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Spatial Distribution and Environmental Risk Assessment of Petrol Stations in Abeokuta Metropolis, Ogun State, Nigeria

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ABSTRACT: This study examined the spatial distribution and risk associated with the proliferation and indiscriminate establishment of petrol stations in Abeokuta metropolis, Nigeria. All effective parameters in petrol stations risks were identified and assessed using Williams–Fine and FMEA methods for petrol stations in the metropolis while structured questionnaire was administered on respondents near the petrol stations to elicit relevant information. Number of existing petrol stations, road networks and other spatial attributes served as input into the GIS environment with ArcGIS 10.0. Distances between road edge and petrol station, petrol station and residential buildings and between petrol stations were determined using preset criteria. The fire risk assessment revealed that 88 of the petrol stations had high risk (range: >201) while 20 and nine had medium (range: 201-101) and low (range: <100) risks respectively. Majority (113) of the 117 active petrol stations in Abeokuta have few or no functioning fire extinguishing systems, which make them vulnerable to fire incidences. Risk analysis indicated that distances between petrol stations and residential buildings in the metropolis does not comply with the 450 m distance standard. Majority were located within residential, commercial and educational land use areas where they constitute environmental risks including fire disasters, and soil and groundwater pollution.

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Keywords: Risk; Fire disaster; Petrol station; urban environment

Accelerated urbanization and rapid population increase are major factors affecting environmental quality in major cities throughout the world. Environment qualities especially in developing countries have deteriorated due to increasing economic activities many of which depends on energy supplied through petrol filling stations. Petrol filling stations are the core of economic development in many parts of the world as they fuel the movements of people, goods and services, which make the economy to function (Samuel, 2011; Ogunkoya, 2016; Douti et al., 2019). However, mounting evidence suggests that in cities nowadays, these fuel stations exact tremendous environmental and social costs (Isabel et al., 2010; Monney et al., 2015), particularly when they do not comply with the standard guidelines for their establishment. The haphazard and unprecedented emergence of petrol stations in residential and other inappropriate areas within the urban milieu in Nigeria shows that owners of these stations do not satisfy the basic requirements or undergo proper processes for approval (Michael, 2008; Abdul *et al*., 2009; Blamah *et al*., 2012; Douti et al., 2019).The socio-economic and environmental changes occurring due to the establishment and operations of the petrol filling stations, which have had impacts on the lives of the people, are often not well examined or documented. Nobody seems to care to regulate how the petrol filling stations operate giving rising to their haphazard establishment with the consequences on the people around. In cities of developed countries like Northern Ireland, the onus is on the employer/responsible person to identify and assess the risks arising from the delivery, keeping and dispensing of petroleum spirit

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and other motor fuels such as liquefied petroleum gas (Northern Ireland Fire & Rescue Service, 2001).

Risk analysis in petrol stations incorporates three components: risk assessment, risk management and risk communication (IPCS, 2010). The first component, risk assessment, consists of scientific analysis; the results of which are quantitative or qualitative expressions of the likelihood of harm associated with exposure level. According to IOMC (2010) acquisition of information appropriate to a scenario of interest is a fundamental challenge in risk assessment. Several studies have been conducted to look at the environment and safety risk associated with petrol filling stations (Mshelia et al., 2015; HSA, 2017; Douti et al., 2019). In study a conducted by Cezar-Vaz*et al.* (2012) on the risk perception of occupation accidents of gas station workers in Brazil, several risk factors were identified such as psychological, physical and chemical risks. Karakitsios *et al*, (2007) presented some results conducted in Greece indicating that people in the vicinity of petrol stations have an increased risk of cancer from 3 to 21%. In Nigeria cities such as Abeokuta metropolis, many petrol stations are located along the roads often too close to each other and residential buildings, place of worship, schools, hospital and markets. These constitute potential danger such as fire incidence, which can destroy lives and properties. Inappropriate handling of petroleum products has the potential to create fire accidents. From 1993 to 2004, approximately 243 incidents related to fire explosion in petrol stations have been reported around the world (Mirza *et al*., 2011).Robert *et al*. (2001) reported that fuel tankers operations and maintenance at petrol station posses various kind of hazards on allied facilities and staff. Fire hazard assessment is an important input for fire management plan (Gould *et al*., 2004). It is therefore necessary to design an appropriate risk assessment system, so that the levels of risk would be assessed and a desired systematic controlling programme would be organized (Nouri *et al.*, 2008). The proliferation and indiscriminate location of petrol stations with extreme accidents and high explosion potential in Nigerian cities including Abeokuta metropolis is quite disturbing. Numerous petrol stations have been established and more under construction along the major routes that link Abeokuta to Ibadan, Lagos and other neighbouring towns.

Petrol is a highly flammable liquid and gives off flammable vapour even at very low temperatures. Released vapour, when mixed with air in certain proportions, forms a flammable atmosphere which burns or explodes if a source of ignition is present (Health and Safety Executive, 1998). The assessment of petrol stations risk requires identification, compilation and integration of information on petrol stations hazards which can be minimized through researches (Kester, 2005). Studies of the environmental risk posed by the petrol stations are scare and the few ones have primarily investigated and described the effects of pollutants from fuel stations on soil and groundwater. However, data on risks such as fire disaster in Nigerian cities are rather scarce. It has become obvious that there is a need for security measures to be put in place in petrol stations in order to avoid or minimize petrol station risks (Olaotse, 2010).

Most often in Nigeria, land development programmes and projects have evolved without an appreciation of the value of land use and land cover information (Adeniyi and Omojola, 1999; Ogunkoya, 2016) making it difficult to anticipate the possible socio-economic and environmental consequences of such developments (Rajeshwari, 2006; Mohammed et al., 2013). Land use/Land cover information is essential for a number of planning and management activities at local, regional and national levels hence the need for tools like the geographical information Systems (GIS). Maps derived from GIS analysis showing maintenance occurrence, impact of breaks or leaks (Cowden, 1990; Manonmani et al., 2012), and impact of future development can assist with infrastructure management and planning, This research therefore aimed to reduce this lack of information and help in minimising risks to operators and members of the public at or near petrol filling stations of fires and explosions from petrol. We examined the spatial distribution and conduct risk assessment of petrol stations in Abeokuta metropolis, Ogun State, Nigeria.

MATERIALS AND METHODS

Study Area: Abeokuta, the capital of Ogun state is located in southwest Nigeria and covers an approximate area of about 808 km^2 (Figure 1). It lies between latitude 7° 10′ N and 7° 15′ N and longitudes 3° 17′ E and 3° 26′E (Ufoegbune *et al.*, 2008). The city is about 81 km south-west of Ibadan and 106 km north of Lagos with population of 593,100 (WPR, 2015). Abeokuta is within the tropical rain forest zone of Nigeria: and enjoys a tropical climate with distinct wet and dry seasons with dry period of about 130 days (Orebiyi *et al.*, 2007). The geographical location of the city makes it easily accessible to Lagos, which is the commercial capital, industrial centre and main seaport of Nigeria.

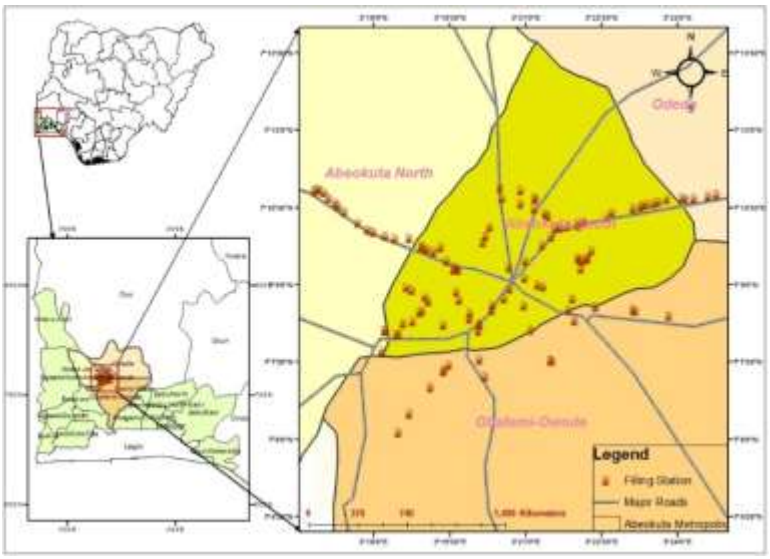

Fig 1: Distribution of Petrol Stations in Abeokuta Metropolis

Data Collection: In this research, primary and secondary data were used. Primary data include measurement of approximate distances between filling stations, proximity of station to utility lines and public/semi-public buildings (Blamah *et al*., 2012). One hundred and twenty (120) structured questionnaires were administered on filling station managers, fuel attendant and residents in neighbouring community in Abeokuta metropolis to elicit relevant information on the risk assessment. Information were also obtained on the number of fire extinguishing, state of pumps and fuel reception systems, the behavior of customers in smoking, use of mobile phone in the petrol stations premises, probable leakages and fire outbreak. Secondary data were obtained from Department of Petroleum Resources (DPR),Weight and Measure Agency (WMA) under the Federal Ministry of Commerce, Federal Secretariat, Oke-Mosan, Abeokuta and Cartography Laboratory at the Department of Water Resources Management and Agrometeorology, Federal University of Agriculture, Abeokuta an order to determine the nature, history, drainage pattern and socio-economic aspects of land-use in the study area.

Geospatial Analysis: Geographical coordinates of the 120 petrol stations in Abeokuta metropolis were obtained using hand-held GPS (Garmin map 76S chart plotting receiver) device (Sule *et al.,* 2011). A proximity analysis to show areas to be included in design of the utility network and those left out was carried out according to Ufoegbune *et al.* (2010), while the optimal location of petrol stations was determined using the overlay functionality in GIS environment using ArcGIS 10.0.

RESULTS AND DISCUSSION

Proximity of Stations to Public/Semi Public Buildings in the Neighbourhoods: The obtained information from the study area indicated that there were 120 petrol stations within Abeokuta metropolis, with three (3) of them presently inactive and the remaining one hundred and seventeen (117) active. Using the Department of Petroleum Resources guideline for proximity of petrol stations to public/semi-public buildings, it was found that thirty-two (32) schools in the study areas fall below the stipulated150m distance from the petrol stations. Twenty-three (23). Some of these schools were located as low as 20m close to the petrol station (Table 1). In fact, some worship centres and residential buildings directly shared boundaries with some of the petrol stations. The location of the petrol station cut across the low, medium and high density residential areas within the metropolis constituting danger to the peoples and their properties.

Table 1: Proximity Analysis of Buildings and Utility Facilities within One Hundred and Fifty Meters (150 m) Distance to Petrol Stations as stipulated by DPR (DPR, 2010)

Public/Semi Public Building	Number	Approximate Distance (m)
Residential	32	5-80
Shopping areas	13	2-100
Hospital	12	20-150
Worship centre	37	10-150
Schools	23	10-100
Industry	-	-

Very few of the stations are at present not located close to public/semi-public buildings and they are mostly those in the outskirt of the city. These public/semi-public facilities were at risk of hazards likely to emanate from the petrol stations because they were

found within the minimum standard radius of 150m away from the petrol stations. One of the most important characteristics of risk assessment in filling station is the location of the station whether within or outside residential areas (Nouri *et al*., 2010).The study showed that most of the petrol stations did not comply with the laid down regulations regarding siting of petrol filling stations in residential areas. From the land use point of view, only 11 percent comply with the agreed 30 m away from residential areas while 89 percent did not comply. This was consistent with the findings of Ahmed et al. (2014).

Rate of Risk for the Petrol Stations For all the 117 active filling stations examined in the Abeokuta, significant hazard and significant risk were calculated and were analyzed in detailed to obtain a more accurate estimation of actual risk. All effective parameters in petrol stations risks were identified and assessed. The method applied in this study was similar to that of Maclntyre *et al.* (2007) who used FMEA method in their study as shown in Figure 2. The results are presented in Table 2 and were evaluated according to the pattern of decision-making process for risk assessment in petrol stations (Table 3). The risk analysis for the petrol stations indicates that, the stations located within the core of the metropolis poses more risk than those in the outskirt did because many of them were very close to residential, commercial and educational land use areas. More than 75 percent of the filling stations are in critical conditions and quick reconstructions are needed. This is potentially very hazardous with regard to the materials stored and it can increase the risk in case of problems (Park et al., 2006).

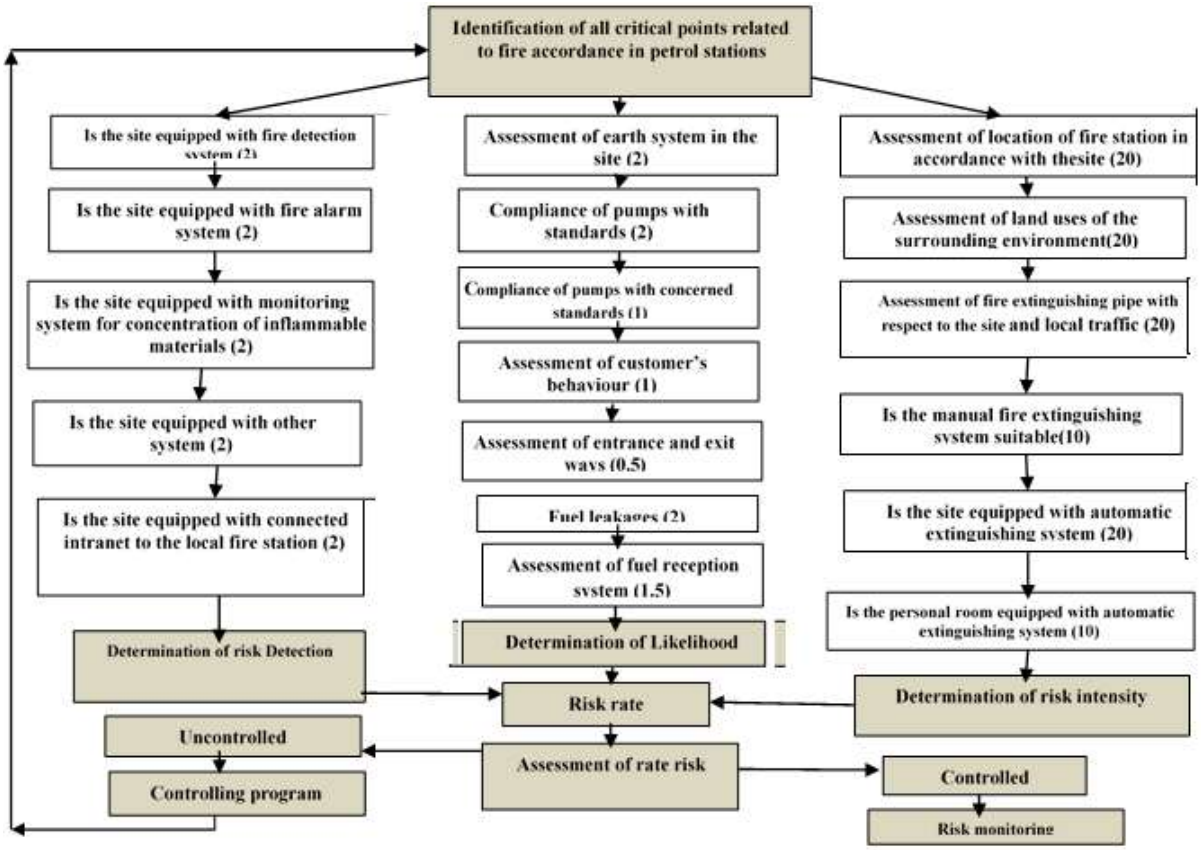

Fig 2: Decision-making process for risk assessment model in petrol stations (MacIntyre *et al.*, 2007)

It is noteworthy that the government owned petrol stations are in better conditions compared to the private and independent ones due to financial and management resources. The results revealed that 88 of the petrol stations had high risk while 20 and 9 had medium and low risk respectively (Figure 3).

Evaluation of Fire Extinguishing System: Other important characteristics of a petrol station are its distance from fire station and fire extinguishers. Evaluation of fire extinguishing systems showed that most of the personnel at the petrol stations were trained on how to extinguish fire, but only 18 % of them have been trained for crisis management.

Table 2: Risk Assessment of some of the selected Petrol Stations in Abeokuta Metropolis

S/No.	Name of Station	Location	Intensity	Likelihood	Detection	Risk
1	Yerevan Global Oil	Lafenwa	40	1.5	2	120
2	Oando Nig. PLC	Lafenwa	50	1.5	5	1125
3	Conoil Nig. PLC	Lafenwa	50	3.5	3	525
4	Dambold Filling Station	Shaje	20	1.5	4	120
5	MAO Filling Station	Arilese-Shaje	50	3.5	4	700
6	Crystal Oil & Gas LTD	Agbeloba	30	2.5	2	150
7	Toy-Apa Nig. LTD	Housing Estate. Olomore	60	2.5	3	450
8	Total Nig. PLC	Adatan	60	3.5	4	840
9	NIPCO	Asero	30	1.5	2	90
10.	CDA Ventures LTD	Fajol, Obantoko	50	3.5	5	875
11	NIPCO	Mile 2	40	1	2	80
12	Olubi Oil LTD	Ogun Radio	50	3.5	4	700
13	Ebenfem Oil	Alogi, Obantoko	50	3.5	3	525
14	NNPC	Car Wash, Adatan	60	3	5	900
15	Oando Nig. PLC	Adatan Roundabout	60	2.5	3	450
16	MRS	Asero	30	2	3	180
17	Fagbems	Asero	60	2.5	4	600
18	Afroil PLC	Ayetoro Road	50	3	3	450
19	AP Nig. PLC	Ake	70	3.5	5	1225
20	Arolat Petr. Nig. LTD	Adedotun	50	1.5	2	150
21	Divine Paks	Idi-Aba	40	1	7	980
22	Suntoy Crown	Sam Ewang Junction	70	3.5	4	280
23	Sanquad Petr. Co. LTD	Adigbe Road	60	4	2	480
24	Conoil Nig. PLC	Omida	30	1.5	3	135
25	Rantipe Ventures	Abiola Way	50	2.5	4	500
26	Fagbems	Kobape	30	2.5	2	150
27	NNPC Mega Station	Kobape	40	0.5	4	80
28	Conoil Nig. PLC	Sapon	30	2	3	18
29	Energy	Abiola Way	50	2.5	4	500
30	Isbra Ventures	Aregbe	60	2.5	3	450
31	RGPG	Lantoro Road	30	2.5	2	150
32	KAAB Petroleum	Abiola Way	30	1	2	60
33	Fowobi	Onikolobo	40	2.5	3	300
34	Oando Nig. PLC	Ijaye	50	2	3	300
35	MAO Petroleum	Olorunsogo	30	3.5	5	225
36	Word Oil	Oke-Ilewo	40	1.5	5	300
37	Oyinkansola Global LTD	Oke-Lantoro	60	3	4	720
38	Africa Petr. Nig. LTD	Lagos Road	40	4.5	3	540
39	JK Oil	Rounder	50	3.5	3	525
40	Ket Int'L Nig. LTD	Sabo-Gaa	50	2.5	5	875

Table 2: Decision Making Based on the Rate of Risk

S/No.	Rank	Description of Danger	Degree of Risk
1	>201	Urgent measures are required, corrective measures should be taken quickly	High
2	200-1001	Corrections should be carried out	Moderate
3	<100	Monitoring and control are required	Low

Source: MacIntyre et al. (2007)

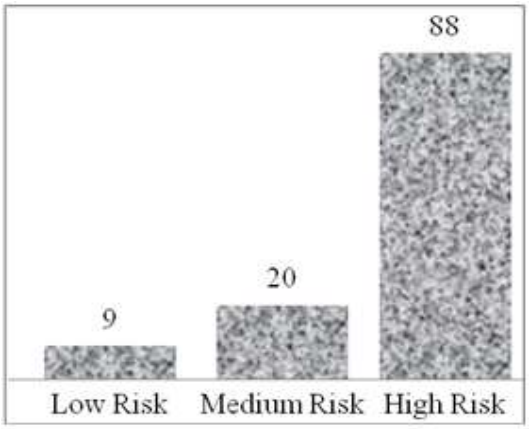

Fig 3: Rate of Risk in the Petrol stations

This agreed with the findings of Nouri *et al*. (2010) on risk assessment and crisis management of gas stations in Iran. Furthermore, none of the petrol stations in the metropolis was equipped with automatic extinguishing system but manual extinguishing systems. Only four (4) petrol stations have more than ten (10) to twelve (12) fire extinguishing system while 113 had less than ten (10) fire extinguishing system. Fewer numbers of the petrol stations (19 %) do not have fire extinguishing system in the office buildings nor do they have enough supply of buckets of dry sand or similar absorbent material, which makes them prone to fire accidents. The possibility of fires or other incidents at the petrol filling stations is high if careful

site planning and design, sound construction and installation of tanks and other equipment, and petrol good operating practices are not in place. In many cases, there is no adequate means for summoning the local fire brigade and suitable equipment for controlling minor incidents and for limiting the escalation of incidents.

Spatial Analysis of the Petrol Stations: According to Guideline for Petrol Station Development (KAPDA, 2007), proposed filling stations should be 450 m away from any other filling station within the nearest vicinity. However, the proximity between petrol stations in the metropolis does not comply with this standard. Distances between stations in the metropolis that was found to have fallen short of the standards, involving about 88 petrol stations out of the 120 stations in the city. This clearly have environmental impacts on the residents in Abeokuta metropolis. From the study, it was found that residents located in Abeokuta South Local Government Area, which forms the core area of the metropolis, are mostly at risk, because majority of the petrol stations were found in the area as shown in Figure 4.

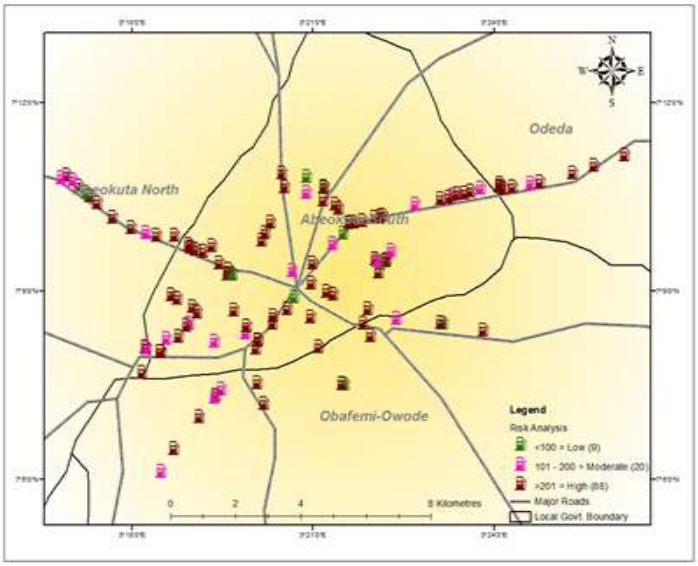

Fig 4: Spatial Spread of Risk of Petrol Stations in Abeokuta Metropolis

Problems that could emanate as a result of the concentration of petrol stations in a particular area are traffic jams, traffic law violations and road traffic accidents, which have devastating effects on the residents (Blamah *et al*., 2012. noise and air pollution impacts on the community from the concentrations of vehicles are also major problems. It is obvious that petrol stations in Abeokuta metropolis were not in good states and were exposed to high risk because over 75 percent of the stations were in critical conditions and quick reconstructions are needed. This is potentially risky with regard to the materials stored, which can increase the risk in case of accidents. This agreed with the findings of Park *et al.* (2006) in their work on Incident Analysis of Bucheon LPG Filling Station Pool Fire in Gyeonggi Province, South Korea. It is noteworthy that the government owned petrol stations are in better conditions compared to the private and independent ones due to financial and management resources. Based on display of no mobile phone usage and no smoking sign, all the petrol stations complied.

Conclusion: The study revealed that most of the petrol stations in Abeokuta metropolis are prone to high risk such as fire explosion which poses hazard on lives and properties due to non- compliance with petrol station establishment guidelines, planning criteria, safety and environmental considerations. The effects of uncoordinated petrol stations activities in urban centres pose significant risks to the neighbourhood and general environments.

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