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Research Paper

Hotspot Assessment And Mapping Of Crude Oil Spill Across Rivers State, Nigeria

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Abstract
Oil pollution remains a major environmental challenge in the Niger Delta, particularly in Rivers State, where extensive petroleum exploration, production and transportation activities have increased the vulnerability of communities and ecosystems to oil-spill incidents. A cross-sectional and analytical research design was adopted. Primary and secondary data were obtained through field observations, published literature, official records and the National Oil Spill Monitor. The findings revealed that oil pollution is widespread and spatially clustered across Rivers State, with notable concentrations in the western, central, southern and south-eastern parts of the state. Communities including Ogu, Okrika, Obagi, Elele, Omoku, Soku, Opobo, Degema, Bonny, Bodo, Eleme, Eberi, Abiam and Kono were identified as being within or close to areas with substantial spill concentrations. The study concludes that GIS-based spatial analysis can be used to provide an effective analysis for identifying oil-pollution hotspots, within localities. The study therefore recommends that more actions should be put in place to reduce the incidence of oil spill across the study area.

Keywords: *Hotspot, oil spill, environmental, ecosystem, mapping*

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I. Introduction

Since the amalgamation of the Northern and Southern protectorates that gave birth to Nigeria in 1914 until the discovery of crude oil in commercial quantities, agriculture remained a major source of revenue in Nigeria (Agoha, 2019; Akpan-Idio, Ibrahim, Udo, 2012). The major products were cocoa from the west, groundnut and cotton from the North, and Palm oil from the east and south. In 1956, Shell British Petroleum (now Royal Dutch Shell) discovered crude oil in the village of Oloibiri in Bayelsa State, Nigeria, within the Niger Delta (Anifowose, 2008; Onuoha, 2008), and commercial production began in 1958. As of 2006, there are eleven (11) oil companies operating one hundred and fifty-nine (159) oil fields and one thousand four hundred and eighty-one (1,481) wells in the Niger Delta in Nigeria (The Guardian, 2006). Human activities and those of oil exploration and exploitation raise a number of issues such as depletion of biodiversity, coastal and riverbank erosion, flooding, oil spillage, gas flaring, noise pollution, sewage and wastewater pollution, land degradation and soil fertility loss and deforestation, which are all major environmental issues facing the Niger Delta region as a result of decades of Crude oil Exploration in the region (Amangabara & Njoku, 2012; Atu bi, 2015).The Niger Delta is classified as a tropical rain forest with extensive mangroves and rain forests that has become one of the world's most polluted places due to decades of oil exploration with ecosystems comprising of diverse species of flora and fauna both aquatic and terrestrial species. The region can be classified into four ecological zones; coastal inland zone, freshwater zone, lowland rainforest zone, mangrove swamp zone and this region is considered one of the ten most important wetlands and marine ecosystems in the world (ANEEJ, 2004; Federal Ministryof Environment, 2006). Nigeria has been a member of Organization of Petroleum Exporting Countries (OPEC) since 1971. As atthe 1980s oil revenue provided 90% of Nigeria foreign exchange earnings and 85% of the government revenue (Odeyemi and Ogunseitan 1985), with estimated reserves extending beyond 20-30 years (NNPC, 1984). Anifowose (2008) and Onuoha (2008) cited in their studies that the region has about 606 oil fields with 355 situated onshore; 251 situated offshore with 5,284 drilled oil wells and 7,000km of oil and gas pipelines. Extensive gas flaring has been continuous in the Niger Delta region since 1970 (NNPC 1984). As of January, 2009, the Oil and Gas Journal

(OGJ) estimates that Nigeria has 36.2 billion barrels of oil reserves, with present oil exploration and production concentrated in the Niger Delta basin and the continental shelf (Ukoli, 2005). Activities mainly in the onshore dry or swamp lands of the Niger-Delta basin and deep offshore locations of the Dahomey Basin (Ukoli, 2005). Over the years, the Niger Delta region has emerged as one of the most ecologically sensitive regions in Nigeria (Wali, Nwankwoala, Ocheje, and Chinedu, 2019). Oil and gas from the region were the main sources of revenue for the Nigerian states, accounting for about 97% of the country's total export (ANEEJ, 2004; Federal Ministryof Environment, 2006). Since the discovery of oil in the region, oil has dominated the country's economy. The Niger Deltaregion is highly susceptible to adverse environmental changes, occasioned by oil exploration and exploitation activities and climate change, because it is located in the coastal region, and these have caused pollution and degradation, and the area has become an ecological wasteland (ANEEJ, 2004; Federal Ministry of Environment, 2006).

An estimated 9 million-13 million (1.5 million tons) of oil has been spilled into the Niger Delta ecosystem over the past 50 years; 50 times the estimated volume spilled in the Exxon Valdez oil spill in Alaska in 1989 (FME, 2006). The first oil spill in Nigeria occurred at Araromi, in present-day Ondo State, in 1908 (Tolulope, 2004). In July 1979, the Forcados Tank 6 Terminal in Delta State, an incident spilled 570,000 barrels of oil into the Forcados estuary, polluting the aquatic environment and surrounding swamp forest (Ukoli, 2005; Tolulope, 2004). The Funiwa No.5 Well in Funiwa Field blew out an estimated 421,000 barrels of oil into the ocean from January 17th to January 30th, 1980, when the oil flow ceased (Ukoli, 2005; Gabriel, 2004; Tolulope, 2004). 836 acres of mangrove forest within six miles of the shore were destroyed. The Oyakama oil spillage of 10th May 1980, with an estimated volume of approximately 30,000bbl (Ukoli, 2005). In August 1983, Oshika village in Rivers State witnessed a spill of 5,000 barrels of oil from the Ebocha-Brass (Ogada-Brass 24) pipeline, which flooded the lake and swamp forest. The area had previously experienced a smaller oil spill in September 1979, involving 500 barrels, with mortality among crabs, fish, and shrimp. Eight months after the spill, there was high mortality among embryonic shrimp and reduced reproduction due to oil in the lake sediments (Gabriel, 2004). The Ogada-Brass pipeline oil spill near Etiama Nembe in February 1995 released approximately 24,000 barrels of oil, which spread across the freshwater swamp forest and into the brackish-water mangrove swamp. The Shell Petroleum Development Company (SPDC), since 1989 recorded an average of 221 spills per year in its operational area involving 7,350 barrels annually (SPDC Nigeria Brief, May 1995:3). From 1976 to 1996, a total of4647 oil spill incident spilling approximately 2,369,470 barrels of oil into the environment, of which 1,820,410.5 (77%) were not recovered. Most of these oil spill incidents in the Niger Delta occur on land, in the swamp, and in the offshore environment (Nwilo & Badejo, 2004; Twumasi & Merem, 2006; Uyigue and Agho, 2007). NNPC estimates 2,300 cubic meters of oil have been spilled in 300 separate incidents annually between 1976 and 1996 (Twumasi & Merem, 2006). Punch newspaper, 1991, reported a total of 2,796 oil spill incidents recorded between 1976 and 1990, resulting in 2,105,393 barrels of oil spilled. The UNDP 2006 also reported that between the period of 1976-2001, 3 million barrels of oil were lost in 6,817 oil spill incidences of which over 70% of the spilt oil was not recovered. In 2001, the western operations of the Shell Petroleum Development Company (SPDC) recorded a total of 115 incidents of oil spills, in which 5,187.14 barrels of oil were spilled, and 734,053 barrels of the spilled oil, representing 14.2%, were recovered. In January 1998, 40,000 barrels of crude oil was spilled by Mobil in Eket but the largest spill in Nigeria was the offshore well blowout in January 1980 with a spill of approximately 200,000 barrels of oil into the Atlantic Ocean from an oil facility which damaged 340 hectares of mangrove forest (Nwilo and Badejo, 2005) The Niger Delta has a complex and extensive system of pipelines running across the region and large amounts of oil spill incidences have occurred through the pipelines and storage facility failures, these failures could be caused by material defect, pipeline corrosion, ground erosion but the oil companies blame most of the spills on sabotage. The Department of Petroleum Resources contends that 88%of the oil spill incidents are traceable to equipment failure. The main causes of oil spills in the Niger Delta are vandalism, oil blowouts from the flow stations, accidental and deliberate releases, and oil tankers at sea (Nwilo and Badejo 2004, 2005).

The history of petroleum development in Nigeria reveals that oil production began with a modest daily output of 5,100-6,000 barrels; after Shell's discovery of oil in Oloibiri in 1956, Nigeria began exporting in 1958 (Egberongbe et al., 2006; Benedict, 2011; Onwe, 2012). The daily output increased to 12,000 barrels per day by the end of 1959 and to 900,000 barrels per day from the late 1960s to the early 1970s. From the late 1970s to the 1980s, Nigeria reached a production level of over 2 million barrels per day, and in 2004, production reached a record of 2.5 million barrels per day. In fact, the government has developed strategies to increase daily production from 2.5 to 4.5 million barrels per day in the near future (Egberongbe et al., 2006; Benedict, 2011; NAPIMS, 2012; Onwe, 2012; NNPC, 2013). Following the discovery of oil, exploration rights in the onshore-offshore dichotomy were extended in 1960 to companies such as Chevron, Exxon, Gulf, Mobil, Royal Dutch/Shell, and Texaco to prospect for and produce oil in the Niger Delta (Onwe, 2012). The proliferation of these companies began to manifest in the number of oil wells being drilled; Ifeadi et al. (1987), cited in Benedict (2011), claimed that, between 1960 and 1985, a total of 3,525 oil wells were drilled. As a result, there are more than 5,284 oil wells existing in both offshore and onshore dichotomy (Achebe et al., 2011, NAPIMS, 2012). Also, there are about 606 oil fields (355 onshore and 251 offshore) and more than 527 flow-stations, plus six export terminals located at

Forcados and Bonny (operated by Shell); Escravos and Pennington (operated by Chevron); Qua'Iboe (operated by ExxonMobil) and Brass (operated by Agip). An extensive network of multiproduct pipelines linking these facilities to ports and Nigerian National Petroleum Corporation (NNPC) depots in the Warri, Port Harcourt, Mosimi, Kaduna, and Gombe regions (Nnubia, 2008; Ugochukwu & Ertel, 2008; Edino et al., 2010; Sojinu et al., 2010; Achebe et al., 2012; Anifowose et al., 2012).

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In 2006, Shell Nigeria claimed an average of 250 oil spill incidents per year since 1997, while the Nigerian National Oil Spill Detection and Response Agency (NOSDRA) could confirm about 327 oil-polluted sites in the Niger Delta region. According to NNPC Limited, pipeline vandalism steadily decreased from 2006 to 2010, then increased sharply in 2011, while pipeline rupture remained steady for the best part of 14 years, except in 2000. There is no particular reason for this, as pipeline vandalism seems to occur across all regions of the country. Pipeline interdiction is so rampant that the SPDC (2007) claimed most of its third-party incidents were caused by interdiction. Intentional TPD involving sabotage and illegal bunkering is a common feature in the Niger Delta; for example, between 1998 and 2009, the average percentage of third-party damage involving sabotage was about 58% according to Steiner (2010). This suggests that Shell has many more rupture problems overall than just in Nigeria, thereby raising questions about the integrity of its pipeline assets.

There are inconsistencies in the number of oil spill incidents published by Shell across different sources; for instance, Amnesty International compared Shell's database with NOSDRA and Shell's parent company, i.e., Royal Dutch Shell, and found significant discrepancies. These inconsistencies may be attributed to regulatory agencies' failure to harmonize data before publication or to the non-disclosure of in-house spill incidents. According to an interviewed source, spills of less than 100kg are not reported to the Department of Petroleum Resources (DPR) or NOSDRA but handled in-house; only spills greater than 100kg are reported to DPR for joint investigation (Shittu, 2014). This buttresses the fact that data provided by MOCs and reported by DPR or NOSDRA do not represent the true magnitude of oil spills. According to Gay et al. (2010), this lack of accurate data prompted some experts in 2007 to estimate that between 9 and 13 million barrels had been spilled over 50 years in the Niger Delta (roughly one Exxon-Valdez, or 1.5 million tonnes, spilled annually for half a century). The deteriorating condition of most pipelines constructed over the years is responsible for oil pipeline spills in Nigeria (Steiner, 2010; Benedict, 2011). Other reasons are indiscriminate disposal of oil waste and lack of 'good oilfield practice' by MOCs (Steiner, 2010; Amnesty International, 2013). In 2006, Shell Nigeria claimed an average of 250 oil spill incidents per year since 1997, while the Nigerian National Oil Spill Detection and Response Agency (NOSDRA) could confirm about 327 oil-polluted sites in the Niger Delta region. Data from the NNPC showed pipeline vandalism steadily decreasing from 2006 to 2010, followed by a sudden increase in 2011, while pipeline rupture remained steady for the best part of 14 years, except in 2000. There is no particular reason for this, as pipeline vandalism seems to occur across all regions of the country. Pipeline interdiction is so rampant

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II. Methods

Rivers State is an oil-rich state in southern Nigeria, located in the eastern part of the Niger Delta on the oceanward extension of the Benue Trough, with headquarters in the town of Port-Harcourt. Rivers State comprises 23 Local Government Areas, many of which are towns and villages. The inland part of the state consists of tropical rainforest, and towards the coast, the typical Niger Delta environment features many mangrove swamps. Rivers State has a total area of 11,077 km^2 (4,277 sq mi), making it the 26th largest state in Nigeria. Surrounding states are Anambra, Imo, and Abia to the north, Akwa Ibom to the east across the Imo River, and Bayelsa and Delta to the west across the Niger River for about 50 km. On the south, it is bounded by the Atlantic Ocean. Its topography ranges from flat plains to a network of rivers and tributaries.

The area is located between Latitude 5º 10' 0''N and Longitude 6º 54' 0''E. The area within the tropical rainforest is characterized by eight months of the wet season and four months of the dry season. The average temperature of the area is between 22ºC and 29ºC with high humidity and rainfall. The major occupations of the people are fishing and farming, with some individuals also engaged in trading and public service (Odalonu, 2016). The socio-economic life of the rivers people is largely dependent on their geography and environment, and they predominantly are fishermen/fisherwomen, traders, and farmers (Orisakwe, 2021).

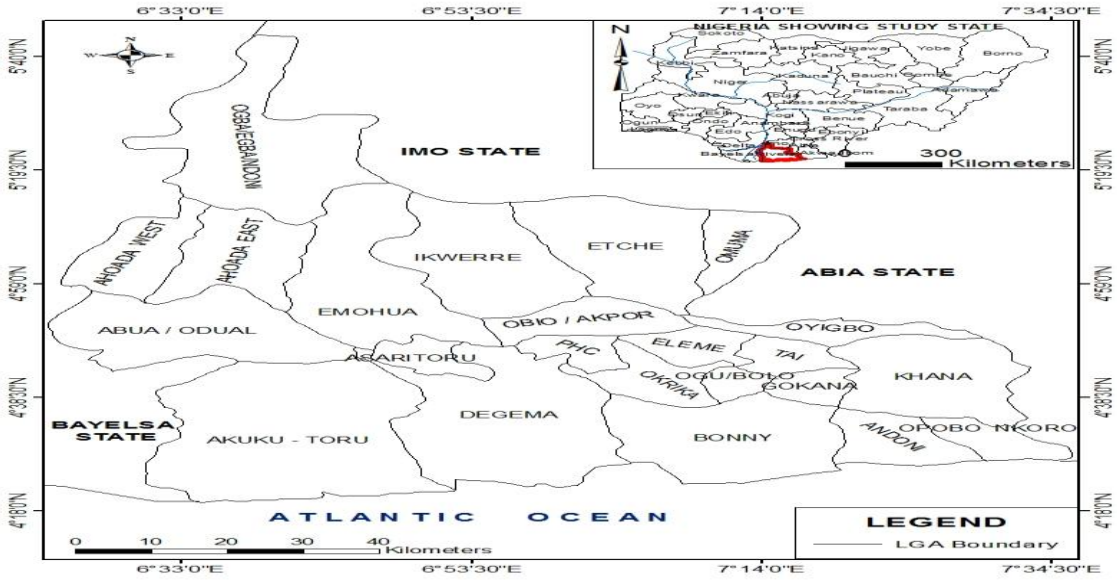


Figure 1Rivers State Showing LGA Area

The spatial datasets were acquired from secondary sources, and some was generated and updated through supervised classification and on-screen digitization using ArcGIS software. The review of secondary data was very useful for this research. A desk study involved the consultation of official reports, articles, legal documents, and published and unpublished literature. Other information items were derived from journal articles, textbooks, dictionaries, encyclopedias, books, political commentary, biographies, dissertations, newspaper, and opinion pieces.

Data obtained from the field survey was transferred to the ArcGIS environment and this aided the research in the mapping and spatial vulnerability assessment of residents and communities to oil spill. the communities affected by oil pollution in the study area were analyzed using data derived from the national oil spill monitor alongside the geospatial map of rivers state showing community locations. The data so derived were analyzed in the ArcGIS environment. Also, image analysis was conducted to evaluate the extent of physical impact of the spill across individual communities.

III. Results

Oil pollution Incidents

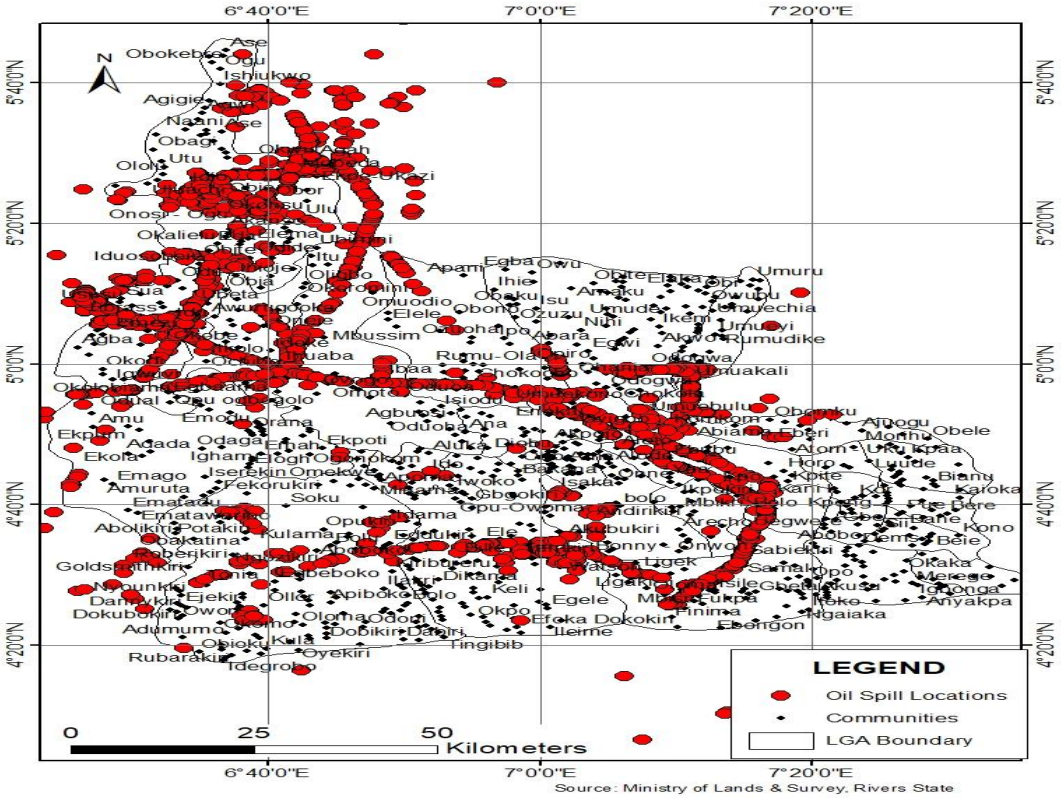


Figure 2Showing communities affected by oil pollution in the study area

From the analysis oil spill and its subsequent pollution cuts across the entire Local government in River's state leaving out only few Local government technically but due to the nature of the terrain which is criss-crossed River network the entire state and its environment have in one way or the other been impacted by oil spill as shown with the red dots.

From the map analysis, communities affected by oil pollution in the spatial overlap/proximity between oil-spill locations and community shows that oil pollution is widespread, but it is particularly concentrated in the western, central, southern and south-eastern parts of the study area.

It should be noted and mentioned that oil-spill locations are not randomly distributed. There are distinct clusters of oil spill locations around most communities within clusters. This concentration occurs around the western-central corridor, the central/southern corridor, and the south-eastern corridor.

The spatial distribution of oil-spill locations indicates that oil pollution affects numerous communities across the study area. The affected communities are concentrated particularly in the western, central, southern and south-eastern portions of the study area. Communities such as Ogu, Ishiukwo, Agigie, Obagi, Utu, Okrika, Ogbogoro, Oroworukwo, Elele, Omoku, Mgbuoba, Rumuoji, Chokocho, Soku, Opobo, Degema, Abonnema, Bonny, Bodo, Eleme, Eberi, Abiam and Kono occur within or close to areas characterized by high concentrations of oil-spill. The pattern suggests that communities located close to petroleum infrastructure and major oil-producing and transportation corridors are more exposed to oil pollution. The concentration of spill locations around these communities also indicates the need for targeted environmental monitoring, remediation and pollution-control measures.

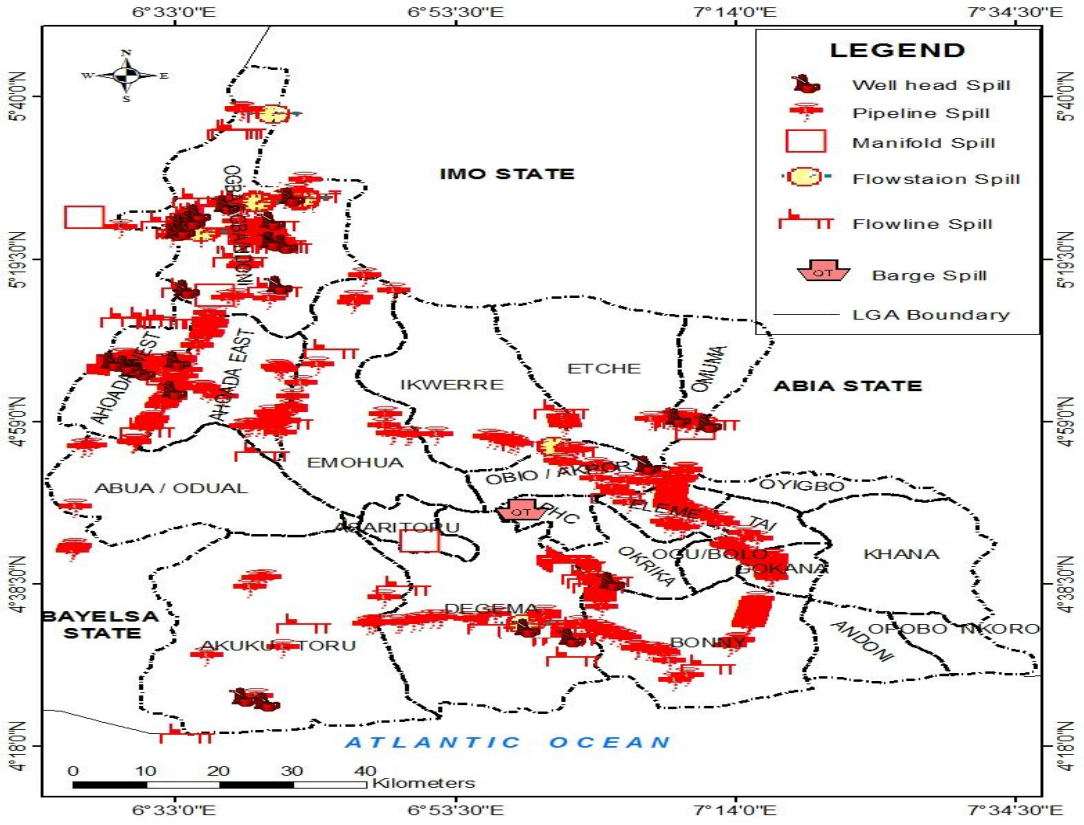


Figure 3Showing Key risk factors associated with the oil pollution in the communities

These factors associated with oil pollution were primarily tied to factors such as proximity of the people to oil infrastructure exploration, illegal oil refining and theft. Expansion of the population especially into oil producing zones and finally the socio-economic vulnerability of the population.

Communities located close to oil wells, flow stations, pipelines, refineries, tank farms and other petroleum facilities face greater exposure as pipeline corridors can be particularly vulnerable to leaks and ruptures. Also, the drilling activities, well servicing, transportation and crude-oil handling can introduce hydrocarbons into surrounding ecosystems via routine operational discharges thereby contributing to chronic pollution.

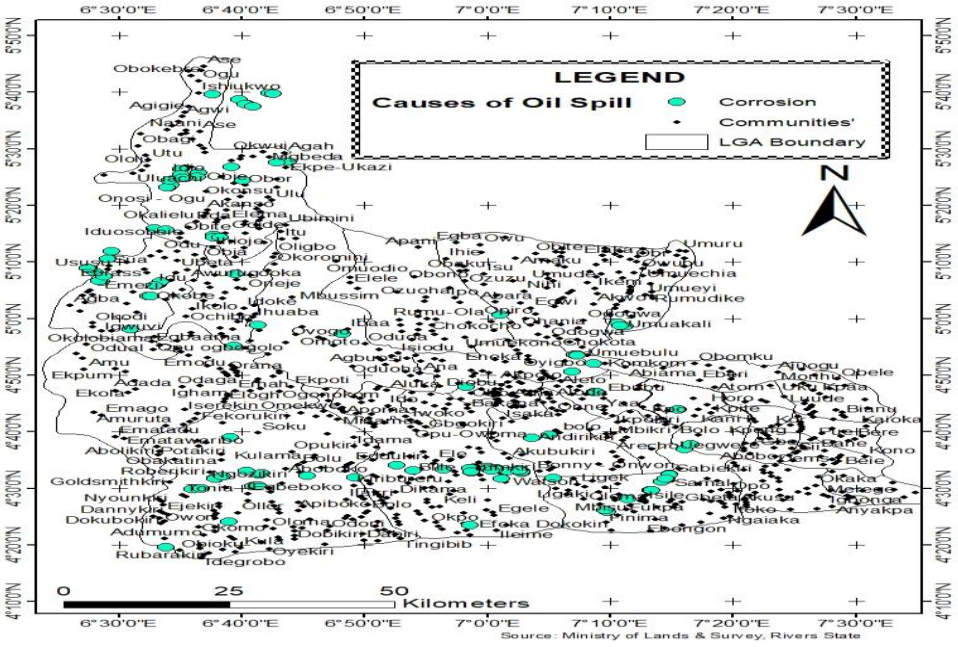


Figure 4Corrosion induced spill hotspots in study area

Corrosion as the major cause of spill is spatially dispersed across the entire stretch of the study areas indicated by the green buttons with dominance in the Orashi region and down the coastal belt of the study area. Looking at the trend, it is obvious that there will be a down transfer of pollutants from the upland region through its network of river and creeks to the riverine region. This situation creates high vulnerability to contaminants from oil spill across the study area.

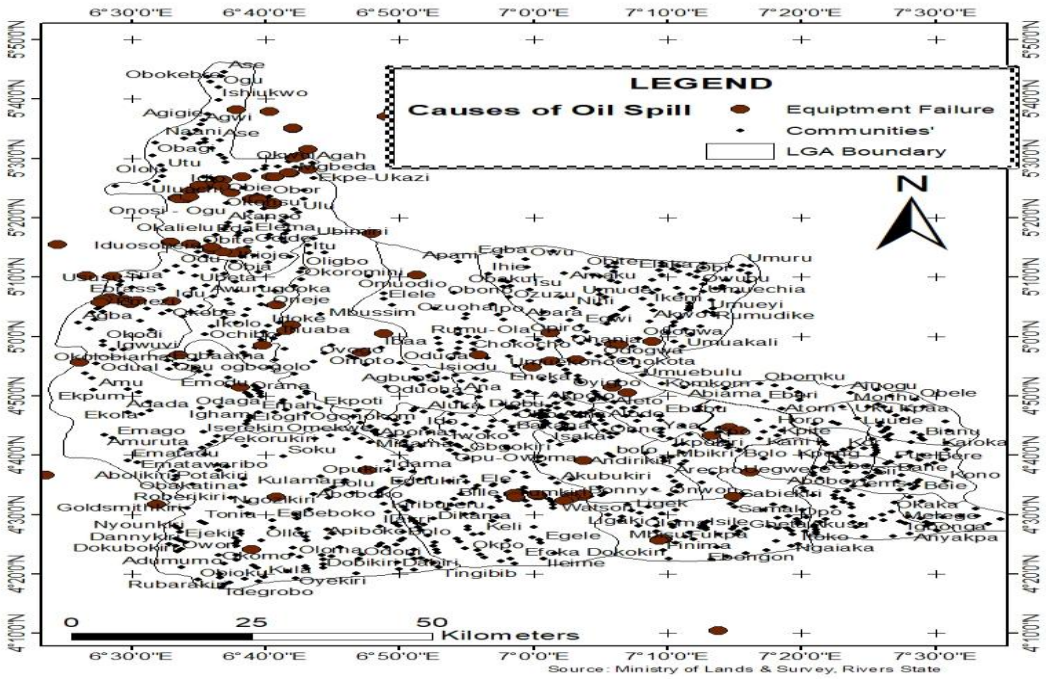


Figure 5 Equipment failure induced oil spill hotspots in study area

Oil facilities and their installation also cut across the entire study area stretching from the upland region to the riverine region. The flow of spill takes the trajectory of the slope which all empties into the Atlantic Ocean cutting across five local government of Akuku-Toru, Degema, Bonny, Andoni and Opobo Nkoro. Looking at the trend, it is obvious that there will be a down transfer of pollutants from the upland region through its network of river and creeks to the riverine region. This situation creates high vulnerability to contaminants from oil spill across the study area.

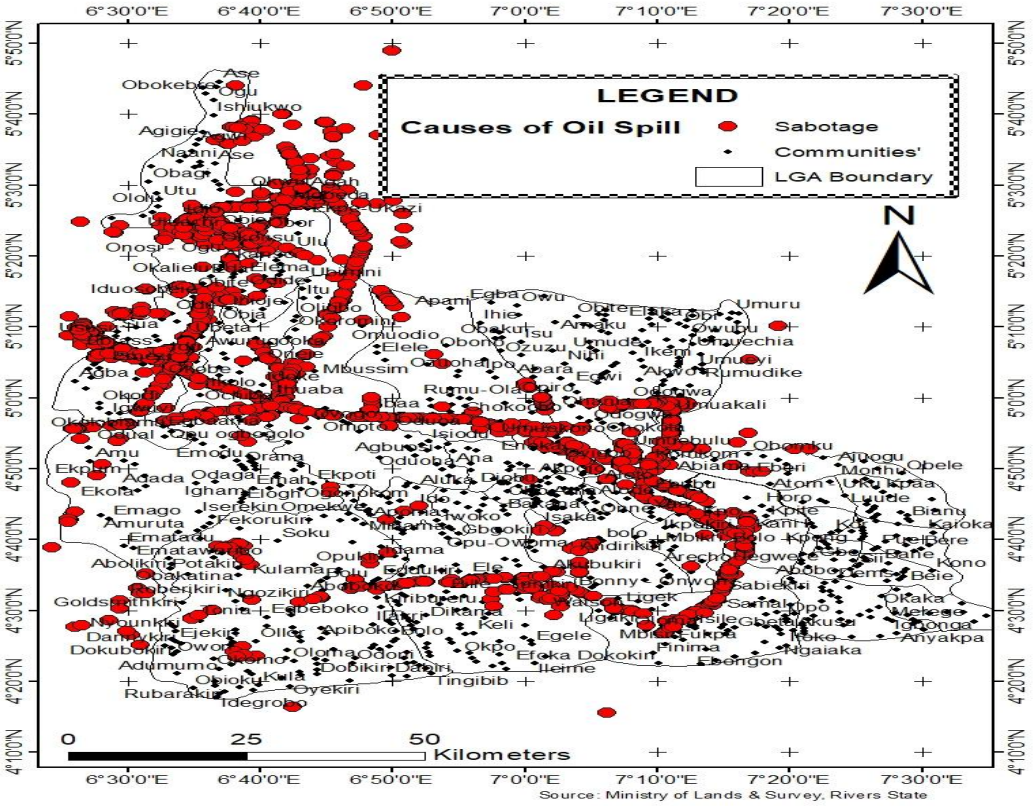


Figure 6 Sabotage induced oil spill hotspots in study area

Sabotage is the most dominating factor resulting in spill across the study area. It stretches from the northern part of the state which is generally categorized as the upland region down to the southern part of the states. Its activity is primarily aimed at extracting oil for economic gain through illegal processes. The remnant of such spill also is transported through the network of rivers within the state. Looking at the trend, it is obvious that there will be a down transfer of pollutants from the upland region through its network of river and creeks to the riverine region. This situation creates high vulnerability to contaminants from oil spill across the study area.

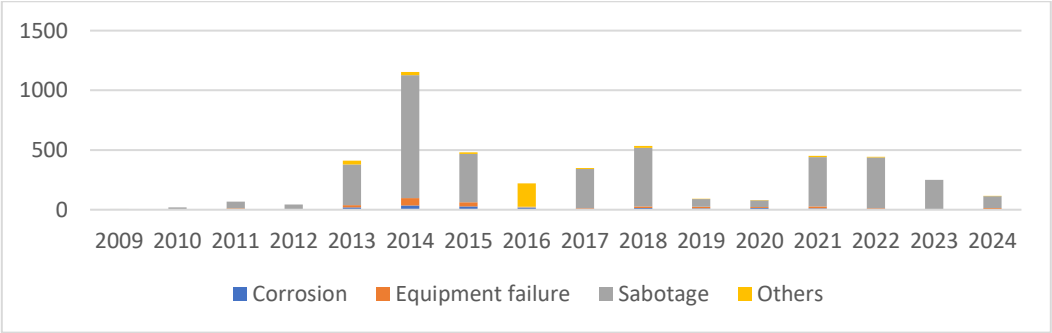


Figure 7 Sowing Annual Spill Sources across the study area

IV. Discussion

The findings of this study reveal that oil pollution causes a widespread environmental problem across Rivers State, which affects communities occurring predominantly in the western, central, southern and south-eastern parts of the study area. The spatial analysis demonstrates that oil-spill locations are not randomly distributed but occur in distinct clusters around several communities. Communities such as Ogu, Ishiukwo, Agigie, Obagi, Utu, Okrika, Ogbogoro, Oroworukwo, Elele, Omoku, Mgbuoba, Rumuoji, Chokocho, Soku, Opobo, Degema, Abonnema, Bonny, Bodo, Eleme, Eberi, Abiam and Kono were identified as being within or close to areas characterized by high concentrations of oil-spill incidents.

This spatial pattern suggests that the occurrence of oil pollution is strongly associated with the distribution of petroleum infrastructure and oil-producing and transportation corridors. The concentration of spills around particular communities indicates that communities located close to oil wells, pipelines, flow stations,

refineries, tank farms and other petroleum facilities are more exposed to oil-pollution risks. The clustering of spill locations also indicates that the environmental consequences of oil pollution may extend beyond the immediate point of occurrence, particularly where contaminated areas are connected by rivers, streams, wetlands and drainage networks.

The finding that oil-spill locations form identifiable spatial clusters is particularly important for environmental management because it demonstrates that pollution-control efforts should not be implemented uniformly across the entire state. Rather, priority should be given to communities and corridors where spill incidents occur repeatedly or where communities are located close to petroleum infrastructure. The concentration of affected communities therefore provides a basis for targeted monitoring, remediation and pollution-control interventions.

Repeated oil spills occurring around communities connected to these aquatic environments have the potential to affect surface water, soils, vegetation and aquatic ecosystems. The findings therefore portray oil pollution as a spatially structured environmental problem rather than a collection of isolated incidents.

V. Conclusion

The spatial analysis revealed that oil pollution affects communities across different parts of Rivers State, with notable concentrations in the western, central, southern and south-eastern portions of the state. Communities such as Ogu, Okrika, Obagi, Elele, Omoku, Mgbuoba, Soku, Opobo, Degema, Abonnema, Bonny, Bodo, Eleme, Eberi, Abiam and Kono occur within or close to areas characterized by substantial concentrations of oil-spill incidents. The clustering of spill locations around these communities demonstrates that oil pollution is not randomly distributed but is closely associated with petroleum infrastructure and major oil-production and transportation corridors. The findings demonstrate the usefulness of GIS and spatial modelling in identifying affected communities, detecting pollution hotspots, analysing temporal and spatial trends, and predicting areas that are potentially vulnerable to future oil-spill impacts.

Recommendations

Based on the findings of this study, is recommended that Since oil-spill incidents were found to be spatially clustered around petroleum infrastructure, particularly pipelines, flowlines, oil wells and flow stations, continuous surveillance should be strengthened in identified high-risk corridors. Modern geospatial technologies, including GIS, remote sensing and satellite-based monitoring, should be integrated into routine monitoring to enable the early detection of leaks, vandalism and other potential spill incidents.

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