

BUILDING A GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR ENVIRONMENTAL SANITATION MANAGEMENT: A CASE STUDY OF AWKA CITY, ANAMBRA STATE, NIGERIA

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Abstract — Environmental sanitation continues to be a major problem for rapidly expanding urban areas in developing countries, especially in Nigeria, since population increase, urban expansion, insufficient infrastructure, bad waste management practices, and a lack of co-ordination among institutions have all led to a deterioration of the environment. Awka City, which is the capital of Anambra State, has seen a great deal of urban growth as a result of rising commercial activity, residential development, and an increase in population. Nevertheless, this growth has put a strain on the present sanitation systems and has therefore given rise to problems including the uncontrolled disposal of waste, clogged drainage channels, flooding, inadequate coverage of waste collection, and environmental pollution.

The study offers a framework based on the use of a Geographic Information System (GIS) in order to enhance environmental sanitation management in Awka City. Since GIS serves as an effective means for collecting, storing, analysing, visualising and managing both spatial and non-spatial environmental data which are needed for making informed decisions, the study incorporates a variety of spatial data—including waste collection points, drainage networks, locations where waste is disposed of, road networks, land use patterns and areas of environmental risk—into a digital database. The GIS model that has been developed allows for the identification of sanitation hotspots, the optimisation of waste collection routes, the monitoring of environmental hazards and the effective allocation of sanitation resources.

A combination of field surveys, Global Positioning System (GPS) data acquisition, remote sensing imagery, existing administrative maps, and secondary environmental data sources is utilised in designing the GIS database. The study demonstrates that GIS can significantly improve environmental sanitation planning by providing accurate spatial information for government agencies, urban planners, environmental managers, and policymakers. The implementation of GIS-based sanitation management in Awka City can enhance waste management efficiency, reduce environmental pollution, improve public health conditions, and support sustainable urban development.

Keywords: *Geographic Information System (GIS), Environmental sanitation, Waste management, Urban planning, Spatial analysis, Awka City, Anambra State, Nigeria, Sustainable development.*

I. Introduction

Environmental sanitation is a critical component of sustainable urban development because it directly influences public health, environmental quality, and the overall well-being of urban populations. The rapid growth of cities in developing countries has created complex environmental challenges due to increased population density, inadequate infrastructure, and insufficient management systems. According to the United Nations, urban areas are expanding at an unprecedented rate, creating the need for improved planning tools capable of supporting sustainable urban management (United Nations, 2019).

Nigeria has experienced significant urbanisation over the past decades. Cities such as Lagos, Abuja, Port Harcourt, Onitsha, and Awka have witnessed rapid physical expansion resulting from population growth, economic activities, and rural–urban migration. However, urban growth has often occurred faster than the development of essential environmental infrastructure. Consequently, many Nigerian cities face sanitation-related problems including poor solid waste disposal systems, inadequate drainage networks, open dumping, flooding, and pollution of water resources (Adegoke et al., 2020).

Environmental sanitation involves activities aimed at maintaining a clean and healthy environment through proper waste disposal, wastewater management, drainage maintenance, pollution control, and public hygiene practices. Effective sanitation management requires accurate information about the location, distribution, and condition of environmental facilities. Traditional sanitation management approaches that rely mainly on manual surveys and paper-based records are often inefficient because they lack spatial accuracy and real-time information capabilities.

Geographic Information System (GIS) technology provides a powerful solution to these challenges by enabling the integration and analysis of spatial information. GIS is a computer-based system designed for capturing, storing, retrieving, analysing, and displaying geographically referenced data (Burrough & McDonnell, 1998). Through GIS, environmental managers can visualise sanitation problems, identify high-risk areas, monitor changes over time, and make evidence-based decisions.

The application of GIS in environmental management has increased globally due to its ability to support sustainable resource management. GIS has been applied in solid waste management, flood risk assessment, pollution monitoring, urban planning, disease mapping, and infrastructure management (Longley et al., 2015). In developing countries, GIS offers significant advantages because it improves planning efficiency and allows limited resources to be directed toward areas with the greatest environmental needs.

Awka City, located in Anambra State, Nigeria, represents an important case study due to its rapid urbanisation and increasing environmental sanitation challenges. As the administrative capital of Anambra State, Awka has experienced expansion in residential areas, commercial centres, educational institutions, and transportation networks. This growth has increased waste generation and placed additional pressure on existing sanitation services.

The absence of comprehensive spatial databases for sanitation facilities and environmental conditions limits effective planning and management within Awka City. Waste collection points, illegal dumping locations, drainage systems, and pollution sources are often not properly mapped, making it difficult for authorities to implement efficient sanitation strategies. Developing a GIS-based environmental sanitation management system can address these limitations by providing a digital platform for monitoring and managing sanitation activities.

This study therefore focuses on building a GIS framework for environmental sanitation management in Awka City, Anambra State. The research aims to demonstrate how spatial technology can improve sanitation planning, waste management operations, environmental monitoring, and sustainable urban development.

II. Concept of Geographic Information System (GIS)

Geographic Information System (GIS) is an information technology that combines hardware, software, spatial data, and analytical techniques to manage geographically referenced information. GIS allows users to collect, manipulate, analyse, and display information based on location.

According to Goodchild (1992), GIS represents a major advancement in geographical information science because it provides methods for understanding spatial relationships and patterns. Unlike conventional databases, GIS incorporates location as a fundamental component, enabling users to answer questions such as:

Where are sanitation problems located?

Which areas have inadequate waste collection services?

What communities are at risk of environmental pollution?

How can sanitation resources be distributed efficiently?

GIS consists of five major components: hardware, software, data, people, and procedures. Hardware includes computers, GPS devices, and servers, while software platforms such as Esri ArcGIS and open-source GIS applications provide analytical capabilities. Spatial data may include satellite imagery, maps, GPS coordinates, and environmental observations.

The ability of GIS to integrate different datasets makes it suitable for environmental sanitation management. For example, waste disposal locations can be analysed together with population density, road networks, and land-use patterns to determine efficient waste collection strategies.

a) Application of GIS in Environmental Sanitation Management

Environmental sanitation management requires continuous monitoring of spatially distributed facilities, environmental conditions, and human activities. GIS has become an important tool for environmental managers because it provides the ability to integrate different forms of information and analyse relationships between environmental factors.

According to Longley *et al.* (2015), the strength of GIS lies in its ability to transform raw geographical information into useful knowledge that supports planning and decision-making. In environmental sanitation, GIS can be applied in areas such as solid waste management, drainage monitoring, landfill site selection, pollution assessment, and environmental health planning.

➤ GIS Application in Solid Waste Management

Solid waste management is one of the most common applications of GIS in environmental sanitation. Urban areas generate large quantities of waste daily, requiring efficient collection, transportation, and disposal systems. Poorly managed waste contributes to environmental pollution, disease outbreaks, blocked drainage systems, and degradation of urban landscapes.

GIS assists waste management authorities by mapping waste generation points, waste collection locations, transfer stations, and disposal sites. Through spatial analysis, authorities can determine optimal waste collection routes, reducing transportation costs and improving service coverage.

For example, route optimisation using GIS considers factors such as road accessibility, traffic conditions, distance, and waste generation intensity. This reduces fuel consumption and improves operational efficiency (Chalkias & Lasaridi, 2011).

In Awka City, where urban expansion has increased waste generation, a GIS-based waste management system can identify areas requiring additional waste bins, collection points, and improved monitoring. Residential neighbourhoods, markets, schools, and commercial areas can be mapped according to their waste generation characteristics.

➤ GIS for Waste Disposal Site Selection

The selection of appropriate waste disposal sites requires consideration of environmental, social, and economic factors. Poorly located disposal sites can contaminate

groundwater, create unpleasant odours, attract disease vectors, and reduce surrounding land value.

GIS provides a multi-criteria decision-making approach for selecting suitable waste disposal locations. Factors such as:

- Distance from residential areas
- Proximity to roads
- Soil characteristics
- Groundwater conditions
- Slope
- Land use

Distance from water bodies can be incorporated into a GIS model to identify environmentally suitable locations (Sener *et al.*, 2010).

For Awka City, GIS analysis can assist government agencies in identifying future landfill locations that minimise environmental risks while remaining accessible for waste collection vehicles.

➤ GIS in Drainage and Flood Management

Poor drainage systems are among the major causes of urban flooding in Nigerian cities. Blocked drainage channels caused by indiscriminate waste disposal reduce water flow capacity and increase flood risk.

GIS enables the mapping and monitoring of drainage networks, flood-prone zones, and areas affected by poor sanitation practices. By combining elevation data, rainfall information, drainage locations, and land-use data, GIS can predict areas vulnerable to flooding.

Awka City experiences flooding problems in some locations due to rapid urban development, inadequate drainage infrastructure, and increased surface runoff. A GIS-based drainage database can support routine inspection, maintenance scheduling, and flood risk reduction.

➤ GIS for Environmental Pollution Monitoring

Environmental pollution often has a spatial dimension. Pollution sources such as waste dumps, industrial activities, sewage discharge points, and contaminated water sources can be mapped and analysed using GIS.

GIS allows environmental agencies to monitor pollution distribution and identify relationships between pollution sources and affected communities. This supports environmental impact assessments and pollution control strategies.

For example, mapping illegal waste dumping locations within Awka City can help authorities identify areas requiring increased enforcement and public awareness campaigns.

b) Environmental Sanitation Challenges in Nigeria

Nigeria faces significant environmental sanitation challenges due to rapid urbanisation, population growth,

inadequate infrastructure, and weak waste management systems. According to the World Bank (2018), waste generation in developing countries is expected to increase significantly due to urban growth and changing consumption patterns.

Major sanitation challenges in Nigerian cities include:

➤ **Poor Solid Waste Disposal Practices**

Many Nigerian urban areas experience indiscriminate waste disposal along roadsides, drainage channels, vacant lands, and waterways. These practices contribute to environmental pollution and increase disease risks.

Inadequate waste collection services often result from limited equipment, insufficient funding, and poor planning. Without accurate information on waste generation patterns, collection services may not effectively cover all communities.

➤ **Inadequate Drainage Infrastructure**

Urbanisation has increased the amount of impervious surfaces such as roads and buildings, reducing natural water infiltration. Combined with blocked drainage channels, this contributes to frequent flooding.

Waste accumulation in drainage channels remains a major environmental issue in many Nigerian cities because plastic materials and other solid wastes obstruct water flow.

➤ **Rapid Urban Expansion**

Urban growth in Nigeria has often occurred without adequate planning. Residential developments may emerge without proper waste collection facilities, drainage systems, or sanitation infrastructure.

Awka City has experienced similar challenges due to increasing population and development activities associated with its role as a state capital.

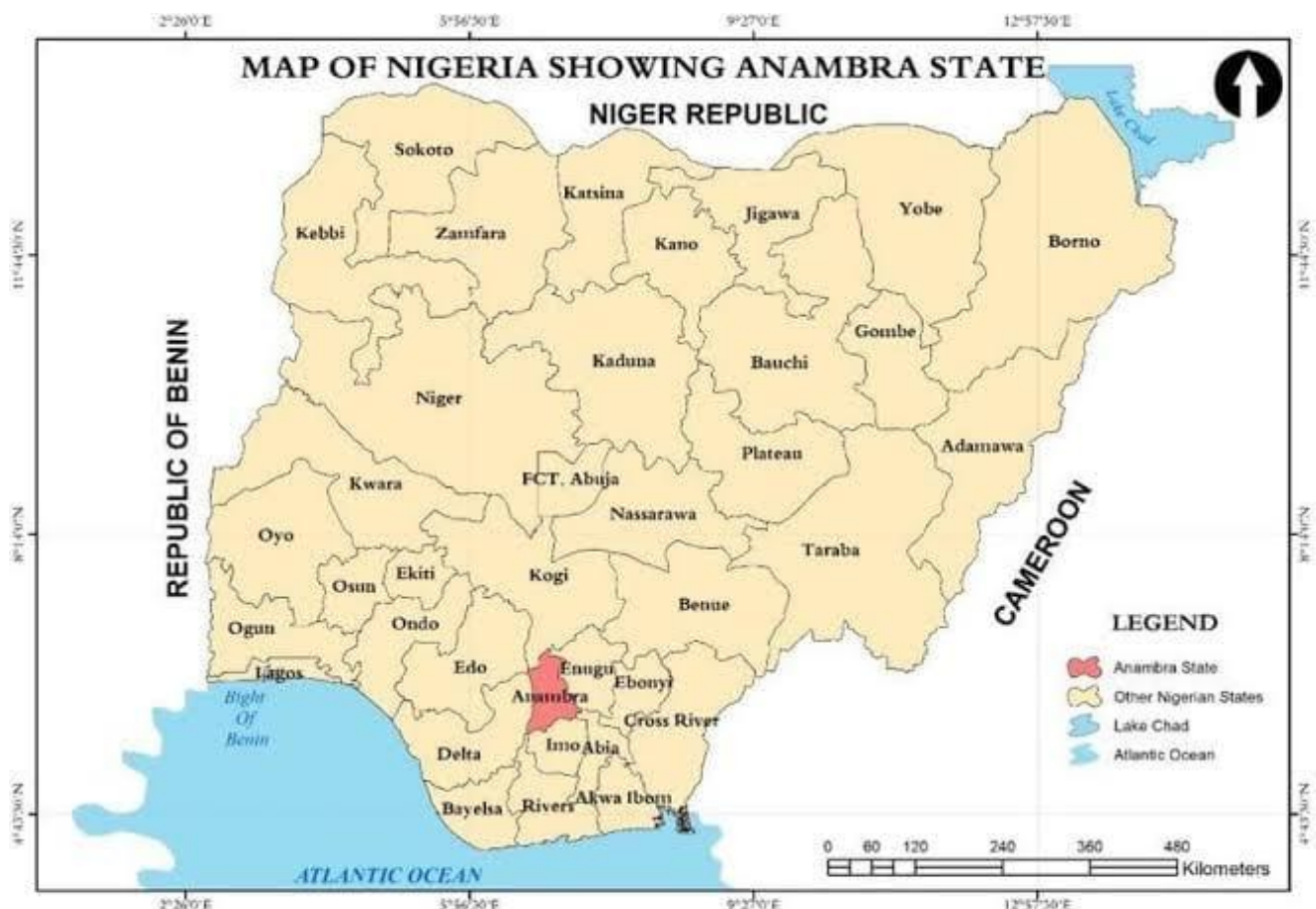
➤ **Limited Availability of Environmental Data**

Effective sanitation planning depends on reliable environmental information. However, many Nigerian cities lack comprehensive databases containing information about waste facilities, pollution sources, drainage networks, and sanitation conditions.

The absence of spatial databases limits the ability of authorities to make informed decisions. GIS provides a solution by creating digital environmental databases that can be updated continuously.

III. Study Area

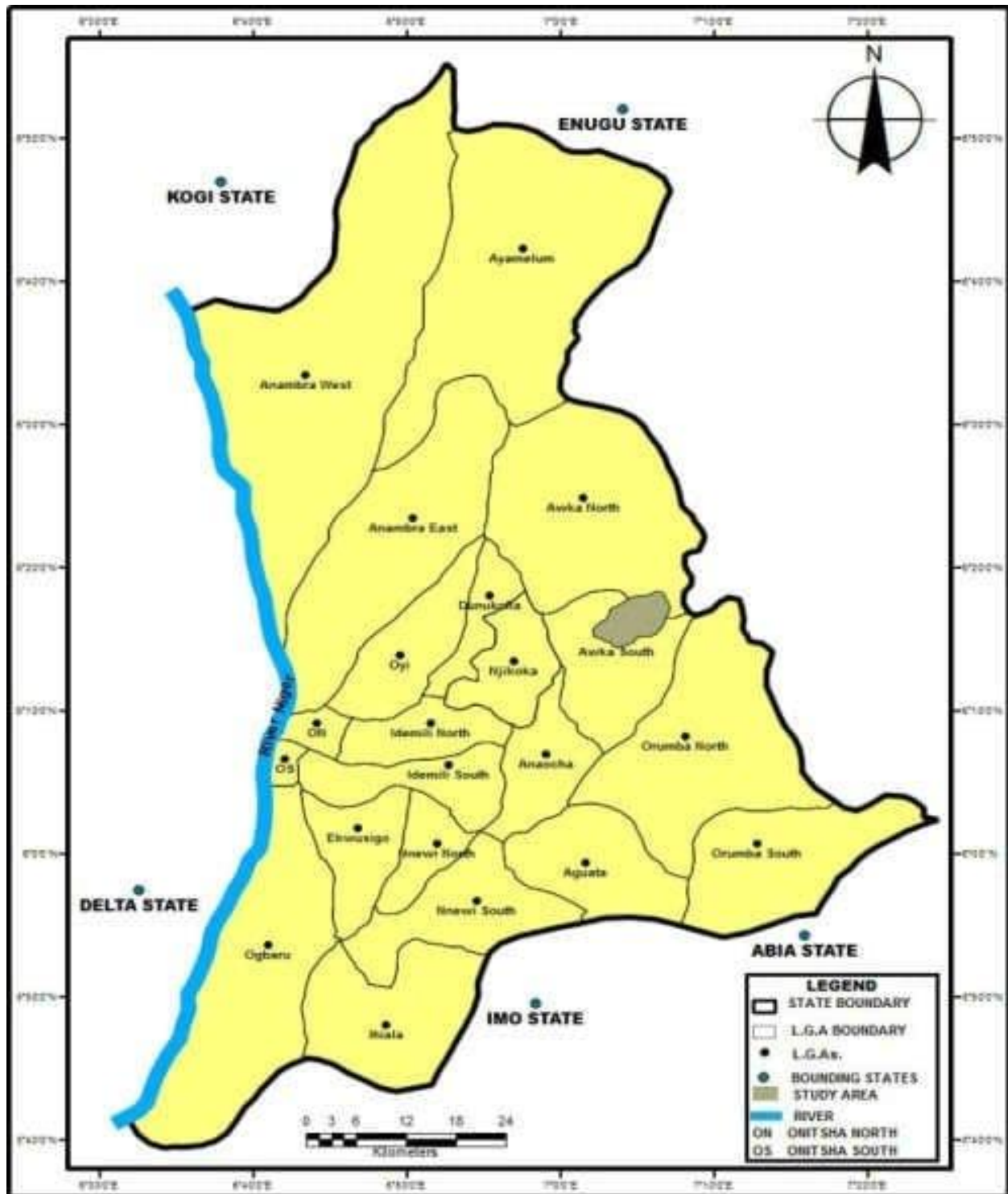
a. Location and Geographic Characteristics of Awka City



Map of Nigeria showing Anambra State

Awka is the capital city of Anambra State, located in southeastern Nigeria. It lies approximately between latitude $6^{\circ}10'N$ and $6^{\circ}15'N$ and longitude $7^{\circ}00'E$ and $7^{\circ}10'E$. The city is situated within the tropical rainforest zone of southeastern Nigeria and serves as an important administrative, commercial, and educational centre.

Awka is strategically located along the Enugu–Onitsha expressway corridor, which has contributed to increased economic activities and urban development. The city consists of several communities including Awka, Nibo, Amawbia, Ifite Awka, Okpuno, and nearby settlements that have experienced increasing urban integration.



Map of Anambra state showing the study area

The city's growth has been influenced by:

- Government administrative activities
- Expansion of educational institutions
- Commercial development
- Residential construction
- Increased transportation activities

b) Population Growth and Urbanisation

Awka has experienced rapid population growth due to migration and increasing economic opportunities. The expansion of residential areas has increased demand for environmental services, including waste collection, drainage maintenance, and sanitation facilities.

Urban expansion has created challenges because environmental infrastructure has not always developed at the same pace as population growth. As a result, some areas experience inadequate waste collection coverage and environmental degradation.

c) Environmental Sanitation Conditions in Awka

Environmental sanitation issues observed within Awka City include:

- Accumulation of solid waste in public spaces
- Illegal dumping along roads and drainage channels
- Blocked drainage systems
- Flooding during heavy rainfall
- Limited waste collection points
- Poor monitoring of sanitation facilities

These challenges demonstrate the need for a systematic approach to environmental sanitation management.

IV. Methodology

a) Research Design

The study adopts a geospatial research methodology involving the collection, processing, analysis, and presentation of environmental sanitation data using GIS techniques.

The methodology consists of:

- Data acquisition
- Field survey
- GPS data collection
- GIS database development
- Spatial analysis
- Map production and interpretation

b) Data Collection

Both primary and secondary data sources are utilised.

Primary Data

Primary data collection involves field observations and GPS surveys. Geographic coordinates of environmental features are collected, including:

- Waste collection points
- Illegal dumping locations
- Drainage channels
- Flood-prone areas
- Public sanitation facilities

GPS technology provides accurate location information that can be integrated into the GIS database.

Secondary Data

Secondary data sources include:

- Administrative boundary maps
- Satellite imagery
- Road network maps
- Population data
- Existing environmental reports
- Previous research publications

Remote sensing images provide information about land use, urban expansion, and environmental changes.



A handheld GPS

V. GIS Database Design and Development

The development of a GIS for environmental sanitation management requires the creation of a structured spatial database capable of storing, managing, and analysing environmental information. A well-designed GIS database ensures that sanitation data can be updated, queried, and used effectively for decision-making.

The GIS database developed for Awka City consists of spatial layers representing different environmental sanitation features and associated attribute information.

a) Spatial Database Structure

The GIS database is organised into thematic layers. Each layer represents a specific environmental feature related to sanitation management.

The major GIS layers include:

- **Administrative Boundary Layer**

This layer contains the boundaries of Awka City and surrounding administrative areas. It provides the basic framework for organising other spatial information.

Attributes include:

- Area name
- Boundary coordinates
- Population information
- Administrative classification

- **Road Network Layer**

The road network layer represents transportation routes within Awka City. Roads are important because they determine accessibility for waste collection vehicles.

Attributes include:

- Road name
- Road classification
- Road condition
- Accessibility status
- Length of road segments

GIS analysis of road networks assists in determining efficient waste collection routes and identifying areas with poor accessibility.

- **Waste Collection Point Layer**

This layer contains the locations of existing waste collection points, waste bins, transfer stations, and collection facilities.

Attributes include:

- Location coordinates
- Facility type
- Capacity
- Operational status
- Frequency of collection

Mapping these facilities helps determine whether waste management services are evenly distributed throughout the city.

- **Illegal Dumping Site Layer**

Illegal waste disposal locations are mapped using GPS coordinates collected during field surveys.

Attributes include:

- Dumping location
- Waste type
- Estimated waste volume
- Environmental impact level
- Distance from residential areas

This layer allows environmental agencies to identify pollution hotspots and prioritise cleanup activities.

VI. GIS Data Processing and Analysis

After data collection, GIS processing involves converting raw information into usable spatial datasets. Data processing includes coordinate transformation, digitisation, classification, database creation, and spatial analysis.

a) Data Digitisation

Paper maps and existing spatial information are converted into digital GIS layers through digitisation. Features such as roads, drainage channels, and administrative boundaries are traced and stored as vector data.

Vector data are represented as:

Points – waste bins, dumping sites, sanitation facilities

Lines – roads, drainage channels

Polygons – neighbourhoods, land-use areas

b) Spatial Query Analysis

Spatial queries allow users to retrieve information based on location relationships.

Examples include:

- Identifying communities without waste collection services.
- Finding illegal dumps located near water bodies.
- Determining areas within a certain distance from waste disposal facilities.
- Locating blocked drainage channels within flood-prone zones.

These analyses support targeted environmental management decisions.

VII. Conclusion

Environmental sanitation remains a major challenge in rapidly developing Nigerian cities. Awka City, as the capital of Anambra State, has experienced significant urban growth

that has increased pressure on sanitation infrastructure and environmental management systems.

This study demonstrates the potential of Geographic Information System (GIS) as an effective tool for improving environmental sanitation management. By integrating spatial information on waste disposal sites, collection points, drainage systems, roads, and land-use patterns, GIS provides a comprehensive platform for analysing environmental conditions and supporting decision-making.

The development of a GIS-based sanitation management system can improve waste collection efficiency, identify environmental risk areas, support flood management, and enhance resource allocation. The technology provides a shift from traditional reactive sanitation management toward proactive and sustainable environmental planning.

For Awka City to achieve improved environmental sanitation, GIS should be incorporated into urban management strategies. Government agencies, environmental organisations, and communities must collaborate to ensure continuous data collection, system maintenance, and effective utilisation of GIS information.

The adoption of GIS-based environmental sanitation management will contribute significantly toward achieving cleaner, healthier, and more sustainable urban environments in Awka City and other Nigerian cities.

References

1. Adegoke, O. S., Olatunbosun, O. O., & Adegboyega, S. A. (2020). Urban environmental challenges and sustainable development in Nigeria. *Journal of Environmental Management and Safety*, 11(2), 45–58.
2. Burrough, P. A., & McDonnell, R. A. (1998). *Principles of geographical information systems*. Oxford University Press.
3. Chalkias, C., & Lasaridi, K. (2011). A GIS-based model for the optimisation of municipal solid waste collection. *Waste Management*, 31(3), 555–565.
4. Goodchild, M. F. (1992). Geographical information science. *International Journal of Geographical Information Systems*, 6(1), 31–45.
5. Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information science and systems*. Wiley.
6. Sener, S., Sener, E., Nas, B., & Karagüzel, R. (2010). Combining AHP with GIS for landfill site selection. *Waste Management*, 30(11), 2037–2046.
7. Tomlinson, R. (2009). *Thinking about GIS: Geographic information system planning for managers*. ESRI Press.
8. United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. United Nations.
9. United Nations. (2019). *World urbanization prospects: The 2018 revision*. United Nations.
10. World Bank. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank.