

Industrialisation, Environmental Exposure and Community Vulnerability: Evidence from Maraban Rido, Kaduna, Nigeria

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Abstract

Industrial growth can improve employment and access to goods and services, but where pollution control and land-use management are weak, industrial activity can transfer environmental costs to neighbouring communities. This study examined the environmental, health, livelihood, and spatial effects of industrial activities in Maraban Rido, Kaduna, Nigeria. A mixed-methods design was used, combining a survey of 400 residents with field observation, environmental measurements of air, water and soil, interviews, and review of available health, agricultural and regulatory records. Geographic information system (GIS) techniques were used to examine the distribution of households within exposure zones. The findings show substantial environmental pressure around the industrial corridor. PM_{2.5} reached 55 µg/m³ against the 15 µg/m³ reference value, while PM₁₀ reached 120 µg/m³ against 45 µg/m³. Soil samples close to industrial premises contained elevated concentrations of lead, chromium, cadmium and nickel, and the river sample near the food-processing facility recorded BOD of 250 mg/L, COD of 580 mg/L and petroleum hydrocarbons of 4.5 mg/L. Health records and survey evidence indicated higher reported respiratory and skin conditions in the highest-exposure zone, including a relative risk of 4.4 for adult asthma. Agricultural livelihoods also weakened, with vegetable yields declining by 44% between 2018 and 2024 and the number of crop-farming households falling from 350 to 150. The evidence indicates that industrial activity, environmental exposure, public health and livelihood change are spatially connected in Maraban Rido. Stronger pollution control, enforcement, public health surveillance, livelihood restoration and GIS-based environmental monitoring are therefore required.

Keywords

Environmental exposure; industrial pollution; Maraban Rido; public health; livelihoods; GIS

Introduction

Industrialisation remains important to urban and regional development because it creates employment, expands markets and supports the production and distribution of goods. These benefits, however, depend on how industrial land uses are located and managed in relation to settlements, water bodies, agricultural land and other sensitive uses. Industrial emissions, untreated effluent, hazardous wastes and poorly controlled dust can impose costs on communities that are not reflected in the value of industrial output. The environmental burden is often greatest where residential growth occurs close to industrial premises and where environmental regulation is weak (UNEP, 2021; Martinez-Alier et al., 2020).

In Nigeria, the relationship between industrial development and environmental quality is particularly important because many cities have expanded around established industrial corridors. Studies have linked industrial and urban activities to deterioration in air and water quality, soil contamination and increasing exposure to environmental health risks (Nwankwo &

Eludoyin, 2020; Okafor et al., 2022; Okoye et al., 2023). The consequences are not limited to physical pollution. Where agricultural land, fishing areas and other livelihood resources are affected, households may experience declining production and a gradual shift away from traditional sources of income. Such changes can deepen spatial inequality because households with fewer resources are less able to relocate or absorb environmental losses (Pegg & Zabbey, 2020; Rahman et al., 2021).

Maraban Rido provides a useful setting for examining these linked effects. The area is exposed to several industrial activities, including petrochemical, chemical, food-processing and brick-manufacturing operations. The Kaduna Refinery and Petrochemical Company (KRPC), Kaduna Indomie Noodles, TY Chemicals and Kaduna Bricks/Clay Products form important elements of the industrial environment. Residential areas, agricultural land and community facilities occur within the wider influence of these activities. The resulting pattern is not simply a question of whether pollution exists; it is also a question of who is exposed, where exposure is concentrated, and how environmental change is reflected in health and livelihoods.

Previous studies have examined industrial pollution as separate problems involving air quality, water contamination, soil degradation or health. A more integrated spatial perspective is useful because these effects can occur together and may reinforce one another. Industrial ecology emphasises the need to consider material flows and wastes across interconnected systems, while systems approaches highlight the relationships between industrial processes, the environment and human settlements (Liu, Diamond, & Keenan, 2021; Lopes, Egenolf, & Barbosa-Póvoa, 2021). Environmental justice research similarly draws attention to the uneven distribution of environmental benefits and burdens (Martinez-Alier et al., 2020).

The present study therefore examined the environmental, health, livelihood and spatial consequences of industrial activity in Maraban Rido. It assessed air, water and soil conditions; examined reported health outcomes and livelihood changes; reviewed available evidence of regulatory compliance; and used GIS to identify household exposure zones. The study was guided by the need to connect measured environmental conditions with the lived consequences of industrialisation rather than treating each environmental problem in isolation. This approach provides a basis for planning and regulatory responses that address the location, intensity and distribution of industrial exposure.

Materials and Methods

The study adopted a mixed-methods design to examine the environmental and socio-economic effects of industrial activity in Maraban Rido, Kaduna, Nigeria. The approach combined quantitative household data with environmental measurements, field observations, interviews and secondary records. The integration of these sources was intended to reduce dependence on a single indicator and to establish the relationship between industrial exposure, environmental quality, health conditions and livelihood change.

A total of 400 residents were included in the survey. Respondents were selected to represent households located at different distances from the industrial sources. The survey collected information on household characteristics, perceived environmental changes, exposure to pollution, health conditions and livelihood effects. Field observation was used to document visible pollution, waste handling, drainage conditions and the relationship between industrial premises and surrounding land uses. Interviews and available institutional records were used to provide contextual evidence on health and regulatory issues.

Environmental sampling covered air, water and soil. Air measurements included particulate matter and sulphur dioxide. The recorded observations included PM_{2.5} of 55 µg/m³ at MZ-A-01

on 15 March 2024, SO₂ of 45 µg/m³ at MZ-A-02, and PM₁₀ of 120 µg/m³ at MZ-B-01. These values were compared with the reference values used in the study. Soil samples were collected from locations close to the KRPC fence, an agricultural area and a residential zone. Lead, chromium, cadmium and nickel were analysed. Water samples were collected from the river near the Indomie facility, a community well in Zone B and a borehole in Zone C. Biochemical oxygen demand (BOD), chemical oxygen demand (COD), lead and hydrocarbons were assessed. Health information was examined by comparing reported conditions in the highest- and lower-exposure zones. Adult asthma, childhood bronchitis and contact dermatitis were considered because they were prominent in the available records and survey evidence. Relative risks were calculated by comparing the proportion affected in Zone A with that in Zone C. Monthly clinical averages from Maraban Rido Primary Health Centre and Kaduna State Specialist Hospital were also reviewed as contextual evidence.

Livelihood change was assessed using agricultural and household records. Crop yields for maize and vegetables were compared between 2018 and 2024, while the numbers of crop-farming and fishing households were examined over the same period. Regulatory evidence included inspection records, fines, pollution-control equipment status and hazardous-waste manifests for the major industrial facilities. These records were used descriptively to examine the extent to which documented pollution-control requirements were being implemented.

GIS was used to organise the spatial evidence and classify households according to distance from industrial sources. Zone A represented 0–1 km, Zone B 1–3 km and Zone C 3–5 km. The source data identified 5,000 households in Zone A and 5,000 in Zone C, while Zone B was recorded as 15,00 in the source table and interpreted in the accompanying study text as 15,000 households. Because the source entry is internally inconsistent, this figure should be checked against the original field dataset before final publication. The spatial analysis was used to identify the concentration of households potentially exposed to industrial activity rather than to imply that distance alone determines individual exposure.

Results and Findings

The environmental measurements show that industrial influence in Maraban Rido is associated with elevated pollutant levels at several sampled locations (Table 1). The highest recorded PM_{2.5} concentration was 55 µg/m³, approximately 3.7 times the 15 µg/m³ reference value used in the study. PM₁₀ reached 120 µg/m³ compared with a reference value of 45 µg/m³, while SO₂ was 45 µg/m³ compared with 40 µg/m³. The pattern indicates that particulate pollution was more pronounced than the recorded sulphur dioxide exceedance. This distinction is important because particulate matter can originate from several industrial and transport-related sources and can remain a significant exposure pathway even where individual gaseous pollutants appear only slightly elevated. Similar concerns about industrial particulate exposure and environmental health have been reported in the wider literature (Mohiuddin et al., 2021; Shukla et al., 2023).

Table 1: Air Quality Measurements at Sampled Locations, Maraban Rido (2025)

Air location	Date	Parameter	Measured value	Reference	Ratio
MZ-A-01	15-03-2024	PM _{2.5}	55 µg/m ³	15 µg/m ³	3.7×
MZ-A-02	2024	SO ₂	45 µg/m ³	40 µg/m ³	1.1×
MZ-B-01	2024	PM ₁₀	120 µg/m ³	45 µg/m ³	2.7×

Source: Field Survey, 2025.

The soil results show a clear spatial gradient in the sampled metals (Table 2). The sample nearest the KRPC fence recorded lead of 450 mg/kg, chromium of 120 mg/kg, cadmium of 5.2 mg/kg

and nickel of 80 mg/kg. Concentrations were lower in the agricultural and residential samples, although metals remained detectable. The pattern is consistent with greater contamination close to the industrial boundary and suggests that industrial emissions, deposition and waste-related pathways may influence surrounding soils. Similar studies have identified industrial activities as important contributors to heavy-metal accumulation in urban and peri-urban soils (Rizwan et al., 2020; Tchounwou et al., 2023).

Table 2: Soil Heavy Metal Concentrations by Sampling Location, Maraban Rido

Soil sample	Location	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ni (mg/kg)
S-01	Near KRPC fence	450	120	5.2	80
S-02	Agricultural Zone A	180	85	2.1	45
S-03	Residential Zone C	90	50	0.8	25

Source: Field Survey, 2025.

Water quality also varied substantially by location (Table 3). The river sample near the Indomie facility recorded BOD of 250 mg/L and COD of 580 mg/L, together with lead of 0.08 mg/L and hydrocarbons of 4.5 mg/L. The community well in Zone B had lower but still measurable values, while the Zone C borehole recorded the lowest concentrations. The spatial pattern indicates that surface water close to industrial discharge points was under greater environmental pressure than protected groundwater sources. Elevated organic loads and hydrocarbons in receiving waters are particularly important because they can affect aquatic systems and create risks where communities depend on contaminated water directly or indirectly (Okafor et al., 2022; Wang et al., 2022).

Table 3: Water Quality Parameters by Sampling Source, Maraban Rido

Water source	BOD (mg/L)	COD (mg/L)	Pb (mg/L)	Hydrocarbons (mg/L)
River near Indomie	250	580	0.08	4.5
Community well, Zone B	8	22	0.05	0.9
Borehole, Zone C	2	8	0.01	0.1

Source: Field Survey, 2025.

The health findings followed the spatial pattern observed in the environmental measurements (Table 4). Adult asthma was reported for 18.5% of respondents in Zone A compared with 4.2% in Zone C, giving a relative risk of 4.4. Childhood bronchitis was 22.0% in Zone A compared with 5.5% in Zone C, while contact dermatitis was 25.5% compared with 6.8%, producing relative risks of 4.0 and 3.75 respectively. These figures do not by themselves establish causation, because health outcomes can be influenced by smoking, occupation, household conditions and other factors. They nevertheless indicate a marked difference between the highest- and lower-exposure zones and are consistent with evidence linking air pollution and environmental contamination with respiratory and other health effects (Prüss-Ustün et al., 2021; Watts et al., 2021; Rahman et al., 2021).

Table 4: Reported Health Outcomes by Exposure Zone (Zone A vs Zone C)

Health outcome	Zone A	Zone C	Relative risk
Adult asthma	18.5%	4.2%	4.4
Childhood bronchitis	22.0%	5.5%	4.0
Contact dermatitis	25.5%	6.8%	3.75

The clinical records provided additional contextual evidence. The Maraban Rido Primary Health Centre recorded monthly averages of 45 asthma cases, 38 bronchitis cases and 52 dermatitis cases, while Kaduna State Specialist Hospital recorded monthly averages of 120, 95 and 40 cases respectively. These figures are descriptive rather than population-standardised rates and should therefore not be interpreted as evidence that industrial pollution alone caused the reported conditions. Their value lies in showing that respiratory and skin conditions formed a continuing part of the local health burden.

The environmental burden was accompanied by changes in agricultural livelihoods (Table 5). Maize yield fell from 2,500 kg/ha in 2018 to 1,600 kg/ha in 2024, a decline of 36%. Vegetable yield declined from 8,000 to 4,500 kg/ha, equivalent to 44%. Over the same period, the number of crop-farming households fell from 350 to 150 and fishing households from 75 to 10. These changes indicate a substantial weakening of resource-based livelihoods. The available data do not isolate the contribution of industrial pollution from other influences such as climate variability, input costs, market conditions or changes in land use. However, the coincidence of declining yields and reduced participation in farming and fishing with the documented environmental deterioration warrants closer investigation. Environmental degradation and livelihood displacement have been linked in other industrial and resource-dependent settings (Pegg & Zabbey, 2020; Xu et al., 2021).

Table 5: Agricultural and Livelihood Indicators, Maraban Rido (2018-2024)

Indicator	2018	2024	Change
Maize yield (kg/ha)	2,500	1,600	-36%
Vegetable yield (kg/ha)	8,000	4,500	-44%
Crop-farming households	350	150	-57%
Fishing households	75	10	-87%

The regulatory records indicate weaknesses in pollution control and enforcement (Table 6). KRPC was recorded as having exceeded the SO₂ emission limit on 10 January 2024, with a fine imposed but unpaid. TY Chemicals was associated with an illegal acidic effluent discharge recorded on 5 November 2023, with the matter before the court. Kaduna Bricks was recorded on 22 February 2024 as having a non-functional air-pollution control device, for which a warning was issued. The fine records similarly show an uneven enforcement outcome: KRPC was fined ₦5 million in 2023 with no payment recorded, Kaduna Indomie was fined ₦1.5 million and paid, while TY Chemicals was fined ₦3 million in 2024 with no payment recorded.

Table 6: Regulatory Compliance Records for Selected Industrial Facilities, Maraban Rido

Facility	Recorded issue	Regulatory response
KRPC	SO ₂ exceedance; fine unpaid	Fine imposed
TY Chemicals	Illegal acidic effluent discharge	Case in court
Kaduna Bricks	Air-pollution control device non-functional	Warning issued

Waste and equipment records reinforce this concern. KRPC generated 2,500 kg of oily sludge and TY Chemicals generated 800 kg of chemical sludge, but the disposal site was not specified in the available manifests. The KRPC flare-gas system was last serviced on 10 August 2023 and was described as partially functional and overdue for servicing. The Kaduna Bricks electrostatic precipitator was last serviced on 5 November 2022 and was recorded as out of service and overdue. These findings suggest that compliance cannot be assessed only by the existence of equipment or regulations; operational status, maintenance, monitoring, and enforcement are equally important. This is consistent with the wider literature emphasising the role of cleaner

production, circular material flows and effective environmental governance in reducing industrial burdens (Lopes et al., 2021; Senthilkumar et al., 2021; Zhao et al., 2024).

The GIS assessment shows that a substantial number of households are located within the defined industrial influence zones. Zone A, covering 0–1 km, contained 5,000 households or 20% of the households recorded in the study. Zone B, covering 1–3 km, was interpreted in the study as containing 15,000 households or 60%, while Zone C, covering 3–5 km, contained 5,000 households or 20%. The spatial pattern is important because exposure is not evenly distributed across the community. The concentration of households closer to industrial sources means that environmental monitoring and public health interventions should be spatially targeted rather than applied uniformly. GIS-based exposure mapping can support this type of planning by linking pollution sources, settlement patterns and vulnerable populations (Okoye et al., 2023; Sabi et al., 2023).

Taken together, the findings point to a connected chain of industrial exposure. The highest measured concentrations occurred close to industrial sources; the highest reported health burdens occurred in the nearest exposure zone; and agricultural and fishing livelihoods declined over the study period. The evidence does not justify treating these observations as proof of a single causal pathway, but their spatial and temporal correspondence is strong enough to require precautionary planning and more systematic monitoring. The study therefore supports an environmental management approach in which industrial regulation, public health, land-use planning and livelihood protection are considered together.

Summary and Conclusion

The study examined the environmental, health, livelihood and spatial consequences of industrial activity in Maraban Rido, Kaduna. Evidence from 400 respondents, environmental measurements, field observations and secondary records shows that industrial activity is associated with significant environmental pressures and uneven exposure across the community. Air measurements recorded particulate concentrations above the reference values used in the study, with PM_{2.5} reaching 55 µg/m³ and PM₁₀ reaching 120 µg/m³. Soil contamination was greatest at the industrial boundary, while the river close to the food-processing facility recorded substantially higher organic loads and hydrocarbon concentrations than the community well and borehole.

The health evidence showed marked differences between the closest and more distant exposure zones. Adult asthma, childhood bronchitis and contact dermatitis were all more frequently reported in Zone A, with relative risks ranging from 3.75 to 4.4. The livelihood evidence also showed substantial change, particularly in vegetable production, crop farming and fishing. Regulatory records indicated that some pollution-control equipment was overdue or non-functional and that some fines remained unpaid. The GIS analysis further showed that a large share of households was concentrated within the 1–3 km exposure zone.

The central conclusion is that the environmental consequences of industrialisation in Maraban Rido extend beyond the industrial premises. Pollution is spatially connected to residential exposure, health conditions and livelihood change. The study consequently supports an integrated planning response rather than isolated interventions. Stronger monitoring and enforcement are needed alongside public health surveillance, environmental restoration and protection of affected livelihoods. The evidence also demonstrates the value of combining environmental measurements with household, health, livelihood and GIS data when assessing industrial impacts in rapidly changing urban and peri-urban communities.

Recommendation

Environmental regulation should be strengthened through regular, independent monitoring of air emissions, effluent discharge, soil contamination and hazardous-waste handling. Compliance records should be updated routinely and made available to relevant public authorities and affected communities.

Industrial facilities should maintain pollution-control equipment according to specified schedules and should not operate equipment recorded as defective or non-functional. KRPC's flare-gas system and the Kaduna Bricks electrostatic precipitator identified in the study require particular attention.

The polluter-pays principle should be applied consistently. Fines should be proportionate to the environmental risk and should be enforceable, while repeated non-compliance should trigger stronger regulatory measures in accordance with applicable law. The purpose should be environmental protection and remediation rather than the collection of penalties alone.

Public health surveillance should be strengthened in communities close to the industrial corridor. Primary health facilities should maintain systematic records of respiratory, dermatological and other potentially environment-related conditions, while referral facilities should support periodic analysis of trends by location and age group.

Affected agricultural and fishing households should be included in livelihood-restoration programmes. Support may include soil remediation, access to safe water, agricultural extension, improved inputs, alternative livelihood training and targeted assistance for households that have lost productive resources.

Land-use planning should establish and enforce appropriate separation and buffer arrangements between industrial premises and sensitive residential, agricultural and community uses. Existing settlements within exposure zones should be incorporated into risk-reduction plans rather than treated as an afterthought to industrial development.

A GIS-based environmental monitoring system should be established for Maraban Rido. The system should combine industrial locations, monitoring points, household distribution, health facilities, land uses and environmental measurements so that changes in exposure can be identified spatially and acted upon promptly.

Finally, industries, regulatory agencies, local authorities, health institutions and community representatives should participate in a regular environmental management forum. Such a mechanism would improve information sharing, strengthen accountability and provide a practical channel through which community complaints and environmental observations can be incorporated into regulatory decisions.

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