Research Output Journal of Public Health and Medicine 6(1):64-70, 2026

ROJPHM **ISSN ONLINE: 1115-9715**

https://rojournals.org/roj-public-health-and-medicine/ **ISSN PRINT: 1115-6147**

https://doi.org/10.59298/ROJPHM/2026/616470

Roads and Malaria Transmission: Unveiling the Epidemiological Impacts of Transport Infrastructure on Anopheles Mosquito Ecology in Sub-Saharan Africa

Nassimbwa Kabanda D.

Faculty of Medicine Kampala International University Uganda

ABSTRACT

Road infrastructure is a cornerstone of economic growth and regional connectivity in Sub-Saharan Africa, facilitating trade, mobility, and access to essential services. However, emerging evidence indicates that road construction and maintenance can inadvertently influence malaria transmission by altering ecosystems and creating favorable habitats for Anopheles mosquitoes, the primary vectors of the disease. This review synthesizes current knowledge on the ecological and epidemiological impacts of transport infrastructure on malaria dynamics, highlighting how road-induced environmental changes, such as water accumulation in borrow pits, poor drainage, deforestation, and land-use modifications, enhance vector breeding and increase human-vector contact. Additionally, improved mobility along transport corridors facilitates parasite dissemination into previously low-transmission areas, compounding public health risks. Mitigation strategies, including eco-sensitive road design, integrated vector management, environmental impact assessments, community engagement, and intersectoral collaboration, are explored. The review identifies critical knowledge gaps, emphasizing the need for longitudinal studies, spatial modeling, and geospatial surveillance to inform evidence-based planning and policy that balance infrastructure development with malaria control.

Keywords: Malaria transmission, Anopheles mosquitoes, road infrastructure, Sub-Saharan Africa, vector ecology.

INTRODUCTION

Transport infrastructure, particularly road networks, plays a pivotal role in advancing economic development, trade, and accessibility across Sub-Saharan Africa. Roads serve as vital arteries connecting rural and urban centers, facilitating the movement of goods, services, and people, while stimulating commerce, industrialization, and social interaction [1-5]. In many African countries, including Uganda, Kenya, Tanzania, and Nigeria, road construction has been prioritized as part of national development agendas to enhance economic integration, reduce poverty, and promote regional trade. However, beyond these socioeconomic benefits, transport infrastructure projects, especially road construction and maintenance, have profound ecological and environmental implications [6-11]. These alterations to the physical environment can inadvertently influence disease ecology, particularly that of malaria, which remains one of the most persistent and devastating public health challenges in Sub-Saharan Africa [12-17].

Malaria, caused by *Plasmodium* parasites and transmitted by female *Anopheles* mosquitoes, continues to exact a heavy toll on human health and economic productivity in the region. According to the World Health Organization (WHO), Sub-Saharan Africa accounts for over 90% of global malaria cases and deaths, with children under five and pregnant women being most vulnerable [18-25]. Despite substantial investments in vector control interventions such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and artemisinin-based combination therapies (ACTs), malaria transmission remains intense and heterogeneous across different ecological zones. This variability in transmission intensity has often been linked to environmental, climatic, and socioeconomic factors [26-30]. However, recent research increasingly recognizes that anthropogenic changes particularly those resulting from infrastructure development may be reshaping malaria transmission patterns in ways that are not yet fully understood.

The expansion of transport infrastructure, while essential for economic growth, inevitably alters landscapes and ecosystems. Road construction often involves clearing vegetation, altering drainage systems, and creating borrow pits, tire ruts, and puddles that can accumulate water [31-39]. These microhabitats provide ideal breeding grounds for *Anopheles* mosquitoes. Additionally, improved road networks enhance human mobility, facilitating the movement of both infected individuals and mosquitoes between regions, thereby influencing the spatial spread of malaria. For instance, the construction of major highways in forested or rural areas has been associated with increased malaria incidence due to environmental disturbances that favor mosquito proliferation [40-45].

In Uganda and other East African nations, road development projects are expanding rapidly as part of national development frameworks such as Uganda Vision 2040 and the African Union's Programme for Infrastructure Development in Africa (PIDA). While these initiatives are crucial for connectivity and trade, they often intersect with malaria-endemic zones where ecological sensitivity is high [46-50]. Studies conducted in various African contexts have shown that areas near newly constructed roads experience higher mosquito densities and increased malaria transmission rates. This is partly due to the creation of stagnant water pools and the migration of non-immune populations into malaria-endemic regions for construction or trade-related activities [51-57].

Furthermore, the presence of roads affects healthcare accessibility. While improved transport can facilitate faster access to medical facilities and malaria prevention programs, it can also accelerate population movements into high-risk zones without adequate preventive measures. This dual impact underscores the complex relationship between infrastructure development and malaria epidemiology, a relationship that demands a multidisciplinary approach integrating environmental management, public health, and transportation planning [58-60].

Despite the evident link between road infrastructure and environmental changes conducive to malaria transmission, this relationship remains inadequately addressed in development planning and disease control policies in Sub-Saharan Africa. Infrastructure projects are often implemented with limited consideration of their long-term ecological and health consequences. Environmental impact assessments (EIAs) rarely incorporate detailed analyses of vector ecology or malaria risk, focusing instead on immediate physical and economic factors [61-65]. As a result, communities living near new or rehabilitated roads frequently experience unanticipated increases in malaria incidence.

Moreover, while numerous studies have examined the influence of climatic factors such as rainfall, humidity, and temperature on malaria transmission, relatively few have investigated how human-driven environmental modifications, particularly through road construction, alter vector breeding and disease dynamics. This knowledge gap limits the ability of policymakers to design integrated strategies that mitigate the unintended health consequences of infrastructure development [66-69]. Consequently, there is a pressing need to examine how road construction and related human activities influence mosquito habitats, modify human movement patterns, and ultimately affect malaria transmission in Sub-Saharan Africa. Understanding these dynamics is essential for developing sustainable solutions that balance economic growth with public health protection [12].

This review aims to achieve several specific objectives focused on understanding the intersection between road infrastructure and malaria transmission in Sub-Saharan Africa. Primarily, it seeks to examine the ecological impacts of road construction and maintenance on mosquito breeding habitats and vector ecology, assessing how changes in the environment create conditions favorable for Anopheles mosquito proliferation. Additionally, the review investigates how transport infrastructure influences human mobility, settlement patterns, and consequent exposure to malaria vectors, while also analyzing epidemiological outcomes resulting from environmental alterations associated with road development projects. A further objective is to evaluate existing strategies and propose integrated approaches for incorporating malaria risk mitigation into transport planning and environmental management frameworks. Central research questions address how road activities modify ecological conditions for mosquito breeding, the influence of transport networks on human-vector interactions, the relationship between road proximity and malaria incidence, and methods for effectively integrating public health considerations into road design and maintenance policies. The study is significant as it informs evidence-based decision-making, promotes intersectoral collaboration between health, environment, and transport sectors, and supports sustainable infrastructure development aligned with global frameworks like the SDGs, enhancing both economic growth and population health.

Ecological Impacts of Road Construction on Anopheles Mosquito Habitats

The construction and expansion of road networks often involve extensive land alteration, including excavation, leveling, grading, and modifications to natural drainage systems. These activities can inadvertently create favorable conditions for the proliferation of Anopheles mosquito larvae, the primary vectors of malaria. Features such as borrow pits, roadside ditches, depressions formed by construction machinery, and wheel ruts can collect and retain stagnant water, forming ideal breeding sites [13]. Empirical studies from Uganda, Kenya, and Nigeria have reported marked increases in Anopheles larval habitats following road construction, particularly in poorly drained or unpaved areas. Beyond initial construction, road maintenance practices, including vegetation clearing, embankment reshaping, and improper drainage management, can prolong the persistence of these aquatic habitats, enabling mosquitoes to thrive over extended periods. In forested and peri-urban regions, road openings alter microclimatic conditions by increasing sunlight exposure and ambient temperatures near water bodies, which accelerates larval development and increases mosquito survivorship. The proximity of these anthropogenic breeding sites to human settlements intensifies vector-human interactions, elevating the risk of malaria transmission. Consequently, the ecological transformation induced by road infrastructure highlights a critical interface between development activities and vector ecology, underscoring the need for integrated engineering, environmental management, and vector control strategies in road planning and maintenance [14].

Human Mobility and Malaria Spread Along Transport Corridors

Road infrastructure not only reshapes local ecosystems and mosquito breeding sites but also significantly influences human movement and settlement patterns, thereby affecting malaria transmission dynamics. Improved transport routes facilitate easier movement of people for trade, employment, agriculture, and social purposes, often leading to the expansion of settlements into previously uninhabited or low-transmission areas [15]. This increased mobility enables the rapid movement of infected individuals and malaria parasites, potentially introducing the disease into regions where it was previously controlled or absent. Similarly, the transportation of goods and livestock along major roads can inadvertently carry vectors or create conditions favorable for mosquito breeding, such as roadside water pools. Empirical studies from Ethiopia and Tanzania indicate that communities located near highways and major transport corridors consistently exhibit higher malaria prevalence compared to more isolated areas. Mobile populations, including truck drivers, traders, seasonal laborers, and migrants, act as important conduits for malaria parasites, bridging regions with varying transmission intensities. While road networks generate significant socio-economic benefits, including improved access to markets, healthcare, and social services, they also pose public health challenges. Without targeted surveillance, vector control, and community education, the expansion of transport corridors can inadvertently exacerbate malaria transmission, highlighting the need for integrated planning that balances development with disease prevention strategies [16].

Epidemiological Evidence of Road-Associated Malaria Transmission

Multiple epidemiological studies have demonstrated a clear association between proximity to roads and elevated malaria risk in sub-Saharan Africa. For instance, research in western Kenya revealed that villages located within two kilometers of a major road experienced significantly higher malaria incidence compared to more remote areas, highlighting the spatial influence of infrastructure on disease transmission [17]. Similarly, in Cameroon, the construction of forest roads was linked to increased populations of *Anopheles gambiae*, the primary malaria vector, which coincided with a rise in malaria cases among nearby communities. The mechanisms underlying this association are multifaceted and involve ecological, demographic, and behavioral dimensions. Roads often promote environmental changes, including deforestation, water accumulation in roadside depressions, and altered drainage patterns, all of which create ideal breeding habitats for mosquitoes. Furthermore, roads facilitate human settlement and movement, increasing human-vector contact and expanding the population at risk. Land-use changes induced by road development can disrupt local ecosystems, favoring vector proliferation, while demographic shifts bring susceptible populations into closer proximity with breeding sites. Collectively, these factors illustrate the complex interplay between infrastructure development and malaria epidemiology, emphasizing the need to integrate vector control and land-use planning into road development policies to mitigate malaria risk in affected regions [18].

Mitigation Strategies and Eco-Sensitive Road Development

Addressing the malaria risks associated with road infrastructure requires a comprehensive, multisectoral strategy that integrates public health considerations into all stages of planning, construction, and maintenance. Roads, while essential for economic development and connectivity, often create conditions favorable for mosquito breeding, particularly through water accumulation in poorly drained areas or along construction sites [19]. To mitigate these risks, improved drainage design is critical; incorporating culverts, proper grading, and effective water flow management can prevent stagnant water that serves as larval habitats for malaria vectors. Environmental impact assessments (EIAs) should include vector ecology evaluations before construction, allowing planners to identify potential breeding sites and implement preventive interventions. Vegetation and landscape management, such as establishing buffer zones and routine maintenance, further reduces larval habitats while preserving ecological integrity. Integrating health surveillance into transport corridors enables early detection of malaria outbreaks and timely public health responses. Active community involvement in environmental management and health education ensures local ownership and sustainability of prevention efforts. Finally, intersectoral collaboration among ministries of health, transport, and environment aligns infrastructure development with disease control objectives. By embedding ecological and health considerations into engineering and policy frameworks, countries can achieve infrastructure growth without compromising public health, ultimately supporting sustainable development and malaria reduction [20].

Knowledge Gaps and Future Research Directions

Although there is increasing recognition of the role that road infrastructure plays in shaping malaria transmission dynamics, substantial knowledge gaps persist that limit the development of effective interventions. Longitudinal studies examining the long-term impacts of different types of road construction and design on vector ecology, breeding site proliferation, and human-vector contact remain scarce, making it difficult to draw robust conclusions about causality [21]. Additionally, there is a critical need for spatially explicit modeling approaches that can predict malaria risk by integrating land-use changes induced by road expansion, including deforestation, urbanization, and alteration of water drainage patterns. The interaction between road-induced environmental changes and climate variability such as temperature fluctuations, rainfall patterns, and humidity also remains poorly understood, despite its potential to modulate vector populations and seasonal transmission peaks. Future research should leverage advanced tools, including remote sensing, geographic information systems (GIS), and high-resolution entomological surveys, to map vector habitats, identify malaria hotspots, and evaluate risk gradients in communities adjacent to road networks [22]. By addressing these gaps, researchers can generate evidence-based strategies for infrastructure planning, targeted vector control, and integrated malaria management that account for the complex interplay between human development and disease ecology in endemic regions.

CONCLUSION

This review highlights the intricate and multifaceted relationship between road infrastructure and malaria transmission in Sub-Saharan Africa. While road networks are crucial for socioeconomic development, trade, and improved access to services, they inadvertently create ecological conditions conducive to Anopheles mosquito breeding and facilitate human-vector interactions that increase malaria risk. Evidence demonstrates that road construction, maintenance, and associated land-use changes, such as water accumulation in borrow pits, poor drainage, deforestation, and settlement expansion, can significantly elevate vector density and disease incidence. Furthermore, increased human mobility along transport corridors amplifies the spread of malaria parasites across previously low-transmission areas, posing additional public health challenges. Effective mitigation requires an integrated, multisectoral approach that combines eco-sensitive engineering, proactive vector control, health education, and interdepartmental collaboration. Environmental impact assessments should incorporate vector ecology considerations, while surveillance and community engagement are essential for early detection and sustainable intervention. Addressing existing knowledge gaps through longitudinal studies, spatial modeling, and advanced geospatial tools will enhance evidence-based planning, enabling road development that supports economic growth without exacerbating malaria transmission, ultimately promoting healthier, resilient communities in endemic regions.

REFERENCES

1. Biber-Freudenberger L, Bogner C, Bareth G, Bollig M, Dannenberg P, Diez JR, Greiner C, Mtweve PJ, Klagge B, Kramm T, Müller-Mahn D, Moseti V, Nyamari N, Ochuodho DO, Kuntashula E, Theodory T, Thorn JPR, Börner J. Impacts of road development in sub-Saharan Africa: A call for holistic perspectives in research and policy. iScience. 2025 Jan 28;28(2):111913. doi: 10.1016/j.isci.2025.111913. PMID: 40028288; PMCID: PMC11869981.
2. Kaiser, N., & Barstow, C. K. (2022). Rural Transportation Infrastructure in Low- and Middle-Income Countries: A Review of Impacts, Implications, and Interventions. *Sustainability*, *14*(4), 2149. https://doi.org/10.3390/su14042149
3. Mezieobi, K.C., Ugwu, O.P.C., Uti, D.E., Alum, B.N., Egba, S.I., et al. Economic burden of malaria on developing countries: A mini review. Parasite Epidemiology and Control.30 (2025), e00435. https://doi.org/10.1016/j.parepi.2025.e00435
4. Ugwu, O.P.C., Egba, S.I., Uti, D.E. (2024). Climate Variability and Malaria Transmission: Unraveling the Complex Relationship. INOSR Scientific Research 11(2):16-22. https://doi.org/10.59298/INOSRSR/2024/1.1.21622
5. Alum, E. U. (2024). Phytochemicals in Malaria Treatment: Mechanisms of Action and Clinical Efficacy. KIU J. Health Sci., 4(2):71-84. https://doi.org/10.59568/KJHS-2024-4-2-06.
6. Chapoterera, B., Naidoo, K., Marume, A.: Impact of climate change on malaria transmission in Africa: A scoping review of literature. J Public Health Afr. 16, 1346 (2025). https://doi.org/10.4102/jphia.v16i1.1346
7. Ugwu O. P. C, Nwodo O. F. C, Parker E J, Odo C. E, Ossai E. C., (2013). The effect of ethanol leaf extract of Moringa oleifera on the lipid profile of malaria-infected mice. Journal of Applied Science 4(1) 1324-1332.
8. Program Infrastructure Development for Africa (PIDA) | African Union, https://au.int/en/ie/pida

9. Egwu, C. O., Aloke, C., Chukwu, J., Agwu, A., Alum, E., Tsamesidis, I, et al. A world free of malaria: It is time for Africa to actively champion and take leadership of elimination and eradication strategies. Afr Health Sci. 2022 Dec;22(4):627-640. doi: 10.4314/ahs.v22i4.68.
10. Toh, K.B., Millar, J., Psychas, P., Abuaku, B., Ahorlu, C., Oppong, S., et al: Guiding placement of health facilities using multiple malaria criteria and an interactive tool. Malaria Journal. 20, 455 (2021). https://doi.org/10.1186/s12936-021-03991-w
11. Kungu, E., Inyangat, R., Ugwu, O.P.C., and Alum, E. U. (2023). Exploration of Medicinal Plants Used in the Management of Malaria in Uganda. NEWPORT INTERNATIONAL JOURNAL OF RESEARCH IN MEDICAL SCIENCES 4(1):101-108.https://nijournals.org/wp-content/uploads/2023/10/NIJRMS-41101-108-2023.docx.pdf
12. Doumbe-Belisse, P., Kopya, E., Ngadjeu, C.S., Sonhafouo-Chiana, N., Talipouo, A., Djamouko-Djonkam, L., et al.: Urban malaria in sub-Saharan Africa: dynamic of the vectorial system and the entomological inoculation rate. Malaria Journal. 20, 364 (2021). https://doi.org/10.1186/s12936-021-03891-z
13. Tufail, T., Agu, P. C., Akinloye, D. I., & Obaroh, I. O. (2024). Malaria pervasiveness in Sub-Saharan Africa: Overcoming the scuffle. Medicine, 103(49), e40241. doi: 10.1097/MD.0000000000040241. PMID: 39654176
14. Talbot, B., Alou, L.P.A., Koffi, A.A., Sih, C., Dangbenon, E., Zoh, M.G., et al.: Ecological drivers of malaria vector habitat and transmission over 1 year of long-lasting insecticidal net intervention in Côte d'Ivoire. Parasites & Vectors. 18, 343 (2025). https://doi.org/10.1186/s13071-025-06984-9
15. Ekpono, E. U., Aja, P. M., Ibiam, U. A., & Ekpono, U. E. Ethanol Root-extract of Sphenocentrum jollyanum Restored Altered Haematological Markers in Plasmodium berghei-infected Mice. *Earthline Journal of Chemical Sciences.* 2019; *2*(2): 189-203. https://doi.org/10.34198/ejcs.2219.189203.
16. Musiime, A.K., Smith, D.L., Kilama, M., Rek, J., Arinaitwe, E., Nankabirwa, J.I., et al.: Impact of vector control interventions on malaria transmission intensity, outdoor vector biting rates and Anopheles mosquito species composition in Tororo, Uganda. Malaria Journal. 18, 445 (2019). https://doi.org/10.1186/s12936-019-3076-4
17. Ainebyoona C, Egwu CO, Onohuean H, Ugwu OP, Uti DE, Alum BN, Echegu DA. Mitigation of Malaria in Sub-Saharan Africa through Vaccination: A Budding Road Map for Global Malaria Eradication. "Ethiopian Journal of Health Sciences,. 2025;35(3):205-217. doi: 10.4314/ejhs.v35i3.9. PMID: 40717722; PMCID: PMC12287706.
18. Thomas, C.J.: Hydropower development and malaria transmission: A geospatial econometric study. Journal of Public Health in Africa. 16, 8 pages (2024). https://doi.org/10.4102/jphia.v16i1.1397
19. Armin R., Michele R. R., (2013). Malaria during pregnancy with parasite sequestration in the villous chamber.Blood, the Journal of the American Society of Hematology, 121, (12), 2173-2173. https://doi.org/10.1182/blood-2012-10-465096
20. Thondoo, M., Mogo, E.R.I., Tatah, L., Muti, M., van Daalen, K.R., Muzenda, T., et al.: Multisectoral interventions for urban health in Africa: a mixed-methods systematic review. Glob Health Action. 17, 2325726. https://doi.org/10.1080/16549716.2024.2325726
21. Olubunmi A., Faoziyat A. S, Abdulmumeen A. H, Azeezat A., Abraham C A., Oloriegbe S, et al (2021). In pursuit of new anti-malarial candidates: novel synthesized and characterized pyrano-benzodioxepin analogues attenuated Plasmodium berghei replication in malaria-infected mice. Heliyon, 7, (12), 8523.DOI:https://doi.org/10.1016/j.heliyon.2021.e08517
22. de Abreu, V.H.S., Santos, A.S., Monteiro, T.G.M.: Climate Change Impacts on the Road Transport Infrastructure: A Systematic Review on Adaptation Measures. Sustainability. 14, 8864 (2022). https://doi.org/10.3390/su14148864
23. Isaac Edyedu PMA, Ugwu OPC, Ugwu CN, Alum EU, et al. The role of pharmacological interventions in managing urological complications during pregnancy and childbirth: A review. Medicine. 2025;104(7):e41381.
24. Alum EU, Ugwu OPC, Obeagu EI, et al. Nutritional care in diabetes mellitus: A comprehensive guide. Int J Innov Appl Res. 2023;11(12):16-25.
25. Obeagu EI, Ahmed YA, Obeagu GU, Bunu UO, Ugwu OPC, Alum EU. Biomarkers of breast cancer: Overview. Int J Curr Res Biol Med. 2023;1:8-16.
26. Uti DE, Alum EU, Atangwho IJ, Ugwu OPC, et al. Lipid-based nano-carriers for the delivery of anti-obesity natural compounds: Advances in targeted delivery and precision therapeutics. J Nanobiotechnol. 2025;23:336.
27. Ugwu CN, Ugwu OPC, Alum EU, Eze VHU, Basajja M, Ugwu JN, Ogenyi FC, et al. Medical preparedness for bioterrorism and chemical warfare: A public health integration review. Medicine. 2025;104(18):e42289.

28. Obeagu EI, Scott GY, Amekpor F, Ugwu OPC, Alum EU. COVID-19 infection and diabetes: A current issue. Int J Innov Appl Res. 2023;11(1):25-30.
29. Offor CE, Ugwu OPC, Alum EU. Anti-diabetic effect of ethanol leaf extract of *Allium sativum* on albino rats. Int J Pharm Med Sci. 2014;4(1):1-3.
30. Asogwa FC, Okechukwu PCU, Esther UA, Chinedu OE, Nzubechukwu E. Hygienic and sanitary assessment of street food vendors in selected towns of Enugu North District, Nigeria. Am-Eurasian J Sci Res. 2015;10(1):22-26.
31. Alum EU, Uti DE, Agah VM, Orji OU, Nkeiru N, et al. Physico-chemical and bacteriological analysis of water used for drinking and domestic purposes in Amaozara Ozizza, Afikpo North, Nigeria. Niger J Biochem Mol Biol. 2023;38(1):1-8.
32. Ugwu OPC, Alum EU, Okon MB, Obeagu EI. Mechanisms of microbiota modulation: Implications for health, disease, and therapeutic interventions. Medicine. 2024;103(19):e38088.
33. Ezekwe CI, Uzomba CR, Ugwu OPC. Effect of methanol extract of *Talinum triangulare* on hematology and liver parameters in rats. Glob J Biotechnol Biochem. 2013;8(2):51-60.
34. Alum EU, Inya JE, Ugwu OPC, Obeagu EI, Aloke C, Aja PM, Okpata MG, et al. Ethanolic leaf extract of *Datura stramonium* attenuates methotrexate-induced biochemical alterations in Wistar rats. RPS Pharmacol Rep. 2023;2(1):1-6.
35. Ugwu OPC, Erisa K, Inyangat R, Obeagu EI, et al. Indigenous medicinal plants for managing diabetes in Uganda: Ethnobotanical and pharmacotherapeutic insights. INOSR Exp Sci. 2023;12(2):214-224.
36. Alum EU, Aja W, Ugwu OPC. Vitamin composition of ethanol leaf and seed extracts of *Datura stramonium*. Avicenna J Med Biochem. 2023;11(1):92-97.
37. Ezenwaji CO, Alum EU, Ugwu OPC. Digital health in pandemic preparedness and response: Securing global health? Glob Health Action. 2024;17(1):2419694.
38. Adonu CC, Ugwu OP, Bawa A, Ossai EC, Nwaka AC. Intrinsic blood coagulation studies in patients with diabetes and hypertension. Int J Pharm Med Bio Sci. 2013;2(2):36-45.
39. Offor CE, Ugwu PC, Okechukwu PM, Igwenyi IO. Proximate and phytochemical analyses of *Terminalia catappa* leaves. Eur J Appl Sci. 2015;7(1):9-11.
40. Enechi YS, Ugwu OC, Ugwu KK, Ugwu OPC, Omeh N. Evaluation of antinutrient levels of *Ceiba pentandra* leaves. IJRRPAS. 2013;3(3):394-400.
41. Alum EU, Uti DE, Ugwu OPC, Alum BN, Edeh FO, Ainebyoona C. Microbiota in cancer development and treatment. Discov Oncol. 2025;16(1):646.
42. Asogwa FC, Okoye COB, Ugwu OPC, Edwin N, Alum EU, Egwu CO. Phytochemistry and antimicrobial assay of *Jatropha curcas* extracts. Eur J Appl Sci. 2015;7(1):12-16.
43. Enechi OC, Oluka HI, Ugwu PCO. Acute toxicity and ameliorative properties of *Alstonia boonei* leaf extract on diabetic rats. Afr J Biotechnol. 2014;13(5).
44. Alum EU, Obeagu EI, Ugwu OPC. Enhancing water, sanitation, and hygiene for diarrhoea control and SDGs: A review. Medicine. 2024;103(38):e39578.
45. Odo CE, Nwodo OFC, Joshua PE, Ugwu OPC, Okonkwo CC. Anti-diarrhoeal effect of chloroform–methanol extract of *Persea americana* seeds in rats. J Pharm Res. 2013;6(3):331-335.
46. Ugwu OPC, Obeagu EI, Alum EU, Michael M, et al. Effect of ethanol leaf extract of *Chromolaena odorata* on hepatic markers in diabetic rats. IAA J Appl Sci. 2023;9(1):46-56.
47. Ibiam UA, Alum EU, Orji OU, Aja PM, Nwamaka EN, Ugwu OPC, et al. Anti-inflammatory effects of *Buchholzia coriacea* leaf extract in arthritic rats. Indo Am J Pharm Sci. 2018;5(7):6341-6357.
48. Obeagu EI, Obeagu GU, Odo EO, Alum EU. Nutritional approaches for enhancing immune competence in HIV-positive individuals. IDOSR J Appl Sci. 2024;9(1):40-50.
49. Obeagu EI, Alum EU, Ugwu OPC. Hepcidin: Gatekeeper of iron in malaria resistance. Newport Int J Res Med Sci. 2023;4(2):1-8.
50. Nyamboga TO, Ugwu OPC, Ugwu JN, et al. Biotechnological innovations in soil health management: a systematic review of integrating microbiome engineering, bioinformatics, and sustainable practices. Cogent Food Agric. 2025;11(1):2519811.
51. Madu ANB, Alum EU, Aloh HE, Ugwu OPC, Obeagu EI, Uti DE, Egba SI, Ukaidi CUA. The price of progress: Assessing the financial costs of HIV/AIDS management in East Africa. Medicine. 2025;104(18):e42300.
52. Alum EU, Ugwu OPC. Beyond pregnancy: Understanding long-term implications of gestational diabetes mellitus. INOSR Sci Res. 2024;11(1):63-71.

53. Ugwu OPC, Alum EU, Okon MB, Aja PM, Obeagu EI, Onyeneke EC. Anti-nutritional and GC-MS analysis of ethanol root extract and fractions of *Sphenocentrum jollyanum*. RPS Pharmacol Pharm Rep. 2023;2(2):rqad007.
54. Eze VHU, Eze CE, Mbabazi A, Ugwu CN, Ugwu PO, Ogenyi CF, Ugwu JN, et al. Qualities and characteristics of a good scientific research writing: Step-by-step approaches. IAA J Appl Sci. 2023;9(2):71-76.
55. Igwenyi IO, Nchi PO, Okechukwu UPC, Igwenyi IP, Obasi DC, Edwin N. Nutritional potential of *Azadirachta indica* seeds. Indo Am J Pharm Sci. 2017;4(2):477-482.
56. Enechi OC, Oluka IH, Ugwu OPC, Omeh YS. Effect of ethanol leaf extract of *Alstonia boonei* on lipid profile of alloxan-induced diabetic rats. Afr J Biotechnol. 2013;24.
57. Ugwu OPC. Anti-malaria effect of ethanol extract of *Moringa oleifera* leaves on malaria-induced mice. University of Nigeria Nsukka; 2011:39.
58. Alum EU, Ugwu OPC, Obeagu EI. Nutritional interventions for cervical cancer patients: Beyond conventional therapies. J Cancer Res Cell Ther. 2024;8(1):1-6.
59. Obeagu EI, Obeagu GU. Advancements in immune augmentation strategies for HIV patients. IAA J Biol Sci. 2024;11(1):1-11.
60. Okechukwu PU, Nzubechukwu E, Ogbanshi ME, Ezeani N, Nworie MO. Effect of ethanol leaf extract of *Jatropha curcas* on chloroform-induced hepatotoxicity in albino rats. Glob J Biotech Biochem. 2015;10:11-15.
61. Ilozue NM, Ikezu UP, Okechukwu PCU. Antimicrobial and phytochemical screening of *Persea americana* seed extracts. IOSR J Pharm Biol Sci. 2014;9(2):23-25.
62. Onyeze R, Udeh SM, Akachi B, Ugwu OP. Isolation and characterization of fungi associated with spoilage of corn (*Zea mays*). Int J Pharm Med Biol Sci. 2013;2(3):86-91.
63. Obeagu EI, Alum EU, Ugwu OPC. Hepcidin: The gatekeeper of iron in malaria resistance. Newport Int J Res Med Sci. 2023;4:1-8.
64. Obeagu EI, Alum EU, Obeagu GU, Ugwu OPC. Prostate cancer: Review on risk factors. Eurasian Exp J Public Health. 2023;4(1):4-7.
65. Offor CE, Okaka ANC, Ogbugo SO, Egwu CO, Okechukwu PC. Effects of ethanol leaf extract of *Pterocarpus santalinoides* on haemoglobin, packed cell volume and platelets. IOSR J Nurs Health Sci. 2015;4:108-112, 93.
66. Offor C, Aja PC, Ugwu O, Agbafor KN. Effects of ethanol leaf extract of *Gmelina arborea* on serum proteins in albino rats. Glob J Environ Res. 2015;9(1):1-4.
67. Alum EU, Uti DE, Obeagu EI, Ugwu OPC, Alum BN. Cancer's psychosocial aspects: Impact on patient outcomes. Elite J Med. 2024;2(6):32-42.
68. Alum EU, Ugwu OPC, Egba SI, Uti DE, Alum BN. Climate variability and malaria transmission: Unravelling the complex relationship. INOSR Sci Res. 2024;11(2):16-22.
69. Alum EU, Obeagu EI, Ugwu OPC, Egba SI, EjimUti DE, Ukaidi CUA, et al. Confronting dual challenges: Substance abuse and HIV/AIDS. Elite J HIV. 2024;2(5):1-8.

CITE AS: Nassimbwa Kabanda D. (2026). Roads and Malaria Transmission: Unveiling the Epidemiological Impacts of Transport Infrastructure on Anopheles Mosquito Ecology in Sub-Saharan Africa. Research Output Journal of Public Health and Medicine 6(1):64-70.
https://doi.org/10.59298/ROJPHM/2026/616470