East African Scholars Journal of Engineering and Computer Sciences
Abbreviated Key Title: East African Scholars J Eng Comput Sci
ISSN: 2617-4480 (Print) & ISSN: 2663-0346 (Online)
Published By East African Scholars Publisher, Kenya
Volume-4 | Issue-10 | Dec-2021 | DOI: 10.36349/easjecs.2021.v04i10.008

OPEN ACCESS

Original Research Article

Geospatial Assessment of Urban Malaria Transmission Determinants in Osogbo, Nigeria

Ismail ALATISE[1*]
[1]Department of Geography, University of Ibadan, Nigeria

Article History
Received: 26.11.2021
Accepted: 18.12.2021
Published: 30.12.2021

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: Low socioeconomic status, sub-standard housing, poor environmental conditions, limited access to healthcare facilities among other factors; are major urban risk factors that have implications on malaria epidemiology. Identifying the causal factor of malaria incidence and transmission in our urban areas is vital for sustainable integrated malaria control programs. Thus, this paper aims at analyzing the bionomics of malaria vector in Osogbo-a rapidly growing urban area and identifying the underlying urban risk factors causing malaria morbidity and transmission using geospatial analysis techniques. Focusing on the aim, the study was based on self-reported malaria cases from the dwellers using structured questionnaire forms; as well as data on the number of clinical reports and residential locations of malaria patients collected from LAUTECH Teaching Hospital and State Hospital, Asubiaro, Osogbo. The data was georeferenced and integrated into a Geographic Information System (GIS) to perform spatial hotspot analysis and proximity studies. Pearson correlation analysis was carried out on geospatial data obtained to determine the spatial association of the surveyed risk factors to malaria incidence. Results gathered reveal the spatial clustering of urban malaria in peri-urban and urban areas of Osogbo. Poor environmental condition in the form of pool of stagnant water (potholes in unpaved roads, water in abandoned containers, and rainwater in abandoned tyres) within or near household significantly correlated with malaria incidence when mapped using spatial interpolation techniques. These environmental factors were identified through spatial analysis as the risk factors serving as the major breeding points for malaria vectors causing febrile condition for the dwellers. Hence, effective environmental management programs guided by GIS-based surveillance is recommended as an essential feature in the sustainable alleviation of malaria burden in Osogbo and other urban areas in Nigeria.

Keywords: Geospatial Analysis, Urban malaria, Urbanization.

1.0 INTRODUCTION

Malaria, though preventable and curable is still widely a major vector-borne infectious disease worldwide. World Health Organization (WHO) in 2017 indicated 219 million cases of malaria, from which 92 percent (i.e. 200 million) cases came from the WHO African region [47]. In addition, ten highest burden African countries experienced 3.5 million more cases in 2017 than in 2016 [48]. Six African countries accounted for 50% of all global malaria burden: Nigeria (23%), Democratic Republic of Congo (11%), United Republic of Tanzania (4%), Burkina Faso (4%) Mozambique (4%) and Niger (4%) [49]. It is evident that fewer significant progress has been recorded in global malaria control and Nigeria remains a malaria hardest-hit country in Africa. Much of these malaria cases occur both in rural and urban areas. Presently, the world is experiencing rapid urbanization; and more people are moving into urban areas. For long, it was believed that urban development greatly reduced vector breeding and malaria transmission [20]. The rise in urbanization has implications for the epidemiology and control of malaria [20, 24, 19]. Urban environments exhibit significant spatial variation in their development level [20; pp.119]. The highly heterogeneous nature of the urban areas affect the transmission of vector borne diseases such as malaria which are water dependent [41].

***Corresponding Author:** Ismail ALATISE
Department of Geography, University of Ibadan, Nigeria

There are two contrasting viewpoints on the effect of urbanization on malaria transmission namely: the positive viewpoint and the negative viewpoint. The negative viewpoint posits that urbanization discourages malaria morbidity. This is because urban environment provides unsuitable breeding sites for malaria vector [44, 27] They posit that, urbanization process is usually accompanied by high population density and infrastructural development. Most suitable breeding sites (vegetative, natural and polluted surfaces) [39, 12] would have been replaced by building structures, paved surfaces, open surfaces etc. Hence, destruction of mosquito territory and breeding sites [19, 34]. High pollution status [40] in urban areas also reduces vector breeding and dispersal. More so, people living in planned urban centers would have access to improved healthcare [11] and long-lasting insecticide or bed net [36] which also prevent malaria morbidity. Studies have also shown that urban dwellers with high socio-economic status [30] will have access to good quality housing [30] and access to better nutritional status and health care which prevent malaria morbidity.

On the other hand, the positive viewpoint postulates that the inherently poor environmental conditions of urban areas such as poor sanitation, poor housing quality, and low socio-economic status greatly aid malaria morbidity [34, 35, 7]. Rapid uncontrolled urbanization can give rise to urban sprawl and shanty towns or slum with high population growth [35]; unpaved roads [13]; poor sewage and water management system, unhealthy environmental conditions [17] aid malaria vector proliferations. More so, proximity of households to vegetation in urban area, in the form of small-scale crop production or urban agriculture or natural vegetation[11] as well as flood plain, fish farms [12] enhance mosquito breeding habitats among other factors.

In Nigeria, the positive viewpoint holds sway; malaria is a major public health burden in urban areas [25]. Concurrently, Nigeria currently witnesses rapid urbanization with 50 percent of the country's population living in urban areas [37]. According to [2], "… unplanned urban growth, inadequate waste disposal, irrigation and poor drainage, usually alter ecosystem and thus promote the breeding of mosquitoes in urban areas of Nigeria". This definitely has transmission and vector control. Osayomi,[34]'s study of the geographical pattern of malaria morbidity in Nigeria validates the existence of urban malaria phenomenon in Nigeria. He attempted to justify its existence (Osayomi, 2014:110):

> *"…most Nigerian cities are generally characterized by unhealthy conditions which increase the …urban population's degree of susceptibility to malaria. It is commonplace to see sewage flow from outdoor bathrooms and toilets onto streets; drainage channels filled with stagnant and filthy water and large heaps line the major highways and neighborhood streets. All these unsanitary surrounding with the appropriate microclimate conditions create malaria mosquito habitats. Subsequently, these vectors breed, feed and infect the numerous urban residents with malaria parasites"* (p.110)

Given the foregoing, this call for a better understanding of the spatial and temporal patterns of urban malaria risk and associated risk factors in order to design effective urban malaria control programme [20, 19]. Hence, this study aimed at analyzing the determinants of malaria vector and identifying the underlying urban risk factors causing malaria morbidity and transmission in rapidly growing urban township of Osogbo. Here, we examine the spatial pattern and determinants of malaria in the ancient and rapidly urbanizing area of Nigeria, Osogbo, Osun State.

Osogbo is a malaria endemic urban centre with a variety of mosquito species [1]. Despite its endemicity, information on environmental risk factor(s) of urban malaria morbidity in Osogbo remains inadequate. The fundamental knowledge about urban malaria and the influence of urbanization on malaria morbidity is yet to be given widely appraisal. Proper understanding of this context is highly dependent on analysis of existing data and imperative for developing unique space-based malaria control and intervention strategies [9]. The findings from this study would be practically helpful in guiding policy makers in making sustainable integrated malaria control programs in Nigerian urban areas.

This paper is divided into six sections. The first section describes the study context. Section two of this paper dwells on the conceptual framework and literature review on the determinants of urban malaria. The third section provides the description of the data sources and methodology adopted for this study. Section four presents the results of the study. The fifth section discusses the results in relation to existing literature. Finally, the last section ends the paper with conclusions and recommendations for policy making.

1.1 STUDY CONTEXT

From a pre-colonial town, Osogbo became the capital city of Osun State, south west Nigeria after it was carved out from the old Oyo State in 1991. Based on the 2006 National Population Census, Osogbo had 287,156 residents (NPC, 2006). Its municipal area covers two local government areas (LGAs) namely: Olorunda and Osogbo. It experiences dry season from November to March and wet season from April to October [2]. Since 1991, Osogbo has been witnessing rapid urban growth. There has been substantial increase in the horizontal growth of Osogbo. The built up area of the town increased from 54.81 square kilometers in 1984 to 105.4 square kilometers in 2014 with an annual growth rate of 2.2 km^2 [43]. Since 1991, important physical changes

have occurred over the years with the construction of new parks, roads, shopping complexes, modern markets and schools. More recently, the city has encroached on neighboring local government areas of Ede North and Egbedore.

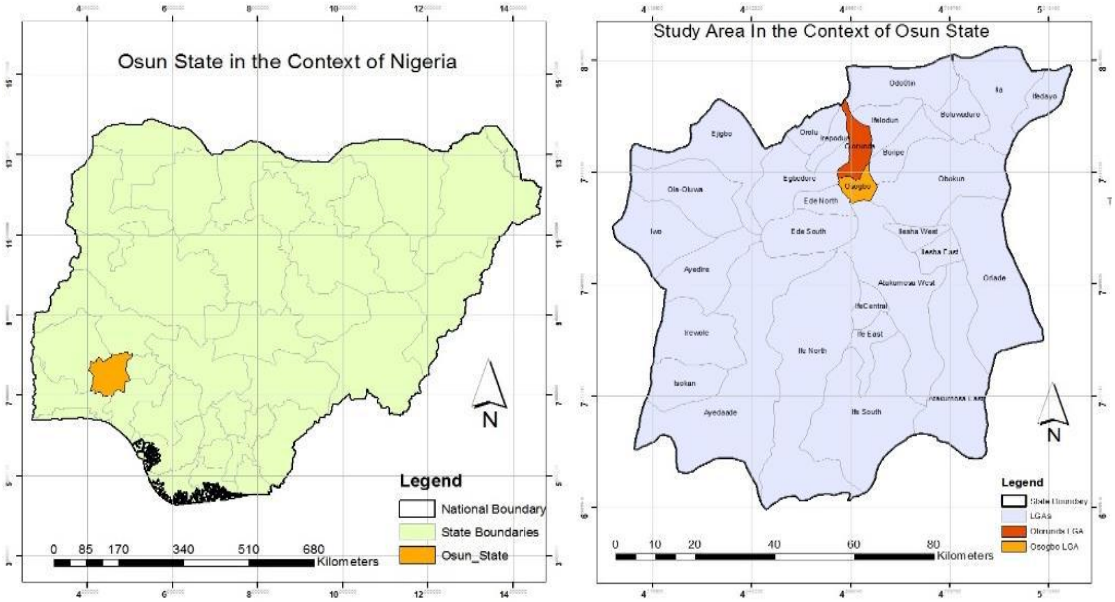

Fig: Map of Osun State in the Context of Nigeria and Osogbo in the Context of Osun State

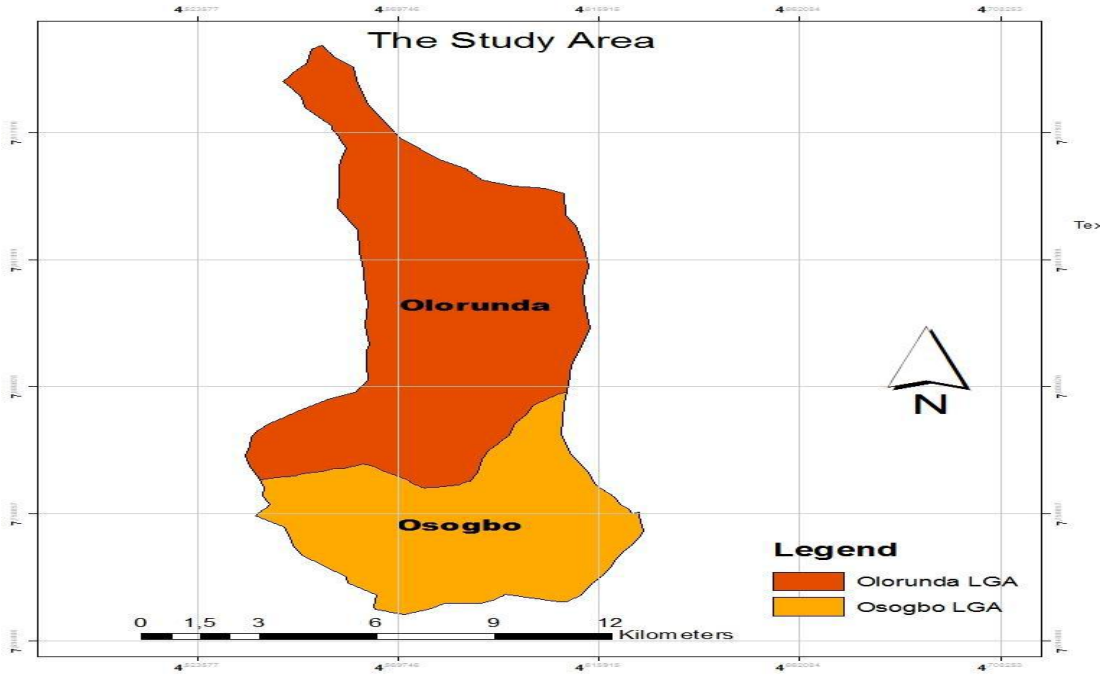

Fig: Map of Osogbo

2.0 ENVIRONMENTAL DETERMINANTS Of URBAN MALARIA

It has been shown with many studies that the nature of the environmental conditions of an area determines malaria incidence in such area. On one hand, lack of sanitation, presence of stagnant water pool [2] nearness to flood plains [13], poor drainage system [32] water in tyre tracks [18], water in unpaved roads or potholes [13] among others, can provide nice conditions and breeding grounds for malaria vector mosquitoes; while increasing malaria prevalence in society. On the other hand, a clean environment with good sanitation and drainage system decreases the risk of malaria infection due to the reduction in malaria-causing mosquito breeding points [19, 44]. For this study, it is hypothesized that environmental conditions especially, nearness to pool of stagnant water contributes to malaria morbidity and transmission.

Water supply

Overhead water tanks and wells are major breeding sources of the local malaria vector *Anopheles Stephensi* in the Indian city of Chennai. Large proportion of over head tanks support *Anopheles*. *Stephensi* breeding compared to wells and others [45]. The most common artificial habitats are drains or gutters, ditches, truck tyres, leaking water pipes and foliage created by urban agriculture. Others are water tanks, construction sites and swimming pools. Rivers and flood plains provide great breeding grounds for mosquitoes in riverside urban communities. Artificial vector breeding sites-swimming pools, tyre track, construction sites, water tanks.

Urban Agriculture

Another important environmental risk factors of malaria morbidity and transmission in cities is the urban agriculture. Urban farming [23, 28], and fish farming [12] provide breeding opportunities for mosquitoes in the form of vegetation and stagnant polluted water respectively. Nearness of these activities to household enables malaria transmission and morbidity. Small scale crop production and other peri-domestic environmental factors are major influences on the local abundance of malaria vectors even in high density urban areas [11]. The practice of urban agriculture combined with poor drainage systems puts the population living in urban areas including those living in the outskirts at risk of contracting malaria. Drainage ditches in farms create potential breeding sites due to the accumulation of very shallow slow-moving water which favours *An. gambiae* [21]. Here, it is hypothesized that urban and fish farming are positively related to malaria incidence and morbidity.

Socio-Cultural Behaviour

Poor management and disposal method [32, 15] as well as travel patterns in the form of frequent movement of the urban dwellers to malaria infected rural areas [8, 5] (for economic purpose) and non-usage of long-lasting treated nets [6, 42] have impacts on malaria morbidity and transmission in urban areas. It is hypothesized in this study that urban dwellers' behaviour contributes to malaria transmission and morbidity.

Housing Characteristics

Poor house structure contributes to malaria risk [46, 7]. Children living in modern, improved housing are less likely to be infected than those in traditional and unimproved housing. House improvements could effectively enhance malaria control [46]. High malaria transmission could occur in urban areas, especially in the core or traditional areas, "slum-like or shanty town" due to poor quality housing [15, 24]. This condition could also occur in the unplanned city periphery (peri-urban zones). Residents in houses made of mud with eaves on the wall are liable to malaria infection when compared to people living in brick house with proper netting in a healthy environment. Consequently, In this paper, this study assumed that there is a positive relationship between housing quality or characteristic and malaria epidemiology. In summary, it is presumed that the transmission of malaria in Osogbo, as a rapidly growing urban area in Nigeria is significantly influenced by environmental risk factors such as stagnant pool of water near household and poor housing quality and conditions.

3.0 DATA AND METHODS

Data were adopted from both primary and secondary sources. Primary data came from a questionnaire survey on malaria prevalence and risk factors affecting morbidity. The questionnaire was divided into three sections. The first section collected information about the demographic and socio-economic characteristics of respondents, such as age, sex, marital status, occupation etc. The second section collected information about the number of times the respondent or member of the household had had malaria in the last one year. Information on household and neighborhood environmental conditions such as number of people living in that household, mode of waste generation and disposal method, water supply; distance to the nearest refuse dump, river, pond or stream, and sanitation facilities, hygiene condition facilities etc. were obtained. The third section collected information about perceived causes and control of malaria e.g. method of prevention, like internal residual spraying, use of insecticide treated nets, nearby available health facilities, traditional methods of treatment etc.

Secondary data comprised retrospective clinical data on malaria cases in Osogbo from LAUTECH Teaching Hospital (Olorunda local government) and State Hospital, Asubiaro, Osogbo (Osogbo local government). All malaria cases were aggregated at the local government area (LGA), based on the residential addresses provided in the medical records. The study covered all the political wards in the two local government areas (Osogbo Local Government and Olorunda Local Government) that make up Osogbo town. The sample size was calculated using the 2006 Population and Housing census data for the Federal Republic of Nigeria from National Population Commission. The sample frame for Osogbo LGA is 32,850 households, while that of Olorunda local government is 28,116 household, based on the National Population Commission (NPC) house count figure (2006) for both local governments. The number of questionnaire forms allotted was derived by finding the 1 % of the total number of houses in both LGAs per the number of political wards in the local government.

Overall, a total number of 610 questionnaire forms were distributed in both local governments. 281 questionnaire forms were administered in Olorunda local governments on the average of 25 questionnaires in each of the 11 political ward i.e.(25x11=275+6=281) but 26 questionnaires in the six (6) political wards in the urban areas. Also, 329 questionnaire forms were administered in Osogbo local government; an average of 22

questionnaire forms in each political ward i.e. (22x15=330). Twenty one (21) questionnaire forms were administered in ward 15 due to its rural nature which was presumed to make up of less population compared to other wards in Osogbo metropolis.

Systematic sampling technique was used in the administration of the questionnaires to the head of the house or any other learned person of at least 18 years of age in every building along the streets in each of the political wards in Osogbo. The questionnaire forms were administered using the English language to learned respondents while the local language (Yoruba language) was used in administering the questionnaire forms to the non-English language speaking respondents. The sampling interval for this research was one (1) questionnaire in every four (4) buildings in an areas to ensure adequate representation and proper coverage of all sampled areas. In cases where there are more than one household in a particular compound the first household approached was surveyed. The effect of environmental and socioeconomic factors on the malaria incidence were done using the simple linear (Pearson) correlation. Thereafter, the effect of each identified risk factor on malaria incidence was determined using simple linear (Pearson) correlation.

4.0 RESULTS

Spatial Pattern of Urban Malaria in Osogbo

From 2018 to 2019, there were a total of 230 cases in Osogbo. In terms of ward distribution, Olorunda wards 1 (24 cases) & 8 (41 cases), and Osogbo wards 4 (34 cases), 5 (28 cases) & 8 (24 cases) had the largest number of malaria cases in Osogbo where some Olorunda wards 3 & 9 and Osogbo ward 11 and 12 had zero cases. This does not mean these areas did not have malaria, their cases of malaria incidence was not recorded; their unreported malaria cases is due to health-seeking behavior of the people living in these areas and distance decay effect. These political wards are farther from the two hospitals where malaria cases data were collected; hence, because of the distance to medical facilities, long waiting time among other factors, dwellers ended up in varied health seeking behavior such as self medication. Consequently, these political wards have no documented record for malaria cases.

Retrospective clinical data

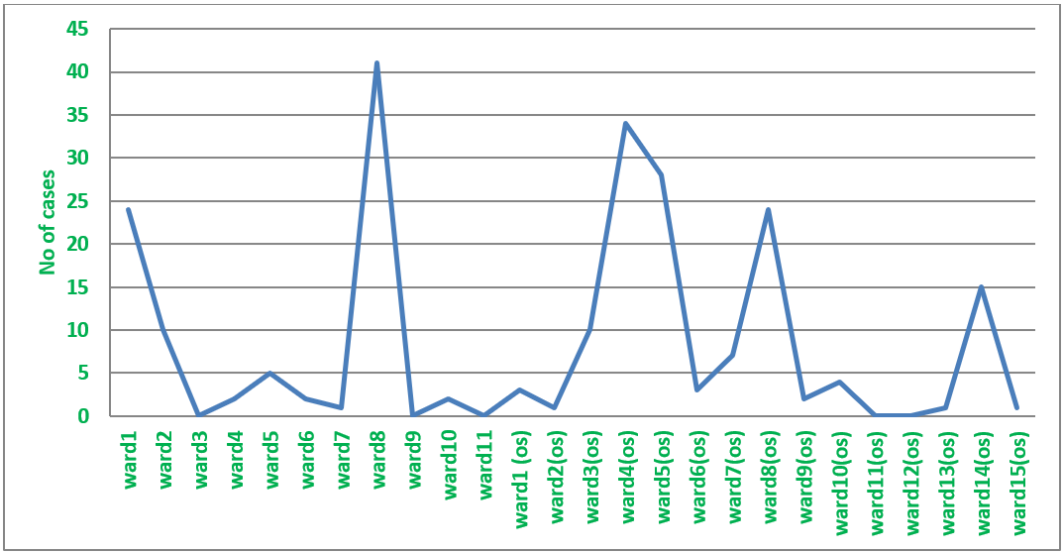

Fig 2: Spatial pattern of Malaria Incidence in Osogbo, 2018-2019
Note: (OS) indicates political wards in Osogbo local government

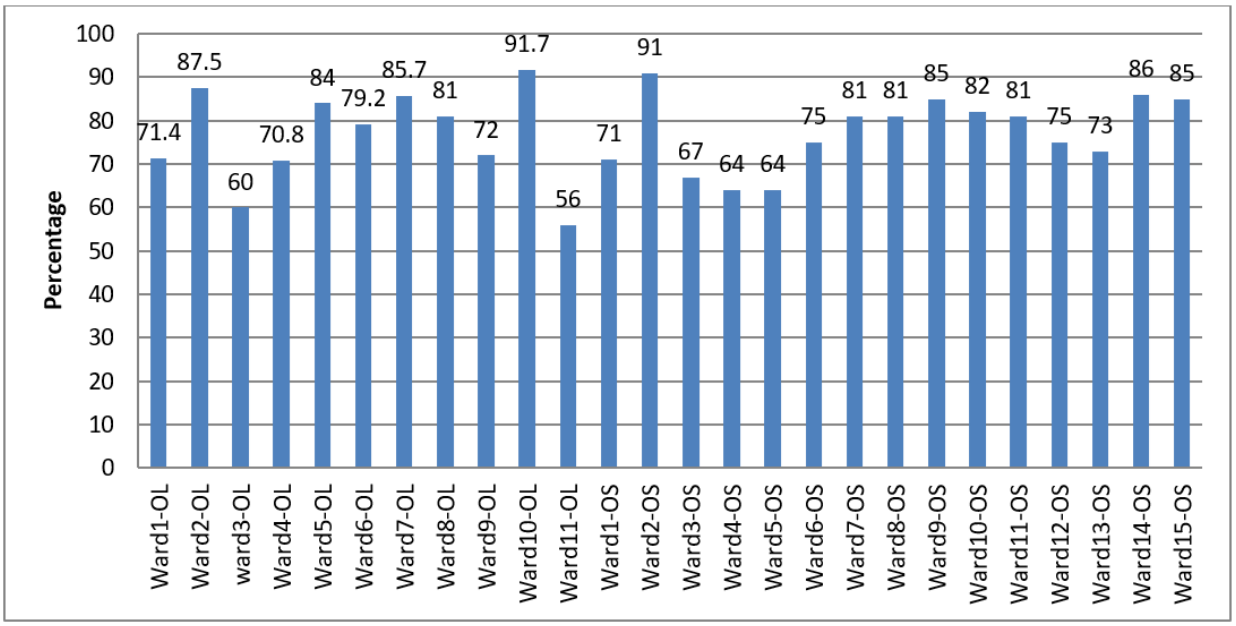

Fig 3: Spatial pattern of self reported malaria in Osogbo

Respondents with highest malaria incidence (above 80% of the respondents) are in ward 2, 5, 7, 8 and 10 of Olorunda local government. All the areas in these political wards are in the urban and peri-urban areas of Osogbo; except few areas in ward 8 (Dagbolu and Ota-Efun and Iragbiji road) and wards 10 (Oba-Oke, Idi-Emi, Idi-Amu and Oke-Ore villages) that are in the rural area. Similarly, in Osogbo local government, there is high malaria incidence (above 80% of the respondents) among the respondents in ward 2 (Isale-Osun, Idi-Oro, Ifelodun areas) which is at the heart of the city and ward 9 (Kajola street, Olugunna and Ibokun road area. Moreover, high malaria incidence was witnessed in ward 14 (Fiwasaye, Gbonmi, A.U.D areas) and ward 15 (Idi-omo, Oluguna street and Ibokun road area) of the Osogbo local government which are also in within the metropolis. The high malaria incidence in these areas are due to housing and environmental risk factors examined in this study.

Risk Factors of Urban Malaria in Osogbo

The distribution of risk factors and descriptive statistics are set out in Table 1. Given the standard deviation values, large variations were observed in the distribution of vegetation (SD: 23.2), waste disposal method (**S.D: 10.98**) and ITNs(**S.D: 10.8**).

Table 4.1: Standard Deviation of the Risk Factors

Political ward	Method of waste disposal Refuse dump	Pools of water	Blocked drainage channels	Presence of vegetation	Distance to dumpsites	Nearness to water bodies	ITNs
Olorunda 1	3.6	56	20	60	16	12	36
2	25	50	29.2	25	2.2	29.2	62.5
3	44	28	12	20	20	32	44
4	29.2	25	25	33.3	12.5	29.2	62.5
5	20	52	24	40	24	4	44
6	37.5	25	12.5	37.5	41.7	29.2	66.7
7	50	54.2	8.3	33.3	16.7	45.8	45.8
8	36	24	8	56	20	36	64
9	36	32	0	92	91.7	29.2	44
10	33.3	45.8	0	91.7	29.2	12.5	29
11	60	32	0	64	36	36	48
Osogbo 1	42.9	28.6	0	38.1	33.3	19	4.8
2	19	47.8	28.6	23.8	19	4.8	61.9
3	23.8	33.3	4.8	23.8	28.6	19	38.1
4	9.1	13.6	9.1	31.8	13.6	9.1	63.6
5	40.9	18.2	9.1	40.9	36.4	13.6	59.1
6	30	35	25	0	40	20	55

7	42.9	28.6	33.3	0	33.3	14.3	47.6
8	33.3	47.6	0	52.4	28.6	14.3	47.6
9	35	65	5	65	30	25	50
10	31.8	36.4	13.6	63.6	18.2	22.7	75
11	47.6	28.6	4.8	71.4	14.3	19	50
12	30	35	5	45	35	25	45
13	27.3	18.2	13.6	36.4	31.8	27.3	50
14	33.3	33.3	4.8	71.4	14.3	19	50
15	50	20	5	60	30	20	60
Mean	34.7	35.1	11.6	44.3	26.2	21.5	51.9
Standard deviation	10.98	13.3	10.2	23.2	8.5	9.9	10.8
Observations				26			

Bi-variate Correlations

No significant associations were detected for malaria incidence whereas only one variable, pools of water was significantly correlated with self-reported malaria (r= 0.50; p<0.01) (Table 2). The corollary of this is that a positive association exists between malaria incidence and presence of pools of water in Osogbo (Figure 4).

Table 4.2: Bi-variate Correlations

Risk factor	Malaria	Self-reported malaria
Refuse dump	-0.279	-0.166
Pools of water	-0.177	0.500 **
Blocked drainage channels	-0.045	0.204
Vegetation	-0.022	0.145
Distance to dumpsites	-0.194	-0.076
Nearness to water bodies	-0.185	-0.162
ITNs	0.155	0.033

Source: Data Analysis Note : ** significant at 0.01

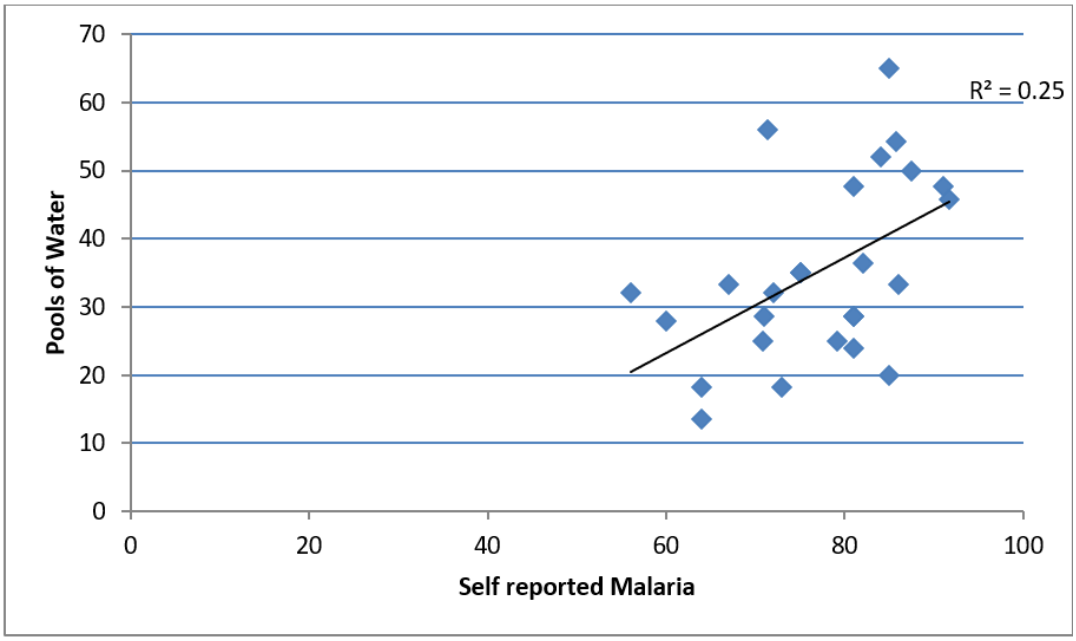

Figure 4.1: Correlation Coefficient of Pool of Water and Malaria Incidence

In Osogbo, most of the respondents associated malaria morbidity to poor environmental conditions that resulted in stagnant water surfaces near household. Pool of stagnant water in the form of water in unpaved neighborhood roads or potholes, abandoned tyre, blocked drainages, fish farm, tyre tracks and flood plain. Pool of stagnant water is significantly associated with malaria incidence in Osogbo; especially in the traditional areas, due to unkempt surroundings that enhances malaria vector breeding points.

5.0 DISCUSSION

There is a spatial variation in the malaria risk factors across space in Osogbo, but results gathered show evidence of malaria within the metropolitan area. Geospatial analysis reveals significant clustering of high malaria incidence in the traditional or core areas and the peri-urban areas of Osogbo. Using GIS to map these spatial patterns, we identified distinct environmental characteristics associated with each zone. In the core areas, most of the houses were built prior to these period of strict enforcement of physical planning laws. Most of the buildings in these areas were made with poor housing construction materials, some were made of mud depicting "slum condition" with high population density, poor drainage and unkempt surroundings. Through spatial overlay analysis, we found strong correlation between these structural variables and malaria hotspots. Additionally, in the peri-urban areas, most of the houses are of good structure and quality. These areas however, are mostly unplanned with unpaved roads, abandoned structures etc which serve as breeding spots for mosquitoes that result in malaria. Our GIS-based buffer analysis identified proximity to these environmental features as significant predictors of malaria transmission. As scholars like [27], noted, improved housing characteristics reduces malaria incidence. Conversely, the risk factors of malaria morbidity and transmission in these areas, based on our spatial analysis findings are poor housing quality which is in line with [11] as well [31] for similar studies in Libreville. Another explanation for high malaria morbidity in these areas are unkempt surroundings with pools of stagnant water from blocked drainage, unused jerry cans and earthen pots within the households, rain water in unused tyre within the neighborhood among other sources of stagnant water that serve as suitable mosquito breeding points. Using interpolation techniques in our GIS framework, we were able to visualize the relationship between these environmental determinants and malaria incidence across the study area.

Additionally, this study found out that there is high malaria incidence in the urban periphery areas of Osogbo. Spatial analysis using GIS tools revealed distinct distribution patterns that are in contrast with [42] in their study of uneven malaria transmission in geographically distinct districts of Bobo-Dioulasso, Burkina Faso. The explanation for this finding, as identified through our geospatial modeling, is as a result of the presence of unplanned nature of these areas in Osogbo which give rise to poor housing and environmental conditions. Using remote sensing techniques integrated with our GIS framework, we were able to detect and quantify these environmental risk factors across different urban zones. This study goes in conformity with [18] where in Malindi, Kenya, 29% of all water bodies responsible for mosquitoes breeding are in tyre tracks. Through spatial mapping of these microhabitats, we identified similar patterns in our study area. It also supported [12] which attributed urban malaria to presence of fish pond or farming in urban areas. In this study, it is also pertinent to note that, pool of stagnant water surfaces from potholes, unpaved surfaces in these areas are due to poor development of our urban areas in Africa. Our GIS-based terrain analysis helped identify these low-lying areas prone to water accumulation and subsequently higher vector breeding activity. Generally, it has been shown by this study that urban malaria is prevalent in Nigerian rapidly growing cities and are caused by varying factors. It is multifaceted, but one of it is poor environmental condition, which can be effectively monitored and managed through continued application of spatial analysis and GIS-based surveillance systems.

This study represents a unique space-based examination of malaria transmission risk factors in a rapidly growing urban area, leveraging Geographic Information Systems (GIS) to analyze spatial relationships between environmental determinants and disease incidence. While providing valuable insights into malaria vector bionomics in Nigerian urban settings through geospatial analysis techniques including hotspot mapping, spatial interpolation, and proximity studies, we encountered limitations such as potential distance decay effects in hospital data which our GIS-based accessibility modeling revealed. Through spatial overlay analysis, we identified correlations between poor housing quality, stagnant water bodies, and malaria incidence in both traditional core areas and peri-urban zones, contradicting findings from similar studies in other African cities. Our terrain analysis highlighted how unpaved surfaces and poor drainage create vector breeding sites, while remote sensing integration helped quantify environmental risk factors across different urban zones. This GIS-based approach provides a solid methodological foundation for future urban malaria studies in Nigeria, with potential for enhancement through additional spatial network analysis to better understand human movement patterns and their relationship to disease transmission.

6.0 CONCLUSION AND RECOMMENDATION

The adaptation of malaria vector to urban environment has been documented by scholars over the years, but the area-specific risk factors enhancing malaria transmission in varying urban areas are to be well understood for effective control strategies. Results found in this study in Osogbo might be area-specific; other studies should investigate if same finding(s) hold for other regions and rapidly growing cities. More so, this idea may be helpful in discussing other diseases influenced by urbanization. This study indicates that environmental factors are major determinants enhancing malaria transmission in Osogbo. Presence of small pool of stagnant water around household are found to be associated with malaria transmission in Osogbo metropolis. The application of Geographic Information Systems (GIS) allowed us to spatially analyze these relationships and identify high-risk zones within the study area. This study, done by proper sampling carried

out in both the urban and peri-urban area in Osogbo provides better insights and understanding of malaria transmission in the city through geospatial visualization and analysis. This research prompted some recommendations useful to decision makers on effective area-specific malaria control strategies and intervention programs that will reduce malaria morbidity in Osogbo to the barest minimum.

Based on the findings from this study, it is suggested that the following actions should be considered:

- Improvement in environmental conditions through better urban planning and management supported by GIS-based modeling and analysis.
- Regular environmental sanitation, waste management and health awareness program should be taken seriously especially in the core areas of the city identified through spatial hotspot analysis.
- Government should endeavor to have good plans to build sustainable healthy cities in yet-to-be-developed areas (virgin land) in Osogbo using geospatial planning tools.
- Development of infrastructure (road construction) and regular maintenance of existing roads should be prioritized in areas identified as high-risk through spatial epidemiological mapping.
- Design effective integrated malaria control program for Osogbo that incorporates GIS-based surveillance to monitor and evaluate interventions and will factor in other issues raised in this paper.

REFERENCES

1. Adefioye O.A., Adeyeba O. A., Hassan W.O. and Oyeniran O.A (2007): Prevalence of Malaria Parasite Infection among Pregnant Women in Osogbo, Southwest, Nigeria; American-Eurasian Journal of Scientific Research 2 (1): 43-45,
2. Adeleke M. A, Mafiana C. F., Idowu A. B., Adekunle M. F, and Sam-Wobo S. O, "Mosquito larval habitats and public health implications in Abeokuta, Ogun State, Nigeria," Tanzania Journal of Health Research, vol. 10, no. 2, pp. 103–107, 2008. View at Google Scholar · View at Scopus
3. Adigun, A. B., Gajere, E. N., Oresanya, O., & Vounatsou, P. (2015). Malaria risk in Nigeria: Bayesian geostatistical modelling of 2010 malaria indicator survey data. Malaria Journal, 14(1). doi:10.1186/s12936-015-0683-6
4. Adlaoui E, Faraj C, El Bouhmi M, El Aboudi A, Ouahabi S, Tran A, *et al.*, Mapping
    a. malaria transmission risk in northern Morocco using entomological and environmental data. Malar Res Treat. 2011;2011:391463.
5. Angelo, J.R.; Katsuragawa, T.H.; Sabroza, P.C.; de Carvalho, L.A.S.; de Silva, L.H.P.; Nobre, C.A. The role of spatial mobility in malaria transmission in the Brazilian Amazon: The case of Porto Velho municipality, Rondônia, Brazil (2010–2012). PLoS ONE 2017, 12, e0172330. [CrossRef] [PubMed]
6. Aregbeshola B.S and Khan S.M: Impact of health facilities on malaria control interventions in Nigeria; South East Asia Journal of Public Health 2017;7(1):35-41:
7. Awuah, R.B., Asante, P.Y., Sakyi, L. *et al.* Factors associated with treatment-seeking for malaria in urban poor communities in Accra, Ghana. *Malar J* **17,** 168 (2018). https://doi.org/10.1186/s12936-018-2311-8
8. Ceesay S. J., Bojang K. A., Nwakanma D. *et al.*, "Sahel, savana, riverine and urban malaria in West Africa: similar control policies with different outcomes," Acta Tropica, vol. 121, no. 3, pp. 166–174, 2012. View at Google Scholar
9. Dal'Asta Ana Paula, Lana Raquel Martins, Silvana Amaral 1, CodeçoCláudia Torres and Antônio Miguel Vieira Monteiro; The Urban Gradient in Malaria-Endemic
    a. Municipalities in Acre: Revisiting the Role of Locality: Int. J. Environ. Res. Public Health 2018, 15, 1254; doi:10.3390/ijerph15061254; www.mdpi.com/journal/ijerph
10. Daramola O.P, Olowoporoku A.O: Living with a Fatal Choice: Effects of Slaughterhouse Activities on Residents' Health in Osogbo, Nigeria; International Journal of Environmental Problems, 2017, 3(1): 26-35 DOI: 10.13187/ijep.2017.1.26 www.ejournal33.com
11. Dear Nicole F., Chifundo Kadangwe, Themba Mzilahowa, Andy Bauleni, Mathanga Don P., Chifundo Duster, Edward D. Walker and Mark L. Wilson: Household level and surrounding peri-domestic environmental characteristics associated with malaria vectors *Anopheles arabiensis* and *Anopheles funestus* along an urban–rural continuum in Blantyre, Malawi; *Malaria Journal (2018) 17:229*,https://doi.org/10.1186/s12936-018-2375-5
12. De Reis, I.C.; Honório, N.A.; de Barros, F.S.M.; Barcellos, C.; Kitron, U.; Camara, D.C.P.; Pereira, G.R.; Keppeler, E.C.; da Silva-Nunes, M.; Codeço, C.T. Epidemic and endemic malaria transmission related to fish farming ponds in the Amazon frontier. PLoS ONE 2015, 10, e0137521.
13. De Silva, P.M. and Marshall, J.M. 2012: Factors contributing to urban malaria transmission in sub-Saharan Africa: A systematic review. Journal of Tropical Medicine 2012: 1687- 9686.
14. Donnelly Martin J., McCall P. J, Lengeler C, Imelda Bates, Umberto D'Alessandro, Guy Barnish, FlemmingKonradsen, Eveline Klinkenberg, Harold Townson, Jean-Francois Trape, Ian M Hastings, and Clifford Mutero: Malaria and urbanization in sub-Saharan Africa," Malaria Journal, vol. 4, article e12, 2005. View at Publisher · View at Google Scholar · View at Scopus

15. Doumbe-Belisse P, Ngadjeu CS, Sonhafouo-Chiana N et al. High malaria transmission sustained by Anopheles gambiaes.l. occurring both indoors and outdoors in the city of Yaoundé, Cameroon [version 1; referees: awaiting peer review] Wellcome Open Research 2018, 3:164 (https://doi.org/10.12688/wellcomeopenres.14963.1)
16. Federal Republic of Nigeria. National Malaria Strategic Plan 2014-2020: http://www.nationalplanningcycles.org/sites/default/files/planning_cycle_repository/nigeria/nigeria_national_malaria_strategic_plan.pdf (accessed May 2017)
17. Hotez PJ (2017) Global urbanization and the neglected tropical diseases. PLoSNegl TropDis 11(2): e0005308. doi:10.1371/journal.pntd.0005308
18. Impoinvil D. E.,. Keating J, Mbogo C. M., Potts M. D., Chowdhury R. R., and Beier J. C., "Abundance of immature Anopheles and culicines (Diptera: Culicidae) in different water body types in the urban environment of Malindi, Kenya," Journal of Vector Ecology, vol. 33, no. 1, pp. 107–116, 2008. View at Publisher · View at Google Scholar. View at Scopus
19. Kabaria, C. W., Gilbert, M., Noor, A. M., Snow, R. W., &Linard, C. (2017). The impact of urbanization and population density on childhood Plasmodium falciparum parasite prevalence rates in Africa. Malaria Journal, 16(1). doi:10.1186/s12936-017-1694-2
20. Keiser J., Utzinger J., Caldas De Castro M., Smith T. A., Tanner M., and Singer B. H., "Urbanization in sub-Saharan Africa and implication for malaria control," American Journal of Tropical Medicine and Hygiene, vol. 71, no. 2, pp. 118–127, 2004. View at Google Scholar · View at Scopus
21. Kweka J. Eliningaya, Humphrey D. Mazigo, Yousif E. Himeidan, Domenica Morona and Stephen Munga(2017): Urbanization, Climate Change and Malaria Transmission in Sub-Saharan Africa: in Climate Change Impacts on Urban Pests (pp. 141-153). Edition 10. Chapter 10; CABI Climate Change Series (ed. P. Dhang)
22. *Kyu HH, Georgiades K, Shannon HS, Boyle MH. Evaluation of the association between long-lasting insecticidal nets mass distribution campaigns and child malaria in Nigeria. Malar J. 2013;12:14.*View ArticlePubMedCentralPubMed Google Scholar
23. Labbo R, Fandeur T, Jeanne I, et al.: Ecology of urban malaria vectors in Niamey, Republic of Niger. Malar J. 2016; 15(1): 314. PubMed Abstract | Publisher Full Text| Free Full Text
24. Lana, R.M.; Riback, T.I.S.; Lima, T.F.M.; da Silva-Nunes, M.; Cruz, O.G.; Oliveira, F.G.S.; Moresco, G.G.; Honório, N.A.; Codeço, C.T. Socioeconomic and demographic characterization of an endemic malaria region in Brazil by multiple correspondence analysis. Malaria. Journal. 2017, 16, 397. [CrossRef] [PubMed]
25. Mabogunje, A.L. 2007. Health challenges of Nigerian Urbanisation. The Ninth Benjamin Oluwakayode Osuntokun Memorial lecture. The Benjamin Oluwakayode Osuntokun Trust, Ibadan.
26. Machault V, Vignolles C, Pages F, Gadiaga L, Tourre YM, Gaye A,: 2012) Risk mapping of *Anopheles gambiaes.l.* densities using remotely-sensed environmental and meteorological data in an urban area: Dakar, Senegal. PLoS ONE. 2012;7:e50674
27. Mark L. Wilson, Donald J. Krogstad, Emmanuel Arinaitwe, Myriam Arevalo-Herrera, Laura Chery, Marcelo U. Ferreira, Daouda Ndiaye, Don P. Mathanga, and Alex Eapen: Urban Malaria: Understanding its Epidemiology, Ecology, and Transmission across Seven Diverse ICEMR Network Sites; Am. J. Trop. Med. Hyg., 93 (Suppl 3), 2015, pp. 110–123 doi:10.4269/ajtmh.14-0834
28. Mattah PA, Futagbi G, Amekudzi LK, *et al.,* : Diversity in breeding sites and distribution of Anopheles mosquitoes in selected urban areas of southern Ghana. Parasite Vectors. 2017; 10(1): 25. PubMed Abstract | Publisher Full Text | Free Full Text
29. Matthys B, N'Goran E, Koné M, Koudou B, Vounatsou P, Cissé G, (2006) Urban agricultural land use and characterization of mosquito larval habitats in a medium-sized town of Côte d'Ivoire. J Vector Ecol. 2006;31:319–33.
30. Mmbando, B.P., Kamugisha, M., Lusingu, J.P., Francis, F., Ishengoma, D., Theander,T., Lemnge, M. and Scheike, T. 2011. Spatial variation and socioeconomic determinants of Plasmodium falciparum infection in Northeastern Tanzania. Malaria Journal 10: 145.
31. Mourou JR, Coffinet T, Jarjaval F, (*2012).*: Malaria transmission in Libreville: results of a one year survey. *Malar J.* 2012; 11: 40. PubMed Abstract | Publisher Full Text | Free Full Text
32. Obonyo Esther, Pareek Sumit and Woldu Dawit Okubatsion (2018): Decision Making within the Built Environment as a Strategy for mitigating the Risk of Malaria and Other Vector-Borne Diseases; Buildings 2018, 9, 2; doi:10.3390/buildings9010002 www.mdpi.com/journal/buildings
33. Olawuni Peter Olabiyi 2007: The Effects of Household Environmental Factors on Residents' Health in Osogbo, Osun State, Nigeria; view at: https://ir.oauife.edu.ng/handle/123456789/2321
34. Osayomi Tolulope 2014: Spatio-Temporal Clustering of Malaria Morbidity in Nigeria (2004-2008); Journal of Science Research (2014) Vol. 13: 99-113
35. Patrick NtongaAkono, Calvin Tonga, Pierre Michel Jazet Dongmo, Sevilor Kekeunou, Nadine Lopedji Tedongmo and Leopold Gustave Lehman (2016): Influence of urbanization on the sensitivity of female adults of the *Anopheles gambiae* complex to

essential oils of some plants from the Littoral region of Cameroon; International Journal of Mosquito Research 2016; 3(6): 45-53
36. Pond B. Malaria indicator surveys demonstrate a markedly lower prevalence of malaria in large cities of sub-Saharan Africa. Malar J. 2013;12:313.
37. Population Reference Bureau (PRB) 2018: PRB Project in World Population Data Sheet. Retrieved18th September, 2018 at www.prb.org
38. *Programme NMC. Nigeria MIS Final Report. Abuja, Nigeria: Federal Republic of Nigeria; 2010.*Google Scholar
39. Qiuyin, Q., Guerra, C. A., Moyes, C. L., Elyazar, I. R. F., Gething, P. W., Hay, S. I., &Tatem, A. J. (2012). The effects of urbanization on global Plasmodium vivax malaria transmission. Malaria Journal, 11(1), 403. doi:10.1186/1475-2875-11-403
40. Robert, V., Macintyre, K., Keating, J., Trape, J.F., Duchemin, J.B., Warren, M. and
    a. Beier, J.C. 2003. Malaria transmission in urban sub-Saharan Africa. American
    b. Journal of Tropical Hygiene 68(2): 169-76.
41. Santos-Vega M, Bourma MJ, Kohli V, Pascual M (2016) Population Density, Climate Variables and Poverty Synergistically Structure Spatial Risk in Urban Malaria in Indian. PLoS Negl Trop Dis 10(12): e0005155. doi:10.1371/Journal.pntd. e0005155
42. Soma Dieudonné Diloma, DaoudaKassié, SeydouSanou, Fatou Biribama Karama, Ali Ouari, WadakaMamai, Georges Anicet Ouédraogo, Gérard Salem, Roch Kounbobr Dabiré and Florence Fournet (2018): Uneven malaria transmission in geographically distinct districts of Bobo-Dioulasso, Burkina Faso: Parasites &Vectors 11:296; https://doi.org/10.1186/s13071-018-2857-x
43. TAIWO Olalekan John 2018: Urban Growth During Civilian and Military Administrations in Osogbo, Nigeria ISSN 2354-9114 (online), ISSN 0024-9521 (print) Indonesian Journal of Geography Vol. 50 No. 1, June 2018 (1- 10) DOI: http://dx.doi.org/10.22146/ijg.13002 website: https://jurnal.ugm.ac.id/ijg
44. Tatem Andrew J, Gething Peter W, Smith David L, and Hay Simon I: Urbanization and the global malaria recession. Malaria Journal 2013 12:133. http://www.malariajournal.com/content/12/1/133 doi:10.1186/1475-2875-12-133
45. Thomas Shalu, Sangamithra Ravishankaran, Johnson Justin, Aswin Asokan, Manu T. Mathai, Neena Valecha, Matthew B. Thomas and Alex Eapen (2016): Overhead Tank is the Potential Breeding Habitat of Anopheles Stephensi in an Urban Transmission Setting of Chennai India: Malaria Journal 15:274, DOI: 10.1186/s12936-016-1321-7
46. Tusting LS, Bottomley C, Gibson H, Kleinschmidt I, Tatem AJ, Lindsay SW, et al. (2017) Housing Improvements and Malaria Risk in Sub-Saharan Africa: A Multi-Country Analysis of Survey Data. PLoS Med 14(2): e1002234. https://doi.org/10.1371/journal.pmed.1002234
47. World *Health Organization (WHO) (2017)*. World malaria report 2018: http://www.who.int/malaria/publications/world-malaria-report-2017. Accessed 08 Dec 2017
48. *World Health Organization (WHO) (2018)*. World malaria report 2019: http://www.who.int/malaria/publications/world-malaria-report-2017. Accessed 08 Dec 2018
49. *World Health Organization (WHO) (2019)*. World malaria report 2020: http://www.who.int/malaria/publications/world-malaria-report-2017. Accessed 08 Dec 2019

Cite This Article: Ismail ALATISE (2021). Geospatial Assessment of Urban Malaria Transmission Determinants in Osogbo, Nigeria. *East African Scholars J Eng Comput Sci*, *4*(10), 173-183.