A Geospatial Appraisal of Oil Spill Health Impacts: A Niger Delta Case Study

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Abstract: Oil spills resulting from pipeline breakages and operational failures during oil exploration have increased in prevalence in the Niger Delta, with more than 8,000 spills occurring over the past decade. Previous research has linked oil spills to human health hazards such as derma-toxic diseases, and various cancers. However, few studies have considered the health effects of oil spills on maternal and child health. This study seeks to fill this gap in literature by focusing on infant diarrhea in the Niger Delta. Diarrheal diseases account for 1 in 9 child deaths worldwide, making diarrhea the second leading cause of death among children under the age of five. Defining the spatio-temporal pattern of infant diarrhea and its relationship to oil spill contamination is critical in understanding mortality risk and enabling policy decisions aimed at reducing infant mortality rates in the region. Despite substantial data limitations, geospatial analysis revealed a statically significant spatial clustering of oil spill incidence and infant diarrhea: a pattern strongly correlated with spatial proximity to rural, low-income households with limited access to improved water sources and sanitation facilities. These locations evidenced higher rates of diarrhea incidence consistently across the region.

Keywords: Oil spill, Geospatial Analysis, Environmental Contamination, Nigeria.

INTRODUCTION

The history of oil exploration and production is long and complex, dating back to the eighteenth-century industrial revolution. Oil exploration has, since its discovery, become a major actor in shaping the world economy, technological advancements, and global energy demands. As the world advances towards development, the demand for fossil fuels, especially petroleum derivatives, are likely to increase along with the concomitant hazards. Although the discovery of petroleum reserves might hold significant economic possibilities for local communities, the risks of oil spills and high exposure to hydrocarbon pollution are equally apparent. Oil spills vary in terms of magnitude and impact. The magnitude of an oil spill refers to the total amount of oil spilled and its persistence in the environment. The magnitude and impacts are determined by the quantity of the spill, the type of product spilled and its mobility or migratory patterns by air, water or on land [1, 2]. In addition to magnitude, oil spills also vary in terms of the total number of human populations exposed; a situation influenced by the proximity of the oil spill to human settlements. In the case of off-shore oil spills removed from coastal settlements, their impacts may undergo some degree of biodegradation before pollutants reach the coasts. However, onshore oil spills immediately impact the surrounding environment and human population and define complex patterns of exposure and vulnerability [2].

Within the Niger Delta, oil spills are a significant and frequently occurring environmental hazard. The Niger Delta residents depend directly on natural environment for their food and livelihood and therefore are in constant contact with and suffer direct exposure to oil pollutants in their environment. Within this region. exposed populations face prolonged and heightened vulnerability to high concentration of hydrocarbons and other petroleum chemicals, particularly with respect to neighborhoods, farms, creeks and waterways. While the health effects of oil spills are of especial interest to public health professionals and researchers in the emerging field of spatial epidemiology, only a relatively small number of studies have been conducted on the health effects of oil spills in the Niger Delta and even less on their effects on child health. This study seeks to fill this gap in literature by focusing on the implications of oil spills on child health, with infant diarrhea as a proxy indicator. The primary objective of this study is to examine the spatial distribution of oil spills in the Niger Delta region of Nigeria and examine its relationship to patterns in infant diarrhea. From this starting point, research will explore the spatial distribution of diarrheal infection among infants in the study area, with the overall aim of defining the degree to which oils spills and incidences of infant diarrhea displays a significant, non-random, pattern.

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ISSN: 1814-8085 / E-ISSN: 1927-5129/19

PROBLEM STATEMENT

Oil Spill Hazard

Oil field hazards are a global problem that has persisted since the discovery and extraction of oil resources [3-5]. The movement and transportation of petroleum products from oil rigs to the final consumers requires extraction and conveyance through various means (pipelines, ocean vessels and tankers, trucks and by rail). Thus, oil spills can result from accidents such as operational failures, oil well blow outs and leakage at any point during exploration, refining, transportation, storage, distribution and final consumption stages. Furthermore, spills vary in terms of magnitude and impact. The magnitude of an oil spill refers to the total amount of oil spilled and its persistence in the environment. The magnitude and impacts are determined by the quantity of the spill, the type of product spilled and its mobility or migratory patterns by air, water or on land [1, 2]. In addition to magnitude, oil spills also vary in terms of the total number of human populations exposed, a variable influenced by the proximity. Petroleum products contain several common fuels, and spills may occur at high speeds across contrasting land surfaces. Although, surface oil spills can be detected by their characteristic signs, such as visible traces of oil stains, odors or sometimes a fire outbreak, sub-surface spills are more difficult to detect, particularly when petroleum infiltrates the subsoil and reaches ground water aquifers. Surface and underground oil spills contaminate soils, sediments, water, and air through the released of several volatile compounds into the atmosphere [4, 6, 7]. Numerous researchers have documented the human health implications of oil spills in residents living near oil spill locations and in workers participating in cleanup activities [6, 8, 9]. A study conducted by Campbell *et al*. (1993) reported that residents living within 4.5 km of the spill site experienced a higher prevalence of sore throats and irritated eyes compared to residents living further away [10]. Similar findings by Lyons *et al*. (1999) reported a range of acute symptoms that ranged from physical symptoms, mental health, perceived health and anxiety for both exposed and non-exposed populations with significant increases in headaches, nausea, sore eyes and throat, cough, and skin infections [11].

Compared to the documentation of acute physical and mental health impacts, relatively little has been documented regarding health impacts of oil spills on maternal and child health. The literature suggests that exposure to oil spills have significant effects on maternal and child health and is one of the major environmental factors contributing to child morbidity and neonatal mortality [12]. An exploratory factor analysis conducted by Peres *et al*. (2016) examined the association between oil spill exposure and the physical health of adult women following and oil spill incident in southern Louisiana [13]. Results revealed that women exposed to the oil spill had significantly higher odds of experiencing symptoms like burning sensations in nose and lungs, sore throat, red eyes, dizziness and wheezing, leading the authors to conclude that proximity and exposure to the Deep Horizon oil spill was associated with an increase in negative physical health outcomes. The implications to childhood heath remains to be understood.

Petroleum and the Niger Delta

The Niger Delta is considered the second largest delta region in the world, with approximately 28000sq/km of land mass and continental shelf stretching about 46300sq/km. The region is also considered the largest wetland and mangrove forest in Africa and third largest in the world [14, 15]. (Figure **1**) Since the discovery of oil in the Niger Delta in the late 1950s, the oil and gas sector has overtaken other sectors to become the backbone of Nigeria's economy. Presently, oil production and exploration from the Niger Delta constitutes approximately 95 percent of Nigeria's export revenues, and 32 percent of gross domestic product (GDP). However, while oil exploration has contributed immensely to the economic growth and development of the country at large, it has resulted in severe environmental degradation, pollution and widespread underdevelopment in the oil-producing communities [16, 17].

Oil spills are common occurrences throughout the region as a result of pipeline corrosion, poor maintenance of infrastructure, operational failures and third-party damage through oil theft and vandalism [16, 17]. Studies estimate that at least 9-13 million barrels of oil have been spilled over more than 5 decades of oil exploration in the Niger Delta with an estimated average of about 240,000 barrels spilled annually [18, 19]. Erhun (2015) attributes the unchecked and frequently occurring oil spills to Nigeria's regulatory failure in environmental governance and to the fact that national interests in economic development are valued over and supersede all concerns for environmental sustainability [20]. Thus, a region popular for its rich biodiversity and delicate ecosystems is threatened by

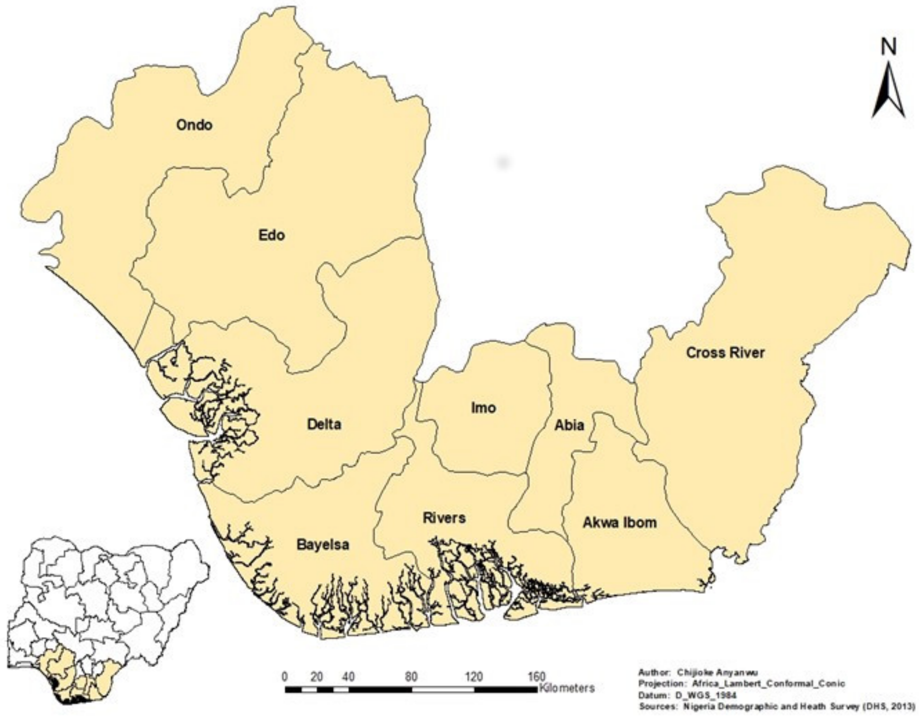

Figure 1: The Niger Delta Region of Nigeria.

severe environmental degradation. The delta region is presently one of the worst oil degraded locations and most severely endangered ecosystems in the world [21-23]. Despite 50 years of oil exploration in the Niger Delta, only recently has the region become an area of environmental concern. Several studies report that the Niger Delta crisis is a direct fallout of the environmental degradation due to oil related activities, other studies assume an environmental justice perspective and submit that the Niger Delta crises is a result of marginalization and alienation in the region [24-29].

The environmental complexities of the region are further underscored by an upsurge in violence and conflict as a result of oil extraction in the area. This increase in violence and unrest has directly led to an escalation of vandalism and attacks on oil infrastructure and associated rise in the occurrences of oil spills in the region [30].

Linking to Childhood Health

Typically, health and epidemiology research in Sub-Saharan Africa including Nigeria, have primarily revolved around demographics and socio-economic risk factors and determinants of health [8, 25]. In general, high rates of child mortality in Nigeria can be associated with the prevalence of such diseases as diarrhea, malaria, and HIV/AIDS. In northern Nigeria attributing factors include the persistence of drought while the prevalence of cough, fever and diarrhea in the southern region are linked to oil spills and environmental pollution [26]. When focus is directed specifically to oil spills in the region, significantly high levels of contamination have been attributed to increased cases of child malnutrition, cancer, kidney diseases, diarrhea, and anemia which are attributable to direct exposure to high level hydrocarbon concentration [3]. Diarrheal infection is generally known to be caused by bacterial and/or viral infections, food intolerance, irritable bowel syndrome or other forms of bowel disorder. Several studies have equally cited an association between diarrhea prevalence and demographic, socio-economic and environmental influences with infant diarrhea more prevalent in low and middle-income countries due to limited access to potable and improved sources of drinking water and improper waste management practices [28]. Infant mortality due to diarrhea is still very high in Nigeria with an estimated 315,000 child mortality cases annually and is often associated with polluted water sources, inadequate sanitation, poor hygiene practices and contaminated food. Establishing the degree to which oil pollution in petroleum producing regions contributes to this pattern remains a challenge for a variety of reasons related largely to data reliability and accessibility constraints. This study identifies one approach to break through this bottleneck.

METHODOLOGY

Geospatial methods have been widely applied in a range of environmental health applications [29-32]. This study contributes to this literature with an expanded focus on establishing the relationship between oil spills and the incidence of infant diarrhea in the Niger Delta. The methods applied in this study functioned to: 1) describe the spatial pattern of infant diarrhea and oil spill contamination in the region, and 2) define the existence and strength of the spatial relationship. Analysis involved three main phases: 1) Data extraction and database design, 2) Pattern analysis, and 3) Statistical Testing (Figure **2**). To facilitate analysis, kernel density estimation was employed to place the point representations into raster surfaces for modeling. Kernel density estimation is a non-parametric way to estimate the probability density function of a variable. The function calculates the density of point features in the neighborhood based on the input data [33]. Density is calculated by weighting the distances of all the data points for each location on the surface to define a neighborhood field. The more points allocated to the field, the higher estimate, indicating that probability of seeing a point at that location.

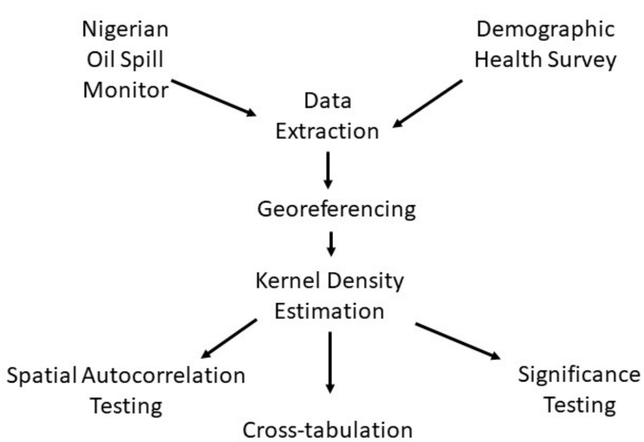

Figure 2: General Methodology and Work Flow.

Data Extraction and Database Design

This study is based on analysis of secondary oil spill data from the Nigerian Oil Spill Monitor, and spatial health data extracted from the 2013 Nigeria National Demographic and Health Survey (DHS). Data on both oil spill incidence and childhood health in the region suffered from collection and representation issues that would easily frustrate geospatial analysis, Careful steps were taken to enable use of these data sets and support a format that would facilitate application in a GIS environment. Georeferenced data of oil spill locations required conducting individual spatial queries from an online maps depicting oil spill locations in the region. From these queries a dataset was assembled that was populated with the geographic coordinates of each recorded spills, dates of the spill, and estimated quantity of petroleum leaked for the period 2008-2013. Because spill data were recorded by different agencies, including petroleum producers, and members of local communities, discrepancies in the data could be noted. For instance, the Shell Petroleum Development Company (SPDC) oil spill data differs from that of NOSDRA and from figures reported by individuals or private investigators. The oil spill investigation process, commonly known as the Joint Investigation Visit (JIV) is carried out with the oil companies as the primary investigators, therefore it is possible that underreporting exists. To reduce error and misrepresentation of data, oil spill incidences with missing information were excluded from the study. Off-shore spills were also excluded from the study due to the inability to expansively document their locations and their migratory capacity.

As noted above, health data applied in this investigation was acquired from the Demographic and Health Survey 2013. The Demographic and Health Survey (DHS) is a nationally representative sample survey that provides information on population, demographics, socioeconomic characteristics, as well as nutrition and health indicator estimates. The 2013 NDHS contains a sample survey of 33,385 women of reproductive age between 15 to 49 and 15,486 men aged 15 to 59 in randomly selected households across the six geo-political zones in Nigeria. Child health and mortality estimates are based on information from mother's birth histories collected through semi structured survey questionnaire for women while infant diarrhea data was collected from questionnaires administered to mothers containing questions about child health in the two weeks preceding the survey. The survey employed a stratified three-stage cluster design consisting of 904 clusters, 372 in urban areas and 532 in rural areas and provides a comprehensive population-based health data. According to the survey, mothers were asked whether any of their children under the age of 5 experienced symptoms of diarrhea any time during the two weeks preceding the survey. As such, there is no information on cases of diarrhea prior to the 2 weeks before the survey. Secondly, it is generally presumed that mothers can tell when their child has diarrhea and are able to distinguish diarrhea from other forms of bowel movements. Thus, the validity of the DHS data on infant diarrhea is affected by mothers' perception of diarrhea as an illness and her ability to recollect past events.

Georeferencing in the DHS is based on GPS latitude/longitude data that have been randomly displaced to preserve confidentiality of survey respondents. Typically, data collection clusters in urban areas are displaced up to 2 kilometers away while rural clusters are displaced up to 5 kilometers. Additionally, the method of collecting the aggregated DHS data produces a point location whereby a single point feature represents a cluster of households rather than individual household unit. The coarse spatial detail of the DHS introduces a level of generalization that limits the scale of analysis and the ability to explain relationships at the individual household level. It is likely that data collection and representation issues are the primary factors that contribute to the absence of research on spill contamination and public health in the region. The data limitations identified above draw attention to the methods of spatial analysis selected to ameliorate the vexing scale and representational issues while still enabling a meaningful assessment of health impact relationships to be understood. Kernel density estimation was a critical step in producing meaningful spatial representations of both oil spill and diarrhea patterns in the region.

Pattern Analysis

With a spatial data set populated from the oil spill and childhood health information sources analysis could proceed. The initial requirement of the study called for a means to measure the spatial distribution of both phenomena to determine whether the patterns expressed are clustered, dispersed, or random. Spatial autocorrelation, interpreted within the context of a hypothesis test used the Global Moran's I Index expressed as:

$$I = \frac{N\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\right)\sum_{i=1}^{n}(X_i - \bar{X})^2} \quad (1.0)$$

Where N = number of observations,

$\bar{X}$ = mean of the variable,

X_i = Variable value at a location

X_j = variable value at another location

W_{ij} = Wight index location of *i* relative to *j*

A positive Moran's I index indicates a tendency towards spatial clustering while a negative Moran's I index value indicates dispersion. In addition to the Moran's I Index, a z-score and a p-value were calculated to evaluate the significance of the Index. When the p-value is statistically significant, the null hypothesis can be rejected which will mean that for example, cases of infant diarrhea in the Niger Delta are clustered, but if the p-value is not statistically significant, the null hypothesis is accepted. The Z-score measures the distribution of high and low values i.e. cluster of high values of oil spills or infant diarrhea.

Statistical Testing

Following the hypothesis test based on Moran's I, cross-tabulation was employed determine the degrees of associate between oil spill geography and infant diarrhea patterns. Cross-tabulation function basically measures the level of association between two or more classified images and calculates an overall as well as per-category indices. For this analysis, oil spills were organized into 5 categories in raster format, category 1 representing the least quantities of oil spill and category 5 representing the highest quantities of oil spill. Similarly, incidences of infant diarrhea were placed into 5 categories with class 1 and class 5 representing the least and highest prevalence rates, respectively.

Three critical statistics are derived via cross-tabulation:

- Cramer's V, which explains the strength of the association between variables along the range 0.0 indicating no associate, to 1.0 which indicates a strong association according to the formula:

$$V = \sqrt{\frac{\chi^2}{n(k-1)}} \quad (2.0)$$

Where: χ^2 = chi-square,

k = the number of rows or columns in the table,

- Chi-Square, which explains the statistical significance of the association. If the Chi-Square is significant, then the Cramer's V will equally be significant.

- Kappa Index of Agreement (KIA) given by:

$$K = \frac{N\sum_{i=1}^{n} x_{ii} - \sum_{i=1}^{r}(x_{ii} + x_{+i})}{N^2 - \sum_{i=1}^{r} x_{ii}(x_{ii} + x_{+i})} \quad (3.0)$$

Where: K = Kappa Index of Agreement;

r = number of matrix lines;

X_{ii} = number of observations in ith row and ith column;

X_{i+} and X_{+I} = total of ith row and ith column, respectively

N = total number of observations (cells)

The Kappa Index ranges from 0.0 to 1.0 indicating no agreement to perfect agreement, respectively. In addition, 5km, 10km and 20km buffer were defined around oil spill locations and selected DHS clusters. The conflation surfaces were used to explore the effect of distance from oil spill location on the prevalence of infant diarrhea.

RESULTS AND DISCUSSION

Oil spills are virtually inevitable accidents associated with oil exploration, transportation and distribution and usually occur in areas of damaged oil facilities. Despite that some researchers have cited oil spills as potential risk factors contributing to the prevalence of infant diarrhea in Nigeria, only very few systematic studies have been documented showing this relationship. Evidence based on a geospatial analysis of the relationship between oil spills and infant diarrhea is generally lacking in the literature and requires further investigation. The spatial distribution of oil spills in the study area are shown in Figure **3**. The patterns display a noticeable concentration in the south-central portion of the region where the petroleum refining and related industries concentrate. The pattern then trends north-east following lines of transportation and pipeline location.

Infant diarrhea displays a most dispersed pattern throughout the region with aggregation of incidence within the central portion of the study area (Figure **4**).

A geospatial analysis of the distribution of oil spills in the Niger Delta defines a significant clustered pattern (p-value of ≈0.0004 and z-score of ≈3.53), suggesting that incidence rates are non-random and closely associated with petroleum extraction and refining activities in the region (Figure **5**). These results are consistent with previous investigations and further supported by the spatial autocorrelation statistics given in Table **1** [34].

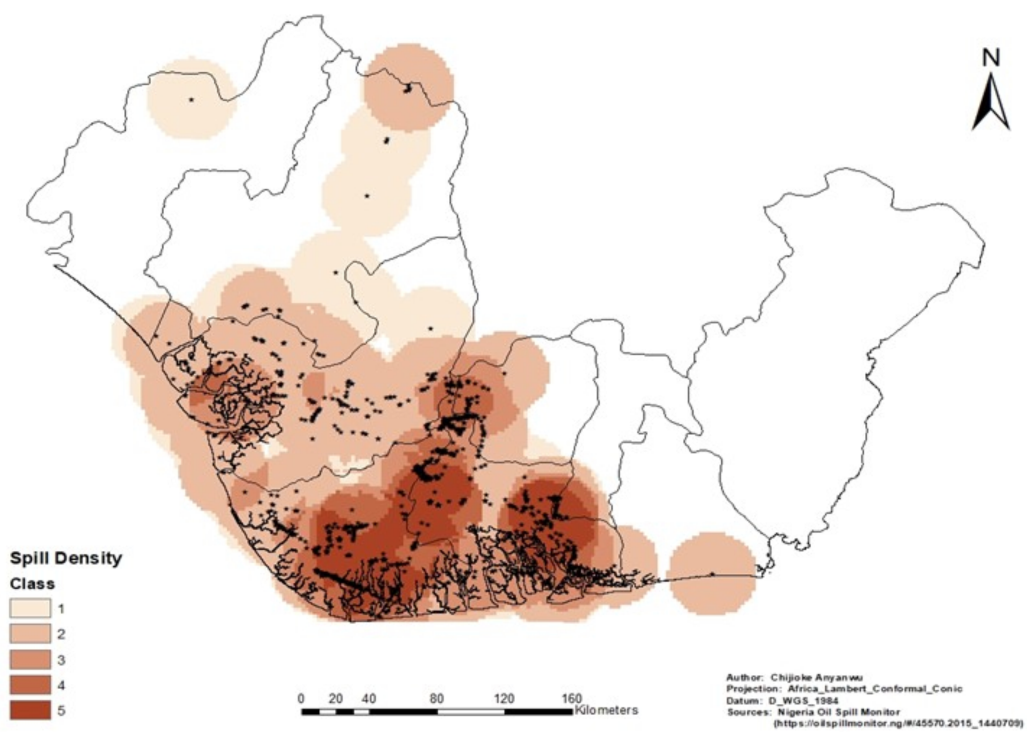

Figure 3: Oil Spill Density by Volume Class.

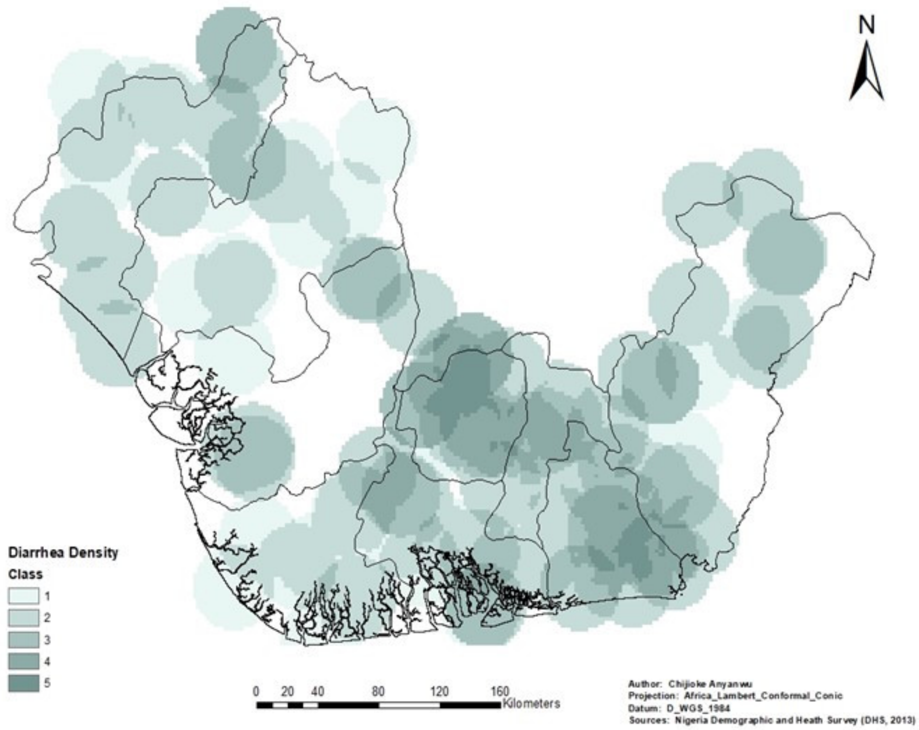

Figure 4: Infant Diarrhea Density by Incidence Class.

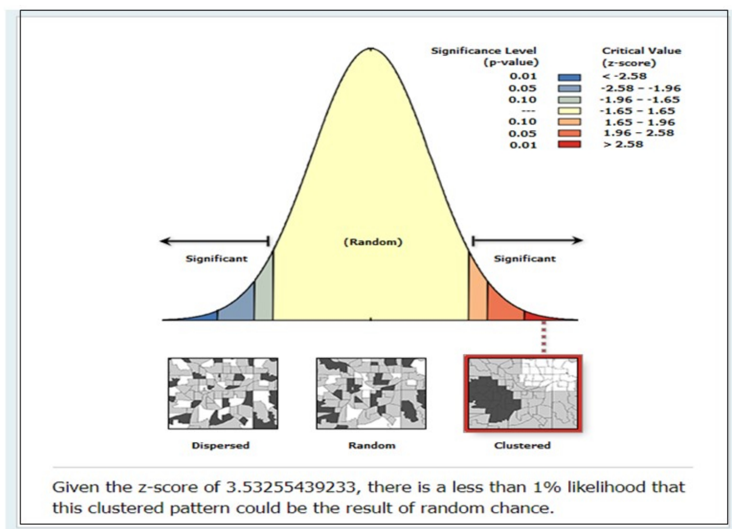

Figure 5: Spatial Autocorrelation Report for Oil Spill Incidence.

Table 1: Moran's I Summary Statistics: Oil Spill Incidence

Moran's Index:	0.080320
Expected Index:	-0.000671
Variance:	0.000526
z-score:	3.532554
p-value:	0.000412

Subjecting infant diarrhea incidence to a spatial autocorrelation analysis found a significantly clustered pattern of cases for the region (p-value = 0.02, z-score 2.27). Given the 95% confidence level established for the test, there is less than a 5 percent likelihood that the incidence of infant diarrhea across the Niger Delta is a result of randomness (Figure **6**). These findings are further confirmed by the summary statistics for Moran's I given in Table **2**.

The degree to which diarrhea incidence could be attributed to oil spills in the region was examined through cross-tabulation of the density surfaces. Cross-

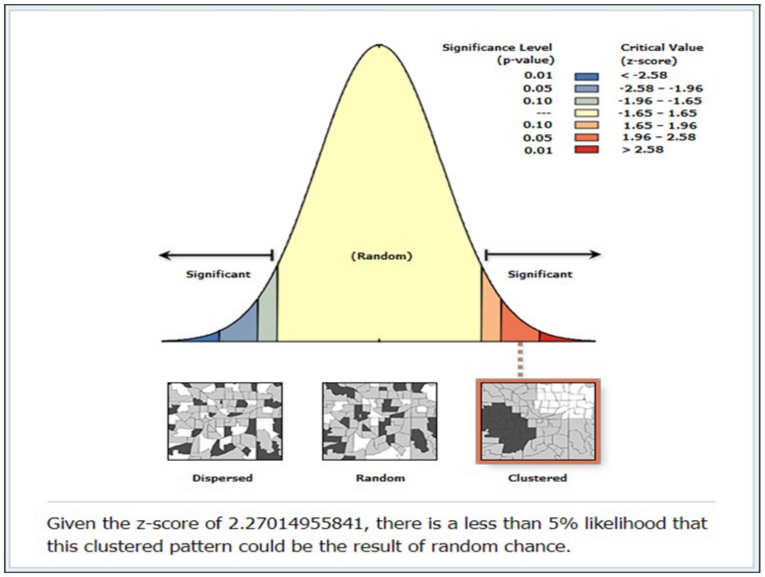

Figure 6: Spatial Autocorrelation Report for Infant Diarrhea Incidence.

tabulation analysis of the spatial association between the two variables evidenced a positive relationship (Cramer's V =0.26) that was significant at the 0.95 confidence interval (Table **3**).

Table 2: Global Moran's I Summary: Diarrhea Incidence

Moran's Index:	0.093425
Expected Index:	-0.004878
Variance:	0.001875
z-score:	2.270150
p-value:	0.023199

The V statistic of 0.26, while small, does suggest that there is a spatial association between the two variables that are not chance-related. While the factors that contribute to infant diarrhea are multi-variate and complex, the results suggest that environmental contamination induced by oil spills does play a substantial and statistically significant role. These findings were further assessed by conducting a proximity analysis using distance criteria to examine distance-decay effects in the pattern (Figure **6**). A complex pattern was observed that displayed a cluster of impacted household units within 5 to 10 KM zones of reported oil spills. A frequency and percentage calculation of the proximity relationship was conducted (Figure **7**).

As illustrated in Figure **8**, households within 5km of a reported oil spill location reported 19 percent prevalence rate of diarrhea, while households 10km and 20km from an oil spill site reported 13 percent and 10 percent of infant diarrhea respectively. These findings support the general pattern revealed through cross-tabulation and are consistent with previous studies that have established that adverse health

Table 3: Cross-Tabulation of Oil Spill (Columns) against Diarrhea (Rows)

	1	2	3	4	5	Total
1	547	854	245	144	118	3463
2	1160	1079	531	489	760	9351
3	137	745	313	344	302	5220
4	51	242	139	154	205	2283
5	0	250	57	5	0	548
Total	2593	5468	1864	1252	1387	288600

Chi Square = 97800.92969.
df = 25.
P-Level = 0.0000.
Cramer's V = 0.2603.

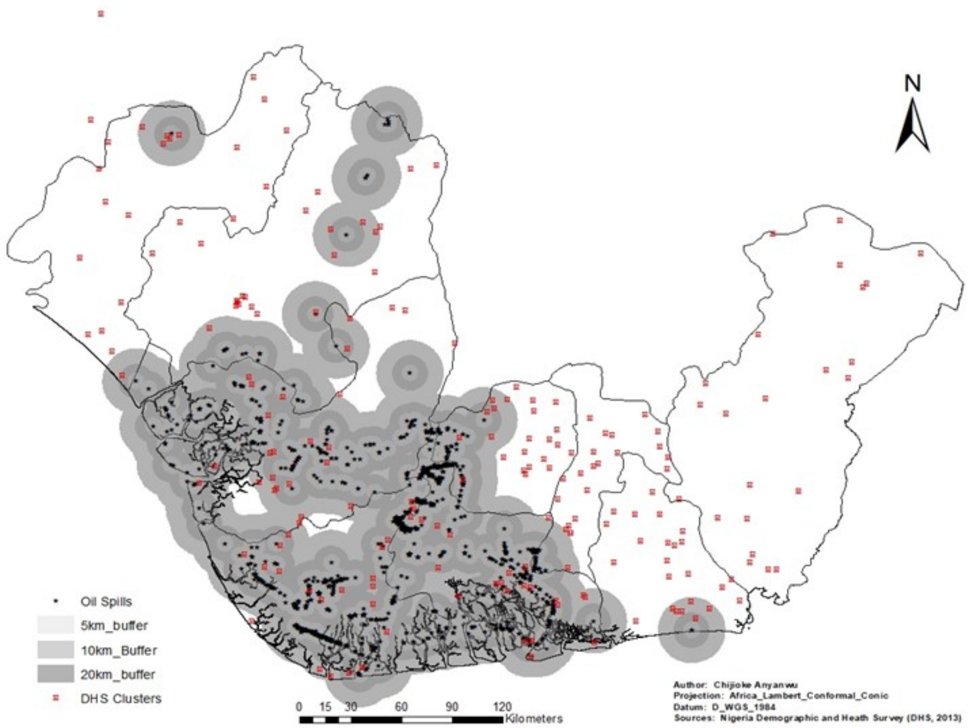

Figure 7: Proximity Surface of DHS Clusters From Oil Spill Incidence Locations.

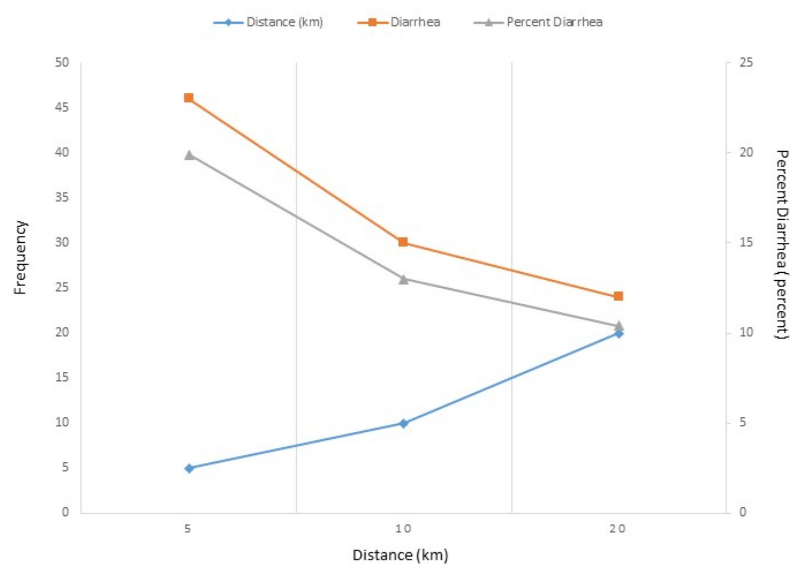

Figure 8: Diarrhea Incidence Within Distance Zone.

outcomes diminish substantially with distance from the point of pollution [11, 35].

A confounding issue specific to the Niger Delta is the fact that a majority pipelines traverse residential neighborhoods and at times are exposed on the surface. Population vulnerability patterns are made more complex because residents in the study area engaged in primary economic activities like farming, logging, forestry and fishing, that are highly dependent on surface water, boreholes and wells principal sources of irrigation and drinking water. These living conditions amplify the likelihood of direct contact with and exposure to oil pollution following a spill. Whanda *et al*. (2018) observed that most significant exposure pathways in the Niger Delta were associated with rural agricultural land use through direct contact with polluted soils and consumption of homegrown produce [34]. They also suggest that residents experience prolonged exposure to hydrocarbon components from oil spills due to the persistent nature of some oil pollutants in the environment and due to the land use types and economic activities they engage in. Imo State appeared to have the highest percentage (12.2 percent) of infant diarrhea and on the other extreme, Bayelsa and Edo States with a sample size 220 and 387 children accounted for 1.8 percent and 2 percent, respectively, of total cases of infant diarrhea in the Niger Delta.

CONCLUSIONS

Oil spills resulting from pipeline breakages and operational failures during oil exploration are endemic in the Niger Delta and poses human health hazards such as derma toxic diseases, cancer, neonatal and child mortality. The low standard of operation of oil companies in the Niger Delta region of Nigeria, amplifies the risk of oil spills and the juxtaposition of infrastructure near human settlements, elevates human exposure and contamination risk to homes, farms and fishing grounds. This study presents an application of geospatial methodologies implemented in a GIS environment to examine the spatial relationship between oil spill incidence and child diarrhea in the Niger Delta of Nigeria. The spatial modelling capability of the GIS is critical to understanding the spatial variation of health impacts and their relationship to environmental hazards.

After detailed investigation, we find that both oil spill incidence and infant diarrhea patterns displayed definitive spatial clusters that are non-random. When cross-tabulation analysis was performed, results showed that 26% of the spatial variance in diarrhea could be explained by oil spill incidence and as proximity to exposure zones decreased, diarrhea rates declined substantially. Furthermore, limited of access to potable water and sanitation facilities strongly correlated with the disease prevalence. To tackle child diarrhea in the Niger Delta, it is imperative to improve access to potable water and sanitary living conditions. Similarly, exposure to oil polluted environments could be minimized by enforcing policies on environmentally sound oil exploration activities and adequate maintenance of existing oil infrastructure to reduce oil spill incidences.

Spatial epidemiology studies are essential in developing integrated environmental management studies about the identification of environmental variables that cause significant adverse health impacts. Disease mapping and specialized socioeconomic indicators is possible using GIS and this technique appears to be an efficient and cost-effective way for obtaining results for both scientific and management purposes.

REFERENCES

[1] Chang SE, Stone J, Demes K, Piscitelli M. Ecology and Society: Consequences of Oil Spills:A Review and Framework for Informing Planning. Ecol Soc 2014; 19(2): 26. https://doi.org/10.5751/ES-06406-190226

[2] Eykelbosh A. Short and Long-Term Health Impacts of Marine and Terrestrial Oil Spills.A Literature Review Prepared for the Regional Health Protection Program, Office of the Chief Medical Health Officer, Vancouver Coastal Health 2014.

[3] Ordinioha B, Brisibe S. The Human Health Implications of Crude Oil Spills in the Niger Delta, Nigeria: An Interpretation of Published Studies. Nigerian Medical Journal: Journal of the Nigeria Medical Association 2013; 54(1): 10-16. https://doi.org/10.4103/0300-1652.108887

[4] Anifowose B. Assessing the impact of oil & gas transport on Nigeria's environment, In U21 Postgraduate Research Conference Proceedings 2008; Vol. 1.

[5] Michel J, Fingas M. Oil Spills: Causes, consequences, prevention, and countermeasures. In Fossil Fuels: Current Status and Future Directions 2016; pp. 159-201. https://doi.org/10.1142/9789814699983_0007

[6] D'Andrea MA, Reddy GK. Health consequences among subjects involved in Gulf oil spill clean-up activities. The American Journal of Medicine 2013; 126(11): 966-974. https://doi.org/10.1016/j.amjmed.2013.05.014

[7] Peres LC, Trapido E, Rung AL, Harrington DJ, Oral E, Fang Z, Peters ES. The Deepwater horizon oil spill and physical health among adult women in Southern Louisiana: the women and their children's health (WaTCH) study. Environmental Health Perspectives 2016; 124(8): 1208-1213. https://doi.org/10.1289/ehp.1510348

[8] Nriagu J, Udofia E, Ekong I, Ebuk G. Health risks associated with oil pollution in the Niger Delta, Nigeria. International Journal of Environmental Research and Public Health 2016; 13(3): 346. https://doi.org/10.3390/ijerph13030346

[9] Cheong HK, Ha M, Lee JS, Kwon H, Ha EH, Hong YC, Kim EJ. Hebei Spirit oil spill exposure and subjective symptoms in residents participating in clean-up activities. Environmental Health and Toxicology 2011; 26. https://doi.org/10.5620/eht.2011.26.e2011007

[10] Campbell D, Cox D, Crum J, Foster K, Christie P, Brewster D. Initial effects of the grounding of the tanker Braer on health in Shetland. The Shetland Health Study Group. BMJ 1993; 307(6914): 1251-1255. https://doi.org/10.1136/bmj.307.6914.1251

[11] Lyons RA, Temple MF, Evans D, Fone D, Palmer SR. Acute Health Effects of the Sea Empress oil spill. J Epidemiol Community Health 1999; 53: 306-310. https://doi.org/10.1136/jech.53.5.306

[12] Hurtig A-K, San Sabastian M. Incidence of Child Leukemia and Oil Exploitation in the Amazon Basin of Ecuador. International Journal of Occupational and Environmental Health 2004; 10(3): 245-50. https://doi.org/10.1179/oeh.2004.10.3.245

[13] Chinweze C, Abiola-Oloke G, Jideani C. Energy Resources Management for Sustainable Development in Nigeria Niger Delta Region: Women Issues and the Environment. World Academy of Science, Engineering and Technology 2009; 54.

[14] Adeola FO. Endangered community, enduring people: Toxic contamination, health, and adaptive responses in a local context. Environment and Behavior 2000; 32(2): 209-249. https://doi.org/10.1177/00139160021972504

[15] Amnesty International. Nigeria: Petroleum, Pollution, and Poverty in the Niger Delta.Amnesty International Publications; London, UK 2009.

[16] Balogun TF. Utility of Microwave and Optical Remote Sensing in Oil Spill Detection in the Mangrove Region of Nigeria. Journal of Geoscience and Environment Protection 2015; 3(01): 16-23. https://doi.org/10.4236/gep.2015.31003

[17] Erhun MO. A Sustainable Approach to Economic Development in Nigeria: A Legal Perspective. Journal of Economics and Sustainable Dev 2015; 6(14): 1-6.

[18] Ngobiri CN, Ayuk AA, Awuoso II. Differential degradation of hydrocarbon fractions during bioremediation of crude of polluted sites in Niger Delta area. J Chem Soc Nig 2007; 32: 151-158.

[19] Atubi AO. Effects of oil spillage on human health in producing communities of Delta State, Nigeria. European Journal of Business and Social Sciences 2015; 4(8): 14-30.

[20] Nwankwoala HO, Nwaogu C. Utilizing the tool of GIS in oil spill management-a case study of Etche LGA, Rivers State, Nigeria. Global Journal of Environmental Sciences 2009; 8(1): 23-33. https://doi.org/10.4314/gjes.v8i1.50820

[21] Ehigie BO. Ethnic differences and perceived marginalization as psychological issues of conflict in Nigeria. Nigerian Journal of International Affairs 2005; 31(1): 67-89.

[22] Ovadia JS. The Nigerian “One Percent” and the management of national oil wealth through Nigerian content. Science & Society 2013; 77(3): 315-341. https://doi.org/10.1521/siso.2013.77.3.315

[23] Obi CI. Oil Extraction, Dispossession, Resistance, and Conflict in Nigeria’s Oil-Rich Niger Delta. Canadian Journal of Development Studies / Revue Canadienne d’études Du Développement 2010; 30(1-2): 219-236. https://doi.org/10.1080/02255189.2010.9669289

[24] Osuji LC, Egbuson EJ, Ojinnaka CM. Assessment and treatment of hydrocarbon in undated soils using inorganic nutrients (N–P–K) supplements: Acase study of Eneka oil spillage in Niger Delta, Nigeria. Environmental Monitoring and Assessment 2006; 115(1-3): 265-278. https://doi.org/10.1007/s10661-006-6552-6

[25] Gay JC, Whitman MA, Thyden MJ, Shepherd OC. The health effects of oil contamination: a compilation of research. Digital WPI, Worcester Polytechnic Institute 2010. https://digitalcommons.wpi.edu/iqp-all/838/

[26] Kandala N-B, Madise N. The Spatial Epidemiology of Childhood Diseases in Malawi and Zambia. African Population Studies 2004; 19: 199-226.

[27] Kandala N-B, Ji C, Stallard N, Stranges C, Cappuccio FP. Spatial Analysis of Risk Factors for Child Morbidity in Nigeria. The American Journal of Tropical Medicine and Hygiene 2007; 77(4): 770-779. https://doi.org/10.4269/ajtmh.2007.77.770

[28] Hussein H. Prevalence of Diarrhea and Associated Risk Factors in Children Under Five Years of Age in Northern Nigeria: A Secondary Data Analysis of Nigeria Demographic and Health Survey 2013. 2017. https://www.giscloud.com/blog/mapping-the-disease-using-gis-for-improving-malaria

[29] Rosenberg M. Global child health: Burden of disease achievements and future challenges. Current Problems in Pediatric and Adolescent Health Care 2007; 37(9): 338-362. https://doi.org/10.1016/j.cppeds.2007.07.003

[30] Dangendorf F, Herbst S, Reintjes R, Kistemann T. Spatial Patterns of Diarrheal Illnesses with Regard to Water Supply Structures - A GIS analysis. International Journal of Hygiene and Environmental Health 2002; 205(3): 183-191. https://doi.org/10.1078/1438-4639-00151

[31] Njemanze PC, Anozie JO, Iheanacho JO, Russel MJ, Uwaeziozi AB. Application of Risk Analysis and Geographic Information Technologies to the Prevention of Diarrheal Diseases in Nigeria. American Society of Tropical Medicine and Hygiene 1999; 33: 207-221. https://doi.org/10.4269/ajtmh.1999.61.356

[32] Cromley EK, McLafferty SL. GIS and Public Health. 2nd Ed. Guilford Press 2012; 1167-9.

[33] Silverman BW. Density Estimation for Statistics and Data Analysis. New York: Chapman and Hall 1986. https://doi.org/10.1007/978-1-4899-3324-9

[34] Whanda S, Adekola O, Adamu B, Yahaya S, Pandey PC. Geo-spatial analysis of Oil Spill Distribution and Susceptibility in the Niger Delta Region of Nigeria. Journal of Geographic Information Systems 2016; 8: 438-456. https://doi.org/10.4236/jgis.2016.84037

[35] Bruederle A, Hodler R. The Effect of Oil Spills on Infant Mortality: Evidence from Nigeria, CESifo Working 2017; Paper, No. 6653.

Received on 05-12-2019 Accepted on 21-12-2019 Published on 30-12-2019

https://doi.org/10.29169/1927-5129.2019.15.10