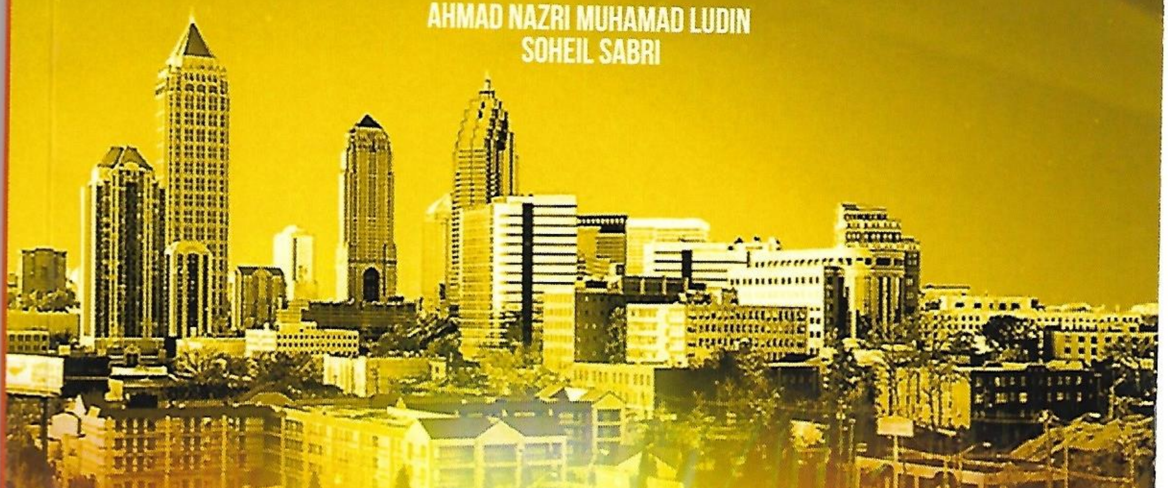
SPATIAL ANALYSIS *in* URBAN PLANNING

Editors

AHMAD NAZRI MUHAMAD LUDIN
SOHEIL SABRI



UTM
UNIVERSITI TEKNOLOGI MALAYSIA

First Edition 2016

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

SPATIAL ANALYSIS IN URBAN PLANNING/ Editors:
Ahmad Nazri Muhamad Ludin, Soheil Sabri
Includes index
ISBN 978-983-52-1155-3
1. Spatial analysis (Statistics). 2. City planning--Statistical methods.
3. Regional planning--Statistical methods. I. Ahmad Nazri Muhamad Ludin,
II. Soheil Sabri.
711.570728

Editor: AHMAD NAZRI MUHAMAD LUDIN & SOHEIL SABRI
Pereka Kulit / Cover Designer: MOHAMAD HAIRY ZOLKEFLE

Diatur huruf oleh / *Typeset by*
AHMAD NAZRI MUHAMAD LUDIN & SOHEIL SABRI
Faculty of Built Environment
UTM Johor Bahru

Diterbitkan di Malaysia oleh / *Published in Malaysia by*
PENERBIT UTM *PRESS*
UNIVERSITI TEKNOLOGI MALAYSIA,
81310 UTM Johor Bahru,
Johor Darul Ta'zim, MALAYSIA.
(PENERBIT UTM ahli MAJLIS PENERBITAN ILMIAH MALAYSIA (MAPIM) dan anggota PERSATUAN PENERBIT BUKU MALAYSIA (MABOPA) dengan no. keahlian 9101)

Dicetak di Malaysia oleh / *Printed in Malaysia by*
JASAMAX ENTERPRISE
No. 55, Jalan Kebudayaan 22, Taman Universiti
81300 Skudai Johor, MALAYSIA

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Spatiotemporal Dynamics of *Meningococcal Meningitis*: Evidence in the Kaduna Urban Area, Nigeria

Umaru Emmanuel Tanko, Ahmad Nazri Muhamad Ludin, and Soheil Sabri

4.1 INTRODUCTION

Meningitis is the breakdown of the defensive sheath that shields the spinal cord and brain, which are together called the meninges (Center for Disease Control and Prevention, 2014). It is a very dangerous disease because it can cause inflammation very close to the brain and spinal cord. Conditions such as this require urgent attention. Different types of germs, both viral and bacterial, can cause the disease, but the bacterium *Neisseria meningitides*, which is commonly known as *Meningococcal meningitis*, is more harmful. This bacterium is very dangerous because it is very harmful to the people it affects and because it has the potential to cause epidemics, unlike most other causes of *meningitis* (WHO, 2000).

Environmental factors play a major role in influencing the spread of the disease, which is associated with poor housing conditions, deprived settlements and household overcrowding (Baker *et al*., 2000; Fone *et al*., 2003; Olowokure *et al*., 2006; Tully *et al*., 2006). Overcrowded settlements that lack ventilation also play a major role in spreading the disease. A study conducted by Tully *et al*. (2006) in the United Kingdom showed that the spread of *Meningococcal meningitis* was common in an overcrowded settlement. Other studies by Fone *et al*. (2003) and

Davies *et al.* (1996) also confirm that overcrowding and poor housing conditions are significant factors in influencing the spread of the disease.

The Kaduna Urban Area (KUA) is within Kaduna, the capital of Kaduna state, which is located in northern Nigeria within the African *meningitis* belt. The socio-economic and built environment aspects of the KUA have led to peculiar variations in the incidence of *Meningococcal meningitis*. The growing number of cases in the KUA and the transmission pattern are poorly understood. The objectives of this study are to evaluate the spatial and temporal patterns of the incidence of *Meningococcal meningitis* in the KUA and to examine the locations of the high and low concentrations of the disease to establish where it is coming from.

4.2 STUDY AREA AND METHODOLOGY

4.2.1 Study Area

The study area for the research is the Kaduna Urban Area, located within Kaduna, the capital of Kaduna state. Within the Kaduna city region lays the legally designated Kaduna Urban Area (KUA), which is an approximate rectangle of 40 km by 30 km that lies roughly northeast/southwest with Kaduna in its centre (Lock, 2010). Figure 4.1 is a map of Kaduna state that shows all of the local governments in the state, and Figure 4.2 is a map of the KUA that shows all 106 neighborhoods.

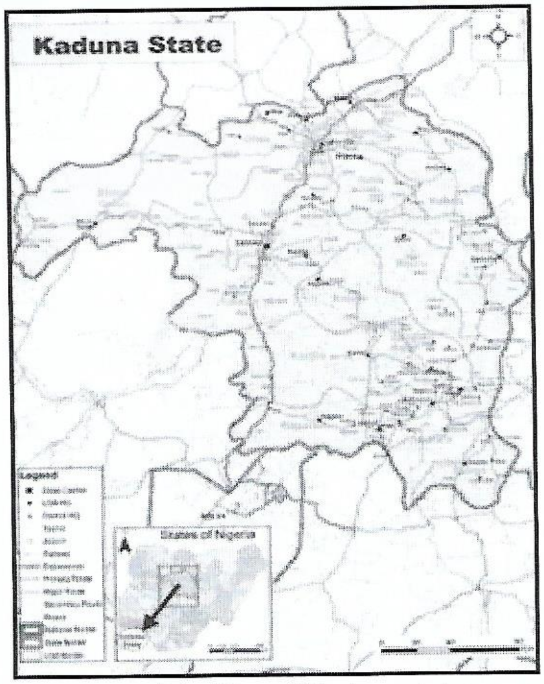

Figure 4.1 Map of Kaduna state
(Source: Lock, 2010)

For many years now, *Meningococcal meningitis* has been affecting the KUA annually. The outbreak of the disease is experienced between the months of February and May, the dry season, when the temperature is highest and the relative humidity is lowest. When the rainy season begins in May, there is a drastic drop in the disease until the next year. There are sporadic cases of the disease, but they are very rare compared with the peak period of the dry season. Table 4.1 shows the number of cases and deaths of *Meningococcal meningitis* in the last five years.

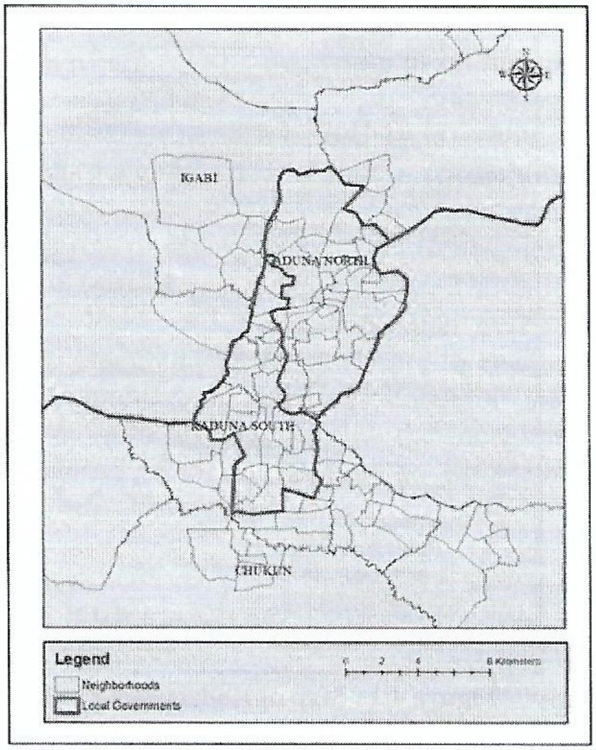

Figure 4.2 Map of Kaduna urban area
(Source: Lock, 2010)

Table 4.1 *Meningococcal Meningitis* cases and deaths in the KUA

Years	Cases	Death
2007	130	31
2008	45	7
2009	275	69
2010	105	37
2011	69	11

(Source: Ministry of Health, Kaduna State, 2012)

4.2.2 Data Collection

Meningococcal meningitis cases were collected for a period of five years (2007–2011) at the neighborhood level.

4.2.3 Spatial Statistics of Disease Evidence

The use of spatial statistics in the study of epidemiology is very critical because of the results they can produce. In the past, conventional statistics could not be combined with spatial analysis, which limited health planners' understanding of their epidemiological studies. Only the distribution of disease maps was assessed by health geographers in the past, but spatial statistics integrate the conventional statistics with spatial analysis to solve epidemiological problems, and the result gives a clear understanding of the epidemiological study that was conducted; additionally, predictions are simpler.

Spatial statistics are used to detect patterns of spatial autocorrelation that represent areas of either high or low risk (Waller and Gotway, 2004). The patterns may represent areas of significant excess or deficits in disease activity, which are known as clusters. The advantage of detecting clusters is identifying spatial patterns that are unique and different from what could be expected in the absence of the phenomenon being studied, which makes clustering the measure of an area's abnormality relative to a null expectation (Fotheringham *et al*., 2002).

4.2.4 Spatial Clusters of the Disease at the Neighborhood Level

Local spatial clustering is mainly concerned with determining the characteristics of clusters, such as the location, intensity and size. The primary objective of this technique is to identify the locations of the clusters, their significance and also the areas they cover. A cluster was defined by Knox (1989) as "a geographically and or temporarily bounded group of occurrences of sufficient size and concentration to be unlikely to have occurred by chance". The objective of this chapter is to evaluate the spatial and temporal patterns of the incidence of *Meningococcal meningitis* and also to detect the locations of high and low concentrations. Clustering is a suitable method for achieving this.

A study was conducted by Greene *et al.* (2005) to investigate the spatio-temporal patterns of viral *meningitis* in Michigan, and the study showed that blacks and infants were the risk group. The cases of the disease were found to be concentrated in the southern part of the study area, and spatio-temporal clusters were identified from 1998 to 2001. Philippon *et al.* (2009), in a study that investigated the spatial patterns of *Meningococcal meningitis* in Mali, found locations with both high and low clusters of the disease.

4.2.5 Detecting High and Low Disease Clusters

Hot spot analysis can be conducted using the Getis and Ord Gi* statistics for every feature in a set of data. The results are evaluated by the z score and p values, which reveal whether the high and low groupings are spatially clustered. The tool operates by estimating each *Meningococcal meningitis* case in view of the neighboring background features; a location that has a high value may not be a statistically significant hotspot. A statistically significant hotspot must have a *Meningococcal meningitis* location with a high value and be near other locations of *Meningococcal meningitis* that also have high values. The *Meningococcal meningitis* incidence of the local sum and its neighbors are compared in proportion to the sum of all of the incidences when a difference is observed in the local sum from the expected sum, and if the difference is not attributable to random chance, there is a significant z score.

Table 4.2 The interpretation of scores for Gi(d) statistics

Situation	Z(Gi)
High next to High	Strongly positive
High next to Moderate	Moderately positive
Moderate next to Moderate	0
Random	0
High next to Low	Negative
Moderate next to Low	Moderately negative
Low next to Low	Strongly negative

(Source: Wong and Lee, 2005)

4.2.6 Choosing a Distance Band for the Spatial Pattern Analysis

In conducting a spatial pattern analysis, the distance band that is chosen is important and will determine the reliability of the result. Spatial statistics integrate space and spatial relationships directly into analysis; therefore, selecting a conceptualization of the spatial relationship between features is required. For hot spot analysis, the most recommended conceptualization of the spatial relationship is 'fixed distance' with a defined threshold limit or distance band (Gajovic and Todorovic, 2013 and Azil, *et al*., 2014). For analyses in which some of the polygons are very small and others are very large, it is recommended that the "zone of indifference" distance band option be used to conceptualize the spatial relations (Saxena *et al*., 2012). In the zone of indifference, the features within the specified critical distance of a target feature receive a weight of 1, and they influence the computations for that feature. Once the critical distance is exceeded, weights diminish with distance.

In this analysis, the "zone of indifference" is used. The distance band that exhibits the highest spatial autocorrelation (peak Z value) is used for the analysis. With the "zone of indifference", a moving window conceptual model of spatial interactions is imposed onto the data such that each feature is analysed within the context of the neighboring features within the specified distance band. At most times, it is very difficult to justify any particular analysis distance, and this is when the incremental spatial autocorrelation tool is used.

To be able to capture in detail the spatial process of the incidence of *Meningococcal meningitis* in the whole of the KUA, the distance interval of 0.5 km is selected and used in selecting the best distance band. As a result, the distance band of 4 km (4,000 m) is considered for the hot spot analysis. Figure 4.3 shows the graph of multiple attempts to gain the peak Z score value.

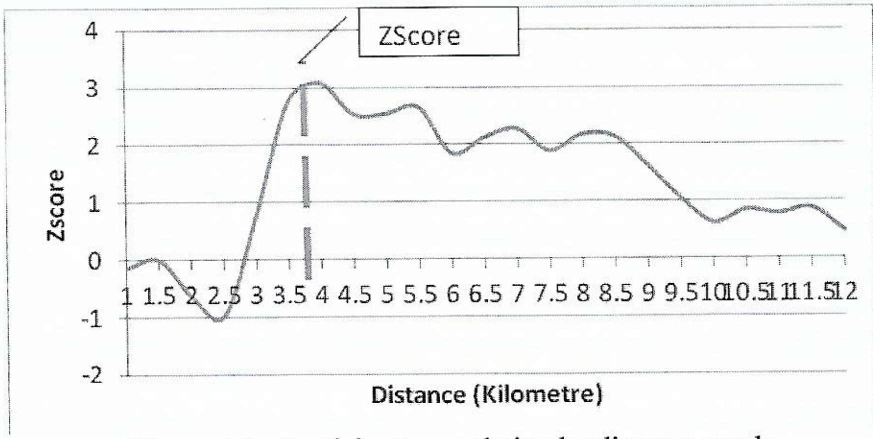

Figure 4.3 Spatial autocorrelation by distance graph

4.3 RESULTS AND DISCUSSION

Getis and Ord local spatial autocorrelation analysis was conducted in the KUA for the 106 neighbourhoods. The map in Figure 4.4 (a) shows a cluster of neighbourhoods with high incidences of *Meningococcal meningitis* at the south-western part of the KUA in 2007. Some of the neighbourhoods fell in the high cluster region, with standard deviations of 1.68–2.58, indicating that the clusters of high concentrations of *Meningococcal meningitis* in those neighbourhoods were significant. Neighbourhoods with z scores greater than 2.58 were considered significant at the 99% confidence level ($p < 0.01$) and placed in the hotspot category.

Neighbourhoods with z scores between 1.65–1.96 and 1.96–2.58 are significant at the 90% and 95% confidence levels ($p < 0.10$ and 0.05) and were categorized as neighbourhoods with high risk of *Meningococcal meningitis*. The other neighbourhoods fell within z scores of -1.65 to 1.65, indicating that there was no statistically significant spatial association of these neighbourhoods with *Meningococcal meningitis* incidence. Therefore, the null hypothesis must be rejected because there is a pattern for the incidence of *Meningococcal Meningitis* in the KUA. The Getis and

Ord results for the five-year period are compared with each other to determine the temporal pattern.

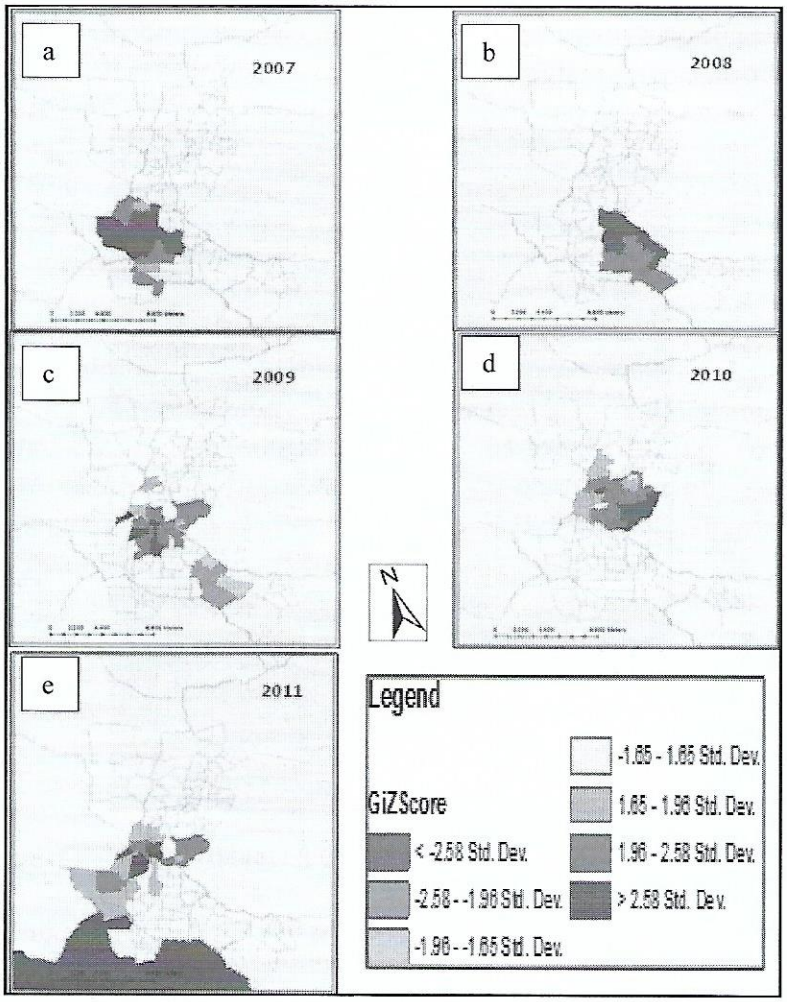

Figure 4.4 Spatial pattern of *Meningococcal meningitis* from 2007 to 2011

Some of the neighborhoods, especially those in the locations where there was a statistically significant pattern of the incidence of *Meningococcal meningitis*, had inadequate urban facilities and services. These neighborhoods include Tudun wada, Sabon gari, Nasarawa, Tudun nupawa and Kakuri, all of which are in the central to south-western part of the KUA; Figure 4.5 is the Nasarwa neighborhood. Other characteristics of such locations include high-density residential neighborhoods and poor housing conditions, as shown in Figure 4.6.

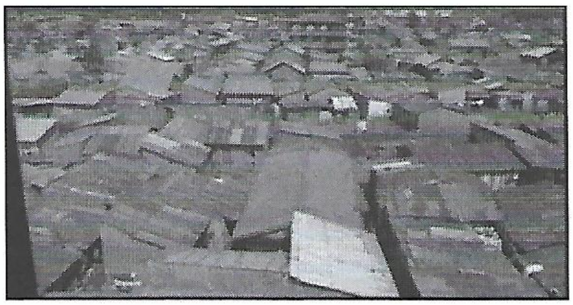

Figure 4.5 Nasarawa neighborhood

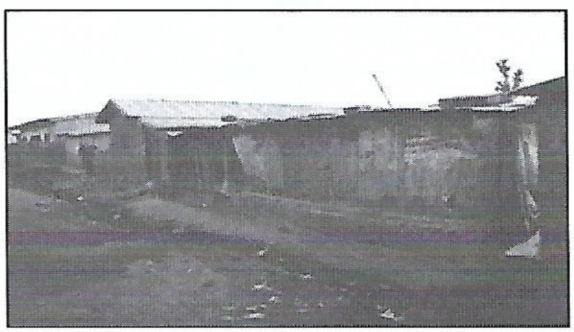

Figure 4.6 Poor housing condition

In 2008, there was a shift in the high concentration of neighborhoods with *Meningococcal meningitis* incidences from the south-western to the south-eastern part of the study area, as shown in Figure 4.4(b). In Figure 4.4(c), there was a twist in the spatial pattern of the incidence of *Meningococcal meningitis* in Kaduna Urban Area for the year 2009: unlike the other years that had only hotspot clusters, there are cold spot clusters in the spatial pattern of *Meningococcal meningitis* in 2009, possibly because 2009 was the year that the incidence of *Meningococcal meningitis* was high in the whole of West Africa and that was reflected in the KUA. These results match those observed in earlier studies conducted by Jafri *et al.* (2013) and WHO (2013) that noted that the 2009 *Meningococcal meningitis* epidemic was the highest between 2007 and 2011. Another reason could be the fact that built environment factors and socio-economic factors such as urbanization, poor housing conditions, housing density and income levels are fully represented in those locations. The neighborhoods in central KUA have the high concentrations of the disease.

The neighborhoods with low clustering values are located in the south-eastern part of the study area, with significant z scores of -1.96 to -1.65, and -2.58 to -1.96, and are termed cold spots. The other neighborhoods fell in the range of -1.65, indicating that there was no statistically significant spatial association pattern of *Meningococcal meningitis* incidence. In 2010, clusters of high values of *Meningococcal meningitis* incidence were observed in the central KUA, as shown in Figure 4.4(d). Those neighborhoods, with z scores >2.58, were considered significant at the 99% confidence level ($p<0.01$), and they are considered hotspots. The map in Figure 4.4(e) shows the incidence of *Meningococcal meningitis* in the KUA for year 2011. The neighborhoods with a high number of clusters are located in the central area extending towards the south-western part of the study area.

4.4 CONCLUSION

This chapter focusses on the spatial patterns of the incidence of *Meningococcal meningitis* in the KUA. Using the Getis and Ord local spatial autocorrelation, incidence patterns were determined. The locations of high and low concentrations of incidence were also detected: predominately the neighborhoods in the central west and towards the southern parts of the KUA. If the disease's influences in these locations are not investigated, it is very likely that the disease will continue to persist. Future studies should focus on identifying the factors that influence the incidence of the disease in the KUA.

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