Geographic Information System (GIS) Approach to Solid Waste Management in Onitsha Urban Anambra State, Nigeria

Johnbosco C. Ojiako, Ebele J. Emengini, and Jude N. Iwuchukwu

Abstract— Solid waste management (SWM) is considered as one of the most immediate and very serious environmental problems confronting authorities in developing countries like Nigeria. SWM comprises of activities such as collection, transportation and disposal of solid waste. The aim of this study was to apply GIS technique in solid waste management in Onitsha urban area. This was achieved by acquiring and digitizing the base map of Onitsha urban environment showing the road networks/streets, water bodies and various land use patterns. The GPS coordinates of individual waste bins/dump sites and other areas of interests were also acquired. The software used includes ArcGIS 9.3 version and G7 Towin software. Various analyses to show the potentials of GIS in management of solid waste were performed. GIS analysis was carried out and several queries were formulated using the query builder in ArcGIS. The database queries produced maps and pictures. The result of analysis obtained include the location map of the waste bins existing in Onitsha which covered about 11.86% of the total land mass of the study area, the contour and flow direction over the dump site area as well as the best possible route for the evacuation of wastes from individual waste bins to the dump site. The findings revealed that there was no waste bin which is in proximity of 20metres from the two main rivers in the area, the waste bins in the area were not evenly distributed and therefore covers a little portion of the total land mass of the area. It is therefore recommended that route planning for waste collection vehicles within the urban area be done by the urban authority. Implementations of vehicular tracking systems like GPS on the vehicles to calculate waste collection timings should be encouraged. Alternative location for the disposal of the waste dump should be provided so as to protect the human population living around the road as well as the road users, from the environmental problems it poses.

Index Terms— GIS, solid waste, urban area, waste management.

1 INTRODUCTION

Over the past decades urbanization has become one settlement [1]. Urbanization in developing countries like Nigeria has been fuelled by rapid population growth, as well as industrialization and uncontrolled expansion of cities with limited economic or productive base [1]. The upsurge of population in the urban city of Onitsha has brought with it pressure on adequate shelter, urban facilities and infrastructure such as solid waste collection. Managing solid waste is a critical issue to deal with in developing countries like Nigeria. Solid Waste Management (SWM) is a function of combination of various activities such as collection, transportation and disposal of solid waste. It also includes processing and the treatment of the solid waste before the final disposal [2]. The major purpose of SWM is to create uncontaminated environment for people without disturbing the natural environment [3]. Not all wastes generated by the Onitsha dwellers were collected and deposited. The uncollected wastes accumulate in various places such as open spaces, streets, drainage channels and ditches. In many cases people throw wastes directly into running water in drainages during rainfall thereby blocking the channels and polluting the rivers and stream water and also causing flooding and other related problems.

Human population increase brought about by urbanization brings about the maximum utilization of natural resources. The maximum resource utilization is sometimes carried out without the sustainable and conservative principle. This gives rise to the generation of waste as well as its indiscriminate disposal. The study area, Onitsha urban environment, due to high population densities commercial, social and political activities going on in the area, generates a high percentage of solid waste. Some of these solid wastes are as a result of construction activities in terms of roads, housing, and others. The lack of efficient waste management system in the urban environment of Onitsha made the area to be widely littered with wastes. The drainages channels are blocked with wastes of assorted materials during the rainy season thereby obstructing the easy flow of flood along the channels. This as a result causes flooding in the area, reduces the aesthetics of the environment and sometimes leads to loss of lives and properties. In recent times, the management of waste in Mega cities with the scientific approach has incorporated both technologies of reuse and recycle as an efficient means of resources recovery, but the adoption of Geographic Information System (GIS) by some developing countries has really helped to strengthen the management system. Thus, this study aims at developing an efficient solid waste management system for Onitesha urban, Anambra state, Nigeria using GIS approach.

2 THE STUDY AREA

The study area is Onitsha, a city in Anambra state, south eastern Nigeria. It is located approximately within latitudes 6o 05' 39"N to 6o 12' 13"N of the equator and longitude 6o 45' 29"E to 6o 50' 07"E of the Greenwich Meridian. The study area (Onitsha Urban Area) covers about 6366.851sq km. It is situat-

ed on the eastern bank of the river Niger and includes areas such as; American quarters, Main market, GRA phase 1&2, Odeakpu, Fegge, Woliwo, Harbour industrial layout, Awada layout and Okpoko. (See figures 1c, 1b and 1c). Onitsha is made up of about 90% Igbo ethnicity. It is a commercial, educational and religious centre and river port on the eastern bank of the river Niger. In 1931, census returned for Onitsha a polulation of 18,084 with slightly more females (9257) than males (8,827). By 1953, the population had risen to 76,921 with greater predominace of males (48,356). By 1953, the population had risen to 76,921 with greater predominance of males (48,356) over females (28,565), pointing to the rapid growth by immigration of male trader, male civil servants etc [4]. In 2006, the population of Onitsha urban area was recorded as 561,000 [5].

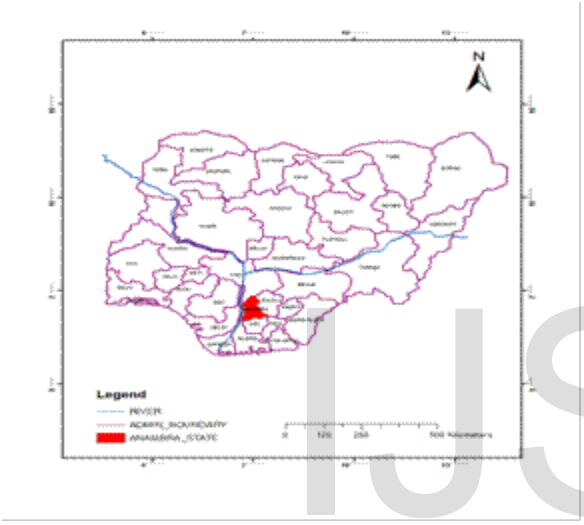

Figure 1a: Map of Nigeria showing location of Anambra State

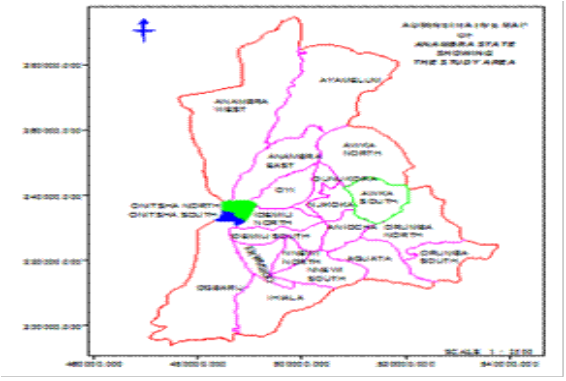

Figure 1b: Map of Anambra State showing location of Onitsha

Figure 1c: Map of Onitsha

3 METHODOLOGY

The methodology adopted in this study is summarised in figure 2.

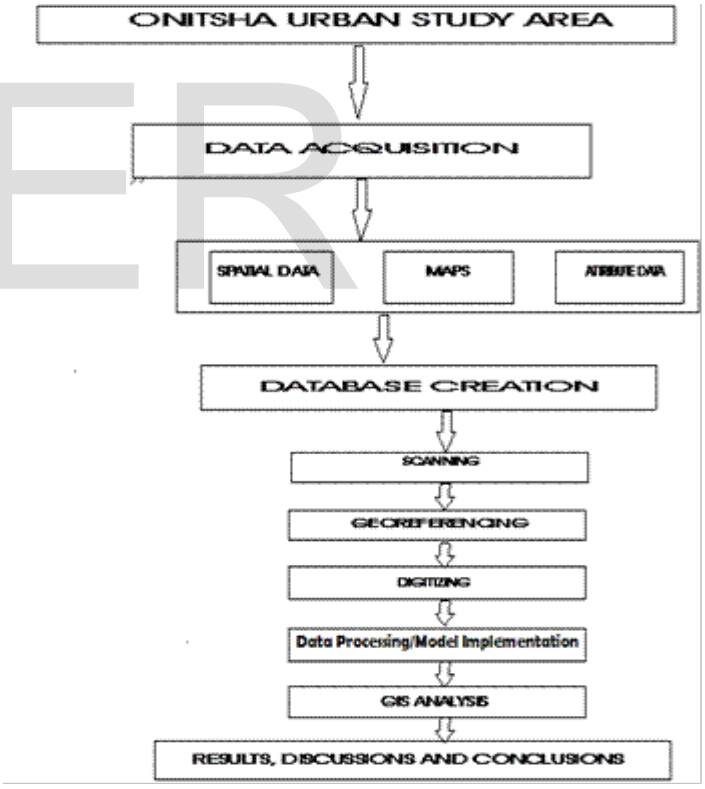

Figure 2: Methodological flowchart

3.1 Data Acquisition

The coordinates of the existing waste bins/dumps sites and other sensitive features like streams and rivers were acquired using GPS -Garmin GPSmap76s) and the attributes of the selected features of interest (address location of the dustbins/waste bins/ authorized dump sites) were collected from the office of the Waste Management Agency, Onitsha). The street map of Onitsha urban area showing road networks and

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districts at a suitable scale were collected from the Ministry of Land and Survey Awka and Scanned in A4 sized images (TIFF format) and imported into Arc GIS 9.3. The scanned maps were georeferenced and digitized so as to enter the spatial information in vector format.

3.2 GIS Database Creation and Modeling

3.2.1 Entity Relationship Model Construction

An entity is an aspect of the real world which can be distinguished from other aspects of the real world [6]. It is an aspect of the real world which can be distinguished from other aspects of the real world (Beynon-Davies, 2004). The unique entities which were of major interest to this study include waste bins/dump sites, roads/ streets, land use types such as; commercial areas/markets, industrial areas and residential areas, surface water bodies.These entities were modeled by creating the database, which contained their class and attributes (see table 1).

TABLE 1
ENTITIES, CLASS AND THEIR ATTRIBUTES

	Entity	Class	Attribute
1	Waste bins/dumpsites	Points	ID, types, North_coord, East_coord
2	Roads/ streets	Line	ID, R_name, R_type, R_status, R_begining, R_end, R_size.
3	Residential areas	Polygon	Shape, ID, Population, Name
4	Commercial area	Polygon	Shape, ID, Name.
5	Industrial areas	Polygon	Shape, ID, Name.
6	Surface water bodies	Polygon	Shape, ID, Name, North_coord, East_coord.

3.2.2 Entity Relationship Diagram

The entity relationship diagram used to show entity sets and relationship sets is shown in figure 3.

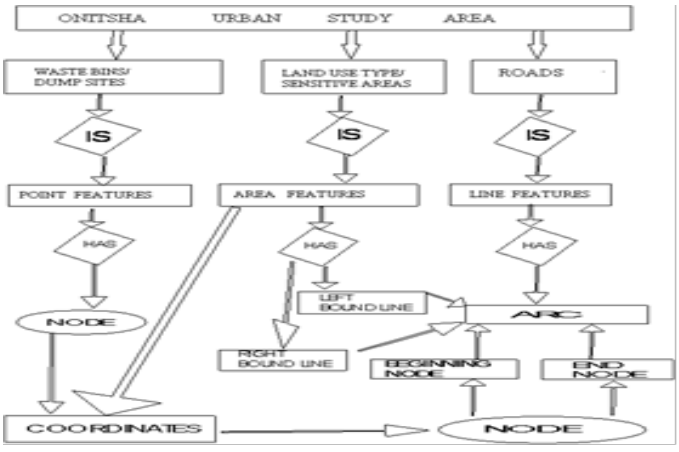

Figure 3. Entity Relationship diagram

3.2.2 Data Processing and GIS Analysis

Hardware components used include A3 sized scanner, A3 sized printer, Sony digital camera, Computer system and accessories, A hand held GPS- Garmin GPSmap76S. The scanner was used for converting analogue maps to digital format, while the printer was used for presenting a visual result of the study. An A4 sized printer and scanner was chosen due to the dimensions of the data required. The GPS and digital camera were used in the field to acquire the coordinates and images of the waste bins/dumpsites respectively and positions of other sites of interest. The major software used includes ArcGIS 9.3 and Surfer 3.2. In order to obtain answers from the database system, several queries were framed and executed. These include: Basic Query, Query with nested basic queries, Query with multiple criteria.

The first analysis was to determine the convenience of the existing waste bins to users. Owing to the compact nature of buildings in the area, a 500 meters buffer analysis was carried around the waste bins (see Fig. 4). The 500 meters buffer was created in radius of 100meters, 250meters and 500meters. This helps to allocate each bin to the usage of people living within 0.5km radius from that particular bin.

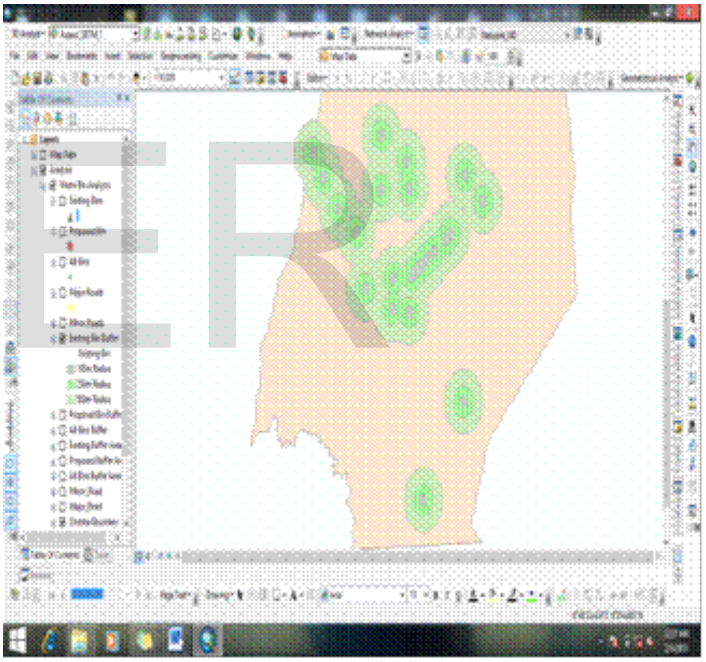

Figure 4. Buffer Analysis of existing waste bins and dumpsites

Futhermore, allocation of waste bins was determined by finding locations on the map that require waste bins. This provided bins within a convenient distance range to all the residents. The proximity range of 0.5km was again checked by applying buffer around the new waste bin locations.

The second analysis was for determining the proximity of waste bins from the environmental sensitive areas (water bodies). A buffer of 20m was created on both sides of the two rivers (see Figure 5). This analysis is expected to identify the bins which come in proximity of 20m of the rivers. This is necessary as waste bins situated close to water bodies aids in pollution of the water bodies. Therefore waste bins should be dis-

couraged from being positioned close to water bodies and other environmental sensitive areas like hospitals, churches and schools.

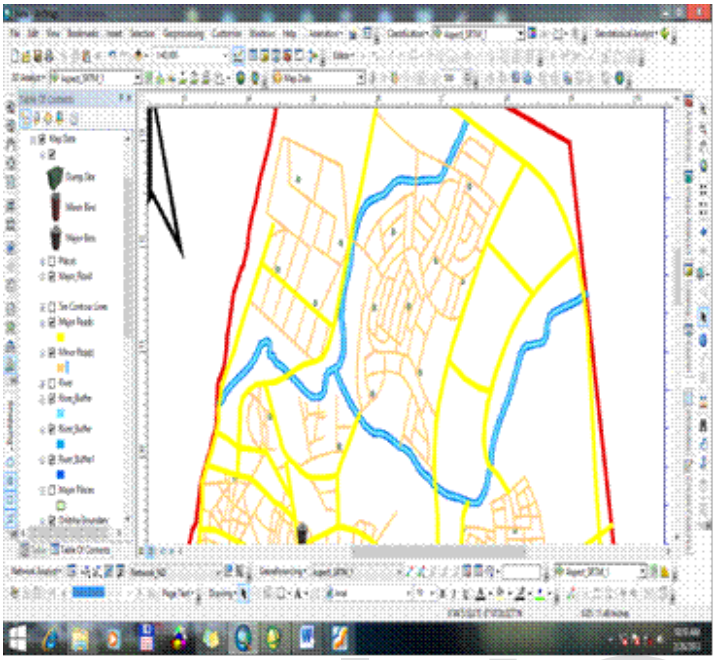

Figure 5. Proximity of the waste bins and dumpsite to environmental sensitive areas (rivers)

In the third analysis, the wastebin locations were overlaid on the existing road networks. The network analysis was performed as seen in figure 6, so as to determine the best possible routes for vehicles during the evacuation of wastes from the individual waste bins to the dump sites along Onitsha- Owerri road.

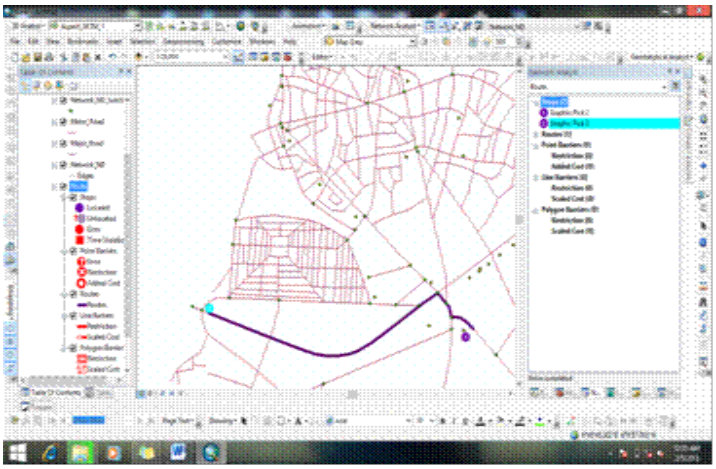

Figure 6 Network analysis showing the best possible route from Low cost housing to Onitsha- Owerri dump site.

In the fourth analysis, the acquired DEM was processed for the generation of contours (5m interval) for some complex analysis of the dumpsite.. The Contour shows the elevation values using lines that cut across places of the same elevation on the image (see figure 7).

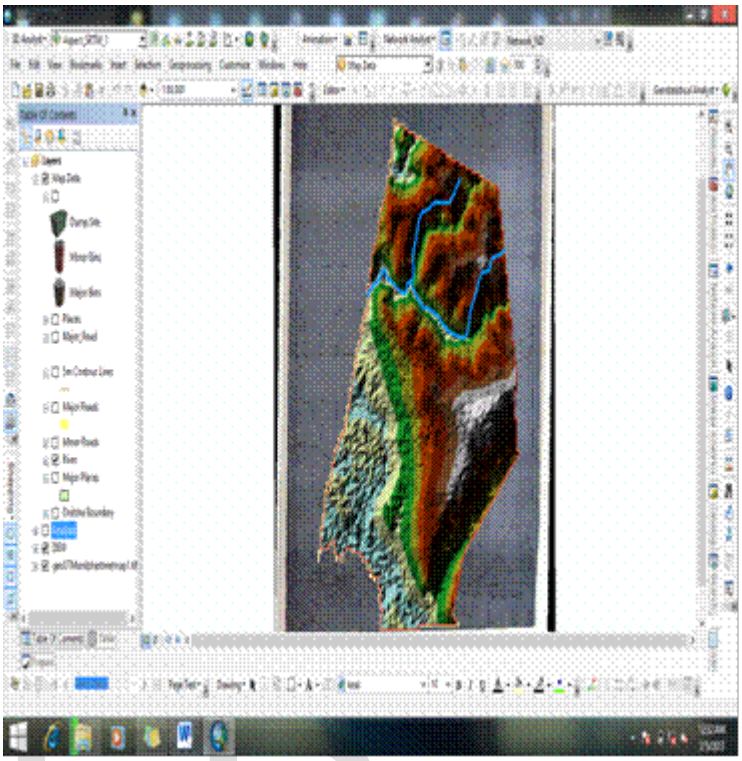

Figure 7. DEM of the study area

The contour map (figure 8) was generated so as to show the detailed description of the contour heights over the dumpsite.

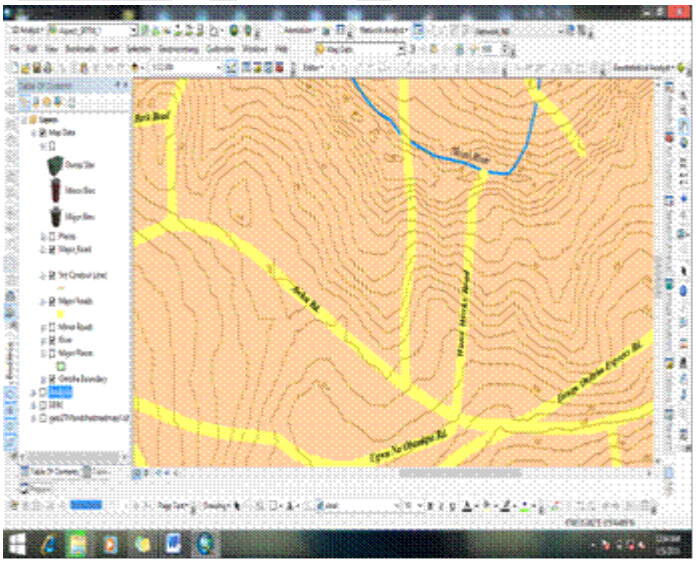

Figure 8. Contour map over the study area

Flow analysis over the dump site along Onitsha –Owerri road, was also performed. This was done by plotting the cordinates of points obtained at intervals around the dump site using the GPS and Surfer 3.2 software.

4 RESULTS AND DISCUSION

Buffering shows that the total area covered by the buffer of the existing waste bins was about 755.359sq km. This amounted to 11.86% of the total land mass. This indicates that most of the areas do not have existing waste bins and therefore it is difficult to manage the waste streams generated from the area. The areas that do not come in the buffer zone indicate that they do not have bins within a distance of 500meters. Therefore these areas require waste bins within distances of 500 meters. Thus, new locations for waste bins were proposed (see figure 9).

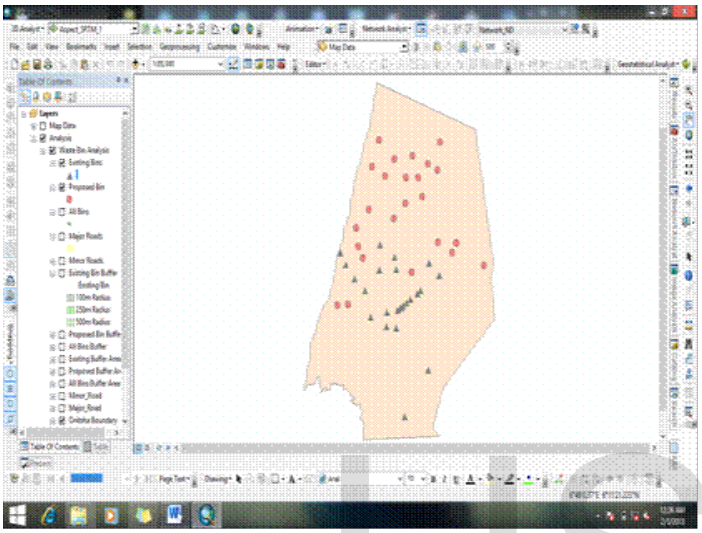

Figure 9. Locations of existing (triangle) and proposed (circle) waste bins and dumpsite

The results obtained from buffer analysis of proposed waste bins and dump sites is shown in Figure 10.

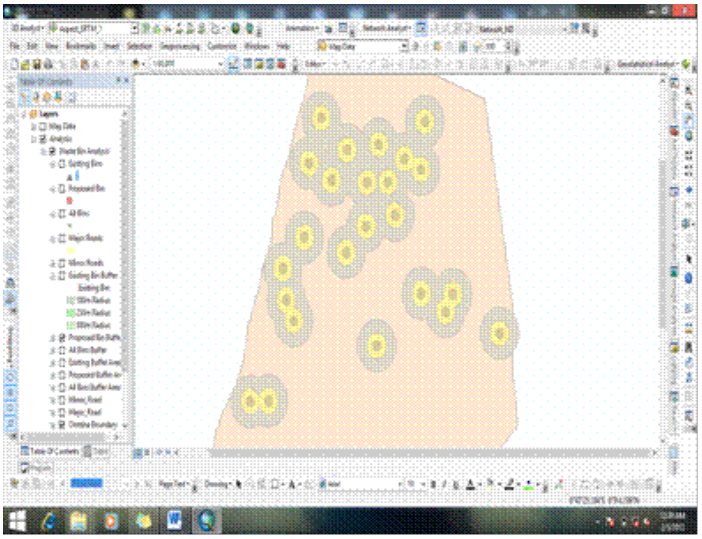

Figure 10. Buffer analysis of proposed waste bins and dumpsite.

From the result, it was observed that the proposed waste bins covered an area of about 1050.506 sq km, which is about 16.5% of the total buffered area. The total area covered by the buffered waste bins were calculated to be 1716.346km2 which is about 26.96% of the total land mass of Onitsha Urban Environment. Areas with no waste bins were areas uninhabited by people or areas of zero generation of wastes. This analysis would be needed when distributing waste bins and dumpsites. Areas without waste bins are proposed to be provided with waste bins.

The proximity analysis of the waste bins and dumpsites to rivers show that there was no waste bin which is in the proximity of the two identified rivers. This buffer is expected to serve as a guideline when allocating bins near the rivers in future.

From the result obtained in the network analysis on the best possible route for evacuation of the waste from the bins at low cost housing estate to the dump site along Onitsha – Owerri road (figure 11), it demands that to evacuate the wastes from the waste bin at State low cost housing estate, the best possible route is to go northwest towards Onitsha-Owerri road, turn right when on Onitsha-Owerri road and again turn left on bridge head road to the disposal site. These routes or direction was calculated to have a driving distance of about 2.4 miles. The best possible route for evacuating the wastes is expected to minimize the driving time and cost on the waste management process.

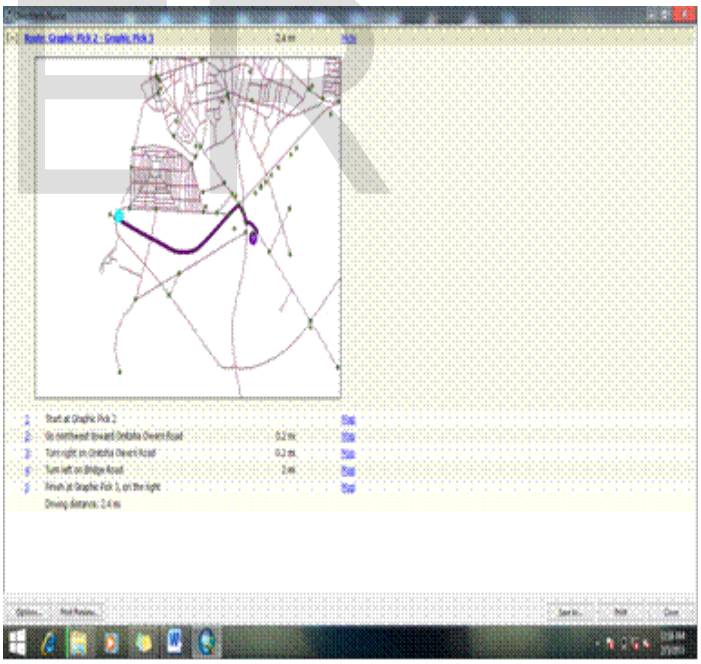

Figure 11. Network analysis on the best possible route for the evacuation of the waste from the bins at low cost housing estate to the dump site along Onitsha –Owerri road.

Detailed description of the contour heights over the dumpsite is shown in figure 12. From the map, it was noticed that the contour number increased towards the north of the area and comfirms that the dumpsite is situated in a gully erosion site with low elevation and thus, will affect the flow of water in the area. The water will tend to flow towards the south and west of the area. This implies that those areas within the south

and west of the dumpsite area will be faced with some environmental problems such as water and land pollution as a result of the flow of water from the dumpsite towards those areas, especially during heavy downpour.

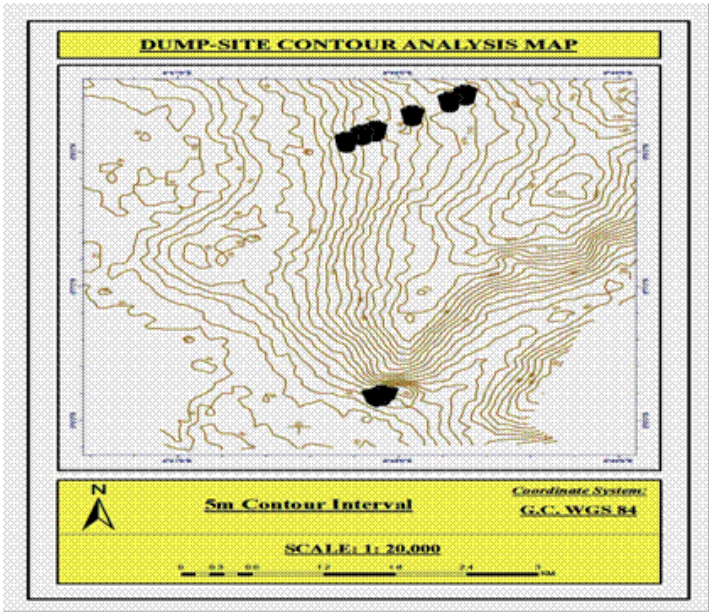

Figure 12. Contour lines over the dumpsite areas

The result of the flow analysis shows the direction of flow of water in the area (figure 12).

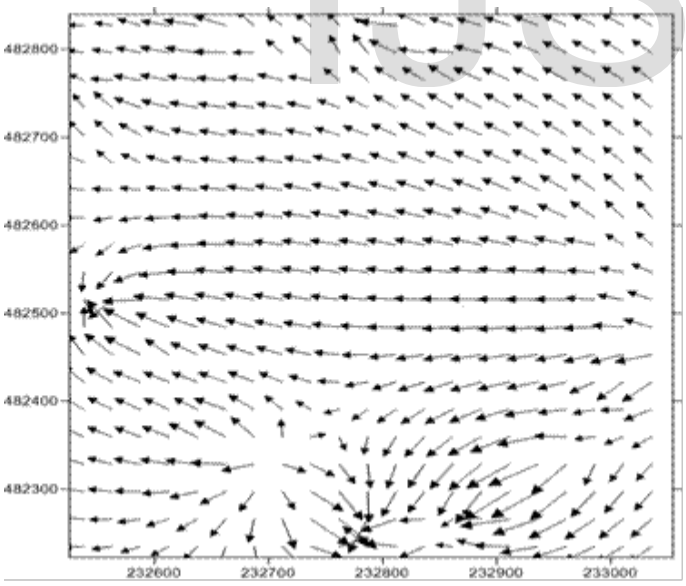

Figure 12. Flow directionin the area

It it was observed that water flows from the east towards the west north and south directions as the arrows indicate. The arrows pointing down towards the southern part of the map (location of the dump site) comfirm that dump sites were sited at erosion site. This indicates that areas especially within the south and western part of flow will experience water pollution especially during the rainy season. The underground water may also be affected because of the percolation into the ground water table by the polluted water from the dumpsite. This polluted water may as well cause water born diseases to the dwellers. It is expected that this result will serve as a guide when locating dumpsites, especially around areas inhabited by human population.

A number of issues emerged from this study including that:

1. Waste generation rates were not yet established in the settlements. This results to under estimation of required waste bins, trucks and number of trips to be made per week. Consequently, causing high piles of waste at waste bin points necessitating crude dumping of wastes.
2. Waste bins were not evenly distributed and there was no background information available to support the sitting of the waste bins.
3. Large part of Onitsha urban area was left without waste bins and dumpsites to take care of the waste generated in the area. This owes to lack of space in the area. The agency resorts to door to door delivery of waste collection services but not on a regular basis.
4. Waste disposal sites poses a serious environmental threat to the people living around it as well as the road users because of the blockage of some part of the road by waste streams (see figure 13).

Figure 13. Refuse dumps blocking part of Onitsha Owerri road

5 CONCLUSIONS AND RECOMMENDATIONS

The application of GIS in solid waste management particularly in an area like Onitsha urban can help improve waste collection as well as minimize the operational cost of contractors involved in solid waste disposal. Based on the results of this study, it is recommended that GIS for solid waste collection be institutionalized by Onitsha urban

authority, private contractors and organization involved in solid waste management. Practitioners need to be trained in the use of GIS as a decision support tool in solid waste management. There is also need to organize courses, seminars and workshops for them in order to build their capacity in waste collection. It is important to introduce a system that will ensure that people deposit their wastes in a nearby waste collection centers (which was found to be most suitable for large and high density areas) rather than the house to house waste collection system. GIS should therefore be utilized to plan the proposed system in high density of Onitsha urban. Route planning for waste collection vehicles and implementations of vehicular tracking systems like GPS on the vehicles to calculate waste collection timings are recommended.

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