupational Health and Safety (CCOHS) (2022) recommends the use of a compatible flammable gas detector to determine the presence and concentration of flammable gas in an indoor location.

In a related measure of reducing the risk associated with siting LPG retailing outlets are many guidelines developed emphasizing that the retail of LPG will only take place in a site for which the Energy Regulation Board has issued a valid construction permit, i.e. a site shall refer only to the area that has been earmarked for installation of the said petroleum facility (Zambian Guidelines for Siting of Petroleum Infrastructure, 2022). The National Farmers Union (NFU) Mutual Risk Management Services Limited (u.d.) added that a fire risk assessment should be undertaken to identify and evaluate the potential for a serious fire at the premises. The safety measures that LPG retail facilities in Nigeria must adhere to include:

1. ***Site Suitability Approval (SSA):*** The chosen site for an LPG retail facility must be spacious, accessible, and located away from hazards like pipelines, high-voltage cables, and public buildings. It should also be at least 100 meters away from existing LPG refilling plants (Tonbofa, 2020).
2. ***Compliance with Health, Safety, and Environmental Standards:*** Facilities must meet the technical standards based on international petroleum industry practices, ensure health, safety, and environmental standards as determined by the regulatory authority, and have an acceptable environmental management plan, (Osinachi-Nwandem, 2023; Tonbofa, 2020).
3. ***Equipment Requirements:*** facilities must have essential safety equipment such as leak testers, fire alarm systems, gas detectors, fire water storage, and perimeter

fencing to enhance operational safety and environmental responsibility (Tonbofa, 2020).

4. ***Approval and License Procedure:*** Operators must follow the application, approval, and license procedure, which include applying through the Automated Gas System portal, paying statutory fees, obtaining necessary approvals from the Department of Petroleum Resources (DPR), and meeting specific conditions for LPG Retailers, (Tonbofa, 2020).
5. ***Sanctions for Non-Compliance:*** Non-compliance with safety measures and guidelines can lead to violations of relevant regulations, resulting in fines, penalties, or even revocation of licenses. Operators must adhere to these measures to ensure the safety of their operations and surrounding communities (Tonbofa, 2020).

By strictly adhering to these safety measures and guidelines, LPG retail facilities in Nigeria can operate safely, protect the environment, and ensure public well-being.

In Nigeria, the Department of Petroleum Resource (DPR) indicated that a fuel station should be sited at least 50m away from the built environment, at least 100m from schools, health facilities, theatres, and other public and semi-public buildings, and a distance of at least 15m from the edge of the road to the nearest pump (NUPRC, 2020a; Arokoyu *et al.*, 2015). LPG is more hazardous to fuel; as such, this measure is applied to the siting of LPG facilities, as failure to adhere to these measures has resulted in several disasters in Nigeria. In the wake of the acetylene gas explosion incident that occurred on January 4th at Sabon Tasha in Kaduna, the DPR, through its North West Zonal Operational Controller, urged LPG plant operators to take necessary measures to ensure the safety of end-users of cooking gas in Kaduna State (NUPRC, 2020a). Other safety challenges that need addressing include the transformation of industrial areas into residential areas, or the siting of LPG facilities in residential areas without adherence to zoning arrangements due to disaster risk drivers such as increasing population density and urbanization (Akpi et al., 2023). Many of the LPG retail outlets are near highly populated residential areas to gain a competitive market advantage while ignoring the risks of the LPG facilities. This practice, leading to disasters and increasing the severity of impact, is now the norm in most countries globally.

2.2 Potential Risk Assessment and Prevention

Minimizing risk in any LPG retail outlet must be one of the foremost goals of all safety measures in place because of the inherent risk attached to its operations with many individuals being sent to the grave early because of non-adherence to safety measures in siting these retail facilities. Nirupama (2010) expresses that risk assessment is a step in a risk management process and an essential tool for analyzing the system and proposing cost-effective mitigation measures, thus making the people and the environment safer. Therefore, it is recommended that appropriate risk prevention measures be implemented to address any potential eventualities (Marfo *et al.*, 2016).

Anon (2014c), as cited in Marfo *et al.* (2016), emphasizes that a risk management program should address hazards related to the siting, distribution, and use of LPG retail outlets. Highlighting the importance of location for ensuring the safety of people, properties, and the environment, Anon (2014b), as cited in Marfo *et al.* (2016), notes that while LPG retail outlets are not inherently hazardous, even small leaks must be addressed immediately.

Understanding the product and exercise control under all conditions is crucial to effectively managing LPG associated hazards. This assessment's outcomes are vital for informed policy

decisions, ensuring that the siting of LPG outlets aligns with environmental conservation, public health protection and property conservation principles. Conducting risk assessments, environmental due diligence and ensuring compliance with safety standards are essential for addressing the environmental safety challenges posed by LPG handling in retail outlets. Prioritizing proper storage, handling, and emergency response protocols can effectively minimize and manage the environmental risks associated with LPG in neighborhoods. The NUPRC (2020a) also emphasizes that, like all forms of energy, LPG is potentially hazardous if mishandled. Therefore, it is necessary to assess the potential risks associated with siting LPG retail outlets and adhere to standard operating procedures when handling the commodity.

Risk assessment helps ensure that LPG retail outlets are sited in a manner that minimizes risks to people and the environment (Neil, 2012). Bernatik and Bartlova (2018) express that risk assessment helps address the domino effect: where an accident in one piece of equipment triggers another, in which the risk assessment must be considered. Issues of risk assessment arise due to the growing number of accidents and incidents involving LPG and the necessity to accelerate efforts to prevent possible accidents and incidents that can cause serious injuries to people even outside inhabited areas and damage to the environment. In preparing the framework of prevention and preparedness for accidents related to LPG retail outlets, risk analysis and assessment represent one of the most significant steps (Bernatik and Bartlova 2018). This is why the Nigerian Guidelines for the Establishment of LPG Refilling Facilities and Retailers' Outlets focus on ensuring compliance with health, safety, and environmental standards. These guidelines stipulate the minimum requirements, procedures, and conditions necessary before granting approvals or licenses for the construction, installation, modification, and operation of downstream gas facilities in a particular location in Nigeria (NUPRC, 2020a; Tonbofa, 2020).

The potential of a risk assessment guide or framework for siting LPG retail outlets is crucial to ensure the safety of the public, employees, and the environment. This assessment involves identifying, evaluating, and prioritizing risks associated with the location, design, construction, and operation of LPG refilling facilities and retailers' outlets. The framework of assessment should consider factors such as proximity to residential areas, schools, hospitals, and other sensitive facilities, as well as the potential for accidents, leaks, fires, and explosions (NUPRC, 2020a). The assessment should include a thorough review of the site's topography, geology, and hydrology, as well as an analysis of potential hazards from nearby infrastructure, such as pipelines, power lines, and roads. The framework should also consider the design and construction of the facility, including the type and quality of materials used, the layout and arrangement of equipment, and the installation of safety systems, such as fire suppression, leak detection, and emergency response plans (Bernatik and Bartlova 2018).

Adhering to the potential risk assessment guide or framework, LPG retail outlets can minimize the risks associated with their operations and ensure the safety and well-being of their customers, employees, and the surrounding community. This is particularly important in Nigeria, where there is an increase in the proliferation of LPG retail outlets due to the increasing demand for LPG as a clean and efficient fuel source. The siting of these retail outlets requires rigorous safety measures and risk management practices, the DPR has warned LPG retail outlets against cylinder-to-cylinder gas refilling, emphasizing the need for safety measures in the industry (NUPRC, 2020b). Mirza *et al.,* (2011) reveal that the retail station safety and risk assessment framework provides a comprehensive approach to managing risks associated with hazardous workplaces, such as LPG retail outlets, which store and sell flammable materials like petrol, diesel, and Compressed Natural Gas (CNG).

3.1 Materials and Methods

The Study Area

The study area is geographically located within Latitudes 11° 10’ 59” N to 11° 25’ 44” N of the equator and Longitudes 07° 10’ 16” E to 07° 35’ 30” E of the Greenwich Meridian, See Figure 1, Chikum LGA in Kaduna State, Nigeria.

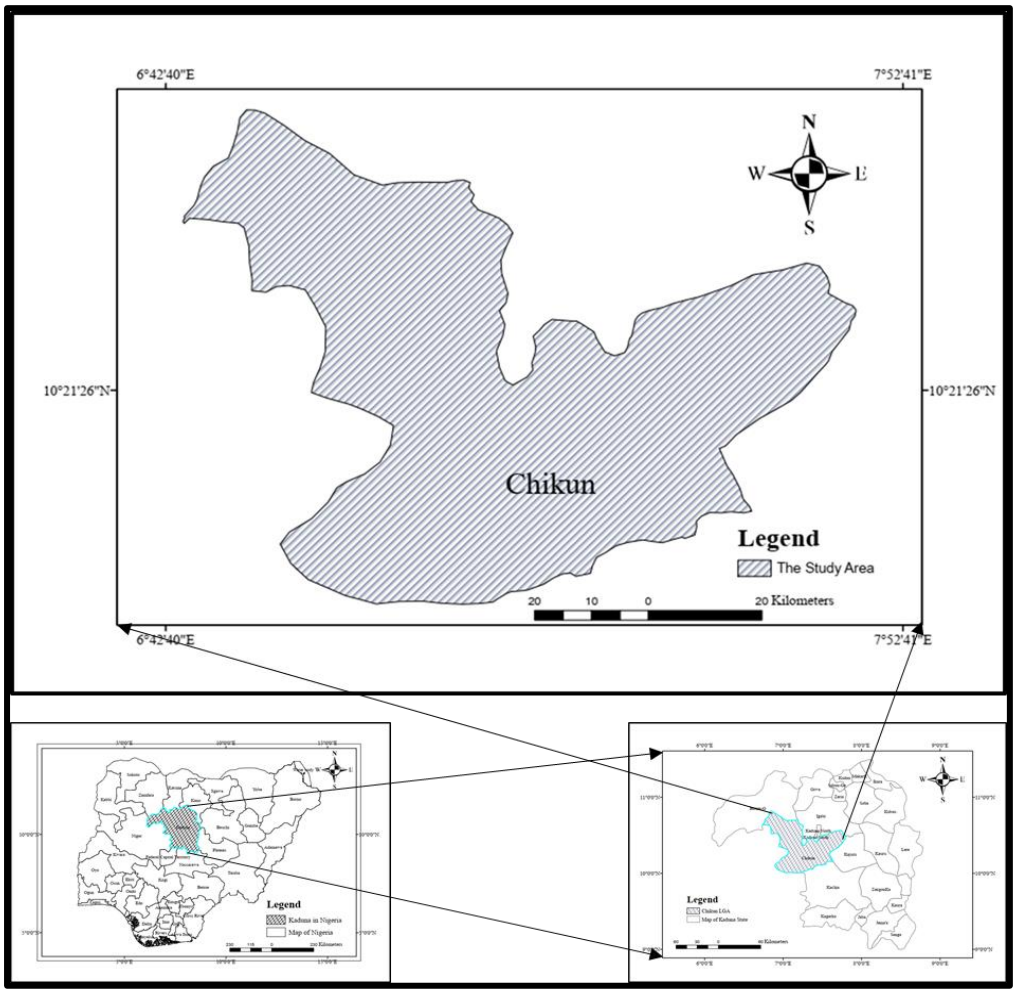

Figure 1: Chikun in Kaduna Nigeria
Source: Department of Geography Nigerian Defence Academy Kaduna (2024)

It has a surface area of approximately 4690.1 km^2 (Adewuyi *et al.,* 2019). Chikun Local Government Area lies on a gently undulating plain ranging from 450 - 650m above sea level, and it is underlined by the crystalline basement complex of the Precambrian age (Laka, 1998 cited in Danjuma, 2015). The study area is drained by small tributaries of river Kaduna (Adebayo et al., 2023). The climate of Chikun LGA is Tropical in nature (tropical dry and wet type), classified under Koppen 1948 climate classification as Aw, it has an average annual temperature of 25.2°C and sometimes it reaches 29 - 30^{0}C between March and April (Abaje *et al.,* 2016; Benedine and Adamu, 2017; Adewuyi *et al.,* 2019). Rainfall durations fluctuate between 150 to 190 days with an annual rainfall of 1500mm to 2000mm. The rainy season starts in late April to early October every year and the dry season sets in from mid-October to April of the following year (Aremu, 2020). The relative humidity falls between 20% and 30% in January and rises to between 60% and 80% in July (Mshelia *et al.,* 2020; Al-Amin and Dadan-Garba, 2014).

This study defined its target population as all LPG retail outlets in Chikun LGA of Kaduna State. Since the number of LPG retail outlets is unknown and for ease of data collection, Accidental/Snowball sampling techniques were employed to identify one major LG retail outlet `in each of the five clustered neighborhoods (Mararban Rido, Refinery/Sabo, Narayi/Barnawa/Television, Gonin Gora, and Kamazou/Karji) with 4 referrals each from the operators to form the sample LPG retail outlets. There will be 1st, 2nd, 3rd, and 4th referrals for data collection. The number of referrals will be 4 (20), major LPG retail outlets will be (5) and the total number of facilities for data collection were 25. An inventory of all LPG retail outlets was taken from which data was collected, these constitute both large refill facilities and roadside retailers' outlets. See Table 1 for the location of LPG facilities in Chikun LGA of Kaduna State. A GPS device, checklists and a Camera were used for data collection. The data was analyzed using frequencies and percentages.

Table 1: Location of LPG Facilities in Chikun LGA of Kaduna State

S/N	Name of Gas Station	Latitude	Longitude	Address
1	A.A Rano command Junction	10.445295	7.4236133	Command Junction Kachia Road, CCWF+58H, Kakuri, Kaduna South 800282, Kaduna, Nigeria
2	Aremas Gas	10.4388981	7.4941399	Refinery Rd, Kaduna 800104, Kaduna, Nigeria
3	CJL Road Site Gas Retail outlet opposite Steam Fast Karji	10.4841333	7.4690233	FFM9+J9Q Steamfast Garden and Recreation, Kamazo 800104, Kaduna, Nigeria
4	Road Site Retail Outlet COCIN Church Junction U/Maigero	10.4879167	7.4651883	FFQ8+42J, Angwan Maigero - Karji Rd, Kamazo 800104, Kaduna, Nigeria
5	Chichi Gas	10.4503566	7.4460033	FC2W+5FV, Saidu Ciroma Street, Ungwan Sunday, Kaduna 800104, Kaduna, Nigeria
6	Del-View Gas Television	10.4444017	7.42743	CCVG+WX2, A 235, Television, Kaduna 800282, Kaduna, Nigeria
7	Demyke Gas plant Gonin Gora	10.4239491	7.4018253	CCF2+JVG, Goni Gora, Pa 800104, Kaduna, Nigeria
8	Edi Jen Cooking Gas	10.4633167	7.4447733	82 King Hassan Street, Barnawa, Barden Yana 800104, Kaduna, Nigeria
9	Grand systems cooking Gas	10.4361133	7.5365417	A235, Rido 800104, Kaduna, Nigeria
10	Road Site Retail Outlet opposite Las Vergas Sabo.	10.455349	7.4537281	150, Poat Office Road, Sabon Tasha, Kaduna South, Ungwan Sunday, Barden Yana 800104, Kaduna, Nigeria
11	Mabsdallah LPG Gas Plant Kaduna Refinery Access Road	10.434905	7.4931683	CFMV+XC5, Ungwan Galadima-Muye, Kaduna 800104, Kaduna, Nigeria
12	NNPC Gas opposite Kad. Poly Sabo	10.44596	7.4460467	A235, Television, Kaduna 800104, Kaduna, Nigeria
13	NPC/KRPC LPG Filling Bay	10.44199	7.4922617	1, KRPC Road, Kura 800104, Kaduna, Nigeria

14	Road Site Retail Outlet Opposite First ECWA U/Maigero	10.487955	7.4652383	FFQ8+42J, Angwan Maigero - Karji Rd, Kamazo 800104, Kaduna, Nigeria
15	Opposite Living Faith Church Sabo	10.4500682	7.4629218	14, Kachia Road, Sabon Tasha, Kaduna South, Tsaunin Kura, 800104, Kaduna, Nigeria
16	Road Site Retail Outlet Opposite the Lord Chosen Junction	10.4751284	7.4425933	FCFV+X2R, Galadima St, Barnawa, Tudun Wada 800104, Kaduna, Nigeria
17	Ozams Gas Plant	10.4337036	7.4941603	CFMV+XC5, Ungwan Galadima-Muye, Kaduna 800104, Kaduna, Nigeria
18	Regent Gas Ltd.	10.4379697	7.493835	Refinery Rd, Kura 800104, Kaduna, Nigeria
19	Road site Opposite St. Fidelis Academy Narayi	10.4783649	7.4516867	FFH2+7HQ, Narayi, Tudun Wada 800104, Kaduna, Nigeria
20	Shafa Gas Energy	10.452665	7.42312	10, Kachia Road, Chikun, Kakuri, 800282, Kaduna, Nigeria
21	Sharon	10.4802072	7.4529339	Unnamed Road, Barnawa, Tudun Wada 800104, Kaduna, Nigeria
22	Sharon Gas Plant Gonin Gora	10.4328817	7.4039267	CCM3+6G6, Gonin gora, Kaduna 800104, Kaduna, Nigeria
23	Stallion Gas plant Gonin Gora	10.4223233	7.4015564	CCC2+XQ9, Goni Gora, 800104, Kaduna, Nigeria
24	Thelifa Gas Plant Gonin Gora	10.4219734	7.4015201	CCC2+JQR, Gonin Gora, Kaduna 800104, Kaduna, Nigeria
25	Zazi Sofi Cooking Gas	10.4365367	7.5159333	A235, Rido 800104, Kaduna, Nigeria

Source: Field Work, 2024

3. RESULTS AND DISCUSSION

3.1 Spatial Locations of LPG Retail Facilities in Chikun LGA

The inventory of LPG retail facilities in the study area is presented in Figure 2, revealing the pattern of distribution of LPG retail facilities. The distribution follows a linear pattern as the facilities are located along access roads. Along Refinery roads and Gonin Gora, two LPG facilities located along the sharing fence, rendering either of the two vulnerable in the event of any incident of fire disaster. This negates the 100m distance requirement between facilities. Also, most of the facilities share fences with residential buildings or commercial properties, which is against the requirement of being located away from a population with a refill facility sharing a fence with an event center. Roadside retail outlets are located in shops that deal in different wares with many occupants residing in these locations, thus negating the desire for safety that this study is aimed at. This non-compliance is in variance to the recommendation of the Department of Petroleum Resource (DPR) that specified at least 50m away from the built environment and at least 100m from schools, health facilities, theatres, and other public and semi-public buildings, and a distance of at least 15m from the edge of the road to the nearest pump (Arokoyu *et al.,* 2015; NUPRC, 2020a).

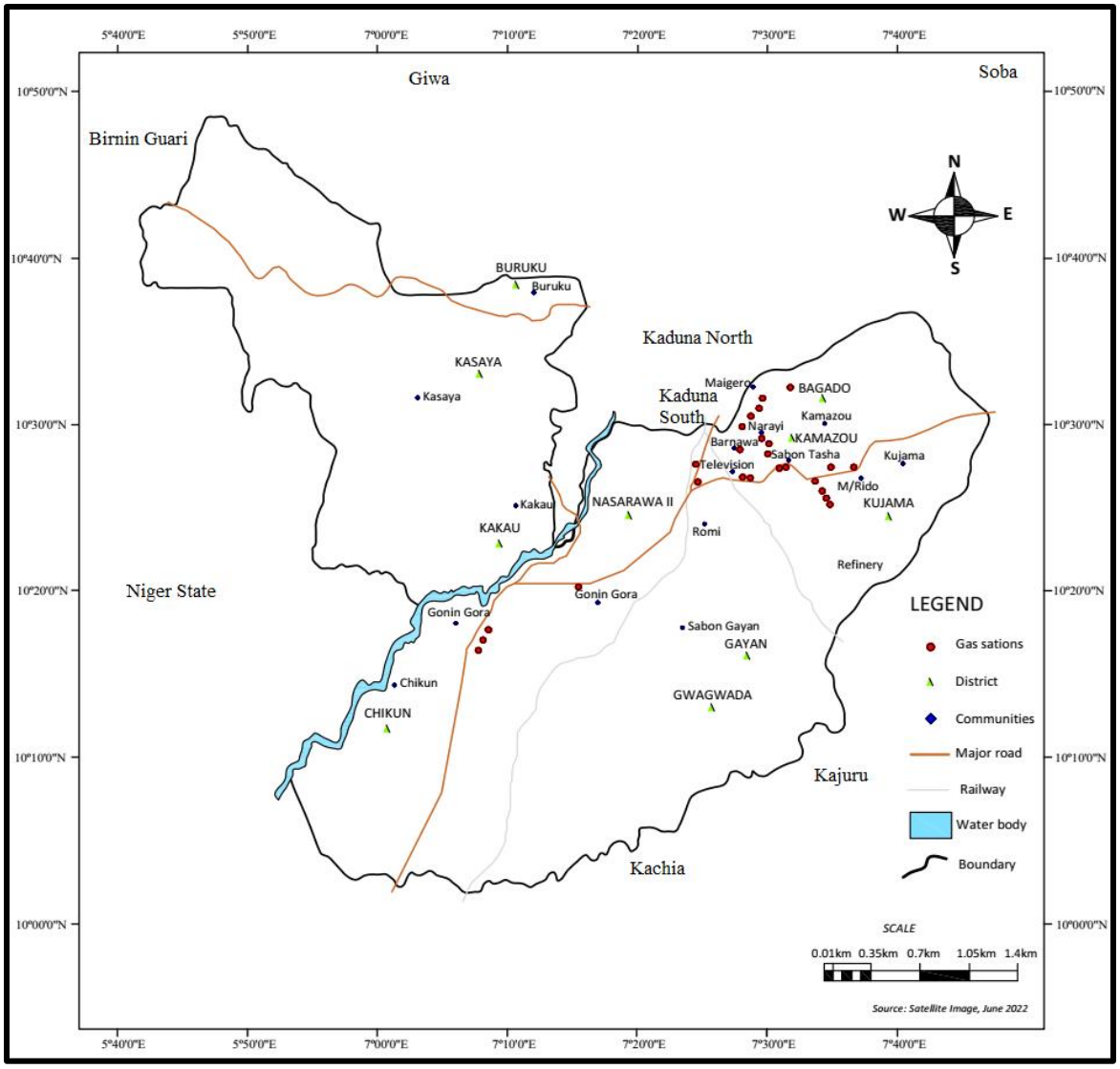

Figure 2: Spatial Locations of LPG Retail Facilities in Chikun LGA
Source: Student Field Work (2024)

3.2 Compliance with Safety Measures to Protect Lives and Properties

This section seeks to discuss the findings from the assessment of the safety measures in LPG refill outlets and whether the siting of the LPG retail outlets was guided by a potential risk assessment. The rationale behind this is to demonstrate the level of compliance with the NUPRC (2020a) framework for siting LPG facilities. This framework specifies that LPG facilities should consider factors such as proximity to residential areas, schools, hospitals, and other sensitive locations, as well as the potential for accidents, leaks, fires, and explosions.

3.2.1 Restriction of Population Close to Facility Dispensing Points

The study also sought to find out whether the population is restricted close to facility dispensing points. The result presented on Figure 3 shows that cumulatively, the study is satisfied with 72% of the LPG retail facilities in their restriction of the population close to dispensing points, these constitute the refill facilities, while the study is dissatisfied with 28% of the LPG retail outlet who are roadsides retailers (vendors) in their restriction of the population close to dispensing points of the facilities. The restriction of the population is because of the inherent risk attached to the handling and usage of the product in which a

small spark can ignite a fire. The findings of the study support the statement that there is often a lack of public awareness about the safe handling of LPG, which can increase the risk of accidents, thereby increasing risks and a reason to seek environmental safety and its sustainability (Ihemtuge and Aimikhe, 2020). To mitigate this disaster, refill facilities restrict people to dispensing points to avoid any unforeseen disaster. This is not the case with roadside vendors.

3.2.2 Promotion of safety within premises by retail staff in the LPG facility

The study sought to find out the level of safety promotion within premises by retail staff in the LPG retail facilities, as poor safety promotion is detrimental to the quest for environmental safety in LPG refill facilities and roadside vendors. Figure 4 presents the findings of the study and reveals that cumulatively, the study is satisfied with 72% as their staff promote safety in the LPG retail facilities, by assisting customers and restricting movement where necessary and engaging in creating awareness on the use of this clean energy sources for various purposes, while dissatisfied with 28% who constitute the road side vendors in the promotion of safety in the LPG retail facilities. The current safety in the premises of the LPG facility could not be unconnected to the DPR recommendations that urged LPG plant operators to take necessary measures to ensure the safety of end-users of cooking gas in Kaduna State (NUPRC, 2020a). See Plate 1. From all indications, roadside vendors are rarely regulated despite these promotion guidelines covering various aspects, including safety standards, environmental impact assessments, and compliance requirements for LPG operators (DPR, 2018).

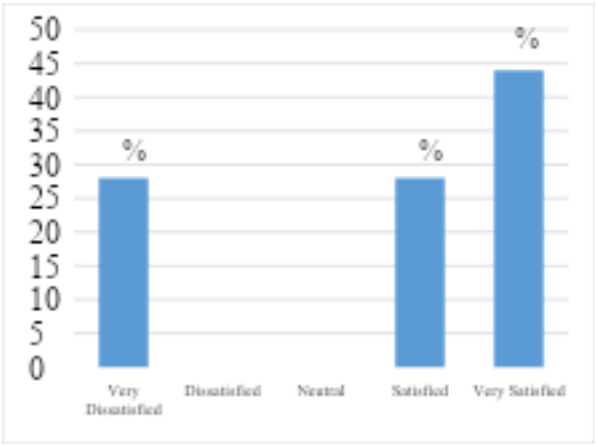

Figure 3: Restriction of Population Close to Facility.
Source: Author's Field Work (2024).

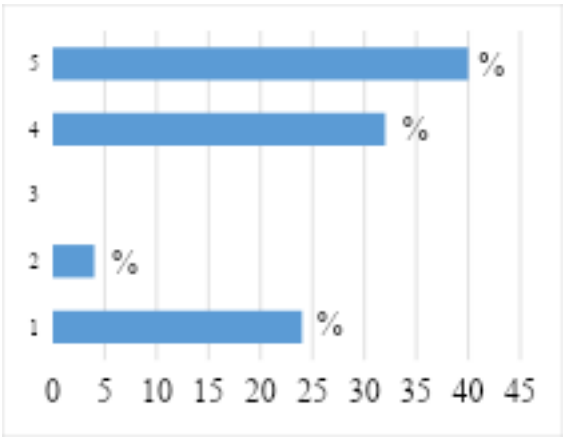

Figure 4: Promotion of safety within premises.
Source: Author's Field Work (2024).



Plate 1: A Protected Retail Point of LPG with Signage Describing Intrinsic Hazard.
Source: Author's Field Work (2024).

3.2.3 Compliance with the identification of hazard and risk prevention methods

The study sought to find out the compliance of LPG facilities in the identification of hazard and risk prevention methods. Findings of the study as presented in Figure 5 reveal that cumulatively, the study is satisfied with 72% of LPG facilities in their compliance with the identification of accidental risk and prevention methods, while the study is dissatisfied with 28% of LPG facilities in their level of compliance with the identification of accidental risk and prevention methods. This compliance level is in agreement with the importance attached to risk identification and assessment to reducing and addressing the domino effect: where an accident in one piece of equipment triggers another (Bernatik and Bartlova, 2018)

3.2.4 Compliance with Emergency Planning and Response to Avoid Injury

The study also sought to know LPG facilities' compliance with emergency planning and response to avoid injury. Figure 6 presents the findings of the study where the study is satisfied with 60% of the LPG facilities in compliance with emergency planning and response to avoid injury as the adhere to (NUPRC, 2020) recommended safety distances for tank locations, ensuring proper operation and storage within the cylinder filling shed and implementing protocols for emergencies to minimize risks. This is evident in most LPG retail facilities where you find fire extinguishers and signage with fire prevention inscriptions. The study is dissatisfied with 40% of the LPG retail facilities in terms of their compliance with emergency planning and response to avoid injury despite the existence of the minimum requirements stipulated in the guidelines and conditions necessary before granting approvals or licenses for the construction, installation, modification, and operation of downstream gas facilities in a particular location in Nigeria (NUPRC, 2020a; Tonbofa, 2020).

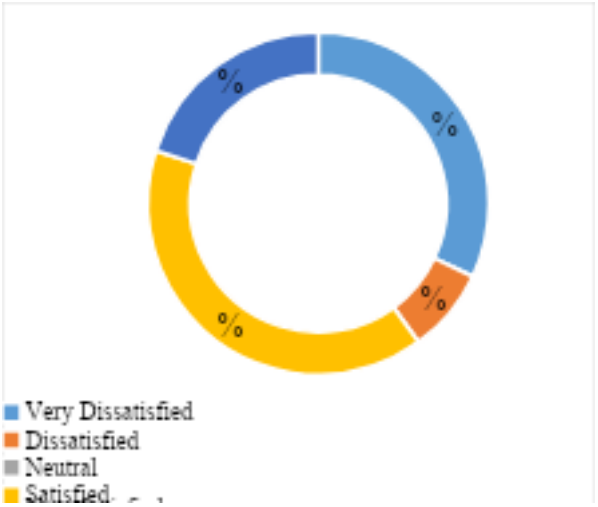

Figure 5: accidental risk and prevention methods.
Source: Author's Field Work (2024).

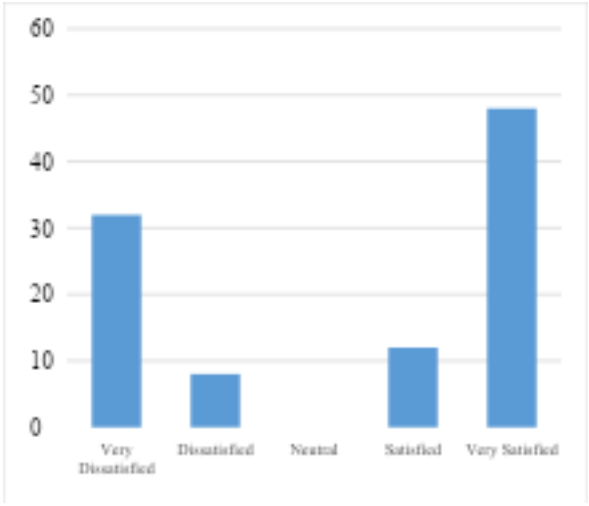

Figure 6: Compliance with Emergency Planning.
Source: Author's Field Work (2024).

3.2.5 Compliance with Construction Away from Large Sensitive Populations

Here, the study sought to find out the level of compliance with safety measures of locating LPG retail outlets away from sensitive populations. The result presented in Figure 7 shows that cumulatively, the study is dissatisfied with predominantly 56% of the LPG retail facilities/vending outlets in the level of their compliance with construction away from large or sensitive populations, this because of the their failure to maintain recommended safety distances from residential areas, schools, hospitals, and other sensitive locations to minimize risks in case of an accident, this is against the outburst of Jimoh (2023) who express that in the world of LPG retail, safety is non-negotiable as the handling and distributing this valuable energy source come with a host of responsibilities to ensure the well-being of employees, customers, and the environment. The study is satisfied 44% of with only the LPG retail facilities in the level of compliance with safety measures of construction away from large or sensitive populations. This finding shows poor adherence to the NUPRC (2018) and (2020) guidelines

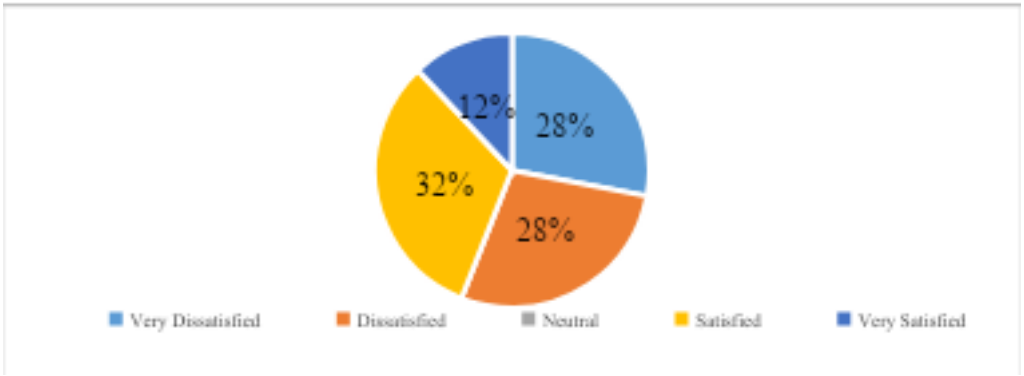

Figure 7: Construction away from sensitive populations
Source: Author's Field Work, 2024.

The findings of the study reveal ineffective of the governance framework in Chikun LGA to enforce compliance in siting of LPG retail facilities which is geared towards environmental safety and sustainability despite gas plant explosions becoming a recurring events across the country and raising questions about public safety, the desire for which is a result of chemical spills, explosions, fires, gas leaks, poisoning and radiation from processing, transportation, storage plants, and retailing in LPG facilities (Leadership, 2018; Akpi *et al.*, 2023).

COMPLIANCE WITH GUIDELINES OF POTENTIAL RISK ASSESSMENT IN SITING OF THE LPG RETAIL OUTLETS

3.3.1 Compliance with 100-Meter Distance between LPG Refilling Facilities

The study sought to determine the level of compliance of LPG facilities with the 100-meter distance requirement between facilities. Figure 8 presents the findings of the study where 92% of LPG retail facilities comply with the 100-meter distance requirement between one another. However, it is noteworthy to expose that 52% of these LPG retail facilities are located within petrol filling stations, another highly inflammable substance in Chikun LGA. Although the NUPRC (2020) allows LPG retail stations to be located within petrol filling stations, provided they meet specific safety and regulatory requirements, the majority of the LPG facilities located in filling stations are not spacious as recommended by the NUPRC (2020) guideline. Additionally, 8% of the LPG retail outlets do not fully comply with the 100-meter distance requirement between LPG refilling facilities to the extent that some are sharing a fence. This non-compliance contradicts the Department of Petroleum Resource (DPR) recommendation that LPG retail facilities should be spacious, accessible, located away from hazards like pipelines, high-voltage cables, and public buildings, and at least 100 meters away from existing LPG refilling plants (Tonbofa, 2020).

3.3.2 Compliance with Perimeter Fencing to Enhance Operational Safety

The study sought to find out the level of compliance with perimeter fencing of the LPG retail facility. Figure 9 reveals that 68% of the LPG retail facilities are fully in compliance with the requirement for perimeter fencing to enhance operational safety and prevent unauthorized access to the facility that may expose the facility to hazards, this will also acts as a barrier to contain potential hazards within the facility, minimizing the risk of accidents and ensuring the safety of nearby populations. This shows that most LPG facilities adhere to the required guidelines that mandate perimeter fencing as part of the safety and security requirements for LPG facilities to mitigate risks to public safety and health. Thirty-eight (38%) of the LPG facilities are not in full compliance with the requirement for perimeter fencing to enhance operational safety. Their non-compliance is against the requirement essentials for equipment and operational safety and environmental responsibility (Tonbofa, 2020)

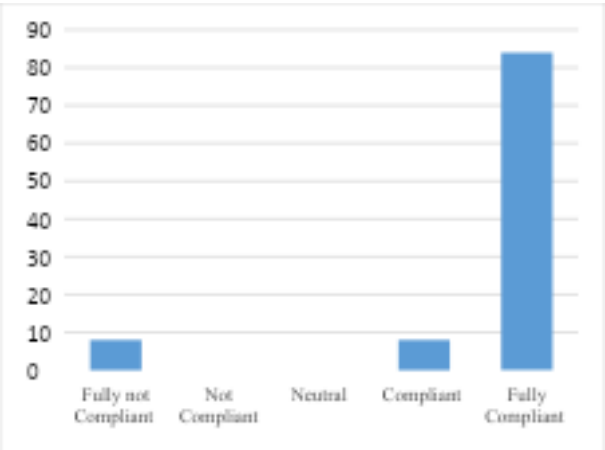

Figure 8: Compliance with 100 Meters Distance Apart.
Source: Author's Field Work (2024).

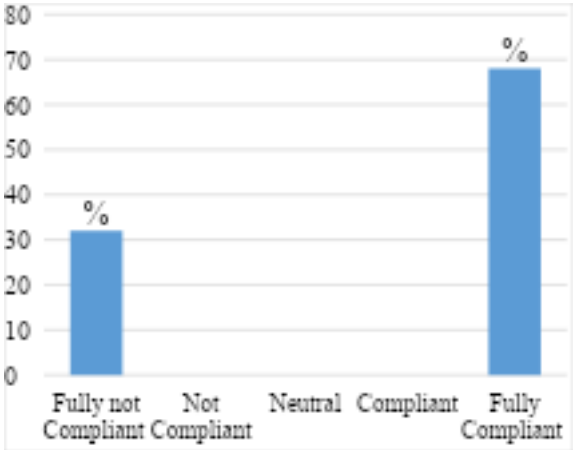

Figure 9: Compliance with Perimeter Fencing
Source: Author's Field Work (2024).

3.3.3 Layout Preparation from the Point of Safety

The study sought to find out if the layout of the retail facilities was prepared from the point of safety as recommended by NUPRC (2020). The findings of the study presented in Figure 10 reveal that cumulatively, the study is satisfied with 60% of LPG retail facilities as they consider safety in the preparation of the layout due to it importance in enhancing the safety this support the exposition of Jimoh (2023) compliance is essential to guarantee safe practices in the industry. While the study is dissatisfied with 40% of the facilities in their non-consideration of safety in the preparation of their layout. Therefore, it increases the susceptibility of the facility to risk and fire hazards and puts people's lives and properties in danger of being engulfed by the ensuing fire hazard. This could explain why the Kaduna State Government banned the retailing of cooking gas within residential areas and also shut down more than 87 gas retail outlets in the Kaduna metropolis, Zaria, and Kafanchan areas (NUPRC, 2020a).

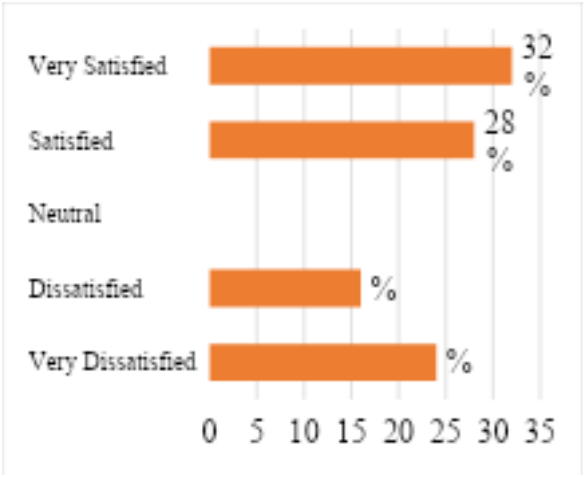

Figure 10: Layout prepared from the point of safety.
Source: Author's Field Work, 2024.

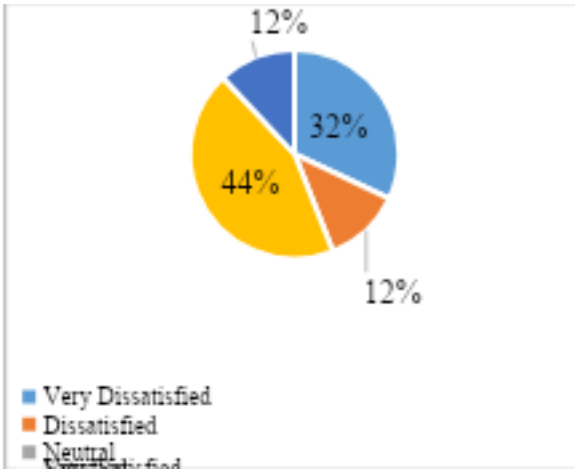

Figure 11: Description of Intrinsic Hazard.
Source: Author's Field Work, 2024.

3.3.4 Facility Compliance with the Description of Intrinsic Hazard

The study sought to find out the descriptions of intrinsic hazards and technical equipment in LPG facilities for safe operation. Figure 11 reveals that cumulatively, the study is satisfied with 56% of the LPG facilities for complying with the description of intrinsic hazard and technical equipment, while in 34% of the LPG retail facilities, the study is not satisfied in compliance with the description of intrinsic hazard and technical equipment. The description of intrinsic hazard increases people's awareness about the danger inherent in LPG facilities and their operations. The findings of the study support Mariani and Vallerotonda (2008) exposition of the description of intrinsic hazed in LPG retail facilities as a measure of protection and intervention to limit the consequences of an accident and supply information to the competent authority for the preparation of external emergency plans and it will help in reducing the vulnerability and the susceptibility of people to the impact of disaster when it occurs.

4.10 Facility Compliance with the Internal Emergency Plans

The study sought to find out compliance with the internal emergency plan, Figure 12 reveals that cumulatively, the study is satisfied with 68% of the LPG facility in their compliance with the internal emergency plans, while dissatisfied with 32% of the LPG facility in their compliance with the internal emergency plans. Compliance with internal emergency plans in LPG facilities is vital for ensuring safety, meeting legal requirements, managing risks

effectively, and fostering a culture of preparedness. This supports why Satest (2023) revealed that it is a comprehensive approach not only to protect employees and the surrounding community but also enhance operational resilience in the face of emergencies

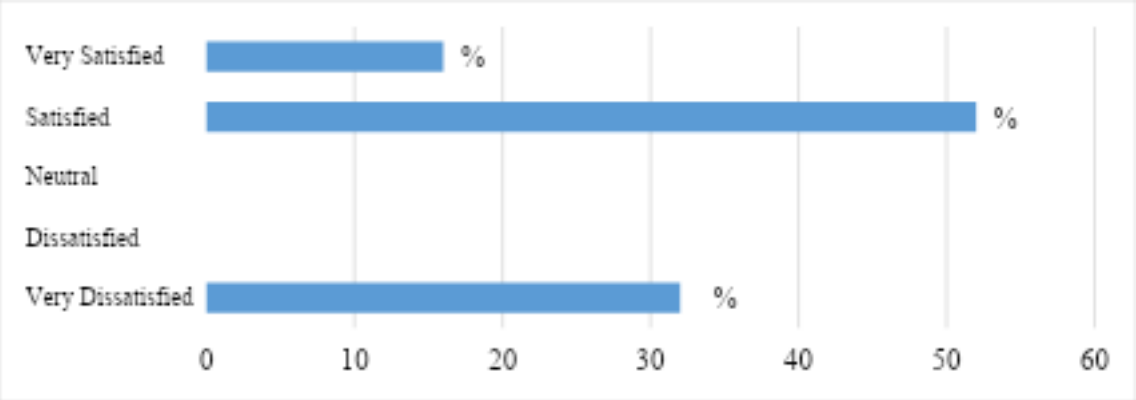

Figure 12: Compliance with the internal emergency plans
Source: Author's Field Work (2024).

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The assessment of LPG retail points in the Chikun Local Government Area revealed significant environmental safety concerns. While essential for meeting community energy needs, improperly regulated siting and retailing of LPG pose risks to the environment and public health. The study highlights the need for a systematic approach to ensuring environmental safety, including regulatory enforcement, GIS mapping, public education, training, environmental impact assessments, and collaboration.

RECOMMENDATIONS

The government, through the planning authorities in the state and local government area, should ensure strict enforcement of regulations governing the location and operation of LPG refill points, including setting minimum distances from residential areas and implementing regular inspections to ensure compliance and check roadside vendors' activities. Local government-wide public awareness campaigns to educate residents and gas station workers about the risks associated with LPG retail points and the importance of fire emergency preparedness should be carried out to propagate the required mitigation strategy in the residents.

No LPG retail facility or retail outlet should be sited without a detailed environmental impact assessment and environmental impact assessments for existing LPG refill points to identify potential risks and mitigate them as operations continue. Provide regular training on fire emergency response and safety procedures for gas station workers that are by the world's best practices and ensure strict adherence to safety guidelines and regulations and enforced by local authorities. Use GIS mapping to identify high-risk areas and inform strategic planning for environmental safety and deploy the necessary countermeasures for the protection of lives and properties of the citizens.

REFERENCES

Adebayo, A., Adamu, S., Audu, Y., & Danzaria, S. (2023). Analysis of Drainage Pattern of Chikun Local Government Area of Kaduna State, Using GIS and Remotely Sensed Satellite Imagery. *Journal of Systematic and Modern Science Research*, 2(2), 17–27. https://berkeleypublications.com/bjsmsr/article/view/95

Adewuyi, T. O., Daful, M. G., & Olofin, E. A. (2019). Characterisation of Land Degraded Sites for Restoration along Kaduna-Abuja Expressway, Chikun L.G.A. of Kaduna State Nigeria. *Ghana Journal of Geography* 11(1), 58 – 71. https://dx.doi.org/10.4314/gjg.v11i1.4

Akpi, A., Mmom, P. C., & Olanrewaju, L. (2023). Liquefied Petroleum Gas Stations Disaster Risk Preparedness Assessment of Port Harcourt City, Nigeria. *Journal of Risk Analysis and Crisis Response*, *13*(3), 209–219. https://jracr.com/index.php/jracr/article/download/385/413

Al-Amin, M. A. & Dadan-Garba, A. (2014). Urban Vegetation Study of Kaduna Metropolis using GIS and Remotely Sensed Data. *Journal of Natural Sciences Research* www.iiste.org 4 (2), 160–171. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=7c9e24eb284c6c21ebd3d28b9002d0c01a7088fc

Almadiana, C. S., & Tualeka, A. R. (2020). Determination of safe benzene concentration at Ciputat gas station. *Indian Journal of Forensic Medicine and Toxicology*, *14*(1), 124–129. https://repository.unair.ac.id/93292/1/2-Co-Author-Abdul%20Rohim%20Tualeka%20edit.pdf

Apeh, S. T., Erameh, K., B., & Iruansi, U. (2014). Design and Development of Kitchen Gas Leakage Detection and Automatic Gas Shutoff System. *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)*, 5(3), 222–228.

Aremu, J. K. (2020). *The Language of Meteorology*. Cee Kay Bee Publisher, Kaduna.

Azi, M. B., Pius, W. W., Sule, B., & Nuhu, G. A. (2023). Hike in Price of Gas: A Threat to Environmental Sustainability in Nigeria. *IMSUCDS International Journal of Development.* 6, 166–181. https://www.imsucds-ijd.com

Badro, O. I. (2022). Liquefied Petroleum Gas. Retrieved from https://www.researchgate.net/publication/360951488

Benedine, A., & Adamu, I. T. (2017). Determining the Rate and Pattern of the Spatio-Temporal Growth of Kaduna Metropolis, Kaduna. *International Journal of Geography, Environment and Earth Science*, *11*(1), 1–10.

Bernatik, A. & Bartlova, I. (2018). Risk Assessment for LPG Storage. *Applied Human Factors and Ergonomics International.* Physical Ergonomics I (2018) *https://openaccess.cms-conferences.org/#/publications/book/978-1-4951-2104-3*

Bhutan: Standard Operating Procedure for Storage and Handling of Liquefied Petroleum Gas At LPG Retail Outlets, (2024). Ministry of Industry, Commerce and Employment. Retrieved from https://www.moice.gov.bt/wp-content/uploads/2024/03/sop-for-storage-and-handling-of-liquified-petroleum-gas-at-lpg-retail-outlets-2024.pdf

Calister N. O., Fidelis, C. O., & Handel, C. E. (2021). Innovative Smart Gas Accident Detection and Prevention System for Nigeria" *Published in International Journal of*

Trend in Scientific Research and Development (IJTSRD), 6(1), 1475–1483, www.ijtsrd.com/papers/ijtsrd48015.pdf

Canadian Centre for Occupational Health and Safety [CCOHS] (2022). Retrieved from: https://www.ccohs.ca/ccohs/rpp/2022/default.pdf

Chinedu, C. (2022). Explosion rocks gas station in Port Harcourt. Retrieved from https://dailypost.ng/2022/10/19/explosion-rocks-gas-station-in-port-harcourt/.

Danjuma, E. S. (2015). *Infant and Child Mortality Differentials in Chikun Local Government Area, Kaduna State.* Unpublished M.Sc Thesis, School of Postgraduate Studies, Ahmadu Bello University, Zaria, Nigeria.

Department of Petroleum Resources (2018*). Procedures and Conditions to be fulfilled before the Grant of Approval and Licence for the Construction / Installation, Modification, Relocation and Operation of Liquefied Petroleum Gas (LPG) Facilities*. Retrieved from https://www.nuprc.gov.ng/wp-content/uploads/2019/05/LPG-Guidelines-Issued-September-2018.pdf?form=MG0AV3&form=MG0AV3

Egufe, Y. **(**2021). *3 victims of Port Harcourt gas plant fire dead. Port Harcourt: Vanguard newspaper,* Retrieved from https://www.vanguardngr.com/2021/01/3-victims-of-port-harcourt-gas-plant-fire-dead/.

Gatawa, N. M., & Abdullahi, Z. (2017). Impact analysis of petroleum product price changes on households' welfare in Zaria Metropolis, Kaduna State. *International Journal of Humanities and Social Science Invention, 6*(4), 40-49.

Gürsan, C., & de Gooyert, V. (2021). The systemic impact of a transition fuel: Does natural gas help or hinder the energy transition? *Renewable and Sustainable Energy Reviews,* 138: 1–21.

Hammeed, G. A., Orifah, M. O., Ijeoma M. C., & Tijani. S. A. (2016). Assessment of the Use of Liquefied Petroleum Gas (LPG) as Cooking Energy Source among Rural Households in Badagry Area of Lagos State. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)***,** 18(1), 16–28.

Ihemtuge, T. U., & Aimikhe, V. J. (2020). Optimization of Liquefied Petroleum Gas (LPG) Distribution in Nigeria. *International Journal of Engineering and Technical Research* (IJETR) 10(5): 8-14. https://www.researchgate.net/publication/341079371_

Jimoh, O. (2023). LPG Safety Practices Among Retailers: A crucial guide to secure operations. Retrieved from https://lpginnigeria.com/details/lpg-safety-practices-among-retailers-a-crucial-guide-to-secure-operations.

Jin, R., Wu, P., Ho, J.K., Wang, X., & Han, C. (2018). Five-Year Epidemiology of Liquefied Petroleum Gas-related Burns. *Burns,* 44(1), 210–217.

Kapı, E., Bozkurt, M., Filinte, G.T., Kuvat, S.V. & Alioğlu, C. (2017). An Unusual Etiology in Cold Injury: Liquefied Petroleum Gas. *Ulus Travma Acil Cerrahi Derg,* 23(3), 258-262.

Khavari, B., Ramirez, C., Jeuland, M. Jeuland**,** M., & Nerini F. F. (2023). A geospatial approach to understanding clean cooking challenges in sub-Saharan Africa. *Nat Sustain* **6**, 447–457 https://doi.org/10.1038/s41893-022-01039-8

Kumar, V. N., & Rajasekaran, D. N. (2016). Consequence Analysis of Hazardous Locations. *International Journal of Advance Research in Computer Science and Management Studies*, 4, (4), 165–175.

Kusumaningrum, D., Aidulsyah, F., and Meilianna, R. (2020). Tiga alasan mengapa Kartu Prakerja hanya memihak pada masyarakat perkotaan dan solusinya. *The Conversation*. Retrieved from https://theconversation.com/tiga-alasan-mengapa-kartu-prakerja-hanya-memihak-pada-masyarakat-perkotaan-dan-solusinya-138425

Lagos LPG Initiative, (2014). *Retrieved from.* http:www.lseb.gov.ng/content/ lagoslpg-initiative-eko-gas-scheme

Leadership (2018, Jan. 16). *Nigeria: gas plant explosions. AllAfrica Global Media*. Retrieved from https://allafrica.com/stories/201801160094.

Ma, G., & Huang, Y. (2019). Safety assessment of explosions during gas stations refilling process. *Journal of Loss Prevention in the Process Industries*, *60*, 133–144.

Marfo, S. A., Tawiah, S., & Naatu, F. M. (2016). *Risk Assessment of LPG Usage by Some Commercial Businesses in Tarkwa Municipality*. This paper was prepared for presentation at the SPE African Health, Safety, Security, Environment, and Social Responsibility Conference and Exhibition held in Accra, Ghana, 4-6 October 2016.

Matori, A. N., & Aulia, B. U. (2010). Suitability analysis of petrol filling station site using GIS. *Malaysian Construction Research Journal,* 7(2), 1–14.

Mirza, M. A., Kutty, S. R. M., Azmi M. S., & Mohd, F. K. (2011). *Petrol Fuel Station Safety and Risk Assessment Framework.* Conference Paper DOI: 10.1109/NatPC.2011.6136346

Mohammad M. K. (2020). Sensor-Based Gas Leakage Detector System. Presented at the 7th Electronic Conference on Sensors and Applications, 15–30 November 2020; Available online: https://ecsa-7.sciforum.net/.

Monney I, Dramani J. B., Aruna A., Tenkorang A. G., and Osei-Poku, F. (2015). Health and safety in high-risk work environments: A study of fuel service stations in Ghana. *Journal of Environmental and Occupational Science* 4(3),132–140. Access from: https://www.researchgate.net/publication/338838093_

Morales Terrés, I. M., Miñarro, M. D., Ferradas, E. G., Caracena, A. B., & Rico, J. B. (2010). *Assessing the impact of petrol stations on their immediate surroundings. Journal of Environmental Management, 91(12), 2754–2762.* doi:10.1016/j.jenvman.2010.08.009

Mshelia, S. S., Mbaya, Y.A. & Emmanuel, G. (2020). Environmental Effects of Cutting Down of Urban Trees for Road Constructions in Kaduna Metropolis. *International Journal of Advances in Engineering and Management*, 2(1), 176–186. www.ijaem.net

Nadi, D. (2018). *Many are feared dead as gas explodes in Nasarawa*. The Nation Online. Retrieved from: http://thenationonlineng.net/many-feared-dead-as-gas-explodes-in-nasarawa.

National Farmers Union NFU (u.d.). *Mutual Risk Management Services Limited*. Retrieved from https://www.nfumutual.co.uk/risk-management-services/#products

Neil, P. (2012). *The Benefits of a Risk-Based Approach to Facility Siting*. A paper Prepared for Presentation at 8th Global Congress on Process Safety Houston, TX April 1 – 4, 2012. https://iomosaic.com/docs/default-source/papers/the-benefits-of-a-risk-based-approach-to-facility-siting-2012.pdf?sfvrsn=20c1cdd4_18

Nigerian Upstream Petroleum Regulatory Commission [NUPRC] (2020a). FG Rolls Out Guidelines for Operations of Downstream Gas Facilities. Retrieved from: https://www.nuprc.gov.ng/fg-rolls-out-guidelines-for-operations-of-downstream-gas-facilities/

Nigerian Upstream Petroleum Regulatory Commission [NUPRC] (2020b). DPR *Prohibits Cylinder to Cylinder Gas Refilling – Official.* Retrieved from: https://www.nuprc.gov.ng/dpr-prohibits-cylinder-to-cylinder-gas-refilling-official/

Nirupama, D. (2010). *Risk assessment of Liquefied Petroleum Gas Storage Facility*. A Dissertation Submitted in Partial Fulfilment of the Requirement for the Award of the Degree of Master of Technology in Chemical Engineering.

Ogbette, A. S., Ori, O. E., Idam, M. O., & Abwage, S. T. (2018). Continuous Gas explosions in Nigeria: Causes and Management. *International Journal of Management Science and Business Research, 7*(10), 24–29. https://www.researchgate.net/profile/Afamefuna-Ogbette/publication/328916865_

Osinachi-Nwandem S. (2023). Ensuring Safe and Legal Operations: Requirements and Procedures for LPG Refilling Facilities in Nigeria. Retrieved from https://www.linkedin.com/pulse/ensuring-safe-legal-operations-requirements-lpg-osinachi-nwandem

Paliwal, G., Agrawal, K., Srivastava, R. K., & Sharma, S. (2014). Domestic Liquefied Petroleum Gas: Are we using a kitchen bomb? *Burns,* 40(6), 1219–1224. doi: 10.1016/j.burns.2013.12.023.

Philippines: Safety Standard Code for Practices, (2016). Code of Safety Practices for LPP in Retail Outlet. Retrieved from: https://doe.gov.ph/sites/default/files/pdf/announcements/dpns_doe_

Rocha, L.P., Cezar-vaz, M.R., Capa, M., Almeida, V., De Bonow, C.A. & Santos, M. (2014). Use of Personal Protective Equipment by Gas Stations Workers: *Text context Nursing,* 23(1):193–202. https://www.researchgate.net/publication/273667412_

Rwandan Provisional Technical Guidelines for LPG Operations (2010). Retrieved from: https://www.scribd.com/document/668156089/Draft-Technical-LPG-Operations

Satest, (2023). Safety First: How Our LPG Gas Franchise Ensures Compliance and Security. Access from: https://shivgas.com/lpg-gas-franchise-ensures-compliance-and-security/

Sehgal, M., Garg, A., Suresh, R., & Dagar, P. (2012). Heavy metal contamination in the Delhi segment of Yamuna basin. *Environmental monitoring and assessment*, *184*, 1181–1196. https://link.springer.com/article/10.1007/s10661-011-2031-9

Seven, E., Horoz, U., Sarı, E., Özakpınar, H. R., Sandıkcı, M. M., İnözü, E., & Tellioğlu, A. T. (2017). A rare type of burn injury due to butane gas inhalation. *Ulus Travma Acil Cerrahi Derg.* 23(3), 212-216. doi: 10.5505/tjtes.2016.37999

Sexton, C. (2024). Clean cooking could save half a million lives each year. Retrieved from https://www.earth.com/news/clean-cooking-could-save-half-a-million-lives-each-year/

Sirdah, M.M., Al Laham, N. A., & El Madhoun, R. A. (2013). Possible Health Effects of Liquefied Petroleum Gas on Workers at Filling and Distribution Stations of Gaza Governorates. *Eastern Mediterranean Health Journal*, 19(3), 289–294. https://pubmed.ncbi.nlm.nih.gov/23879082/

Tonbofa LP (2020). *Guidelines for the Establishment and Operations of Downstream Gas Facilities.* Retrieved from: https://tonbofa.com/guidelines-for-the-establishment-and-operations-of-downstream-gas-facilities/

United Nations Environment Programme (1998). *LP Gas Safety: Guidelines for Good Safety Practice in the LP Gas Industry*. Retrieved from https://wedocs.unep.org/20.500.11822/30155.

United Nations Environment Programme [UNEP], (2018). Guidelines for Good Safety Practices in the LP Gas Industry. Retrieved from https://wedocs.unep.org/xmlui/handle/20.500.11822/30155?show=full

Wang, W., Jiang, F., Jiang, Q., Shen, H., Zhang, R., & Liang, D. (2019, October). Characteristic and Fire Experiment of Gasoline Spraying in Gas Stations. In 2019 9th International Conference on Fire Science and Fire Protection Engineering (ICFSFPE) (pp. 1–7). IEEE.

World Health Organization (2018). Ambient (outdoor) Air Pollution. Retrieved from http://www.who.int/mediacentre/factsheets/fs313/en/index.html

World LPG Association (WLPGA). Guidelines for Good Safety Practices in the LPG Industry, 2018: https://www.wlpga.org/wpcontent/uploads/2015/09/wlpgabusinesspractices-2011-2.pdf

Zambian Guidelines for Siting of Petroleum Infrastructure (2022). Retrieved from https://www.erb.org.zm/wp-content/uploads/REVISED_