

AN ASSESSMENT OF THE IMPACT OF INDUSTRIAL ARCHITECTURE ON THE BUILT ENVIRONMENT IN THE TROPICS: A CASE STUDY OF EMENE INDUSTRIAL LAYOUT, ENUGU STATE

Odoh Peter E¹, Jonas Obianuju M², Anih Kingsley E³, Egbo James C⁴, Okoye Ugochineyere N⁵.

^{1,2,3&5} Department of Architecture, University of Nigeria, Nsukka

⁴ Department of Architecture, Enugu State University of Science and Technology.

Abstract- This study examines the environmental and health impacts of industrial architecture in tropical regions, using Emene Industrial Layout in Enugu State, Nigeria as a case study. The research identifies the negative effects of industrial activities on the human environment, including air and water pollution, thermal discomfort, and poor waste management. Two (2) case-studies within the study area were selected in order to analyze their architectural characteristics as it relates to their environmental impacts. This led to the proposal of active and passive design strategies to mitigate the negative impacts, such as efficient energy use, proper waste management, and adequate integration within the local context. The study recommends the adoption of sustainable design practices and the enforcement of rules to control industrial pollution. The findings are geared towards contributing to the development of industrial architectural practices, as it suggests strategies that balance economic growth with ecological sustainability in tropical regions.

Index Terms- Industrial Architecture, Built Environment, Tropical Region, Emene Industrial Layout

I. INTRODUCTION

Industrial architecture involves designing buildings for manufacturing and production, supporting efficient operations (Scott, 2023). However, rapid industrialization has caused significant environmental threats globally, including resource depletion and pollution, harming agriculture, property values, and human life (Benson, 2024). Nigeria, too, has experienced industrialization since the late 19th century. It is one of the countries identified to be experiencing the highest rate of rapid urbanization (Jonas and Basil 2022). This has significantly triggered industrial growth in tropical regions, leading to air and water pollution, endangering ecosystems and communities (Ebong, 2023). Industrial waste has contaminated rivers, harming water quality and aquatic life (Kanu, 2011), while increasing

water scarcity has heightened awareness of pollution issues (Kanu, 2011).

In Emene, Enugu, industrial activities, including chemical and food processing, have exacerbated pollution, with over 80% of Nigerian industries contributing to environmental degradation and less than 18% recycling waste (Joseph, 2019). The Emene River, a discharge point for effluents, has suffered significant water quality degradation (Onuigbo, 2013). This research aims to promote sustainable industrial architecture in Emene and Nigeria by assessing its environmental impact and proposing passive and active design measures to mitigate harm. Objectives include evaluating industrial architecture's effects in tropical regions and suggesting solutions to reduce its negative impact on the built environment.

II. LITERATURE REVIEW

HISTORICAL CONTEXT OF INDUSTRIAL ARCHITECTURE IN NIGERIA: The evolution of industrial architecture in Nigeria is closely tied to the country's colonial history. The introduction of British colonial rule in the late 19th century marked the beginning of industrial development in Nigeria, as the British sought to exploit the country's natural resources for economic gain (Chidubem, 2020). Over time, industrialization led to the establishment of numerous industrial zones across Nigeria, including the Emene Industrial Layout in Enugu State. The design of these industrial areas often prioritized economic efficiency and production over environmental sustainability, resulting in significant environmental challenges.

ENVIRONMENTAL IMPACT OF INDUSTRIAL ARCHITECTURE:

Industrial activities are known to contribute to environmental degradation significantly. According to Benson (2024), modern industries utilize vast amounts of natural resources, raw materials, and energy, resulting in substantial waste and pollution. When improperly managed, these wastes often include hazardous materials that can lead to soil, water, and air contamination and a gradual loss of biodiversity. For instance, the release of industrial effluents into water bodies, a common practice in many industrial zones, poses a severe threat to aquatic ecosystems.

Water Pollution: In Nigeria, several rivers are contaminated with industrial waste. This is primarily a result of poor sewage systems within industrial complexes and layouts, thus, adversely affecting water quality and the health of aquatic organisms (Anih et al, 2017; Kanu, 2011; Okoye et al., 2018). Emene Industrial Layout, with its concentration of chemical and food processing industries, exemplifies the impact of industrialization on water resources. Onuigbo (2013) notes that the discharge of untreated effluents into the Emene River has led to significant water quality degradation. The presence of contaminants such as Total Coliform Bacteria (TCB) and Escherichia coli (E. coli) has been linked to potential outbreaks of waterborne diseases like cholera, dysentery, typhoid, and yellow fever in the surrounding communities. This highlights the urgent need for better waste management practices to protect human health and the environment.



Figure1: Discharge of Factory waste. Source: Zurn, (2023)

Air Pollution: In addition to water pollution, industrial activities contribute to air pollution, which poses serious health risks to nearby populations (Ebong, 2023). Emissions from industrial

processes release pollutants such as carbon dioxide (CO₂), sulfur dioxide (SO₂), and particulate matter into the atmosphere, contributing to respiratory problems, cardiovascular diseases, and other health issues (Ebong, 2023). The impact of air pollution is particularly pronounced in tropical regions, where high temperatures and humidity can exacerbate the effects of airborne pollutants. In residential areas, this heightened pollution burden often coincides with increased indoor heat gain, especially in homes with poor ventilation and inadequate shading. The combined effect of trapped pollutants and solar heat can create dangerously uncomfortable and unhealthy living and learning conditions in nearby buildings, including residences and schools (Echeta et al., 2023a; Munonye et al., 2021).

Radiation Exposure: Another environmental concern associated with industrial architecture is radiation exposure. Ugbede (2018) highlights that the use of raw materials containing naturally occurring radioactive materials (NORM) in industrial processes has led to increased levels of background ionization radiation (BIR). Continuous exposure to elevated radiation levels can have long-term health implications, including an increased risk of cancer and other radiation-related diseases. These findings underscore the importance of regulating radiation levels in industrial settings to ensure the safety of workers and the surrounding communities.

III. THE STUDY AREA

The study area is Emene Industrial layout, Emene, Enugu state, Nigeria. As it is a mapped-out sector for industrial purposes containing numerous industrial facilities of varying scales for different purposes. This makes it appropriate for data collection.

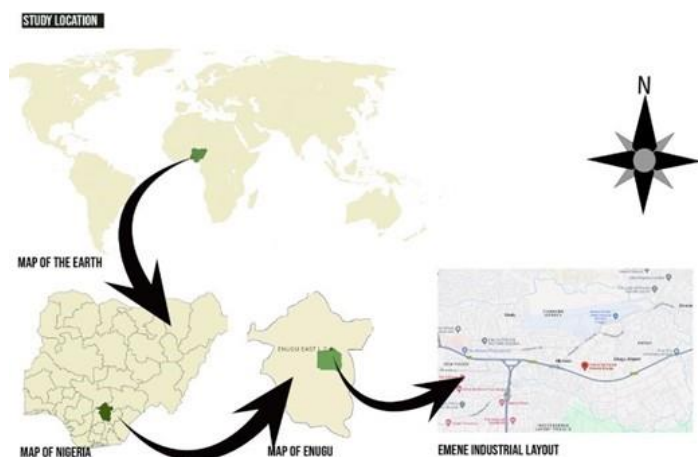


Figure 2: Map of the Study Area. Source: Authors fieldwork

The population of study consists of active industrial facilities within Emene industrial layout, Enugu State. The population of study is only limited to active industrial buildings because they are currently in use and operational. The sample frame consists of Two (2) purposefully selected Industrial complexes within Emene Industrial Layout that are currently active. They include: **Aniuzo International LTD**, and **Innoson Technical and Industrial Company Limited**. These locations were selected for their significant role in the industrial sector, diversity of activities, and varied urban-rural contexts. The aim is to provide a comprehensive overview of industrial impacts across different settings.

IV. RESEARCH METHODOLOGY

A qualitative approach was chosen due to the broad scope of the research issue, which required in-depth analysis of factors, causes, effects, and characteristics. Data was collected through extensive literature reviews and case studies, ensuring thorough research and accurate data. Tools like a still camera and measuring tapes were used, and findings were documented through written texts, sketches, and photographs

Table 1: Indicating the Case-Studies Selected

Location	Address	Description	Urban/Rural
Aniuzo International LTD	Emene Industrial Layout, by Proda junction	They specialize in the production of vegetable oil.	Urban

Innoson Technical and Industrial Company Limited.	Plot 1 Emene Industrial Layout, Enugu Nigeria.	They specialize in the production of household plastics.	Urban
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V. DATA PRESENTATION, ANALYSIS AND DISCUSSION

Case Study 1: Aniuzo International Limited.

Aniuzo International Limited specializes in the production of palm Vegetable oil, a highly sought-after commodity used in various products such as cosmetics and food. The major raw material involved in this production is palm kernels.



Figure 3: Aniuzo International Limited. Source: Researchers field work.

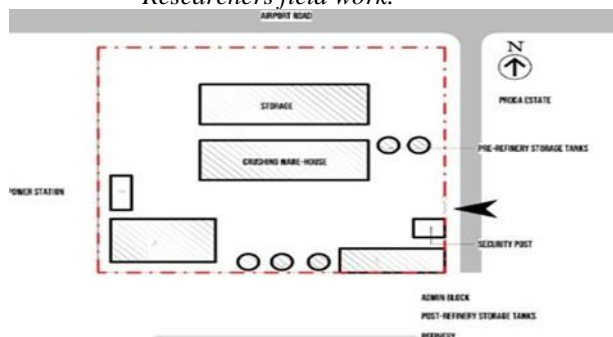


Figure 4: Sketch of Site Layout Facility. Source: Researchers field work.

Case-Study 2: Innoson Technical And Industrial Company Limited.

Innoson Technical and Industrial Company is a subsidiary of the Innoson Group that specializes in the production of household plastic products such as chairs, trays, spoons, jerry cans, and various types of plates and helmets.



Figure 5 and 6: External and interior views of Innoson Technical and Industrial Company LTD.
Source: Researchers Field Survey

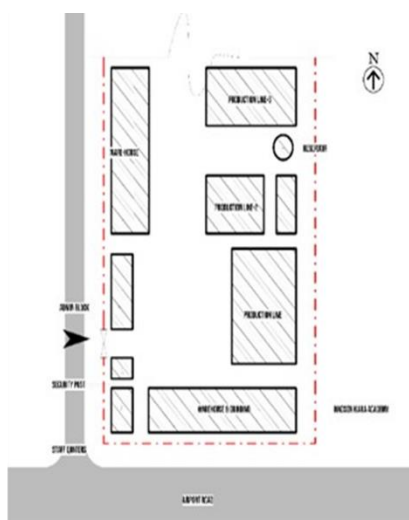


Figure 7: site Layout Source: Researchers Field Survey

VII. DATA ANALYSIS

Analysis obtained using the earlier stated research instruments is presented using tables. Discussion of findings obtained from the fieldwork is also made to better understand the variables and conditions noticed during the fieldwork. The analysis of results for this study was done in line with the research objectives.

Table 2: Key Findings from the studies

Aspect	Aniuzo International Limited	Innoson Technical and Industrial Company
Industry Name	Aniuzo International Limited	Innoson Technical And Industrial Company
Location	Proda Junction, Emene, Enugu	Plot 1 Emene Industrial Layout

	State, Nigeria	Enugu, Nigeria
Product	Vegetable Oil	Household Plastic Products
Site Layout	Simple rectangular layout with specified buildings	Simple rectangular layout with specified buildings
Building Shape	Majority rectangular	Majority rectangular
Flooring	Concrete German floors	Concrete German floors
Building Envelope	Sandcrete block walls (crushing), corrugated aluminum (refinery)	Sandcrete block (older), corrugated aluminum panels (recent)
Openings and Ventilation	Limited fenestration (crushing), extractor fans (some areas)	Proper fenestration, extractor fans (some areas)
Ceiling and Roofing	Gable roofs, corrugated aluminum roofing sheets	Gable roofs, corrugated aluminum roofing sheets
Landscaping	Majority concrete slabs	Concrete slabs, green vegetation
Waste Generation and Management	Palm kernel husks used for fuel, grease, domestic waste	Recycling of plastic materials, minimal waste generation
Thermal Comfort and Air Quality	Moderate due to limited fenestration, heat conductive materials	Decent with proper fenestration, seasonal discomfort observed
Power Consumption	PHCN, diesel generators (500kva, 1500kva)	PHCN, suspends production without electricity
Merits	Raw material reuse, skylights for lighting, buoyancy ventilation	Plastic recycling, natural ventilation, skylights, no fossil fuels
Demerits	Poor thermal comfort, fume release, heat conductive materials	Poor waste management, heat conductive materials
Recommendations	Adopt eco-friendly technologies, improve ventilation, insulation	Modern waste management, renewable energy adoption, insulation

Objective-1 To identify the negative impacts of industrial architecture on the human environment in the tropics.

Table 3: Impacts of industrial activities on the environment

Negative Impacts	Aniuzo International Limited	Innoson Technical and Industrial Company
Thermal Discomfort	Limited fenestration and heat-conductive materials cause moderate indoor heat during the day, affecting worker comfort.	Heat-conductive building materials led to poor thermal comfort, especially during the dry season.
Poor Air Quality	Burning of palm kernel husks releases fumes into the atmosphere, contributing to air pollution.	Seasonal discomfort and potential air quality issues due to heat conduction.
Energy inefficiency	Reliance on diesel generators for electricity during power outages increases carbon emissions.	Sole reliance on public source of electricity, with production halted during power outages.
Environmental pollution	Release of fumes from burning kernel husks; potential for grease and domestic waste pollution.	Minimal waste due to recycling, but improper waste collection and routes could contribute to localized pollution.
Land use and Aesthetics	Extensive use of concrete slabs for landscaping reduces green space and affects the local microclimate.	Similar use of concrete slabs, though mitigated by some green vegetation areas.
Building Material Impact	Use of heat-conductive materials in building envelopes worsens thermal comfort and increases energy needs.	Heat-conductive materials in newer buildings contribute to thermal discomfort.

Objective-2 To propose active and passive design strategies to mitigate the negative impacts of industrial architecture on the human environment applicable to the tropical regions.

Active And Passive Design Strategy Proposals

- i. Efficient Energy Use and Integration of Sustainable Building materials:



Figure 8: Autoclaved Aerated Concrete (AAC)

Source: Benson's (2024)

This can be achieved through passive means such as

- Proper orientation and layout Natural ventilation.

Active measures can be taken such as:

- The use of efficient building envelop that has low conductivity in other to reduce heat gain such as: hollow clay bricks and Autoclaved aerated concrete (AAC) Blocks which have a thermal conductivity.
- ii. Proper waste management: On site wastewater treatment with compact wastewater treatment systems such as BioKube compact wastewater treatment plant to clean the dirty water from industrial processes before sending it into the city's main sewer system. Also, Incorporate dedicated spaces within the building for sorting, storing, and processing recyclable materials like metals, plastics, paper, and glass.



Figure 9: BioKube compact waste Management treatment Plant

Source: Benson's (2024)

- iii. Adequate Integration within the Local Context:
 - use design elements that reflect the local culture and architectural traditions. This can include roof styles, materials, and colors that resonate with the surrounding community.
 - Utilize materials that are readily available in the local area to reduce transportation costs and environmental impact. This also supports local economies.
 - Choose materials with low embodied energy and environmental impact, such as bricks, or recycled materials, which are suitable for tropical climates.
- iv. Adaptability to Climate change:

- Utilizing passive design strategies that enhance natural ventilation and cooling
- Incorporating shading elements like overhangs, awnings, and louvers to minimize direct sunlight on the building façade (Echeta et al., 2023b).
- Designing adaptable spaces that can be easily modified for different uses or expanded as needed. This flexibility allows the building to respond to changing needs and conditions over time (Anih et al, 2019)

VIII. CONCLUSION

This research examined the impacts of industrial architecture on the human environment in tropics specifically in Emene Industrial Layout Enugu. The study Investigated the rapid growth of industrialization and its threats to both developing and developed countries. Findings highlighted the importance of evidence-based design and planning strategies that promote environmental sustainability and human health. The findings align with Benson's (2024) statement that rapid industrialization poses serious threats to both developed and developing countries. Industrial activities in Nigeria, such as crude oil processing and manufacturing, have been linked to air and water pollution, thereby causing harm to the human environment. The research emphasized the importance of considering the impact of industrial buildings on the surrounding environment and people's well-being in order to improve architectural practices and urban policies in Nigeria. The key recommendations from the study include the following:

Firstly, to Encourage sustainability consciousness in the design process of architects especially on industrial project commissions as this influences the orientation of the building, size and proportions as well as building materials. Again, to implement policies that mandates more modernized waste management and recycling practices among industries in Nigeria. Secondly, Architects, Policy makers and Stakeholders should create more awareness and educate people on the dangers of industrial pollutions to the human environment, enforcing rules in order to control them.

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REFERENCES

- [1] Anih E.K, C. Sam-Amobi, Okere C.E, Odoh P.E, Andy, N.N, Onubueze, I.P and Ugwu C.C; (2019); Design adaptability as a tool for achieving affordable housing in developing economies. [IOP Conference Series: Materials Science and Engineering, Volume 640, 1st International Conference on Sustainable Infrastructural Development 24–28 June 2019, Covenant University, Canaan Land, Ota, Nigeria](#)
- [2] Anih E.K, Andy N.N, Sam-Amobi C, Mba E. J, Ugwu C. C, Odoh P. E, Okere C. E(2017). Assessment of waste disposal and management in the University of Nigeria, Enugu Campus (UNEC). *Journal of Environmental management and Safety* Vol. 8 No. 1 (2017): ISSN 2141-1824. Pg 45 – 57. Published by Center for Environmental Population Activities.
- [3] Benson, J. (2024). Industrialization and its Impact on the Environment. *Journal of Environmental Management*, 58(2), 123-134.
- [4] Chidubem, A. B. (2020). The Historical Development of Industrial Architecture in Nigeria. *Nigerian Journal of Architecture*, 45(1), 78-89. *Cool Geography*. (n.d.). Retrieved from https://www.coolgeography.co.uk/gcsen/EW_Nigeria_Ec_Dev_Env.php
- [5] Chidubem, O. E. (2020). An overview of the state of industrial design education in Australia. *Australian Journal of Science and Technology*.
- [6] Ebong, G. A. (2023). Air Pollution and Public Health Risks Associated with Industrialization in Nigeria. *Environmental Health Perspectives*, 131(5), 453-467.
- [7] Echeta, I. B., Ezeji, K. E., Onwuzuligbo, C. C., & Nwoke, I. O. (2023a). Impact of materials used in construction of shading devices on quantity of indoor heat gain in residential buildings in Owerri, Nigeria. *African Journal of Environmental Research*, 4(2), 54-66. <https://www.researchgate.net/publication/373989365>
- [8] Echeta, I. B., Olotuah, A. O., Ezeji, K. E., & Onwuzuligbo, C. C. (2023b). Effect of geometry of shading devices on quantity of indoor heat gain in residential buildings in Southeast Nigeria: A case study of Owerri. *African Journal of Environmental Research*, 4(1), 94-109. <http://ajer.coou.edu.ng/index.php/journal>
- [9] Jonas, O.M. and Basil, A.M. (2022). The Role Of Architecture In The Infrastructural Development Of Rural Areas In Nigeria. *Journal of Environmental Management and Safety* Vol. 13, No. 1, (2022) 79 -94
- [10] Joseph, I. D. (2019). Entrepreneurship Development and Poverty Reduction in Nigeria: A Study of Industrial Layout, Emene, Enugu State, Nigeria. *The IUP Journal of Entrepreneurship Development*, 68-85.
- [11] Kanu, I. (2011). Water Pollution from Industrial Waste in Nigeria: Challenges and Solutions. *African Journal of Environmental Science*, 22(4), 301-315.
- [12] Kanu, I. A. (2011). Industrial Effluents and Their Impact on Water Quality. *Journal of Applied Technology in Environmental Sanitation*.
- [13] Munonye, C., Ngobili, M., Umeora, C., Oluchi, I., Maduka, N., & Onwuzuligbo, C. (2023). Comparative analysis of comfort temperature of school children and their teachers. *Research & Development*. <https://doi.org/10.11648/j.rd.20230401.15>
- [14] Munonye, C. C., Ezeji, K. E., Umeora, C. O., & Onwuzuligbo, C. C. (2021). Assessing thermal performance in two classroom building types in warm humid climate Imo State, Nigeria. *COOU African Journal of Environmental Research*, 3(1). <http://ajer.coou.edu.ng/index.php/journal>
- [15] Okoye, B. S. A., Umeora, C. O., Ifeji, O. C. & Onwuzuligbo, C. (2018). Effects of sewage disposal systems on the environment in public housing estates in Enugu metropolis. *African Journal of Environmental Research*, 1(1). <http://journal.coou.edu.ng/index.php/ajer>
- [16] Onuigbo, A. N. (2013). Water Quality Assessment of Emene River: Impact of Industrial Effluents. *Journal of Water Resources and Protection*, 5(9), 872-882.
- [17] Onuigbo, A., (2013). Assessment of Impact of Effluent Discharge on the Quality of Emene River, Enugu, Nigeria. *New York Science Journal* 2013;6(8).
- [18] Scott Zurn, P. (2023). Level Engineering & Inspection. Retrieved from Level Engineering & Inspection: <https://levelengineering.com/what-is-industrial-architecture/amp/>
- [19] Ugbede, F. O. (2018). Assessment of outdoor radiation levels and radiological health hazards in Emene Industrial Layout of Enugu State, Nigeria. *Academic Journals*, 265-272.
- [20] Ugbede, F. O. (2018). Radiation Exposure in Industrial Environments: The Case of Emene Industrial Layout. *Journal of Environmental Radiation*, 36(3), 215-229.
- [21] Zurn, S. (2023). Fundamentals of Industrial Architecture. *Architectural Design and Planning Journal*, 77(1), 21-34.

AUTHORS

First Author – Odoh Peter Ejike, Bsc & M.Sc Architecture, University of Nigeria, Nsukka.

Second Author – Jonas Obianuju Miriam, B.Tech & M.Tech Architecture, Abubakar Tafawa Balewa University, Bauchi..

Third Author – Anih Ejike Kingsley, Bsc,M.Sc & Ph.D Architecture, University of Nigeria, Nsukka.

Fourth Author – Egbo James Chinwuba, Bsc & M.Sc Architecture, Enugu State University of Science and Tech.

Fifth Author – Okoye Ugochinyere Nneoma, Bsc & M.Sc Architecture, University of Nigeria, Nsukka.

Correspondence Author – Kingsley Ejike Anih,