Environmental Sensitivity Index Mapping: A Case Study of PPMC Pipeline along Ugbomro Community and Environ, Delta State, Nigeria

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Abstract Environmental Sensitivity Index (ESI) mapping provide a concise summary of coastal/inland resources that are at risk if an oil spill occurs nearby. Environmental sensitivity index (ESI) maps can be used for oil spill contingency planning, environment management planning and emergency response. To this end, the study attempts to establish the inland habitats and their sensitivity to oil spill along the 4.95km of the pipeline passing through Ugbomro community and as it relates to its environs. Ikonos image of the area obtained from Google Earth, were digitized manually and the land use/land cover map of the areas were derived using ArcGIS 10.1. The ESI classification and ranking was done for the inland habitat by considering the importance of indigenous flora/fauna species to rural livelihood, oil ecosystem interaction, and ease of clean up. The result suggests that built up area, water body and wetland having ESI ranking to be Very High and ESI classification of 5A, 5B and 5C respectively. Farmland ESI ranks High with ESI classification of 4, Semi natural vegetation has ESI ranking of Medium with ESI classification of 2 and bare surfaces had ESI ranking to be Low and ESI classified as 1. An emergency response zone and priority booming were proposed along the pipeline route as a means of curtailing the spread of oils to sensitive resources.

Keywords ESI; Emergency; Oil spill; Pipeline; Risk; Zone

1. Introduction

Crude oil remained one of the most sort after commodity which man cannot do without. Consequently, oil spills will continue to cause damaging effect on the environment because it is difficult to separate from oil exploration and exploitation (Aroh et al., 2010). In the Niger Delta, huge oil exploration and production are associated with frequent and rampant crude oil spills. The regular occurrence of oil spills in Niger Delta are results of deliberate act of vandalism of flowline, pipeline leakages, failures of oil facilities and overflow of process components. These caused considerable degradation of the environment, fundamental changes to social and environmental policies. Several barrels of oil have been spilled through oil pipeline into the environment due to lack of regular maintenance of pipelines (Nwilo and Badejo, 2010). Spilled oil is able to impair living things since its chemical constituents are
poisonous (Sojinu et al., 2010). The impacts of the oil spillages in the Niger Delta are numerous; such as adverse effect on the growth of plants due to widespread contamination of soil, pollution of water bodies (Batzias et al., 2011), impingement on organisms through internal exposure (ingestion and inhalation) and external exposure (skin and eye irritation) that causes infertility and cancer (Ordinioha and Brisibe, 2013).

Pipelines remain one of the most convenient and economical means of transporting crude oil across difficult terrain and over long distances from production facilities to distribution outlets (Alencar and De Almeida, 2010; Dey, 2010; Lins and de Almeida, 2012), though pipeline brings danger closer to homestead and farms (Phil-Eze and Okoro, 2009; Williams and Benson, 2010).

Oil pipeline spills can be caused by structural failure, operation error and third party damage (TPD) such as accidental rupture of pipelines (Achebe et al., 2012; Kandiyoti, 2012). Consequently, the present quest to increase production without addressing the animosity between host communities, government, and MOCs may further worsen existing problems of oil interdiction in oil-producing communities (Onuoha, 2008; Achudume, 2009). Despite global awareness of oil spill incidents, little attention is paid to onshore oil spills compared to offshore (Fingas, 2000; Reible, 2010; Chen and Denison, 2011). Most pipelines pass through various inland habitat and human settlements as is the case of the case of Ubgomro Community and Environ where the Federal University of Petroleum Resources is also situated. To this end, it is important to evaluate the proximity of human dwellings, sources of water, farms and other ecological habitat from sources of hazards (pipeline) (Shittu, 2014), with the specific objective of generating environmental sensitivity index classifications and maps of the ecosystem along the PPMC pipeline corridor across Ubgomo community and environ.

2. Materials and Methods

General Methodology

Developing ESI maps involves gathering spatial and non-spatial data to create strategic maps of sensitive resources (Human, Biological and Ecological feature) which are priority for response agencies involved in the emergency clean-up of oil spill in the environment. To accomplish the aim of this study the following procedure were employed; data acquisition, data manipulation, data analysis and presentation of the results (Figure 1).

![Figure 1: Methodology flow chart](chart.png)
Data Sources and Characteristics

Generating ESI maps requires interdisciplinary approach as such wide-ranging data and information are required on the biological and inland habitat types, image and data from agency responsible for oil spill emergency response as shown in Table 1 below.

Table 1: Types of data, characteristics and sources

| Type of data                          | Resolution | Date | Source                                                                 |
|---------------------------------------|------------|------|------------------------------------------------------------------------|
| Ikonos Image                          | 0.25m      | 2015 | Google Earth                                                           |
| Google Earth Pro                      | Eye altitude between 6.0 km-6.50 km. | 2017 | Data SIO, NOAA, U.S Navy, NGA, GEBCO, (c) 2017 Google Image, (c) 2017 Digital Globe |
| Literature on biological, ecological & marine (Fauna & Flora) resources | None | 2015 | Department of Biological Science University of Lagos, NOSDRA |

Inland Habitat Classification

The study focused on inland habitat along PPMC pipeline in the study area. The google earth image of the study area were downloaded and georeferenced. Based on the prior knowledge of the area of study coupled with a brief examination of researches in the study area, a classification scheme for landuse/cover was developed for the study area (Table 2).

Table 2: Land use/cover classification scheme adopted for the study

| S/N | Landuse/Cover Class          |
|-----|------------------------------|
| 1   | Built-Up Area                |
| 2   | Wetland                      |
| 3   | Semi natural vegetation      |
| 4   | Farmland                     |
| 5   | Bare surfaces                |
| 6   | Water body                   |

Categorization and ESI Ranking Classification of Inland Habitat

The main criteria considered to establish the degree of sensitivity to oil spill and other stress factor of an ecological class include its biological productivity, oil/ecology interaction and ease of clean up, and social, economic and human importance as posited by Fasona et al., 2011 was adopted in this study and shown in Table 3.

Table 3: Land use/cover sensitivity ranking and classification

| Land use/cover Classes                | Environmental Sensitivity Index (ESI) Rank | ESI class |
|---------------------------------------|-------------------------------------------|-----------|
| Built Up Area                         | VH                                        | 5A        |
| Water Body                            | VH                                        | 5B        |
| Wetland                               | VH                                        | 5C        |
| Farmland                              | H                                         | 4         |
| Semi Natural Vegetation               | M                                         | 2         |
| Bare Surfaces                         | L                                         | 1         |
Buffering

Buffer zones of various standards were created along the PPMC pipelines corridor based on local standards prescribed by PPMC and international standards used in Gundlach E. et al., 2005 as shown in Table 4.

Table 4: Buffer Standard Zones used and Sources

| S/N | Buffer zone | Source         | Standards   | Location          |
|-----|-------------|----------------|-------------|-------------------|
| 1   | 75m         | PPMC           | Local       | Nigeria           |
| 2   | 250m        | Gundlach et al., 2005 | International | Turkey & Azerbaijan |
| 3   | 500m        | Gundlach et al., 2005 | International | Turkey & Azerbaijan |

Emergency Response Zones

Emergency response zones is usually strategically positioned at areas considered to be easily accessible; between area where the inland habitat features are likely to suffer great harm and where responders and equipment can easily be deployed within a short time after oil spill incident has been reported. The proposed emergency response zone along the study area is chosen by considering; i) the most delicate inland habitat features and ii) the proximity and accessibility of required responders and equipment deployment along the pipeline route.

3. Results and Discussion

This discussion the results of the of image processing, ecological classification of the inland habitat and its ESI ranking and the use of buffer standards, of 75m, 250m and 500m respectively for the establishment of the various habitat classes are presented.

Buffer Zones of the Land use/cover along PPMC Pipeline Corridor

The inland habitat classes were identified and represented in the land cover/use feature within the established buffer of 75m, 250m and 500m according to local and international standards (Figure 2).
Using the established buffer standards in Figure 1, Table 5 shows that bare surfaces occupy 6.56%, 6.83% and 8.32% of the land area respectively, built up areas occupy 11.36%, 26.68% and 35.08% respectively, farmlands is apportioned 2.42%, 1.73% and 1.67% respectively, semi natural vegetation has 53.81%, 39.68% and 29.57% respectively, water body within the specified buffer zones occupied 0.58%, 0.68% and 1.13% respectively and wetland has 25.26%, 24.48% and 24.22% respectively. The habitat that would be of most concern within the 75m buffer is the built up area of the presence of socio-economic and cultural activities that have direct relationship with the people and the impact increases for buffer zones of 250m and 500m, while this is closely followed by farmland that also has direct impact on the people of the study area but with a decreasing impact as the buffer zone increases.

Table 5: Statistics of the land use/cover for the different buffer standards

| Buffer standards | Local buffer 75m | International Buffer 250m | International Buffer 500m |
|------------------|------------------|--------------------------|--------------------------|
| Land use/Cover class | Area (ha) | 100% | Area (ha) | 100% | Area (ha) | 100% |
| Bare Surfaces | 4.87 | 6.56 | 16.64 | 6.83 | 39.41 | 8.32 |
| Built Up Areas | 8.44 | 11.36 | 64.96 | 26.68 | 166.1 | 35.08 |
| Farmland | 1.8 | 2.42 | 4.02 | 1.73 | 7.93 | 1.67 |
| Semi Natural Vegetation | 39.97 | 53.81 | 96.6 | 39.68 | 140.04 | 29.57 |
| Water Body | 0.43 | 0.58 | 1.66 | 0.68 | 5.35 | 1.13 |
| Wetland | 18.76 | 25.26 | 59.59 | 24.48 | 114.68 | 24.22 |
| Total | 74.28 | 100 | 243.46 | 100 | 473.52 | 100 |

**Figure 3:** Environmental sensitivity index map of study area

**Sensitivity Index Ranking and Classifications of the Land use/Cover**

The Environmental Sensitivity Index map of the study area is shown in Figure 3, with built up area, water body and wetland having ESI ranking to be Very High and ESI classification of 5A, 5B and 5C respectively. Farmland ESI ranks High with ESI classification of 4, Semi natural vegetation has ESI ranking of Medium with ESI classification of 2 and bare surfaces had ESI ranking to be Low and ESI classified as 1. The details of each land use/cover are discussed in subsections below.
Built-Up Areas ESI Classification and Ranking for the Buffer Zones

The built-up area within the study area generally comprises of pockets of communities and other settlements within Uvwie Local Government Area. The Built-up area has environmental sensitivity index classification of 5A and ranks Very High (VH) for ESI (Table 6 and Figure 4). The very high SI is a result of the presence of the socio-economic and socio-cultural activities that present as a result of the presence of the Federal University of Petroleum Resources that is centred in the study area. When built up areas are impacted by oil it poses direct or indirect impact on the people and the flora and fauna. Oily sheens are formed on the soil surface and the oil can sticks to the walls of built up structures if the spill is heavy. Oil may come in contact with domestic material such as paper, broom and domestic waste which generates oily waste which must be properly managed to minimize pollution. When pipeline cuts across the communities they are at risk of accident that may lead to fire disaster and destroy lives, properties and means of livelihood. This very high SI ranking would therefore call for urgent attention and priority response in times of oil spill incident.

![Figure 4: Portion of built-up area along the pipeline corridor](image)

Table 6: Land use/cover sensitivity ranking and classification

| Land use/cover classes     | Environmental Sensitivity Index (ESI) Rank | ESI class |
|----------------------------|-------------------------------------------|-----------|
| Built Up Area              | VH                                        | 5A        |
| Water Body                 | VH                                        | 5B        |
| Wetland                    | VH                                        | 5C        |
| Farmland                   | H                                         | 4D        |
| Semi Natural Vegetation    | M                                         | 2E        |
| Bare Surfaces              | L                                         | 1F        |

Water Body ESI Classification and Ranking for the Buffer Zones

The environmental sensitivity index classification of water body is 5B ranking Very High (VH) next to built-up area (Table 6 and Figure 5); this is because marine environment is very sensitive to oil. Marine spill maybe difficult to contain, recover and remediate. It contains floras and faunas that include aquatic plants, fishes, water birds (either breeding or migratory ones) and reptiles. Other varieties of species are water snail, frog, toad and water hyacinth. Oil tends to float and spreads on water because it is lighter. Depending on the nature of the oil spill and type of water body it is spilled on; when the spilled oil is acted upon by factors such as specific gravity, wind action and direction it...
may result in processes such as dispersion, weathering, evaporation, oxidation, biodegradation and emulsification.

Figure 5: Portion of water body along the pipeline corridor

Wetland ESI Classification and Ranking for the Buffer Zones

Wetland in this study has environmental sensitivity index class of 5C and ranks Very High next to water body (Table 6 and Figure 6). The wetland is generally characterized by swampy and marsh/grass surfaces. They also comprise of biological lives such as crustacean, fishes, snapping shrimp, water snail, mudskipper and reptiles. Birds can be found here seasonally as they migrate for breeding and mating purpose and also supports another habitat around them. Oil spilled in this habitat usually persists for long as underlying wet soil below marsh and grasses restrict oil from flowing; leading to percolation of oil and seepage into the subsoil. As a result, hydrocarbons are deposited in the ground water aquifer. Grass covered with oil get sticky and soggy leaving residue over the surface when spillage is heavy.

Figure 6: Portion of wetland along the pipeline corridor
Farmland ESI Classification and Ranking for the Buffer Zones

Farmland has ESI classification of 4D with High as ranking of its ESI (Table 6 and Figure 7). Farmland as used in this study describes area where agricultural activities are carried out for subsistence purposes. The biological lives found here are different flora species and fauna like snakes, ground squirrel, monitor lizard, and agama lizard. When farmland is polluted by oil the flora and fauna are affected as well as the ground water as oil seeps through soil. Plants may bioaccumulate residue of hydrocarbon in the soil; if they are ingested by human or animal it can have adverse health implications.

Figure 7: Portion of farmland along the pipeline corridor

Semi Natural Vegetation ESI Classification and Ranking for the Buffer Zones

The feature semi natural vegetation is found mostly along the pipeline route south of Ugboromro, sparsely distributed between Ebrumede and Ugbolokposo communities and largely in FUPRE. The semi natural vegetation has ESI classification of 2E and is ranked Medium (Table 6 and Figure 8). Some floras found here include varieties of shrubs and grass species and faunas like rodent, Xerus sp (ground squirrel) and Rattus sp. (giant rat). Generally spilled oil travels slowly in this environment. Oil penetrates the topsoil and seep into the ground to infiltrate the soil leaving a silvery surface on the topmost soil layer.

Figure 8: Portion of semi natural vegetation along the pipeline corridor
Bare Surfaces ESI Classification and Ranking for the Buffer Zones

They are found at different section of the habitat. They have been exposed to human activities mostly in bid to reclaim land portions while some sections of it have been impacted by various natural components. Its ESI is ranked low (L) and its ESI classification is 1F (Table 6 and Figure 9). It would suffer the least impact in case of an oil spill. Generally, very few animals exist in this habitat some of them are lizard, cricket, small rodents and some other creeping insects. Oil tends to accumulate on topsoil and slowly seeps into the ground. Oil spill leaves stain on the soil surface as oil seeps into the soil and pollute micro biological species and ground water aquifer.

Figure 9: Portion of bare surfaces along the pipeline corridor

Figure 10: Proposed emergency response zone along the pipeline corridor

Emergency Response Zone (ERZ-1)

Emergency Response Zones (ERZ) is usually strategically positioned at areas considered to be easily accessible; between area where the inland habitat features are likely to suffer great harm and where responders and equipment such as hard booms, skimmers, storages and vehicles can easily be deployed within a short time after oil spill incident has been reported.
The emergency response zone (ERZ) has been proposed to be established along the PPMC pipeline corridor around the point at which the pipeline pass through the Federal University of Petroleum Resources, Delta which falls within the 500m buffer zone (Figure 10). The rationale being that the agency responsible for emergency response to oil spill and PPMC are some distant away and with the pipeline passing through the University, there is the danger of sabotage from student unrest anytime. To this end the institution can serve as ERZ to cater for emergency spills.

4. Conclusion

The PPMC pipeline safety can be evaluated as an individual risk, where the safety zone is set as the right-of-way. Thus, the surrounding ecosystem features that are endangered by oil spill can be predetermined. The generation of buffer zone based on the standards encapsulates the endemic ecological resources that are susceptible to contaminants from pipeline oil spill, vandalism and ruptures due to mechanical or human errors along the study area. These ESI maps aids involved authorities and agencies responsible in managing this disaster in understanding what and where to respond to and the required equipment to use in managing the pipeline spill.

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