

GIS-based system analysis for waste bin location in Enugu municipality

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Abstract: Waste collection in Enugu has been a major challenge requiring urgent attention. The aim of the work therefore was to study with GIS the management of the existing bin distribution and collection system in order to determine the optimal frequency for waste collection. The methods adopted include questionnaires, oral interviews and field observations to determine the state of waste collection. Waste collection points both legal and illegal dumpsites were identified using handheld Global Positioning System (GPS) and the points were incorporated into a map using Arc GIS 10.2 software. A total of 177 dumpsite locations were discovered during the study. Illegal dumpsites were 35 in number and legal dumpsites instituted by ESWAMA were 142. Out of the 142 authorized dumpsites, 55 dumpsites were clean and well managed while 87 sites were dirty and overflowing with waste. Central Public Health and Environmental Engineering Organisation Manual was used in determining the optimum location of bins. A total of 635 dumpsites were proposed with two 1 m³ waste bins at each point to accommodate daily waste generation in the municipality. Factors considered in recommending the frequency of optimum waste discharge include waste generation rate, population density, volume of dumpster and socioeconomic factors.

Keywords: dumpsites; bin location; GIS, GPS; solid waste; collection; system analysis.

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1 Introduction

The total solid waste generated annually worldwide is approximately 17 billion tones and by 2050 it is expected to reach 27 billion tones (Karak et al., 2012). Enugu is a major service centre in southeastern Nigeria. Much of the city's waste is disposed of at the *Department for International Development (DFID)* -supported Enugu State Waste

Management Authority (ESWAMA) landfill site located at Ugwuaji at the outskirts of Enugu (Barratt and Diyoke, 2003a, 2003b; Government of Enugu State of Nigeria, 2004; Government of Enugu State of Nigeria, 2005). Informal recyclers congregate at this landfill for waste recovery, aggregation, processing, buying or selling of recovered materials (Nzeadibe 2009). The operational efficiency of ESWAMA was evaluated by Uwadiogu and Iyi (2014). They identified major problems of the agency as crude equipment, low staff remuneration, poor awareness of the citizens on the hazards cause by poor waste management. They encouraged the government to invest more on waste management in the city.

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The continuous increase in solid waste generation therefore calls for management systems, such as Geographical Information System (GIS) which will address these environmental problems and contribute significantly towards more environmentally sustainable society (Laurent et al., 2014; Karadimas et al., 2007; Lasaridi et al., 2006; Nithya et al., 2012). The GIS software ArcGIS 10 (Environmental Systems Research Institute, ESRI) is a great tool to analyze land use suitability, store and handle spatial data, and combine different types of numeric and descriptive values with spatial data (Al-Hanbali et al., 2011). Many researchers have applied GIS to capture, store, analyze, manage, and present data on waste collection, transportation, transfer method, specific site situation, distribution of road network in Nigeria cities (Ojiako et al., 2014; Iyi, 2014; Oyinloye and Fasakin, 2013; Iro et al., 2012; Chukwuma et al., 2018; Oyinloye, 2013) and across other cities in the world (Vijay et al., 2005; Gbanie et al., 2013; Sultana and Kumar, 2012; Sumathi et al., 2008; Tavares et al., 2011; Javaheri et al., 2006; Nas et al., 2010; Şener et al., 2006; Wang et al., 2009; Aragonés-Beltrán et al., 2010; Tralhão et al., 2010; Ahmed, 2006). Therefore this work focuses on using GIS integrated with Global Positioning System (GPS) in managing municipal solid waste (MSW) collection in Enugu with emphasis on waste bin location and the number of bins needed. The specific objectives are to (i): review current MSW management practices including waste generation, location of collection bins, type and size of collection bins and collection frequency of MSW from the bins (ii) find and allocate new collection bins based on MSW generation using GIS 10.2 software and (iii) find the optimal proximity distance for the collection bins by generating buffer zone based on Central Public Health and Environmental Engineering Organization (CPHEEO) (2000) guideline.

2 Materials and methods

2.1 Description of study area

The study was carried out in Enugu municipality. Enugu city is the capital of Enugu State of Nigeria. It

developed with the discovery and mining of coal in the 1920s (Okoye, 1975; Ofomata, 1975; Ofomata and Umeuduji, 1994). Enugu municipality is made up of three Local Government Areas (LGAs) namely Enugu North, Enugu South and Enugu East (Nzeadibe, 2009). The Enugu State Waste Management Authority is the government agency in charge of MSW management in the area. The city has a population of 722,664 (National Population Commission [NPC], Nigeria, 2010).

2.2 GIS work flow model and analysis

The methodology is established by GIS technique in the research area was achieved by the following phases (Nithya et al., 2012): (1) Data collection, (2) Development of geospatial database, (3) Present analysis of MSW collection in the municipality, (4) The optimal allocation of collection bins for the proposed model based on road network, land use, environmental sensitive areas etc., and (5) Analysis of optimal proximity distance by creating buffer zone of the existing and proposed model. The conceptual flow of the work is shown in Figure 1.

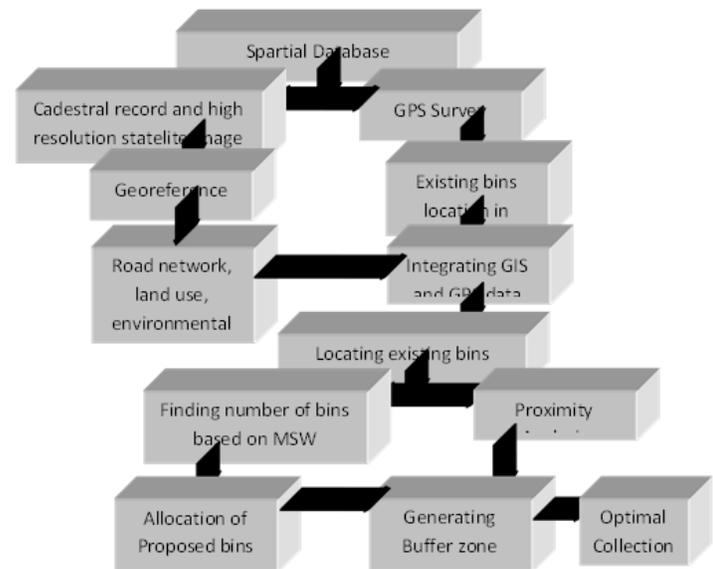


Figure 1 GIS work flow model and analysis

2.2.1 Data collection

In collaboration with the ESWAMA, primary and secondary database of MSW management of Enugu municipality such as population, population density; waste generation rate for mixed waste; number, type and positions

of collection bins; the road network; land use, environmental sensitive areas, truck capacities and their characteristics; and the geographic borders and characteristics of the waste collection sectors were collected. The main sources of developed database were derived using the digital maps from ESWAMA and satellite image of Enugu municipality. The existing location of the collection bins were derived from on-site capturing with the use of GPS technology. Other sources of information were collected through literature review, questionnaire and personal interview with stakeholders.

2.2.2 Development of geo spatial database, identification of dumpsites and waste bins

The geospatial database was framed in Arc GIS 10.2 for the allocation and analysis of collection bins. The database was derived through the sources such as digital maps from ESWAMA, interview with government authorities and online capturing with the use of GPS technology. The description of the database is presented in the Table 1. Information on the possible locations of the existing dumpsites was collected from ESWAMA office prior to field trip. Hand held GPS was used to identify the coordinates of the dumpsites.

Table 1 Description of geospatial data base

Spatial Data	Type	Attributes	Geometry
Road Linkages	Vector	-	Line
Collection Bin Location	Vector	-	Point
Rivers	Vector	-	Line
Hospitals, Churches and Schools	Vector	-	Point
Road Linkage attributes	Tabular	Road Length Longitude, Latitude, Number, type and size of	-
Collection bin attributes	Tabular	collection bins	-
Rivers Attributes	Tabular	River length	-
Hospitals, Churches and Schools Attributes	Tabular	Longitude, Latitude,	-

2.2.3 Convenient distance

The first analysis was to determine the convenience of the existing waste bins to users in terms of distance. CPHEEO (2000) guidelines on allocation of waste bins were adopted. It stipulates that the distance between two bins should not exceed 500 m. Therefore, the distance between a bin and a residential building should not exceed

250 m. Furthermore; allocation of waste bins were determined by finding locations on the map that require waste bins subject to the maximum distance of 200 m.

2.2.4 Proposed model for the optimal allocation of collection bins

In order to enhance the current MSW collection services in the ward, the present work examined the insufficiency of existing collection bins and their service areas. Thus, initially the number of bins required was calculated on the basis of per capita MSW generation and population. It is given in the following equation (Nithya et al., 2012).

$$N = \frac{W}{(D \times S \times F_1 \times CF)} \quad (1)$$

Where N is the number of collection bins; W is the total quantity of waste generated per day (kg); D is the density of waste(kg m⁻³); S is the size of bins (m³); F₁ is the average filling rate of bin (Generally 80 %); CF is the collection frequency.

Then obtained numbers of bins were allocated at new locations based on the following criteria (Nithya et al., 2012): (1) With reference to existing bin location (2) The road network and population density and (3) Unserved area. The land use pattern of the proposed collection bins was also analyzed with creating buffer zone around the collection bins by following three cases: (1) Buffer zone of about 20 m was assumed around schools and religious places, (2) 10 m for industrial, commercial and residential buffers and (3) 70 m buffer zones created around water features/river to avoid locating bin at close proximity to them.

3 Results and discussion

3.1 Status of waste disposal in Enugu municipality

Enugu suffers from indiscriminate dumping of waste on the streets, in open spaces, commercial places, residential and drainage systems. The available waste bins are overflowing thereby blocking parts of the road where vehicle can pass. The pedestrians hardly find a way to cross the areas where bins are located. Overflowing of waste bins

in Enugu municipality are caused by poor timing of waste disposal, poor location of bins and dumpsites, using small containers to service large area and places that have high rate of waste generation. Moreover, Enugu municipality has a good natural drainage, this helps to prevent water logging as most of the southern part of Nigeria experience. Unfortunately, most residents take it as an opportunity to dispose their refuse in drainages during rainfall. These wastes are carried by flood to the nearest water body downstream.

According to CPHEEO (2000), the density of mixed waste is considered as 500 kg m^{-3} which has also been established by Vijay et al. (2005). MSW in Enugu is generally disposed as mixed waste. The mixed density of the wastes in the area according to previous researchers (Holmes, 1984; Federal Ministry of Environment, 2002; Sha'Ato et al., 2007; Ogueleka, 2013) agrees with the range recommended by CPHEEO (2000). Based on this fact, the capacity of the existing waste bins in Enugu was calculated as 500 kg for the small steel bin and 2500 kg for bigger steel bin. The survey result shows that there is no current plan by ESWAMA for separate collection of waste with different containers. Some of the containers have no lid to prevent predators. Wind can also be a major challenge for the uncovered waste bin. Waste management processes are difficult during the rainy season. Since the waste bin is directly exposed to rain, the rate of water absorption increases thereby increasing the moisture content of the waste materials. This waste becomes bulky and more stressful to carry or evacuate. There is offensive odor accompanied by dripping leachates from the waste bins. There is no such trend amongst the citizens to wrap garbage in paper or polythene bag so it is disposed directly into the bins. People usually have a small waste container in their houses which they empty in the municipal bins and take back their bins for waste storage at their residents. It often happens that the waste instead of falling inside the bin falls partly outside the bin, thus making the area around the bin dirty. It makes the situation worse when the waste spreads around the bin. People find it inconvenient to get

close to bin and to throw the garbage so they try to throw the garbage being away from the bin. In doing this the garbage spreads more waste thus increasing the waste spread around the bin.

The other reason of spreading the waste around the bin is due to the activities of the scavengers or waste pickers. According to Nzeadibe (2009), the scavengers make their livelihood by selling the recyclable waste collected from the municipal waste. Even the stray animals like cat, dog, goat, cow and others spread the waste in search of food and more over they are attracted due to the smell of the waste which contains vegetables and food waste.

3.2 Recycling of waste in Enugu municipality

Presently, ESWAMA is engaged in basically three processes in solid waste management they include: (1) collection, (2) transportation and disposal. Scavengers are the people majorly involved in waste recycling in Enugu. The most common consumer products recycled include aluminium such as polyethylene and PET bottles, beverage cans, copper such as wire, steel food and aerosol cans, glass bottles and jars, old steel furnishings or equipment, paperboard cartons, newspapers, and corrugated fibreboard boxes (Nzeadibe, 2009; Agunwamba, 2003).



Figure 2 The taskforce vehicle NASWIDEN Enugu Chapter

The recycled product reduces the volume of waste significantly. The pickers make a living out the business, as it stands now many people are venturing into the business most especially children. They go from one dumpsite to another searching for recyclable products sometimes they buy the recyclables from the owners. The gathered

materials are sold to the middle men who sales directly to the companies involved in recycling. The recyclables are sold by their weight and the type of material.

National Association of Scrap and Waste Dealers Employers of Nigeria (NASWDEN) is the body guiding all the waste pickers in Nigeria and the Enugu Chapter is well organized. They protect interest of her members and through their task force ensure that all their dealers comply with the laws guiding waste management in Enugu. Figure 2 shows the taskforce vehicle of NASWDEN Enugu Chapter.

3.3 Existing waste bins locations

A total of 177 waste bin locations were discovered during the course of the work. There were 35 illegal dumpsite sites recorded in this work. Most of the illegal dumpsites are located in Abakpa Zone.

During the course of locating the dumpsites, 55 dumpsites were clean and well managed. The clean areas were mostly located at Okpara Avenue, Zik Avenue and other major roads in Enugu municipality. This indicates that ESWAMA officials are more keen to make sure the major road of the town is kept clean to put up a good image of the city with lesser effort in other places. Some points were also discovered to be under evacuation by the ESWAMA staff.

The number of bins in each location depends on the amount of waste generated in the area. The higher the amount of waste generated the higher the number of waste bin to be kept at that point. The commercial areas like Ogbete, Ekulu junction make use of big waste containers in order to accommodate a higher amount of waste.

Overflowing bin is when refuse exceeds it carrying capacity making people to dump waste around the waste container. A waste bin is said to be clean when the container is not filled to the capacity and the surroundings are tidy. According to ESWAMA, a waste bin location is considered to be illegal if there is no ESWAMA authorized container at the location. Although there are a lot of illegal dumpsites in Enugu, ESWAMA tries as much as possible to

evacuate waste from those locations from time to time. Sometimes the residents in that location burn the waste in order to reduce the volume and odor from the dumpsite.

Locations of the existing dumpsites in Enugu were geo referenced (Figure 3a). There is concentration of dumpsites in some areas especially at the major roads and places with high population density. There are a lot of dumpsites along Zik Avenue, Agbani Road, Ogui Road, Upper and Lower Chime (New Haven) and Presidential Road. Enugu urban is made up of highlands which encourages good drainage. The topography of Enugu with the existing dumpsite is shown in Figure 3b.

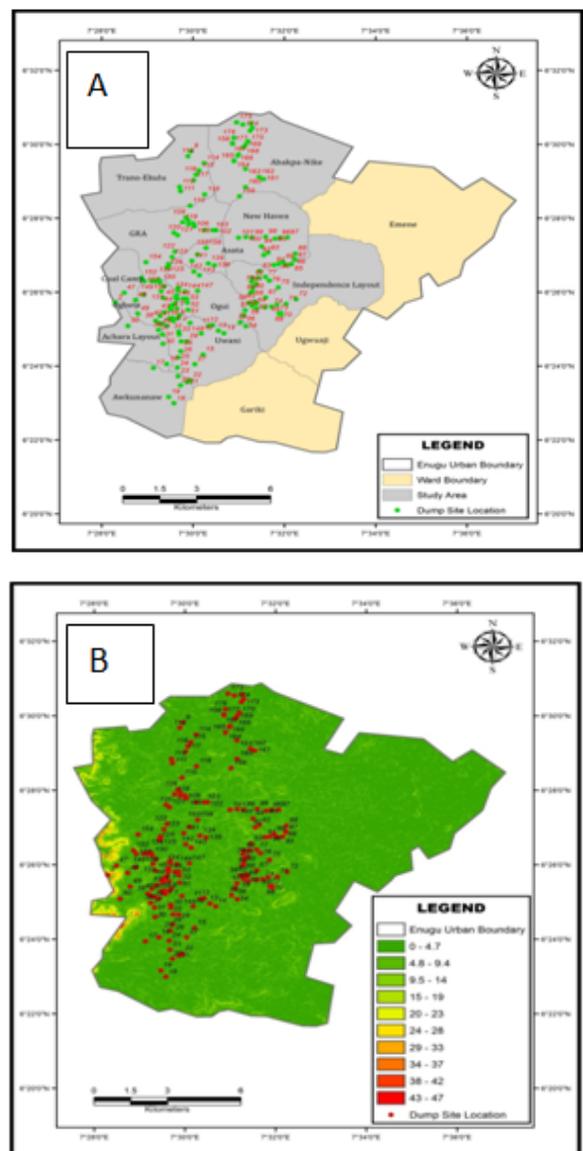


Figure 3 (a) Map of Enugu showing Geo referenced waste bin locations (b) Topography of Enugu and existing Dumpsites

Most of the so-called legal dumpsites were poorly located very close to utility areas like hospitals, churches and malls. Some were located very close to large drainage systems. When the containers were filled up people usually dispose their waste directly inside the drainage thereby causing flooding and wide spread of diseases as can be seen in Figure 4.

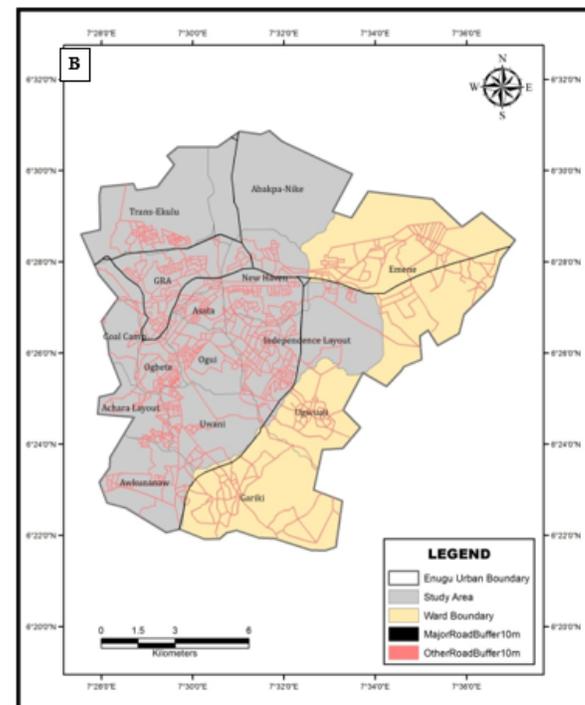
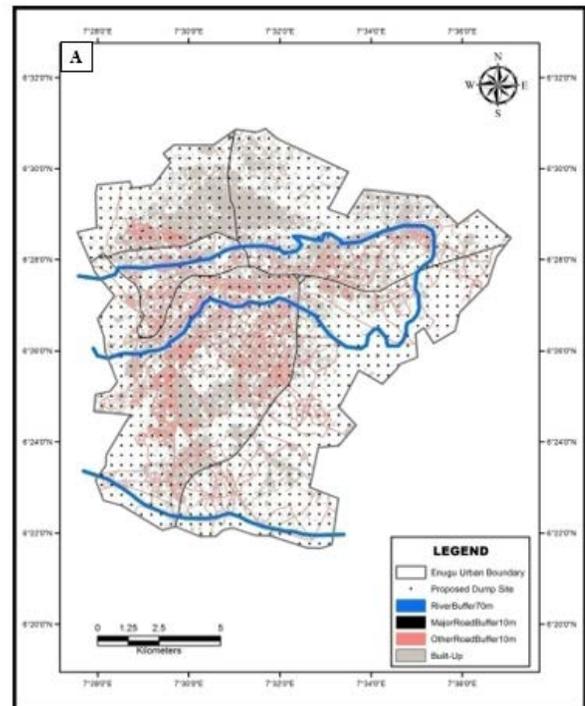


Figure 4 Legal dumpsites poorly located close to utility areas in Enugu

3.4 Optimum bin location to physical features

Many residents living around the river disposed refuse inside the river body; this is one of the major challenges in waste management in Enugu. Large drainage channels as can be seen in Figure 4 are also used for dumping refuse. A buffering of 70 m was used for rivers in siting the dumpsites (Figure 5a). The road linkages both the major and minor roads have a buffer of 10 m. The buffer was to ensure that waste bins do not cause obstruction to the movement of vehicles as shown on Figure 5b. The buffer zones are necessary to ensure that bins do not affect the

utilities within the area to which it is sited. The buffers were 10 m for residential, commercial and industrial areas, 10 m for major and minor roads (Figure 5c). A buffer of 20 m was used for schools, churches and schools. A good aesthetic view is needed in the public places. Figure 5d shows the buffer map for hospitals, churches and schools in Enugu.



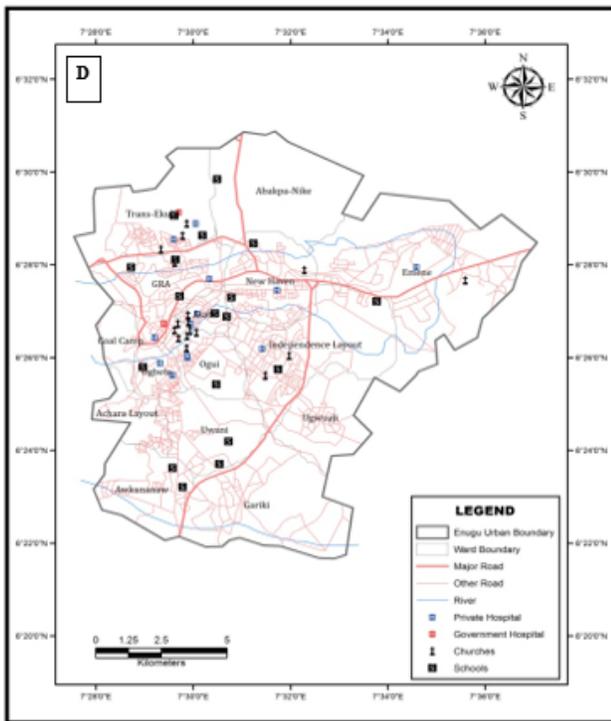
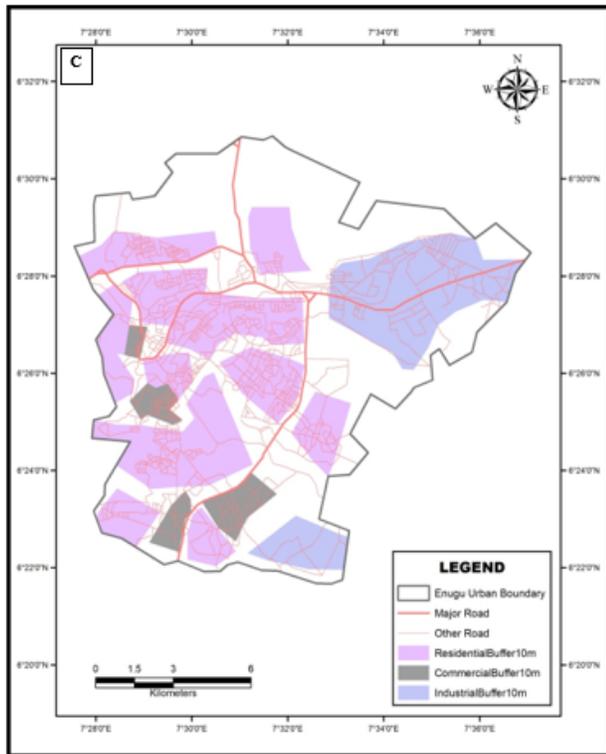


Figure 5 Maps showing buffer zones for (a) rivers (70 m) (b) road linkages (c) major/minor roads, commercial, residential and industries (10) (d) hospitals, churches and schools (20 m)

3.5 Proposed optimum bin location

The proposed optimum location for siting of waste bins takes all the physical features as well as the utilities features

such as schools, roads, hospitals, industrial and commercial areas with their buffering w put into consideration. A 200 m distance was adopted between waste bins as can be seen in Figure 6. A total of 635 dumpsites were proposed with two 1 m³ waste bins at each point to accommodate daily waste generation in the municipality.

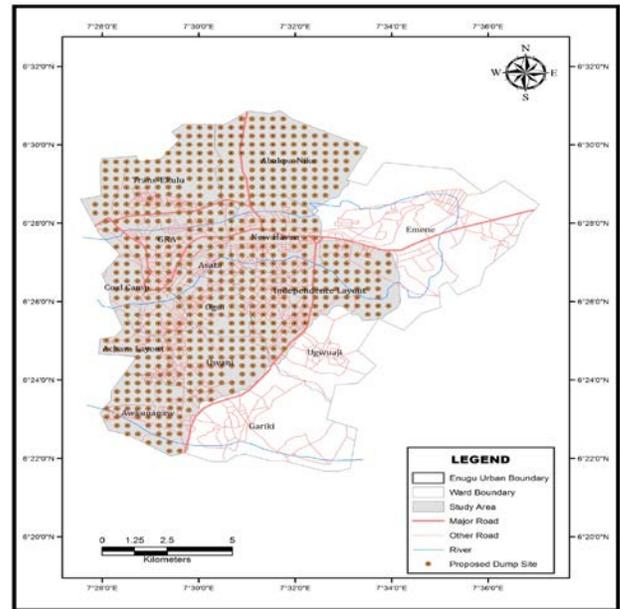
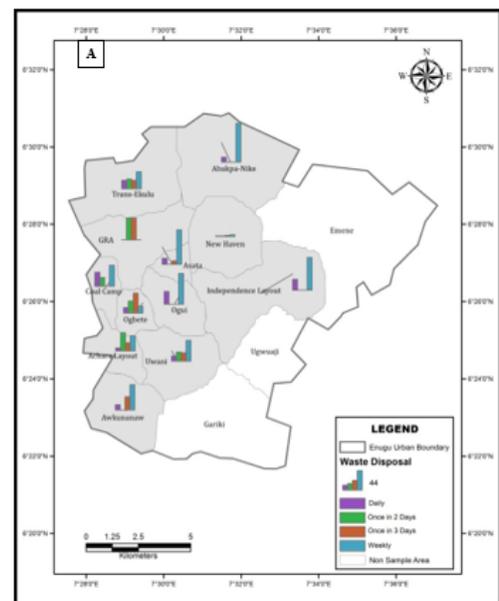


Figure 6 Proposed optimum bin location in Enugu municipality

3.6 Frequency of waste collection and disposal

The frequency of waste disposal by residence in Enugu based on this study is shown in Figure 7a, while the frequency of waste collection by ESWAMA is presented in Figure 7b.



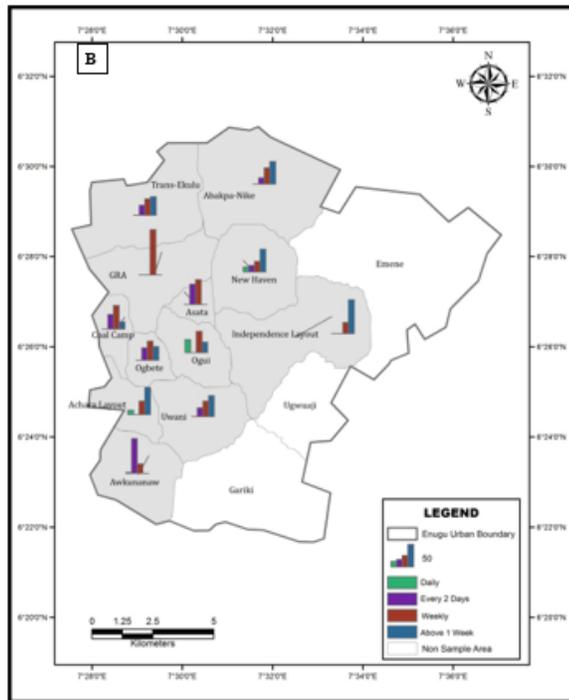


Figure 7 Waste management in Enugu (A) and Frequency of waste disposal by residents (B)

Most residents in Independent layout, New Haven, Achara Layout, Abakpa Nike and Trans-Ekulu reported that waste collection in their areas exceeds one week interval while weekly collection of waste by ESWAMA is mostly recorded in GRA, Asata, Coal Camp, Ogui and Ogbete.

4 Conclusions

Incessant dumping of refuse on the streets, in drainages, empty plots of land and along road sides is still a norm in most areas. From the research, a total of 177 dumpsite locations were discovered and geo-referenced in a map using ArcGIS 10.2 software. Illegal dumpsites were 35 in number and 142 legal dumpsites instituted by ESWAMA. Out of the 142 authorized dumpsites 55 dumpsites were clean and well tidied while 87 sites were dirty and overflowing with waste.

Waste management in Enugu lacks planning especially in siting dumpsters at strategic positions as well as in the frequency of its disposal. Analysis of optimum location of waste bin were performed using Central Public Health and Environmental Engineering Organization Manual (CPHEEO, 2000) distance guidelines, a distance of 200 m

was used between waste bins. A total of 635 dumpsites were proposed with two 1 m³ waste bins at each point to accommodate daily waste generation in the municipality.

For convenience and cost effectiveness we suggest that seven waste bins should be sited at each point with twice a week evacuation. For the areas with high waste generation more waste bins should be added to accommodate the amount of waste they generate.

Based on the findings, the following recommendations have been made to further improve waste management in Enugu: (1) Provision of enough waste bins to service the suggested new locations; (2) The waste bin should have a cover/lid to prevent wind and animal from scattering the waste; (3) Residents should be sensitized on the importance of waste separation from point of primary waste collection. This will enhance reuse and recycling of waste; (4) ESWAMA should develop a cordial relationship with the residents so that they can be communicated in case of any emergency for waste evacuation; (5) A stringent action should be taken against those disposing their refuse in drainage channels. The Chairman of ESWAMA should establish a monitoring team to take the responsibility of punishing those that hid to such act; (6) ESWAMA should digitize all the waste bin locations and upload it in their data based so that people can easily access the nearest waste bin through the internet; (7) There is need to invest in research and development for new waste management technologies that will improve Enugu State; and (8) Further research should be carried out on waste management in Enugu market.

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