Communication in Physical Sciences, 2026, 13(12):1901-1917

Data-Driven Assessment of Environmental Quality, Pollution Trends, and Sustainable Environmental Management in Selected Communities in Nigeria

Ifiok Dominic Uffia*, Rose Okopide Esen, Ofonimeh Emmanuel Udofia, Utibe Evans Bassey and Iniobong Bruno Nsien

Received: 19 September 2026/ Accepted: 19 October 2026/Published: 05 November 2026
DOI: 10.4314/cps.v13i12.4

Abstract : *Environmental pollution remains a major challenge to sustainable development in Nigeria, driven by inadequate solid waste management, wastewater discharge, urban expansion, industrial activities, and other anthropogenic pressures. This study develops a data-driven framework for assessing environmental quality, identifying pollution patterns, and recommending sustainable environmental management interventions in selected Nigerian communities. The assessment integrates secondary environmental evidence, water-quality indicators, air-pollution measurements, solid waste management practices, and national environmental sustainability indicators. Evidence from published studies in Akwa Ibom State, Lagos, Abuja, Anambra State, and Rivers State demonstrates the relevance of spatial variability, seasonal changes, waste disposal practices, and differences in environmental infrastructure to pollution management. National Sustainable Development Goal data indicate that 30% of Nigeria's population used safely managed drinking water services in 2024, while 41% of domestic wastewater flows were safely treated in the same year. In addition, 51% of monitored water bodies were classified as having good ambient water quality in 2023. These indicators illustrate persistent challenges in water supply, wastewater management, and the protection of aquatic environments. The study proposes an integrated assessment framework combining descriptive statistics, pollution indices, geographic information systems, temporal trend analysis, and a composite environmental quality index. The framework supports evidence-based prioritisation of pollution hotspots, infrastructure investment, regulatory enforcement, and community participation. The study concludes that sustainable environmental management in Nigeria requires harmonised monitoring systems, reliable longitudinal data, stronger institutional coordination, and measurable performance indicators. Because the community-level evidence is derived from studies with differing locations, periods, and methodologies, the findings are interpreted comparatively rather than as a single statistically pooled dataset.*

Keywords*: environmental quality; pollution trends; environmental management; water quality; solid waste; air pollution; Nigeria; data-driven assessment.*

Ifiok Dominic Uffia*
Department of Genetics and Biotechnology, Akwa Ibom State University, P. M. B. 1167, Uyo, Akwa Ibom State, Nigeria
Email: ifiokuffia@yahoo.com
https://orcid.org/0009-0006-3068-1267

Rose Okopide Esen
Department of Biochemistry, Akwa Ibom State University, P. M. B. 1167, Uyo, Akwa Ibom State, Nigeria
Email: roseesen@aksu.edu.ng
https://orcid.org/0009-0007-6292-8698

Ofonimeh Emmanuel Udofia
Department of Genetics and Biotechnology, Akwa Ibom State University, P. M. B. 1167, Uyo, Akwa Ibom State, Nigeria
Email: udofiaofonime17@gmail.com
https://orcid.org/0009-0009-0663-2299

Iniobong Bruno Nsien
Swamp Forest Research Station, Forestry Research Institute of Nigeria, Ibadan, Oyo, Nigeria
Email: inibruno@ymail.com

Utibe Evans Bassey
Department of Biochemistry, Akwa Ibom State University, P. M. B. 1167, Uyo, Akwa Ibom State, Nigeria
Email: utibeevans@yahoo.com
https://orcid.org/0009-0004-9547-8564

1.0 Introduction

Environmental quality is fundamental to public health, ecosystem stability, economic productivity, and sustainable development. Rapid urbanisation, population growth, industrialisation, agricultural intensification, and inadequate environmental infrastructure have increased the pressure on air, water, and land resources in many developing countries. In Nigeria, these pressures are evident in indiscriminate waste disposal, contaminated water sources, particulate matter emissions, untreated wastewater, and land degradation (Uffia *et al*., 2013). Effective environmental management therefore requires reliable data that can identify pollution sources, establish spatial and temporal patterns, and support the allocation of limited environmental protection resources.

Water pollution is a particularly important concern because communities depend on surface water and groundwater for drinking, domestic activities, agriculture, and livelihoods. A comprehensive review of Nigerian water-quality research identified persistent concerns relating to contamination, monitoring capacity, and enforcement of water-quality requirements (A comprehensive review of water quality monitoring and assessment in Nigeria, 2021). More recent research has also highlighted the influence of industrial discharge, domestic sewage, agricultural runoff, and flooding on the quality and accessibility of freshwater resources in Nigeria (Isukuru *et al*., 2024). These pressures demonstrate the need to integrate water-quality measurements with information about land use, sanitation, waste disposal, and community infrastructure.

Solid waste management is similarly important. Where waste collection and disposal services are inadequate, household refuse may accumulate in open spaces, enter drainage channels, or reach streams and rivers. Decomposing waste can generate unpleasant odours and landfill gases, while rainfall can transport contaminants into surrounding soil and water. A study of rural communities in Akwa Ibom State documented widespread reliance on disposal practices that included dumping waste into rivers and nearby bushes, with implications for the microbial quality of drinking-water sources (Okon *et al*., 2022: Uffia *et al*., 2024). Research around major dumpsites in Lagos has also examined pollution burdens associated with waste disposal locations (Olaniyan *et al*., 2024). Such studies demonstrate the importance of assessing waste management alongside environmental quality indicators rather than treating waste disposal as an isolated municipal service issue.

Air pollution presents another dimension of environmental risk. Road traffic, generators, industrial combustion, dust resuspension, open waste burning, and other combustion processes can contribute to particulate matter and gaseous pollutants. The magnitude of these emissions varies with location, weather, land use, and the intensity of human activities. A study in Anambra State reported spatial and seasonal differences in particulate matter around municipal dumpsites, with higher concentrations of $PM_{1.0}$ and $PM_{2.5}$ during the dry season than during the wet season (Nnoli *et al*., 2024). Similarly, research in Rivers State has examined the spatial and temporal variability of air pollutants and meteorological influences across six local government areas

(Ogbuagu *et al*., 2025). These findings support the use of repeated measurements and spatial analysis to distinguish persistent pollution hotspots from seasonal episodes.

Despite the availability of individual studies, environmental information in Nigeria is often fragmented across research institutions, government agencies, community surveys, and monitoring programmes. Studies may differ in sampling periods, analytical procedures, locations, pollutant indicators, and reporting formats. This makes direct comparison difficult and limits the development of consistent environmental performance measures. National indicators provide useful context, but they may not reveal the specific conditions of individual communities or explain why some locations experience greater environmental pressures than others.

Data-driven environmental management offers an approach for addressing these limitations. It combines field measurements, historical monitoring records, published studies, satellite observations, geospatial information, and statistical methods to identify patterns and guide interventions. Descriptive statistics can summarise pollution levels; trend analysis can identify changes over time; pollution indices can support interpretation of water and air quality; and geographic information systems (GIS) can reveal the spatial distribution of environmental pressures. When combined with socioeconomic and infrastructure data, these techniques can help environmental authorities prioritise locations for remediation and monitoring.

The principal aim of this study is to develop a data-driven assessment of environmental quality, pollution trends, and sustainable environmental management in selected communities in Nigeria. Specifically, the study seeks to examine evidence on air, water, and solid waste pollution; identify recurring spatial, seasonal, and management-related patterns; develop an integrated framework for environmental quality assessment; and recommend practical measures for strengthening environmental monitoring, pollution control, and community-level environmental governance.

The study contributes to environmental management by linking evidence from different Nigerian settings to a common assessment framework. Rather than assuming that measurements from different studies are directly interchangeable, it emphasises indicator harmonisation, transparent data quality assessment, and the distinction between observed pollution measurements and contextual environmental indicators.

Environmental quality refers to the condition of the natural environment as determined by physical, chemical, biological, and ecological characteristics (Uffia *et al*., 2025). In community-level assessments, environmental quality is commonly examined through air pollution, water contamination, soil degradation, solid waste accumulation, sanitation conditions, and the availability of environmental services. Because these dimensions interact, an integrated assessment can provide a more comprehensive picture than a single-indicator study.

Water quality can be assessed using pH, turbidity, electrical conductivity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nutrients, heavy metals, and microbiological indicators. Air quality assessment commonly includes $PM_{2.5}$, PM_{10}, nitrogen dioxide, sulphur dioxide, carbon monoxide, and ozone, depending on the sources and monitoring capacity. Waste management indicators include collection coverage, disposal methods, frequency of collection, waste composition, recycling rates, open burning, and the proximity of disposal sites to homes and water bodies.

The choice of indicators should reflect the intended environmental decision. For example, a drinking-water assessment requires microbiological and chemical parameters relevant to human consumption, whereas an

assessment of aquatic ecosystem health may place greater emphasis on dissolved oxygen, nutrients, habitat conditions, and biological indicators.

Evidence from Nigerian communities indicates that environmental pollution is closely associated with local waste disposal practices, sanitation infrastructure, settlement patterns, and human activities. In Kubwa, Abuja, Eze *et al*. (2019) investigated the effects of solid waste disposal on Usuma River water quality and reported spatial variation in water contamination. The study identified waste dumping along the riverbank as an important pollution pressure.

In Akwa Ibom State, Okon *et al*. (2022) examined household waste disposal and drinking-water quality across four rural communities. Their findings highlighted inadequate waste disposal infrastructure and practices that exposed water sources to potential contamination. This evidence is particularly relevant to communities where household sanitation and solid waste services are limited.

At larger urban waste-disposal sites, Olaniyan *et al*. (2024) investigated pollution levels near major dumpsites in Lagos. Such research illustrates the importance of monitoring environmental conditions around waste disposal locations rather than assuming that the effects of waste remain confined to the disposal site.

Air pollution is influenced by the type and intensity of emission sources, local meteorology, topography, and land use. In Nigeria, these factors may differ substantially between industrial areas, transport corridors, residential neighbourhoods, markets, and dumpsites. Particulate matter can arise from combustion, road dust, construction, industrial operations, and waste burning (Udofia, *et al*., 2023; Uffia *et al*., 2026).

The World Health Organization's Ambient Air Quality Database provides annual mean measurements of $PM_{2.5}$, PM_{10}, and nitrogen dioxide for cities and settlements worldwide. Its 2026 edition covers measurements for 2010–2024, although the completeness and comparability of records differ between locations. The WHO cautions against using this database to rank cities because monitoring coverage and data quality vary.

World Health Organization

For environmental management, seasonal monitoring is important because rainfall, wind, temperature, and atmospheric mixing can affect observed concentrations. A single short monitoring campaign may not represent annual exposure. Accordingly, air-quality data should be interpreted alongside monitoring duration, instrument type, sampling location, and meteorological conditions.

National Sustainable Development Goal indicators provide a useful baseline for assessing environmental service delivery and water resource management. According to the UN-Water SDG 6 Data Portal, approximately 30% of Nigeria's population used safely managed drinking-water services in 2024, while approximately 32% used safely managed sanitation services. The same portal reported that 41% of domestic wastewater flows were safely treated in 2024 and 51% of monitored water bodies had good ambient water quality in 2023.

SDG 6 Data

These indicators describe national conditions, not the measured performance of every community. Their relevance lies in identifying broader service-delivery gaps and providing context for local environmental assessments. They also support the use of indicators linked to SDG 6 (clean water and sanitation), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDG 13 (climate action) (Uffia *et al*., 2025).

Data-driven environmental management combines environmental measurements with statistical analysis, geospatial tools, and decision-support methods. Descriptive statistics help summarise pollution levels and

variability, while trend analysis identifies temporal changes. GIS enables the mapping of pollution hotspots and the relationship between pollution sources and sensitive receptors, including residential areas, schools, wells, rivers, and wetlands.

Composite environmental indices can simplify the interpretation of several indicators, but their design requires careful selection of variables, normalisation procedures, and weighting methods. An index can obscure severe pollution in one environmental medium if that pollution is averaged with better performance in another. Therefore, a composite score should be accompanied by individual pollutant results and, where appropriate, threshold-based alerts.

Existing Nigerian studies provide useful evidence on water pollution, dumpsite impacts, air-quality variability, and waste disposal practices. However, the results are often reported using different indicators, units, sampling periods, and methods. This limits direct comparison and the development of a consistent environmental management framework for multiple communities.

The gap addressed by this study is the need for a transparent framework that combines evidence from diverse environmental settings while preserving the distinction between measured observations, national indicators, and contextual findings. The framework is designed to support harmonised monitoring, spatial prioritisation, and the evaluation of environmental management interventions.

2.0 Materials and methods

2.1 Research design

The study adopts a comparative, secondary-data environmental assessment. It combines published research from selected Nigerian communities with national environmental indicators and proposes a common framework for evaluating environmental quality and pollution management.

The manuscript uses the term selected communities to refer to locations represented in the reviewed evidence, rather than implying that a new field survey was conducted. The comparative assessment is descriptive and analytical; it does not claim to establish causal relationships between pollution sources and environmental outcomes.

2.2 Study settings

Five Nigerian environmental settings were selected to represent different pollution-management contexts: Kubwa in the Federal Capital Territory, rural communities in Akwa Ibom State, major dumpsite environments in Lagos State, dumpsite locations in Anambra State, and selected areas in Rivers State. These locations were chosen because published studies address one or more relevant environmental issues.

Table 1. Selected study settings and environmental assessment focus

Study setting	Environmental issue	Evidence or monitoring focus
Kubwa, Abuja	Surface-water pollution	Waste disposal and river water quality
Rural communities, Akwa Ibom State	Solid waste and drinking-water quality	Household disposal practices and microbial contamination risk
Major dumpsite environments, Lagos State	Dumpsite-related pollution	Environmental conditions near waste disposal sites
Selected towns, Anambra State	Air pollution	Spatial and seasonal particulate matter variability

Selected areas, Rivers State	Air pollution	Pollutant variability and meteorological influences

Source: Compiled from Eze *et al*. (2019), Okon *et al*. (2022), Olaniyan *et al*. (2024), Nnoli *et al*. (2024), and Ogbuagu *et al*. (2025

2.3 Data sources and selection criteria

The assessment draws on peer-reviewed studies, international environmental databases, and national SDG indicators. Studies were considered relevant when they provided information on environmental pollution, monitoring methods, environmental quality indicators, or management practices in Nigeria. The WHO Ambient Air Quality Database was identified as a potential source of annual mean air-quality data, while the UN-Water SDG 6 Data Portal supplied national indicators for drinking water, sanitation, wastewater treatment, and ambient water quality. Published community studies supplied contextual evidence on local pollution sources and environmental management challenges. The proposed data selection criteria are summarised in Table 2.

Table 2. Data sources and analytical use

Data source	Variables or information	Intended analytical use
Peer-reviewed community studies	Water-quality parameters, waste practices, pollutant measurements	Compare local environmental pressures and findings
WHO Ambient Air Quality Database	Annual mean $PM_{2.5}$, PM_{10}, NO_2	Examine available urban air-quality records
UN-Water SDG 6 Data Portal	Drinking water, sanitation, wastewater treatment, ambient water quality	Establish national environmental service context
Meteorological records, where available	Rainfall, temperature, wind speed and direction	Interpret seasonal and weather-related variations
GIS and satellite-derived datasets, where available	Land cover, settlement growth, proximity to waste sites and water bodies	Map environmental pressures and sensitive receptors
Community or agency records, where available	Waste collection, disposal facilities, environmental complaints and enforcement	Evaluate management performance

2.4 Data extraction and harmonization

Information from each study should be extracted into a standardised data matrix containing the location, sampling period, environmental medium, indicator, unit, sample size, method of measurement, reported result, applicable guideline, and study limitations.

Measurements should only be compared when their units, analytical methods, sampling periods, and relevant environmental conditions are sufficiently compatible. Where measurements are not comparable, findings should be synthesised narratively rather than combined numerically.

For a future field-based extension, water samples should be collected from upstream, pollution-source, and downstream locations where appropriate. Air-quality monitoring should include locations near emission sources and comparable background sites. Waste audits should document generation, composition, collection, disposal, and burning practices.

Sampling should cover relevant wet and dry seasons to capture temporal variation.

2.5 Descriptive statistical analysis

For a numerical dataset containing (n) observations, the arithmetic mean and standard deviation were calculated using equations 1 and 2, respectively.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (1)$$

$$SD = \sqrt{\frac{(x_i - \bar{x})}{N-1}} \quad (2)$$

The mean summarises the central tendency of an indicator, while the standard deviation describes its dispersion. The median and interquartile range should also be reported when measurements are skewed or contain extreme values.

Where sufficient repeated observations exist, seasonal differences may be examined using appropriate parametric or non-parametric tests. Regression or time-series methods may be used to evaluate trends when sampling frequency, duration, and data quality support such analysis. Statistical significance should not be interpreted as evidence of causation.

3.6 Pollution indices and guideline comparisons

Water-quality measurements should be compared with the applicable Nigerian standards and relevant WHO guideline values for the intended water use. The assessment should not treat all environmental thresholds as interchangeable: a value suitable for one use may be inappropriate for another.

For an indicator where higher concentrations represent greater pollution, a simple normalised exceedance ratio can be defined as:

$$E_i = \frac{C_i}{G_i} \quad (3)$$

where C is the measured concentration and G_i is the applicable guideline value. An exceedance ratio greater than one indicates that the measured concentration exceeds that particular guideline. This ratio is not, by itself, a complete water-quality or health-risk index.

For air pollutants, the selected guideline should match the averaging period of the observation. Annual mean measurements should not be compared directly with short-term exposure limits.

3.7 Environmental quality index

A composite Environmental Quality Index EQI_j) is proposed to summarise multiple environmental indicators. Indicators are first transformed to a common scale from 0 to 100, with higher scores representing better environmental quality. Pollutant exceedance scores should be reversed so that greater pollution corresponds to a lower environmental-quality score.

The composite index is defined as:

$$EQI_j = \sum_{i=1}^{m} w_i s_{ij} \quad (4)$$

where EQI_j is the index for communitys_{ij} is the normalised quality score for indicator, j, in community w_i is the weight assigned to that indicator, and (m) is the number of indicators included. The weights must sum to one. Equal weights may be used as an initial transparent approach, followed by sensitivity analysis using alternative weights. If key indicators are missing, the index should not be interpreted as a complete measure of environmental quality. Air, water, and waste management scores should also be presented separately.

3.8 Spatial and temporal analysis

Where georeferenced observations are available, GIS can be used to map sampling locations, pollutant concentrations, waste disposal sites, water bodies, and nearby sensitive receptors. Spatial interpolation should only be undertaken when the number and distribution of observations justify it.

Temporal analysis should distinguish long-term trends from seasonal fluctuations. A consistent increase or decrease in a pollutant can be assessed using a suitable trend estimator

and significance test, provided that the time series is sufficiently complete. Short, irregular, or methodologically inconsistent records should be described as observations rather than definitive trends.

3.9 Quality assurance and quality control

Data quality assurance should include checks for missing values, duplicate records, unit consistency, instrument calibration, sampling documentation, laboratory quality-control results, and traceability to the original source. Published data should retain the original study's units and limitations.

For new laboratory or field measurements, the protocol should include calibrated equipment, field blanks where relevant, duplicate samples, appropriate preservation, documented chain of custody, and validated analytical methods. Missing data should not be replaced with assumed measurements without a documented and defensible imputation procedure.

3.10 Ethical considerations

The secondary-data component uses published environmental studies and public indicators. If the research is extended to household questionnaires, interviews, or new sample collection involving identifiable participants or sensitive community information, the necessary institutional ethical approval, informed consent, and applicable environmental sampling permissions should be obtained.

3.11 Analytical workflow

Fig. 1 presents the proposed data-driven environmental assessment framework for evaluating environmental quality, identifying pollution trends, and developing sustainable environmental management strategies in selected communities in Nigeria. The flowchart illustrates a systematic, nine-stage process that begins with defining the study objectives and selecting representative communities, followed by identifying relevant published studies and official datasets. Environmental and management indicators are then extracted, and the collected data are screened for completeness, quality, consistency, and comparability before statistical analysis is undertaken.

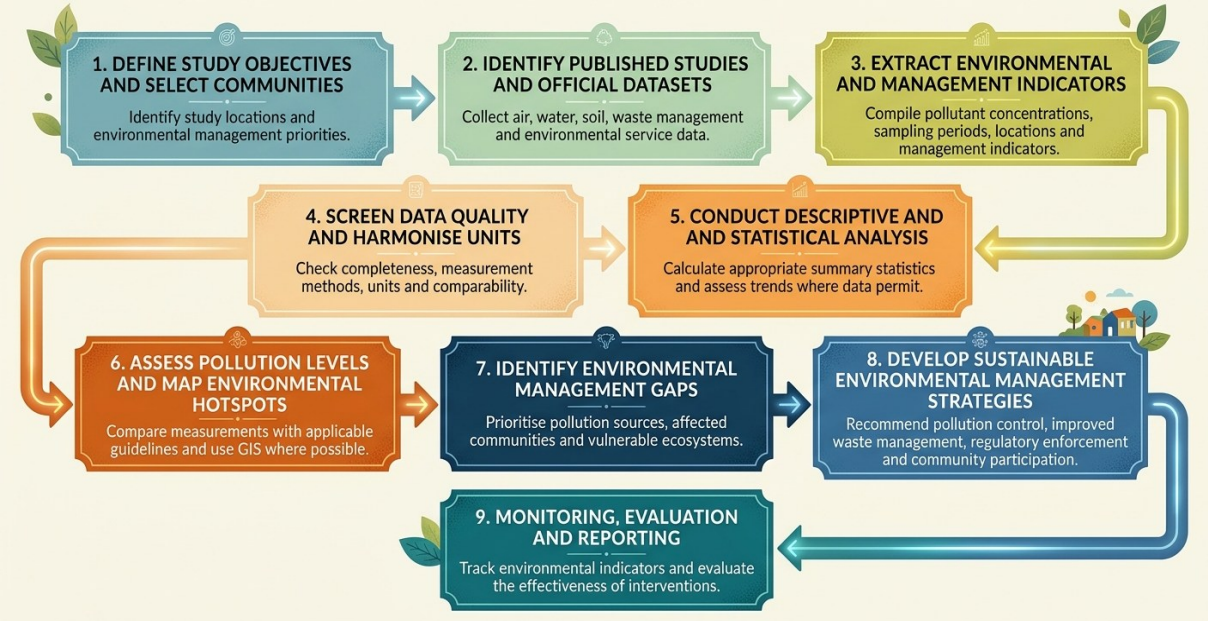


Fig. 1: presents the proposed data-driven environmental assessment framework for evaluating environmental quality, identifying pollution trends, and developing sustainable environmental management strategies

The subsequent stages involve assessing pollution levels, mapping environmental hotspots using geographic information systems (GIS) where appropriate, and identifying environmental management gaps based on pollution sources, affected populations, and vulnerable ecosystems. The framework then translates the assessment findings into targeted management strategies, including pollution control, improved waste management, regulatory enforcement, and community participation. Finally, continuous monitoring, evaluation, and reporting are incorporated to determine the effectiveness of implemented interventions and support evidence-based decision-making. Overall, the framework provides an integrated approach for transforming environmental data into practical management actions that can improve environmental quality and promote sustainability in Nigerian communities.

4. 0 Results and discussion

4.1 National environmental quality indicators

The national indicators provide a baseline for understanding environmental management challenges in Nigeria. The UN-Water SDG 6 Data Portal reports that 30% of the population used safely managed drinking-water services in 2024, 32% used safely managed sanitation services, and 41% of domestic wastewater flows were safely treated in that year. It also reports that 51% of monitored water bodies had good ambient water quality in 2023 (UN-Water, 2026).

These figures show why environmental management should address water supply, sanitation, wastewater treatment, and the protection of receiving water bodies as connected priorities. However, the indicators describe different dimensions of environmental services and should not be interpreted as measurements from the same population, locations, or sampling period.

Table 3. Selected national environmental and water-management indicators for Nigeria

Indicator	Reported value	Reference year	Environmental management implication
Population using safely managed drinking-water services	30%	2024	Need to improve access to safe, reliable water supplies
Population using safely managed sanitation services	32%	2024	Need to expand sanitation infrastructure and safe waste containment
Domestic wastewater flows safely treated	41%	2024	Need to strengthen wastewater collection and treatment
Monitored water bodies with good ambient water quality	51%	2023	Need to protect and restore water bodies and improve pollution monitoring
Implementation of integrated water resources management	47%	2023	Need to strengthen coordinated water-resource planning

Source: UN-Water SDG 6 Data Portal, Nigeria country profile.

The data indicate that safe water access and sanitation remain important environmental management priorities. The proportion of monitored water bodies with good ambient quality also suggests that the protection of aquatic ecosystems requires sustained attention. Nevertheless, the indicators do not establish that all communities experience the same level of environmental stress. Local pollution measurements are required to identify

individual hotspots and determine the most appropriate interventions.

4.2 Evidence of pollution across selected communities

The reviewed studies demonstrate that environmental problems differ according to the dominant pollution source and the characteristics of each location.

In Kubwa, Abuja, Eze *et al*. (2019) investigated surface-water pollution associated with indiscriminate waste disposal around Usuma River. The study reported spatial variation in contamination, indicating that water quality differed among sampling locations. This finding supports the need to monitor water bodies at multiple points rather than relying on a single sampling location.

In rural communities in Akwa Ibom State, Okon *et al*. (2022) examined waste disposal practices and the microbial quality of drinking-water sources. Their findings indicate that inadequate household waste disposal infrastructure can create pathways for environmental contamination. In these settings, the environmental management response should integrate waste collection, sanitation, source protection, and routine water-quality testing.

The Lagos dumpsite study by Olaniyan *et al*. (2024) further demonstrates the relevance of assessing environmental conditions around major waste disposal sites. For such locations, the monitoring programme should consider surface water, groundwater, surrounding soils, air quality, and the proximity of sensitive receptors, depending on the characteristics of the site.

Table 4. Comparative synthesis of environmental pollution evidence

Location	Main environmental pressure	Evidence reported in the literature	Management priority
Kubwa, Abuja	Solid waste disposal near surface water	Spatial variation in river water contamination	Prevent riverbank dumping and strengthen water monitoring
Rural communities, Akwa Ibom State	Household waste disposal and inadequate sanitation	Waste disposal practices associated with potential drinking-water contamination	Improve waste collection, sanitation, and water-source protection
Major dumpsites, Lagos State	Waste disposal and surrounding environmental exposure	Investigation of pollution levels near major dumpsites	Monitor potential contaminant pathways and improve site management
Selected towns, Anambra State	Dumpsite-related particulate matter	Spatial and seasonal variation in particulate matter	Control open burning and improve seasonal air monitoring
Selected areas, Rivers State	Air pollution and meteorological variability	Investigation of pollutant variability across six local government areas	Integrate air monitoring with meteorological observations

Sources: Eze *et al*. (2019); Okon *et al*. (2022); Olaniyan *et al*. (2024); Nnoli *et al*. (2024); Ogbuagu *et al*. (2025)

The comparison reveals three broad patterns. First, solid waste disposal can affect more than one environmental medium, particularly where waste is deposited near surface water or where leachate can enter the surrounding environment. Second, air pollution varies

across locations and seasons, making repeated monitoring necessary. Third, the appropriate management intervention depends on the dominant local pollution source and the environmental pathways through which contaminants move.

The findings also highlight the limitations of comparing results from separate studies. Differences in analytical procedures, monitoring duration, and sampling locations mean that a pollution value from one study cannot automatically be interpreted as higher or lower than a value from another. The evidence is therefore used to identify recurring environmental problems rather than produce a numerical ranking of the selected communities.

4.3 Air pollution and the need for temporal monitoring

Air-quality studies in Anambra and Rivers states provide evidence that particulate matter and other air pollutants should be assessed in relation to location, emission sources, and meteorological conditions. Nnoli *et al*. (2024) reported seasonal differences in particulate matter around municipal dumpsites in Anambra State, while Ogbuagu *et al*. (2025) examined spatial and temporal pollutant variability and meteorological influences in Rivers State.

These studies support the adoption of repeated monitoring at locations with potentially high emissions, including dumpsites, transport corridors, industrial areas, and densely populated settlements. They also show why an isolated measurement cannot reliably represent annual air quality.

A more robust assessment would collect measurements at consistent intervals in both wet and dry seasons, document instrument specifications, and record meteorological variables. Where suitable historical observations exist, time-series analysis could be used to examine whether pollution is increasing, decreasing, or remaining relatively stable.

The WHO Ambient Air Quality Database can provide additional context through annual mean $PM_{2.5}$, PM_{10}, and nitrogen dioxide measurements. However, the WHO warns that its records vary in coverage and methodological quality and are not intended to provide a definitive ranking of cities.

Consequently, environmental authorities should interpret air-quality records in conjunction with local monitoring information and avoid attributing observed trends to specific sources without supporting evidence.

4.4 Solid waste management and environmental quality

Solid waste management is a cross-cutting environmental concern because inadequate collection, transportation, treatment, and disposal can contribute to land, water, and air pollution. The reviewed studies indicate that environmental pressures arise not only from the amount of waste generated but also from how waste is handled and where it is deposited.

Open dumping near rivers can increase the likelihood of physical and chemical contamination. Uncontrolled burning can generate particulate matter and other combustion products. Poorly managed dumpsites may also expose nearby residents to odours, pests, and potentially contaminated runoff. These pathways require different interventions and should be assessed separately.

The table (Table 5) provides a common monitoring structure, but the indicators should not be treated as a substitute for direct measurements. For example, waste collection coverage measures service delivery rather than the chemical quality of soil or water. Likewise, the presence of a waste disposal site does not establish the degree of contamination without appropriate sampling.

4.5 Integrated environmental quality assessment

The evidence suggests that an integrated environmental quality assessment should

combine pollution measurements with information about environmental services and management performance. The national indicators in Table 3 establish broad context, while the community studies in Table 4 identify specific pollution pathways. Table 5 provides a set of measurable indicators for a harmonised monitoring programme.

Table 5. Proposed indicators for evaluating environmental quality and management performance

Environmental dimension	Indicator	Unit or measurement	Management interpretation
Air quality	$PM_{2.5}$ concentration	$\mu g/m^3$	Fine particulate exposure
Air quality	PM_{10} concentration	$\mu g/m^3$	Coarse and fine particle pollution
Air quality	Nitrogen dioxide	$\mu g/m^3$	Combustion-related air pollution
Water quality	Ph	pH units	Acidity or alkalinity
Water quality	Turbidity	NTU	Water clarity and suspended material
Water quality	Dissolved oxygen	mg/L	Oxygen availability for aquatic organisms
Water quality	Nitrate or phosphate	mg/L	Nutrient enrichment and possible contamination
Water quality	Indicator microorganisms	Appropriate microbiological units	Potential faecal contamination
Solid waste	Collection coverage	Percentage of households or waste collected	Access to waste services
Solid waste	Uncontrolled dumping	Number or proportion of observed sites	Extent of inadequate disposal
Solid waste	Recycling or recovery rate	Percentage of generated waste	Resource recovery performance
Environmental governance	Inspection and enforcement coverage	Percentage or number of sites inspected	Regulatory implementation
Environmental governance	Community participation	Attendance, participation or reported involvement	Community engagement in environmental management

Source: Authors' proposed monitoring framework. The parameters and units should be adapted to the environmental medium, applicable standards, and local monitoring capacity.

An Environmental Quality Index could be useful for summarising the performance of individual communities, provided that the index is calculated from compatible and sufficiently complete observations. Separate scores should be maintained for air, water, waste management, and governance before any overall score is calculated. This approach would prevent relatively good performance in one dimension from concealing serious pollution in another.

At the current stage, a numerical community-level EQI cannot be calculated defensibly from the reviewed evidence alone because the

underlying studies do not provide a complete, harmonised dataset covering all the required indicators and communities. Reporting a single score or statistical ranking would therefore imply a level of comparability that has not been established.

4.6 Proposed data-driven environmental management framework

Fig. 2 presents the proposed framework for translating environmental observations into practical management decisions. The framework links environmental pressures, monitoring, data analysis, prioritisation, intervention, and performance evaluation.

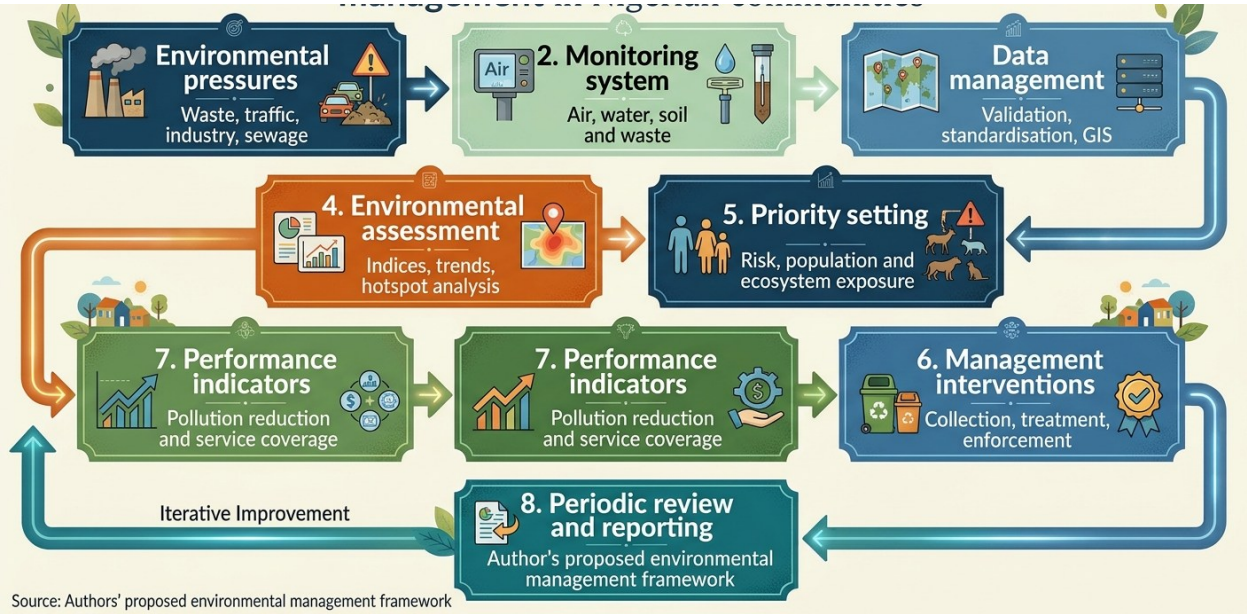


Fig: 2: Integrated framework for data-driven environmental management in Nigerian communities

The framework begins with the identification of environmental pressures and the collection of appropriate measurements. Data are then validated and analysed to identify locations where environmental quality is poor or management services are inadequate. Interventions are selected according to the dominant pollution source, the affected population, ecological sensitivity, technical feasibility, and available resources.

The final stage involves evaluating whether the intervention improves environmental conditions. For example, a programme to prevent dumping near a river should be assessed using evidence on observed dumping, waste collection, and water quality before and after implementation. A programme to reduce air pollution around a dumpsite should monitor particulate matter and open burning rather than relying solely on the number of awareness campaigns conducted.

4.7 Implications for sustainable environmental management

The results have several implications for environmental governance in Nigeria.

First, environmental monitoring should be standardised across relevant agencies and research institutions. Common indicator definitions, sampling procedures, data formats, and reporting periods would make comparisons more reliable and reduce duplication.

Second, management priorities should reflect the environmental pathways identified in each community. Riverbank dumping requires source control, waste collection, and water

protection. Dumpsite-related pollution requires appropriate site management and monitoring of relevant air, soil, and water indicators. Air pollution from traffic or industrial activity requires source-specific interventions supported by reliable measurements.

Third, environmental authorities should link performance indicators to practical outcomes. Examples include changes in pollutant concentrations, the proportion of households served by waste collection, the number of uncontrolled disposal sites remediated, and the proportion of identified pollution incidents resolved. These measures provide stronger evidence of progress than activity counts alone.

Fourth, community participation should be incorporated into monitoring and intervention design. Residents can help identify recurrent dumping locations, drainage problems, waste burning, and changes in local water conditions. Their observations should complement, rather than replace, technical measurements.

Finally, environmental management programmes should include periodic evaluation. Pollution controls may be ineffective if infrastructure is not maintained, waste collection is irregular, or enforcement is inconsistent. A continuous monitoring and feedback system would enable authorities to modify interventions when evidence shows that expected improvements have not occurred.

5. 0 Conclusion

This study developed a data-driven framework for assessing environmental quality, pollution patterns, and sustainable environmental management in selected Nigerian communities. The synthesis of published community studies and national environmental indicators demonstrates the importance of examining air pollution, water contamination, solid waste disposal, sanitation, and environmental service delivery as interconnected dimensions of environmental sustainability.

The reviewed evidence identifies several recurring environmental management challenges, including inadequate waste disposal infrastructure, pollution pressures on surface water, spatial variation in environmental contamination, and seasonal changes in particulate matter concentrations. National SDG indicators further highlight gaps in safely managed drinking water, sanitation, and wastewater treatment. These challenges require coordinated monitoring and interventions that address both pollution sources and the infrastructure responsible for environmental protection.

The proposed framework integrates data collection, quality assurance, statistical analysis, geospatial assessment, pollution prioritisation, and performance evaluation. It offers a practical basis for developing community-level environmental quality indices and monitoring progress towards sustainable environmental management.

However, the present study is a comparative secondary-data assessment, not a new field investigation. The reviewed studies differ in sampling periods, indicators, and analytical methods, preventing the calculation of a defensible, unified pollution trend or environmental quality score across all selected communities. Future research should therefore apply the framework to harmonised longitudinal datasets collected using consistent procedures.

Overall, evidence-based environmental management in Nigeria will depend on reliable environmental data, effective regulatory implementation, improved waste and wastewater infrastructure, public participation, and systematic evaluation of environmental interventions.

Based on the findings and proposed framework, the following recommendations are made.

1. Establish integrated environmental monitoring systems. Relevant federal, state, and local authorities should strengthen coordinated monitoring of air, surface water, groundwater, soil, and solid waste



management. Monitoring records should use standardised indicators and documented quality-control procedures.

2. Improve solid waste collection and disposal. Local authorities should expand collection coverage, provide suitable waste receptacles, improve transportation and final disposal facilities, and discourage open dumping and uncontrolled burning.

3. Strengthen water-quality protection. Communities that depend on surface water or groundwater should receive periodic water-quality assessments. Waste disposal near rivers, wells, and other drinking-water sources should be controlled, and contaminated sources should be investigated and managed appropriately.

4. Expand wastewater treatment and sanitation infrastructure. Investment should prioritise locations where untreated wastewater and inadequate sanitation threaten public health and aquatic ecosystems.

5. Introduce seasonal air-quality monitoring. Monitoring programmes should capture both wet- and dry-season conditions, particularly around dumpsites, industrial areas, transport corridors, and densely populated settlements.

6. Adopt GIS-based environmental planning. Geospatial information should be used to map pollution sources, vulnerable receptors, waste disposal locations, drainage networks, and environmentally sensitive areas.

7. Develop measurable environmental performance indicators. Environmental programmes should be evaluated using changes in pollution levels, service coverage, waste recovery, remediation progress, and compliance with applicable standards.

8. Strengthen environmental enforcement. Regulatory agencies should improve inspections, require compliance with applicable environmental regulations, and ensure that documented violations receive appropriate follow-up.

9. Promote community participation. Environmental education, reporting mechanisms, community clean-up initiatives, and collaboration with local organisations should complement formal monitoring and enforcement.

10. Conduct longitudinal field research. Future studies should collect standardised observations across selected communities over multiple seasons and years. These data would support statistically defensible pollution trend analysis, community-level environmental quality indices, and evaluation of intervention effectiveness.

7.0 References

Eze, O. F., Ahmadu, J., & Hanis, B. (2019). Effects of solid waste on the surface water quality of Usuma River, Phase IV, Kubwa–Abuja, Nigeria. *International Journal of Environmental Protection and Policy,* 7(6), 150–160. https://doi.org/10.11648/j.ijepp.20190 706.13

Igbemi, I. A., Nwaogazie, I. L., Akaranta, O., & Abu, G. O. (2019). Water quality assessment by pollution indices in Eastern Obolo coastline communities of Nigeria. *American Journal of Water Resources,* 7(3), 111–120. https://doi.org/10.12691/ajwr-7-3-4

Isukuru, E. J., Opha, J. O., Isaiah, O. W., Orovwighose, B., & Emmanuel, S. S. (2024). Nigeria's water crisis: Abundant water, polluted reality. Cleaner Water, 2, Article 100026. https://doi.org/10.1016/j.clwat.2024.100026

Nnoli, N. G., Onwuka, S. U., Mbakwe, U. I., & Ezeasor, I. C. (2024). Spatial and seasonal variations in particulate matter emissions from municipal solid waste dumpsites in selected towns in Anambra State, Nigeria. *Journal of Environmental Management and Safety*, 15(2). https://doi.org/10.83032/jems.vol15no2.327

Ogbuagu, K. R., Ubuoh, E. A., & Ogwo, P. A. (2025). Spatiotemporal variability of air pollutants and meteorological influences in selected parts across six local government areas in Rivers State, Nigeria. *Journal of*

Applied Sciences and Environmental Management, 29(5), 1393–1400. https://doi.org/10.4314/jasem.v29i5.3

Okon, A. J., Inyang, I. B., Ugbe, U. M.-J., Ekpenyong, B. N., & Olanrewaju, O. E. (2022). Effect of domestic solid waste disposal practices on quality of drinking water sources in some rural communities of Akwa Ibom State, Nigeria. *Environmental Monitoring and Assessment*, 194(10), Article 799. https://doi.org/10.1007/s10661-022-10435-8

Olaniyan, U., Massoud, M. A., Alameddine, I., & Al Hindi, M. (2024). Beneath the surface: Assessing pollution levels near major solid waste dumpsites in Lagos, Nigeria. *Environmental Monitoring and Assessment*, 196(11), Article 1148. https://doi.org/10.1007/s10661-024-13357-9

Udofia, O. E., Nwafor, P. A., Uffia, I. D. & Nya, E. (2023). Aphrodisiac potentials of methanol extract of Homalium letestui root in male rats. *International Journal of Biochemistry Research & Review*, 32(5): 68-78.

Uffia, I. D., Ekpo, F. E., & Etim, D. E. (2013). Influence of heavy metals pollution in borehole water collected within an abandoned battery industry, Essien Udim, Nigeria. *Journal of Environmental Science and Water Resources*, 2(1), 22–26.

Uffia, I. D., Udofia, O. E., Nsien, I. B., Duruanyim, I. E., & Udofia, C. S. (2025). Ecological impacts of anthropogenic activities on biodiversity and ecosystem functioning in changing climates. *Applied Sciences, Computing and Energy*, 2025, 2(2), 410-418 g

Uffia, I. D., Udofia, O. E. & Udofia, C. S. (2024). Study of potential effect and health benefits of soaking time on the nutritional composition and some anti-nutrient factors in cowpea (Vigna unguiculata). *Communication in Physical Sciences*, 11(3): 429-437.

Uffia, I. D., Udofia, O. E., Bassey, U. E., & John, G. E. (2026). Long-term temporal trends and seasonal variability of ambient air pollutants in Nigeria: A satellite-based assessment (2010 2024). *Journal of Natural and Artificial Scientific Systems*, 3(2), 169–200.

World Health Organization. (2026). WHO ambient air quality database (Version 8.0). https://www.who.int/data/gho/data/themes/air-pollution/who-air-Quality-database

UN-Water. (2026). SDG 6 data: Nigeria. Retrieved October 29, 2026, from https://www.sdg6data.org/en/country-or-area/nigeria

Declarations

Funding

The author declared no external sources kf funding

Conflict of Interest

The author declared no conflict of interest

Data Availability

Data shall be made available upon request

Ethical Considerations

Not applicable

Author Contributions

Ifiok Dominic Uffia conceptualised the study, developed the methodology, and coordinated the research. Rose Okopide Esen contributed to literature review, data curation, and manuscript editing. Ofonimeh Emmanuel Udofia participated in data analysis and interpretation. Utibe Evans Bassey contributed to environmental data assessment and manuscript review. Iniobong Bruno Nsien contributed to environmental management perspectives, interpretation of findings, and critical revision of the manuscript.