Fire Risk Evaluation for Petroleum Products handling Facilities in Niger Delta Region, Nigeria

ABSTRACT

This study is an evaluation of the level of fire and explosion risks in petroleum handling facilities in the Niger Delta Region, Nigeria. A descriptive cross-sectional research design was employed using Stratified & Purposive sampling techniques for data collection. A Standard checklist of 17 compliance specifications of Nigerian Upstream Petroleum Regulatory Commission (NUPRC) was adopted and a walk-through survey was carried out in 118 identified facilities in 3 urban locations: Eket, Port Harcourt and Warri, respectively. Inferential and descriptive statistics were analysed using XLSTAT version 17,and the level of risk calculated as the product of the likelihood of the hazard occurring and its consequence (Severity). The level of Risk was then rated on a 5x5 Risk Assessment Matrix. The result obtained revealed that 95.37% of the 118 stations sampled rated from Medium to High Risk. This calls for a great concern and urgent need for intervention. It is therefore recommended that Facility owners should demonstrate more seriousness to safety policies; provide adequate safety measures to safeguard their facilities and engage qualified Safety officers to carry out Facility specific Fire and explosion risk assessments and manage their safety concerns.

KEY WORDS: Risk Assessment, Filling station, Dispenser, seal, storage tank area, panel, nozzle, Fire, Explosion. Niger Delta.

1. INTRODUCTION

Accidents occur everywhere in the world and the consequences impact everyone including the employees; the Organization and members of the public, in one way or another. The International Labour Organization (ILO) statistics data estimates that about 2.3 million people worldwide would die due to work-related accidents and diseases yearly, which amounts to 6000 deaths every single day, (ILO, 2022). There are about 340 million Occupational accidents and 160 million victims of work-related illnesses, (Omrane, Mesrati, Khalfallah, Bouzgarrou, & Aissaoui, 2021).

Petroleum products handling facilities are important installations that maintain adequate and steady supply of the much-needed fuel for power generation for residential and industrial end-users (Arokoyu, Ogoro, & Jochebed, 2015). However, despite their profitability, these facilities are prone to fire and explosion risks notwithstanding the technological advancements targeted at designing out hazards (Afolabi, Olajide & Omotayo, 2011; Zhang, 2014). Most of the world's worst industrial disasters have been known to occur in these facilities resulting in multiple fatalities, adverse environmental pollution and huge economic losses (Zhou, Zhao, Zhao & Chen 2016).

Noteworthy are the Liquefied Petroleum Gas (LPG) storage and distribution facility explosion at San Juanico, Mexico which resulted in 500 fatalities and 7000 injuries (De Souza Porto & De Freitas, 2003). The reportedly most expensive industrial disaster: the Buncefield oil depot explosion in England, which occurred on 11th December 2005 in Britain which cost about $1.6 Billion in damages and several millions of dollars paid as fines and compensation (Capelle-Blancard & Laguna, 2008). Post explosion assessment revealed serious inadequacies in the system of fire and explosion risk assessment (FERA), which failed to identify inefficiencies in the design and maintenance of both the overfill protection systems and the liquid containment system. According to the report, the inefficiencies reportedly became the immediate causes of the accident.

In Nigeria, the frequency of these accidents during storage, loading or offloading, dispensing, pipeline vandalization and transportation of petroleum products is alarming with high number of casualties and adverse impact on the environment, (Ede & Edokpa, 2017). Various scientific studies have reported the negative impact of these accidents. Among these are: the Liquefied Petroleum Gas (LPG), station explosions in Lafia, Nasarawa State in which 9 people died and several others injured (Folorunso, Raheem, Akinyemi, & Raji 2019); Fire and explosion accident at OVH Energy Terminal in Lagos; a Petrol Station fire and explosion accident on Iwofe in Port Harcourt (See picture 1 below) in which nearby buildings and properties worth millions of naira were destroyed, (Itode, 2020) and Gas explosion in a Filling station at Agbor, Delta state resulted in 4 fatalities and 11injuries with various degrees of burns (Vanguard, 2021). These fire and explosion accidents in several parts of Nigeria portray lack of safety preparedness and poor management of fire and explosion risks at the petroleum products handling facilities (Ede & Edokpa, 2017; Adekitan, Matthews & Olasunkanmi, 2018).

(Source: https://www.onuafrica.com/just-in-a-p-filling-station-along-iwofe-road-port-harcourt-rivers-state-is-on-fire/)

Figure 1: Picture of fire and explosion incident at Petrol Station on Iwofe road, Port Harcourt

A comprehensive fire and explosion risk assessment in any large flammable liquid storage system is very crucial in managing fire and explosion risks. This research was therefore aimed at evaluating fire and explosion risks in petroleum product handling facilities using the Filling Stations in the Niger delta Region, as a case study.

2. MATERIALS AND METHODS

2.1 Study Area

The study was performed in three cities in the Niger-Delta, Nigeria; namely Warri in Delta State, Port Harcourt in Rivers State and Eket in Akwa-Ibom State.

Eket is regarded as the second largest city in Akwa Ibom State, Nigeria. It is an industrial city has a population of over 200,000. Port Harcourt metropolis in Rivers State, another study location for the present study, the city is located between latitudes 4°51’ 30’’N and 4° 57’ 30’’N and longitudes 6°50’ 00’’E and 7°00’ 00’’E. it covers approximately 370 km2 with an estimated population of over 3 million persons. Warri is located within latitude 5.544230 and longitude 5.760269. It has a land area of approximately 1,520 square kilometers and a population of 303,417 at the 2006 census. It harbours many industrial establishments including all the major oil companies operating in Nigeria; and petrol and gas stations in the state.

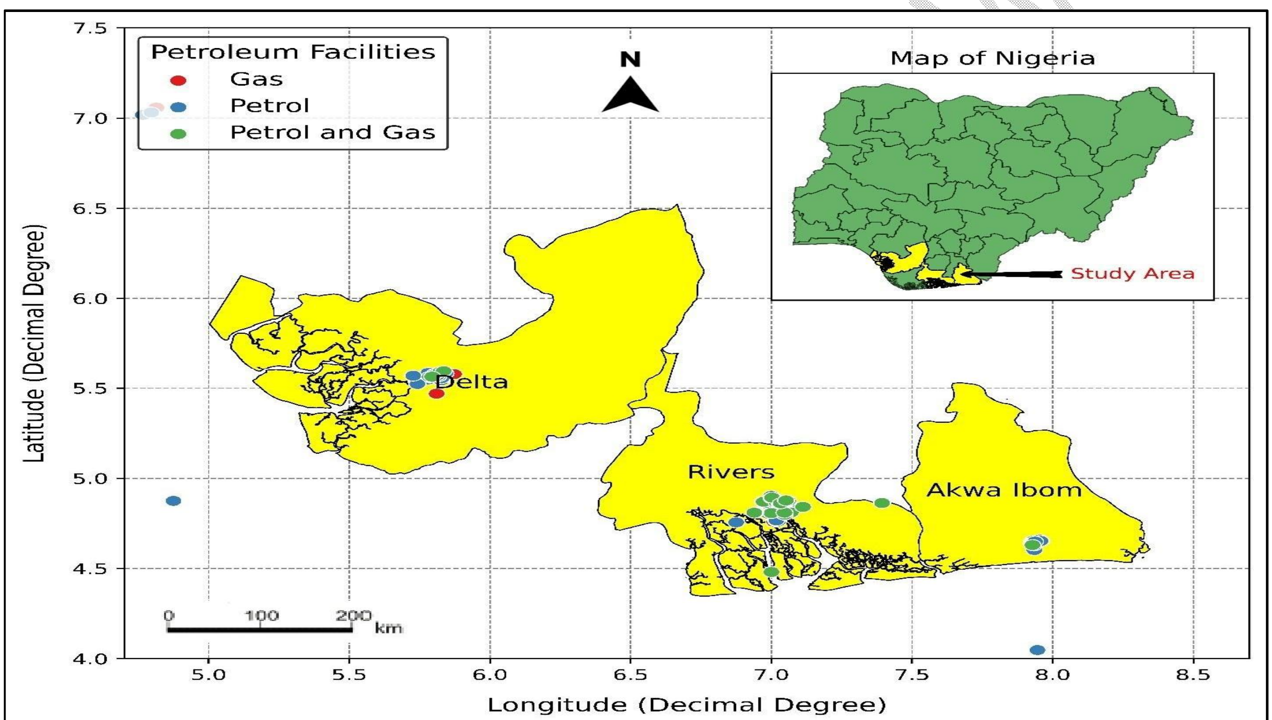

Figure 2: Niger Delta Region showing Study Area. (Source: GIS unit of the Department of Geography and Environmental Management, University of Port Harcourt, 2021).

2.2 Study design

This study adopted a descriptive cross-sectional design. The flow chart of the research is as shown in Figure 3.

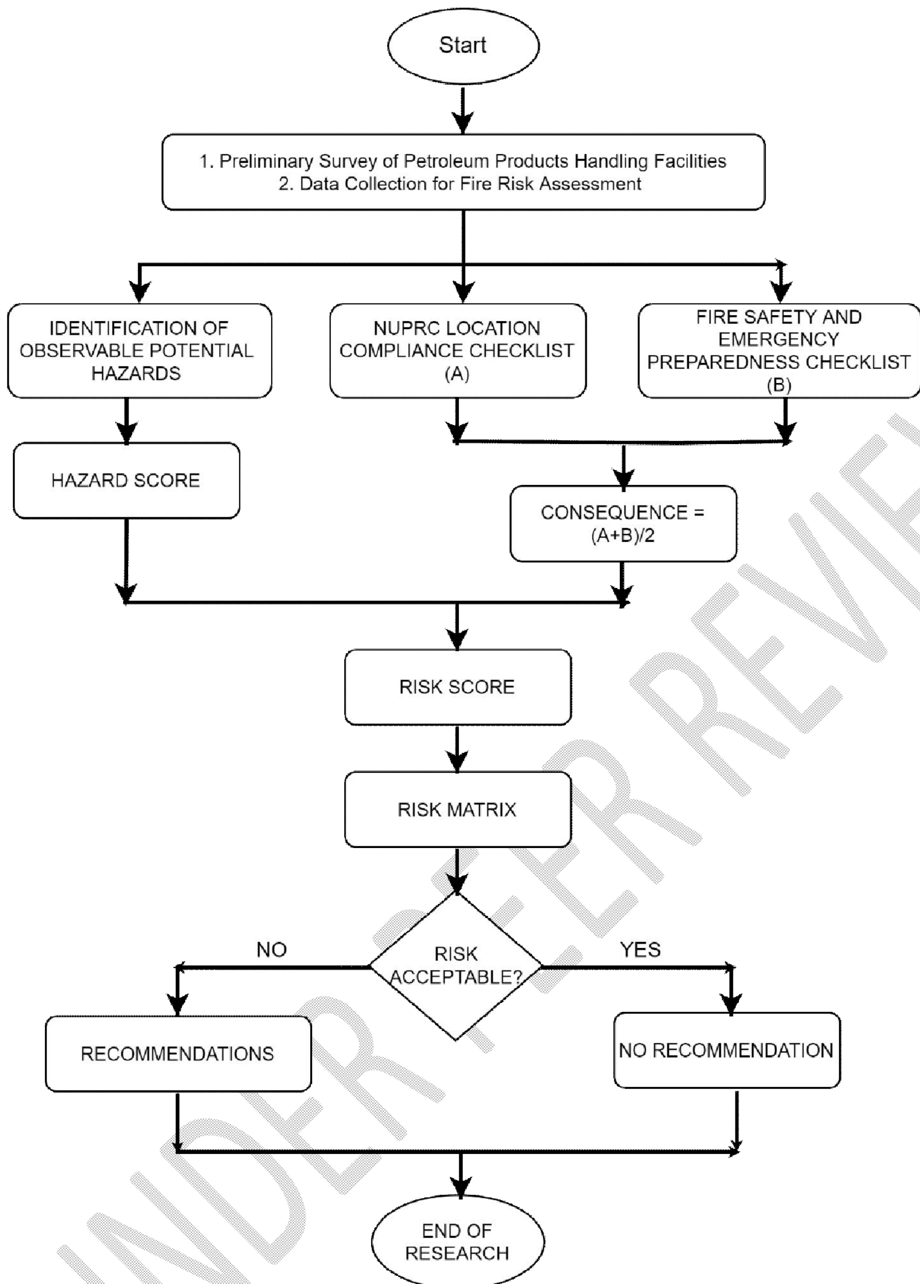

Figure 3: Fire Risk Evaluation Research Design Flowchart

2.3 Sampling and Sampling Techniques

A multistage cluster sampling technique was adopted for selecting the urban locations from the Niger Delta region (Nwaogazie, 2021 The following inclusive criteria were adopted as part and parcel of sampling technique: i) Must be a functioning retail filling stations; ii) The Filling station must have a dispensary capacity of 30000 litres (or above); and iii) The station must have up to 10 persons at risk within 100m radius of its environment

.Cochran's Formular (Nwaogazie, 2021), was sed in estimating the sample size of 180 Filling Stations. A hundred & eighty (180) copies of NUPRC Standard Checklist containing 17 specifications were used in collecting the data. One Hundred and eighteen (118) out of (180) sample size was used in the survey.

2.4 Method of Data Collection

A walk-through survey was done for a total of 118 petroleum handling facilities. The instrument for this study was a well-structured and standard Nigerian Upstream Petroleum Regulatory Commission (NUPRC) Checklist containing specifications for Location compliance, Hazardous area (Dispenser and Storage Tank area) and Fire Safety measure. The likelihood of fire and explosion occurring in the study area was determined through evaluation of Locational compliance, identification of potential fire and explosion hazards (at the dispensing points and the storage tank area) and the availability of Safety measures as stipulated by the NUPRC Standard.

2.5 Method of Data Analysis

The data collected were presented on a modified 5-point Likert scale and rated as: 1, 2, 3, 4, and 5, to represent Extremely Satisfied, Satisfied, Neutral, Dissatisfied and Extremely Dissatisfied respectively. By using the XLSTAT version 17, the Inferential and Descriptive statistics were performed and percentage compliance calculated to determine the compliance status for all the locations sampled.

2.6 Risk Evaluation

The data analysis output were used in evaluating the level of fire and explosion risk. Risk is defined as a function of probability of occurrence (likelihood) and consequence of a particular accident scenario.

Risk = Probability of the hazard × consequence due to hazard …… (1)

To evaluate the risk of fire and explosion occurring for each of the petroleum product handling facilities, the likelihood of all possible fire and explosion hazards in the stations were identified and rated. The consequence is the measure of expected effects as a result of the fire and explosion. Thus, evaluation of the risk was based on the following assumptions:

Assumptions 1: The likelihood of the fire and explosion hazards were determined from the observable potential hazards in the hazardous area (Dispenser and Storage tank areas)

Assumption 2: The consequence was evaluated based on the fact that violation of the Safety measures and locational compliance specifications will determine the extent (severity) of the incidence.

Thus, Stations with low safety measure (example: lack of fire extinguisher) will most likely result to higher consequence (more death or loss of asset) should fire and explosion occur at a particular station

Consequence = Locational compliance score + S&EP ……. (2)

Where S&EP = Safety and Emergency preparedness

Risk score = Hazard x Consequence ……….. (3)

The value of the Risk Score is cross checked with the Risk Assessment Matrix to obtain the Risk Rating (see Table 1a & b).

Table 1a: Risk Assessment Matrix

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Low Medium High

Table 1b: Explanatory key to Table 1a

RISK	DESCRIPTION	ACTION
15-24	High	A HIGH risk requires immediate action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form including date for completion.
5-12	Medium	A MEDIUM risk requires a planned approach to controlling hazard and applies temporary measure if required. Actions taken must be documented on the risk assessment form including date for completion.
1-4	Low	A risk identified as LOW may be considered as acceptable and further reduction may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded.

(Source: http://www.ehsdb.com/hira.php?disable_mobile=true)

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Case Study of Petroleum Products Handling Facilities

Hazard Rating

The average hazard score was computed from the data on visible or observable potential fire risk factors at the dispenser point and tank storage area which represented the likelihood of fuel release occurring at the station, (see Table 2).

Table 2: Hazards, Likelihood & Rating

Hazardous Area	Hazards	Likelihood	Hazard Rating
Dispenser	Panels and W&M seals condition.	Extremely Dissatisfied	5

	Hoses for kinks and damage.	Extremely Dissatisfied	5
	Nozzle cut-off device and individual dispenser isolation switches are working.	Extremely Dissatisfied	5
	Containment integrity.	Satisfied	2
Underground Storage Tank	Water build-up on tanks.	Dissatisfied	4
	Manholes free from water, product and adequately labelled on tanks.	Dissatisfied	4
	Filled pipes are locked appropriately.	Dissatisfied	4
	Ground offset fill point chambers are free from products, debris and labelled adequately.	Dissatisfied	4
	Manholes covers are seated correctly and can easily be lifted using appropriate lifting device.	Dissatisfied	4
	Tanks are of high quality.	Dissatisfied	4
		Average Hazard Score	4.1

Consequence rating

The consequence was rated using both the locational compliance and the safety measure.

Safety Rating is shown in the Table 3. The average safety and emergency score for the case study was 3.93

Table 3: Safety Measure, Rating & Safety Score

Safety Measure	Rating	Safety Score
All fire extinguishers are present, fully charged and the correct number are present with signs of damage.	Satisfied	2
Sand bucket are full of dried sand.	Extremely Satisfied	1
Test fire alarms/sensors are working perfectly.	Dissatisfied	4
Emergency switches (panic buttons) and loud speakers system are functioning properly.	Dissatisfied	4
First aid box contents are all complete.	Extremely Satisfied	1
Borehole water is readily available.	Extremely Dissatisfied	5
Fire action notice displayed and complete.	Extremely Dissatisfied	5
Assembly point sign displayed.	Extremely Dissatisfied	5
Safety policy statement is prominently displayed.	Extremely Dissatisfied	5
Lighting levels are adequate in all areas.	Extremely Dissatisfied	5
PPEs such as nose masks, reflective safety vests etc. are provided.	Satisfied	2
Presence of warning signs/advice notice conspicuous enough to draw the attention; clean and legible.	Extremely Dissatisfied	5
Quantity of Foam agent available.	Extremely Dissatisfied	5
Sprinklers available and functioning.	Extremely Dissatisfied	5
Facility appropriately classified according to probable Hazardous zones and clearly marked.	Extremely Dissatisfied	5
	Average Safety Score	3.93

The average Location compliance score (4.12) for the case study is presented in Table 4.

Table 4: Distribution of Locational Compliance scores

Locational Compliance	Rating	Locational Compliance Score
Minimum plot-size of fuel station shall be 35m x 35m.	Extremely Dissatisfied	5
Maximum plot coverage is 60%.	Satisfied	2
Mini vehicle manoeuvring area is $1100m^2$ with a minimum frontage of 9m facing the primary street.	Extremely Dissatisfied	5
Buildings inside the station must be at a minimum of 12m from the road property boundary.	Extremely Dissatisfied	5
Petrol pumps must be located at a minimum of 30m from residential buildings.	Extremely Dissatisfied	5
There should be a minimum distance of 10m UST and dispensing pumps.	Dissatisfied	4
There shall be a minimum of 3 dispensing pumps (one for each of the petrol, diesel and kerosene).	Extremely Satisfied	1
Minimum set back of stations to a 330kv line is 32m.	Extremely Dissatisfied	5
Minimum set back of stations to a 66kv power line is 8m.	Extremely Dissatisfied	5
Minimum set back of stations to a 132kv line is 16m.	Extremely Dissatisfied	5
The number of stations within 2km stretch on both sides of the road will not be more than 4.	Extremely Dissatisfied	5
Distance from the edge of the road to the nearest pump (not less than 15m).	Extremely Satisfied	1
The distance between stations will not be less than 400m.	Extremely Dissatisfied	5
The drainage from the station will not go into a stream or river/good drainage network.	Extremely Dissatisfied	5
Stations must be located at a minimum of 150m from any public building such as school, place of worship, market place, hospital etc.	Extremely Dissatisfied	5
The distance of station to residential structure (dwelling house) must be a minimum of 50m.	Extremely Dissatisfied	5
Wall fence demarcating the station (minimum height of 1.5m high).	Satisfied	2
	Average Safety Score	4.12

The Risk score for the filling station can be computed by combining the hazard score and the consequence score. The average value of the location compliance score and safety score made up the consequence score.

Consequence score = (4.12 + 3.93)/2= 4.025

Therefore Risk score = Hazard score x Consequence

= 4.1 x 4.025 = 16.50 (approx. to 17).

Risk score = 17.00.

Based on the foregoing sample calculations the risk rating for the case study is as shown in Table 5

Table 5: Risk rating for the case study

Stations	Type	State	Hazard Score	Land Score	Safety Score	Consequence	Risk Score	Risk Rating
A	Petrol	Port Harcourt	4.10	4.12	3.93	4.03	17	High Risk

This procedure was repeated for the 118 stations in the study area. The result for the top 10 stations with the highest likelihood of fire and explosion occurring is shown in Table 6.

Table 6: Top 10 Stations with high likelihood of fire and explosion

Stations	Type	State	Hazard Score	Land Score	Safety Score	Consequence	Risk Score	Risk Rating
A	Petrol	Port Harcourt	4.10	4.12	3.93	4.03	17	High Risk
B	Petrol	Warri	4.10	3.53	4.20	3.86	16	High Risk
C	Petrol	Port Harcourt	3.70	3.94	4.60	4.27	16	High Risk
D	Petrol	Port Harcourt	3.50	4.18	4.27	4.22	15	High Risk
E	Petrol and Gas	Port Harcourt	3.70	3.29	4.60	3.95	15	High Risk
F	Petrol	Port Harcourt	3.60	4.00	4.00	4.00	14	High Risk
G	Petrol	Port Harcourt	4.10	2.94	3.93	3.44	14	High Risk
H	Petrol and Gas	Warri	3.20	3.94	3.80	3.87	12	Medium Risk
I	Petrol and Gas	Warri	3.30	3.59	3.80	3.69	12	Medium Risk
J	Petrol and Gas	Port Harcourt	3.50	3.29	3.67	3.48	12	Medium Risk

3.2 Discussion

3.2.1 Fire and Explosion risk evaluation

The result of the study indicates that Fire and Explosion risk evaluation for Petroleum Products Handling Facilities could be based on the observable potential hazards, Fire safety and emergency measures and Location compliance. The result showed that of the 118 stations sampled in the Niger Delta region, 9(7.63%) were rated as high risk; 95(80.51%) as medium risk and 14(11.86%) as low risk.

Basically, petroleum products can be released either in liquid form or as vapour during maintenance or normal operations such as delivery, storage and dispensing at the filling stations, (Hilpert et al., 2015). A small quantity of unburned fuel vapour released during storage and delivery may not be noticed as it quickly dissipates into the atmosphere. Consequently, there is a potential reason to be worried as this study has revealed that 95.37% of all the 118 sampled stations rated from medium to High risk as a result of their poor condition. The cumulative effect of the fuel-air mixture concentration may build up to the appropriate flammability/explosive limit or range where Fire and Explosion incidence can occur in the presence of an ignition source, (Kundu, Zanguneh and Moghtaderi, 2016).

3.2.3 Observable conditions of Dispensing panels

Generally, the result of this study showed that 66.1% of the 118 stations sampled had their dispensing panels and seals in good condition while 33.9% of the total stations sampled were in dissatisfactory conditions because their dispenser panels were in poor condition, they had loosed seals, kinked/damaged hose, faulty nozzle cut-off device, uncovered fill points, corroded storage tanks and pipework, among others.

These could be potential sources for the release of petroleum products or fuel vapour. Similar findings were also reported in 68% of the sampled gas filling stations in Tehran and these were in high risk of fire and needed urgent reconstruction, (Nouri et al., 2010). Chaiklieng, Dacherngkhao, Suggaravetsiri and Pruktharathikul, (2020) observed that 40 out of 47 stations had intolerable fire risks in the fire hazardous zone 1of the dispenser area (within 1.5m radius of the dispenser pump and the refuelling area) while 7 stations had moderate risk level. They attributed the high risk to the presence of combustible vapours in high concentrations within ignitable range.

It is important that facility owners should endeavour to maintain dispenser unit, tanks and pipework etc. in good condition to prevent fire and explosion incidence in their facilities. Installation of Vapour Recovery System will significantly reduce the presence of flammable vapours in high concentration,(Chaiklieng et al. 2020).

3.2.3 Fire safety and emergency measures

The Fire safety and emergency measures in a petroleum product handling facility is critical in preventing the start of a fire or reduce the severity of its consequence. The result of this study shows a general poor appreciation for safety as majority of the safety parameters were dissatisfactory or extremely dissatisfactory. From the result, 69% of the total sampled stations did not have Fire alarm/sensor, 84% had no safety policy and no clearly marked hazardous area. However, 55.08% of 118 sampled stations had the correct number of Fire extinguishers which were fully serviced. Similar poor findings were observed in Dutse, Jigawa State in Nigeria where the overall fire safety preparedness within the petrol filling stations were rated as average, and only 27% of the total sampled stations had the correct number of fire extinguishers (Yunus, 2019).

One parameter assessed was the display of the Fire actions notice which contains Fire Service Emergency numbers critical for calling for assistance in event of fire. 65% of the stations did not comply with requirement contrary to the 81% compliance reported by Yunus, (2019).

3.2.4 Non-compliance to NURC Locational compliance specifications

The result of the study equally revealed gross non-compliance to the NURC Locational compliance specifications with only 6(35%) compliance by the 118 stations sampled.

Considering the requirements on the minimum set back distance from the residential areas and public infrastructures, the result shows that only 24% and 26% of the total stations sampled respectively complied with these requirements. The gross non-compliance is worst among the top ten stations rated high and medium risks as shown in Tables 5 & 7. Nouri et al. (2010) acknowledged that one of the key issues in assessing fire risks in filling stations is the location of the station to residential and public infrastructure because that could cause irreparable damage in event of fire and explosion incidence and their result showed that more than 89% of stations in Tehran were located close to residential homes. Also, Ojiako et al. (2016) reported only 18.42% compliance to residential buildings and Njoku and Alagbe, (2017) revealed 90% non-compliance in Oyo town, Nigeria. Olapeju and Farotimi, (2017) noted that 11(32.35%) of the samples PFS complied with the minimum setback distance of 100m from places of worship, 16(47.06%) from schools and 29(85.29%) from hospitals whereas Odikpe et al., (2018), reported 3% to schools, 76% to commercial areas, and 4% to hospital.

In contrast, Yunus, (2019) observed that none of the filling stations sampled in Dutse town in Jigawa state were located less than 100m from Schools, hotels/Guest houses. This disparity in compliance rate could be attributed to difference in the rates of development of the towns. The rate of urbanization in the oil rich Niger Delta region is obviously faster than in Jigawa state (the northern part of Nigeria) due to the rapid industrialization.

Rapid urbanization is a major driver for overpopulation, overcrowding, proliferation of Petroleum products filling stations and the consequent unavailability of land in the cities. In some places, the high cost of land rent has resulted in frequent conversion of spaces formerly designated as sites for Filling stations to residential areas. The close proximity of filling stations to the residential areas could play a significant role in increasing the severity of fire and explosion incidence due to the types of building materials used in construction and the distance between the buildings, (Mshelia et al., 2015; Wadembere & Apaco, 2020).

CONCLUSION

This study showed that fire and explosion risks in a petroleum product handling facility could be evaluated by assessing the Locational compliance specifications, identifying observable potential hazards and assessing the fire safety and emergency preparedness. The result showed that of the 118 stations sampled in the Niger Delta region, 9(7.63%) were rated as high risk; 95(80.51%) as medium risk and 14(11.86%) as low risk. Thus, revealing that 95.37% of stations sampled were rated from Medium to High risk. Out of these, top ten worst stations were presented here. Although the level of observable hazards at the dispenser point and Storage tank area were moderately low, yet there are clear indications that the fire and explosion risks are inevitable considering the levels of poor locational compliance and inadequate safety preparedness.

RECOMMENDATION

It is therefore imperative that facility owners must improve on their fire safety practices. Fire extinguishers should be adequately provided and maintained properly. Facility workers should be trained on how to use them. It is recommended that Facilities should have Safety Policy to define their commitments to no harm to people and the environment.

In addition, the NUPRC regulators and non-governmental organizations should carry out fire safety sensitization programs to educate the public especially those living around these facilities who are at risk of irreparable damage should fire and explosion accident occur. New permits for the construction of filling stations should not the awarded expect the NUPRC specifications are fully complied with.

REFERENCE

Adekitan, A. I., Matthews, V. O., & Olasunkanmi, O. (2018, September). A microcontroller-based gas leakage detection and evacuation system. In *IOP Conference Series: Materials Science and Engineering 413(*1), pp. 012008). IOP Publishing

Afolabi, O. T. (2011). Assessment of safety practices in filling stations in Ile-Ife, South Western Nigeria. *Journal of Community Medicine and Primary Health care, 23*(1-2), 9-15.

Arokoyu, S. B., Ogoro, M., & Jochebed, O. (2015). Petrol Filling stations' Location and Minimum Environmental Safety Requirements in ObioAkpor LGA, Nigeria. *International Journal of Scientific Research and Innovative Technology, 2*(11), 19.

Capelle-Blancard, G., & Laguna, M. A. (2008). The Buncefield oil depot explosion: where there's smoke, there's (stock market) fire?. *Applied Financial Economics Letters, 4*(2), 103-107.

Chaiklieng, S., Dacherngkhao, T., Suggaravetsiri, P., & Pruktharathikul, V. (2020). Fire risk assessment in fire hazardous zones of gasoline stations. *Journal of occupational health, 62*(1), e12137.

De Souza Porto, M. F., & De Freitas, C. M. (2003). Vulnerability and industrial hazards in industrializing countries: an integrative approach. *Futures, 35*(7), 717-736.

Ede, P. N., & Edokpa, D. O. (2017). Satellite determination of particulate load over Port Harcourt during black soot incidents. *Journal of Atmospheric Pollution, 5*(2), 55-61.

Folorunso, C. O., Raheem, W. A., Akinyemi, L. A., & Raji, A. A. (2019). Development of a Liquidified Petroleum Gas Leakage Detector, Level Indicator and Automatic Shutdown System. *Covenant Journal of Engineering Technology*

Hilpert, M., Mora, B. A. Ni, J., Rule, A. M., & Nachman, K. E. (2015). Hydrocarbon Release During Fuel Storage and Transfer at Gas Stations: Environmental and Health Effects. Current Environmental Health Reports, 2(4), 412–422. https://doi.org/10.1007/s40572-015-0074-8.

International Labour Organization, ILO, (2022). World Statistics: The Enormous Burden of Poor Working Conditions. *ILO Report*. Retrieved from: https://www.ilo.org/moscow/areas-of-work/occupational-safety-and-health/WCMS_249278/lang--en/index.htm

Itode, S. (2020, September 22nd). Tanker discharging petrol in Rivers explodes, destroys property. *Punch*. Available Online: https://www.nairaland.com/6135102/a.p-filling-station-port-harcourt-fire

Kundu, S., Zanganeh, J. & Moghtaderi, B. (2016). A review on understanding explosions from methane-air mixture. Journal of Loss Prevention in the Process Industries 40 (2016) pp. 507-523. Available online: www.elsevier.com/locate/jlp

Mshelia M., Abdullahi, j. and Dawha, D. (2015). Environmental Effects of Petrol Stations at Close Proximities to residential buildings in maiduguri.pdf. *IOSR Journal Of Humanities And Social Science, 20*(4), 01–08. www.iosrjournals.org

Njoku, C. G., & Alagbe, A. O. (2015). Site suitability assessment of petrol filling stations (PFSs) in Oyo Town, Oyo State, Nigeria: a geographic information systems (GIS) approach. *ISOR Journal of Environmental Science, Technology and food Technology (IOSR-JESTFT) 9*(12) 8-19. e-ISSN, 2319-2402.

Nouri, J., Omidvari, M. & Tehrani, S. M. (2010). Risk Assessment and Crisis Management in Gas Stations. *International Journal of Environmental Research, 4*(1), 143-152.

Available Online: https://scholar.google.com/scholar_url?url=https://www.sid.ir/EN/VEWSSID/J_pdf/108220100115

Nwaogazie, I. L., (2021). Probability and Statistics for Science and Enginnering Practice. (4th Edition), Print Konzults; Uniport Printing Press; De-Adroit. ISBN 978-8137-47-4

Odipe, O. E., Lawal, A., Adio, Z., Karani, G., & Sawyerr, O. H. (2018). GIS-based location analyses of retail petrol stations in Ilorin, Kwara State, Nigeria. International Journal of Scientific & Engineering Research, 9(12).

Omrane, A., Mesrati, M. A., Khalfallah, T., Bouzgarrou, L., & Aissaoui, A. (2021). When the Hijab causes death in the workplace…: A case series. *Forensic science international, 327*, 110965

Ojiako, J. C. ., Ekebuike, A. N., & Ndu, C. G. (2016). Locational Analysis of Filling Stations in Portharcourt Local Government Area Area, River State, Nigeria Using G GIS Approach. International Journal of Advanced Engineering, Management and Science (IJAEMS), 2(10), 1655–1658.

Olapeju, O & Farotimi, A. O. (2017). Assessing the Location and Spatial distribution of Petrol Filling Stations in Ilaro Ogun State. [Conference Paper presentation], 5th National Conference of School of Environmental Studies,8th-11th July, 2017. Ilaro, Ogun State Nigeria

Vanguard, (2021, January, 24). Agbor Gas Explosion: 4 dead, over 11 hospitalised. *Vanguardngr*. https://www.vanguardngr.com/2021/01/agbor-gas-explosion-4-dead-over-11-hospitalised/

Wadembere, I., & Apaco, J. (2020). Urban Spatial Risk Assessment of Fire from Fueling Stations on Buildings Case Study: Lubaga Division, Kampala City, Uganda. *Journal of Building Construction and Planning Research, 08*(01), 57–72. https://doi.org/10.4236/jbcpr.2020.81005

Yunus, S. (2019). Analysis of Locational Compliance and Fire Safety Preparedness among Petrol Filling Stations in Dutse Town , Jigawa State. *Confluence Journal of Environmental Studies, 1*(13, November), 107–118. http:www.journalhome.com/cjes

Zhang, H. Y. (2014). The research about fire prevention of vehicle refuelling stations. *Procedia engineering, 71*, 385-389.

Zhou, Y., Zhao, X., Zhao, J., & Chen, D. (2016). Research on fire and explosion accidents of oil depots. *Chemical Engineering Transactions, 51*, 163–168. https://doi.org/10.3303/CET1651028