Spatial Pattern of Generation and Management of Household Hazardous Waste in Enugu Metropolis, Enugu, Nigeria

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Abstract The paper examined the spatial pattern of Household Hazardous Waste (HHW) generation and management options in the Enugu Metropolis. Ten (10) layouts were randomly selected from forty one (41) residential layouts that make up Enugu Metropolis. A total of 300 structured questionnaires were randomly administered to households, while oral interviews were conducted in the Enugu State Waste Management Agency (ESWAMA). The study showed that home cleaning waste was the most frequently generated HHW, accounting for 19%. This was followed by glasses (17%) and batteries (14.8) while the less generated include e-waste (10.4%), motoring products (8.7%), and paints (7.1%). Government Residential Area (G.R.A) generated the highest amount of HHW with a percent value of 13.1%, followed by New Haven (12.7%), Iva-Valley (10.6%), Ogui (10.2%) and Independence layout (10%). The relationship between dwelling type and quantity of HHW generated showed that the buildings with multiple rooms generated the highest (31%) amount of HHW, followed by three bedroom apartments. Lowest income earners (5,000-20,000 naira) were known to generate highest quantity, while houses with income above 250,000 naira generate less quantity. The study showed that 22.7% of the households indicated that they have no means of disposing of HHW, 2.7% indicated that they keep them or reuse them, 2.6% pour liquid HHW down their sinks or drains, 5% take them to a landfill site, the remaining 67% dispose of them in anyhow. Thus, there is a need for sensitization as this will encourage waste sorting, as well as help in educating the public on the need to purchase fewer hazardous products.

Keywords: Household Hazardous Waste, HHW Generation, HHW Management, Awareness

Introduction

Global production of waste has practically doubled over the past ten years and is expected to reach 2.5 billion tons per year in 2025 as a result of the combined effect of urban development and changes in consumption patterns (Périou, 2012). Moreover, while solid waste generation has kept pace with urbanization, the management of waste has been highly inadequate and studies have shown that most countries in developing nations often resort to unsustainable waste disposal methods that are proven to be destructive to human health and the environment, such as open dumping and burning (or unregulated landfills); because they feel they have no other options to manage their solid waste (Mwanthi & Nyabola, 1997; Goett, 1998; Narayana, 2009; Al-Khatib et al., 2015; Hilburn, 2015). This problem is exacerbated due to the obvious lack of waste segregation facilities to aid solid waste recycling, reuse and recovery; as a result of which household hazardous waste also constitutes part of the waste stream in developing countries. Household Hazardous Waste (HHW) is a term used to describe hazardous waste entering the municipal waste stream from homes. It represents a variety of waste types classified together based on the possession of hazardous properties (Slack, *et al.*, 2008). When materials such as fluorescent tubes, batteries, paints, motor oil, detergent, television sets, computers, pesticides, insecticides, etc. are no longer useable or wanted, they become HHW. Household Hazardous Waste has for many years been seen as a waste stream of low significance compared to other more problematic wastes. However, the withdrawal of a number of chemicals from use in households (*e.g.* creosote, various pesticides including dichlorprop and resmethrin, chromated copper arsenate (CCA) treated timber, etc) have raised the profile of the hazardous nature

of certain household products and hence generated concern regarding their disposal (Slack et al., 2004). In developing countries, one of the problems with daily household products is that their chemical formulation is largely unknown, both quantitatively and qualitatively. Nigerian inhabitants are fast becoming more and more sophisticated with respect to their preferences and appetites and this improvement may be directly linked to the intractable problems of HHW generation and management in Nigerian cities. Poor HHW management is the key factor in the spread of potential toxic compounds in the environment. When materials such as fluorescent tubes, batteries, paints, motor oil, detergent, television sets, computers, pesticides, insecticides, etc. are no longer useable or wanted, they become HHW. Although the hazardous wastes only make up a small percentage of household waste in general, they pose a serious problem which ranges from health to environmental problems (Butt & Oduyemi, 2003; Santos et al., 2006; Demitriou et al., 2008; Din et al., 2008; López et al., 2008; Singh et al., 2009; Li et al., 2012). In landfills, leachate from the waste pollutes soil, surface water and groundwater reservoirs (Ikem, 2002; Mor et al., 2006; Islam et al., 2013).

In Enugu Metropolis, HHW is usually stored in bins or cartons along with other wastes in individuals' homes and later deposited into public bins placed on the curbside or thrown inside built dumps for collection. The mixing of HHW with other household wastes not only poses problems of disposal but also difficulty in monitoring the waste content or estimating the extent of pollution risks at dumps. This state of affairs, in addition to the lack of separate facilities for collecting HHW tends to compound the problem of HHW management. Most studies on solid waste management in Nigerian urban areas have also tended to ignore the issue of HHW. However, it is against this background that underscores the imperative of the study. Thus, the objective of this study is to examine the spatial pattern of generation and management of HHW in Enugu metropolis, Enugu, Nigeria.

Material and Methods

Description of study area

Enugu Metropolis is the capital of Enugu State. It is located approximately between latitude 6^0 30'N and 6^0 40'N of the equator and longitude 7^0 20'E and 7^0 35'E of the Greenwich meridian. It covers an area of about, 145.8 square kilometres. It is administered by three local authorities, namely, Enugu North, Enugu South, and Enugu East local government authorities. The climate of the study area is the tropical wet and dry type according to the Koppen climatic classification system and experiences two seasons (wet and dry) both of which are warm. Rainfall occurrence is high, with mean annual total of 1600 mm. The rainy season generally lasts from April to October, while the dry season lasts from November to March. Due to its latitudinal location, our study area receives abundant and constant insolation. Temperatures are high, usually varying between 25^0-29^0C, reaching the maximum with the approach of the rainy season. The mean daily temperature is above 27 ^{0}C all over the year. The topographical features of Enugu Metropolis can be classified into two: to the west is the escarpment, which is erosional and is continually eroded backwards by the east-flowing rivers, and to the east are the Cross River Plains that are generally low and of monotonous relief. Enugu lies at the foot escarpment, of the Cross River Plains, (Mamman, et al., 2000). Enugu Metropolis is bounded in the northeast by Isi-Uzo and northwest by Igbo-Etiti Local Government Areas (L.G.As.), in the east and south by Nkanu East and Nkanu West L.G.As. respectively and in the west by Udi L.G.A (Figure1).

Enugu Metropolis has had a rapid growth. Its population rose from a handful of mineworkers in 1915 to 3,170 inhabitants in 1921. When the first census was taken in 1931, the population had increased fourfold to 13,000 and in 1953, Enugu Metropolis had a population of 62764 people. In 1963, the population had increased to 138,457 people. The population of Enugu Metropolis in 1991 was 369,373, in 2006, the population census figure for Enugu Metropolis was given as 722,665 (Federal Republic of Nigeria Official Gazette, 2007).

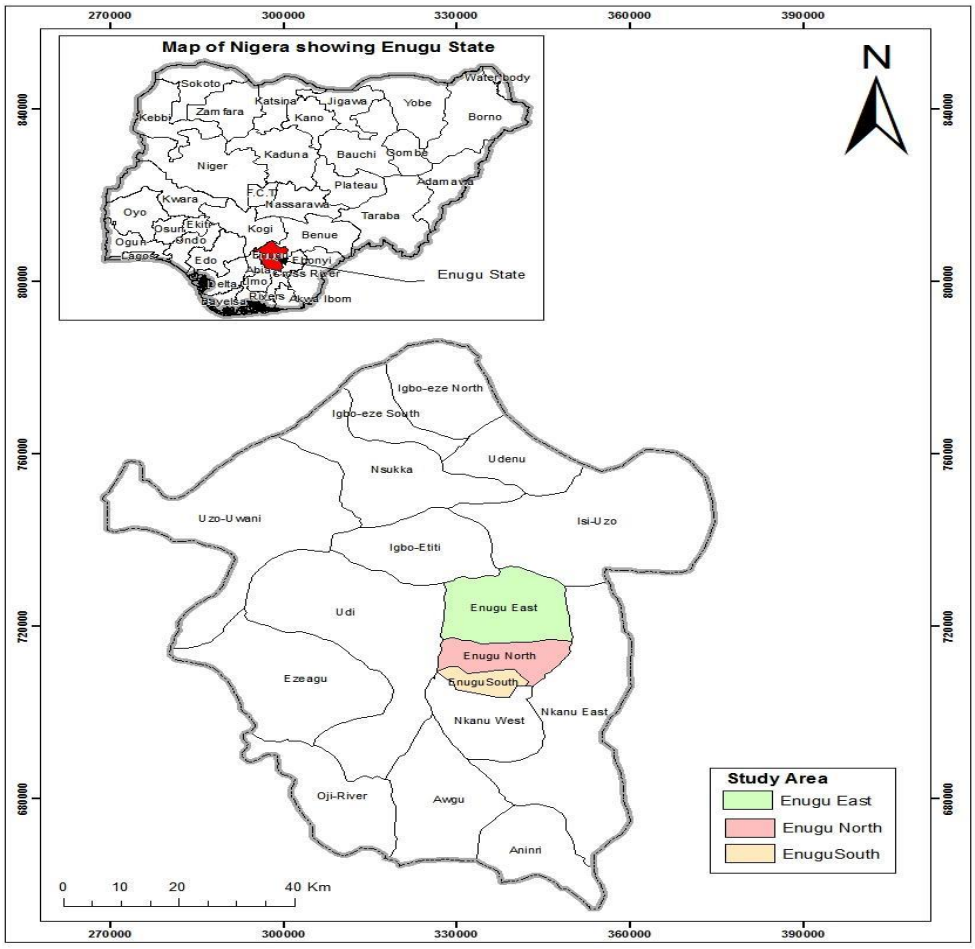

Figure 1: Study area

Site Selection for the Survey

Enugu Metropolis has forty-one (41) residential layouts (Figure 2), but for the purpose of this work, 10 layouts were randomly selected. The criteria for selection of these ten layouts were to include typologies of layouts and the diversity of households among the selected layouts. The 10 layouts for this study include Abakpa, Achara, Asata, Awkunanaw, G.R.A., Independence layout, Iva-Valley, New Haven, Ogui, and Uwani. The sampling framework for this study was three hundred (300) households comprising thirty (30) households from each of layouts named above.

Questionnaire survey

The study is largely quantitative and utilized data collected through household questionnaire survey. The questionnaire was administered for the analysis of the management of HHW in Enugu Metropolis. The questionnaire was detailed and contained close-ended questions and a checklist.

A total of 24, (twenty-four) checklists were used to evaluate the responses of householders to determine their level of awareness of HHW in Enugu Metropolis. Analysis of the awareness data was based on the frequency values obtained from our checklist. This enabled us to obtain the mean scores, standard deviation and variance of the frequency counts of the response values, whose sum total is 15 for each variable. Twenty-four (24) variables were assessed on the Likert five-point response continuum scales. The Strongly Agree was rated 5, Agree 4, Undecided 3, Disagree 2, and Strongly Disagree 1. Adding all the ratings together gave us a total of 15 points. In our interpretation,

any mean above 3.5 indicates that they agree, and they are aware. Mean below 3 implies that they disagree, and the level of awareness is low and exactly 3 or between 2.5 and 3.4 shows a moderate level of awareness. Thus, each of the variables was assessed to determine the degree of the level of public awareness of HHW in Enugu Metropolis. An interview was carried out with Municipal Solid Waste Management officials to provide information on the institutional framework for HHW management, officials' attitudes and efforts at HHW collection and management in Enugu Metropolis.

Interview and field observation

Interview was carried out with ESWAMA officials to provide information of the institutional framework for HHW management, officials' attitudes and efforts at HHW collection and management in Enugu Metropolis. The Enugu State Sanitary landfill site of Enugu State Environmental Protection Authority (ENSEPA) was visited and workers in the site were interviewed, and pictures were taken at the site.

Method of data analysis

The generated data were subjected to statistical analysis. The data were analyzed using descriptive and simple statistical analysis to relate the factors affecting HHW generation and also the magnitude of generation of HHW. The checklists method was used and coded with Likert five-point response continuum scale with total of 24 structured questions to evaluate the level of awareness of HHW for this study.

Results and Discussion

Composition and distribution of household hazardous waste (HHW)

In Enugu Metropolis, the different categories of HHW generated include, paints, garden chemicals, motoring products, batteries, e-waste, medicine, home cleaning products, and household glasses (Table 1).

Table 2: Composition of Household Hazardous Waste Categories in Enugu Metropolis

I Paints and related product	II Garden chemicals	III Spent Motoring products	IV Used Batteries	V Electrical/ Electronic Waste	VI Medical Waste	VII Home cleaning Waste	VIII Glasses/ Others
Strippers	Insecticides	Brake fluid	Torch batteries	Spoilt Computers	Used needle	Air fresheners	Fluorescent tubes
Thinners	Weed killers	Old tyres	Rechargeable batteries	Spoilt Stabilizers	Expired Tablets	Aerosols spray containers	Glasses
Water based paints	Soil fertilizers	Used motor Oils		Used handsets	Expired Syrup	Soap bars	Shoe polish
Solvent	Rat Poisons	Used Lubricant		Old T.V sets	Used Swabs	Disinfectants	Bulbs
		Used Brake oil		Condemned radio	Blood Stained cotton	Oven cleaners	Plastics
				E-Waste			Nail polish

The classification of HHW in the study area is in line with the convention in the U.K, U.S and other developed cities. All the different HHW were detected in the entire layout. Table 2 shows the quarterly frequency of generation of HHW in the study area in the months of July-September 2019. The Table 2 was compiled using the frequency counts of respondent's response in each layout respectively. As per Table 2, home cleaning waste was the most frequently generated HHW in the study area with a generation rate of 19%. This was followed by glasses (17%) and batteries (14.8%). The others frequently generated include garden chemicals (12.6%), medical waste (10.5%), E-waste (10.4%), motoring products (8.7%), and paints (7.1%) (Figure 2).

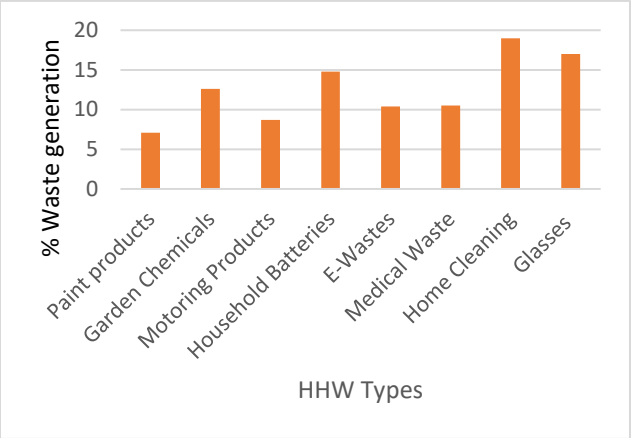

Figure 2: Frequency distribution of HHW generated in the study area

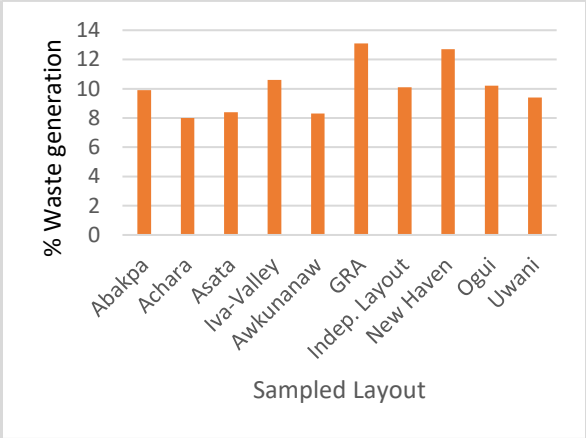

Figure 3: Spatial frequency distribution of HHW generation in the study area

In terms of spatial distribution total HHW generated in the study area, G.R.A generated the highest quantity of HHW of (13.1%), followed by New Haven (12.7%), Iva-Valley (10.6%), Ogui (10.2%) and Independence layout (10%). HHW was also generated at Abakpa (9.9%), Uwani (9.4%), Asata (8.4%), Awkananaw (8.3%), and Achara (8%). The least quantities were generated in Achara and Asata layouts. They were moderately generated in Abakpa, Ogui, Independence Layout, Awkunanaw, and Uwani (Figure 3).

In terms of quantity of individual HHW per layout, generation of paint-related products was highest in Ogui layout, followed by volume generated in Uwani. Least paint-related products were generated in Achara layout. The generation of garden chemicals was highest in Achara layout, followed by quantities generated in Iva-valley and New-Haven. In the opinion of respondents, motoring products accounted for 8.7% of all the quarterly HHW generated in the study area. This type of waste was highly generated in G.R.A, moderately generated in Ogui, Independence Layout, and Uwani, and least generated in Awkunanaw, Abakpa, Iva-Valley, Asata, and Achara layout respectively. Highest amount used batteries were generated in G.R.A, Abakpa, Iva-Valley, New Haven, Awkunanaw, and Achara layout, while in Ogui, Asata and Uwani used batteries were generated in moderate quantities (Table 2).

E-waste generated was highest in G.R.A, Iva-Valley and New Haven, while moderately generated in Asata, Awkunanaw, Uwani, and Abakpa respectively. Least generation of E-waste was in Independence Layout, and Achara Layout. Medical wastes were generated in all the layouts in the study area. From their spatial distribution, it can be concluded that G.R.A, Iva-Valley, New Haven, and Uwani generated the highest, while in Ogui and Abakpa, they are moderately generated. E-waste was least generated in Awkunanaw, Achara, Asata and Independence Layout respectively. E-waste accounted for 10.5% of the HHW generated in the study area. Home cleaning products were generated in all the study areas. It was most generated in the study area. In terms of locational distribution, Abakpa, GRA, Independence Layout, New Haven

and Ogui Layouts recorded the highest volumes. The spatial distribution of household glasses shows that apart from Awkunanaw, Uwani, and Achara Layout where they were moderately generated; household glasses are highly generated in the other layouts in the study area (Figure 2).

Table 2*:* Frequency of Quarterly Generation of HHW in Enugu Metropolis

HHW	Abakpa	Achara	Asata	Iva-Valley	Awkunanaw	G.R.A	Independenc Layout	New haven	Ogui	Uwani	Total HHW in the study area	Total %
Paint Related Products	5	2	12	9	9	12	10	12	18	15	104	7.1
Garden Chemicals	15	26	9	24	12	24	20	24	12	18	184	12.6
Motoring Products	10	10	9	9	9	21	20	15	12	12	127	8.7
Household Batteries	25	20	18	21	21	30	25	24	18	15	217	14.8
E-waste	15	5	12	21	17	24	10	21	12	15	152	10.4
Medical waste	20	7	6	21	6	21	7	24	18	24	154	10.5
Home Cleaning	30	27	27	27	27	30	30	30	30	21	279	19.0
Glasses	25	20	30	24	20	30	25	27	30	18	249	17.0
Total for each layout	145	117	123	156	121	192	147	177	150	138	1466	%Total
Total %	9.9	8.0	8.4	10.6	8.3	13.1	10.0	12.7	10.2	9.4	%Total	100

The fact that all the sampled HHW are found in the study area and more in GRA area is an indication of the impact of urbanization process on HHW generation and more so the fact that Africa is also one of the main destinations of illegal transboundary trade of urban and hazardous waste from industrialized countries (Marsili et al., 2009). A similar pattern was reported by Ojeda-Benítez et al., (2013) and Buenrostro et al. (2007) in Mexico. According to Ojeda-Benitez (2013) the problem in urban areas is clearer than in rural areas due to the different styles of life in the two areas. Scientific research has confirmed that in recent decades, rapid global urbanization and increases in living standards, buying power and easier access to products that are convenient but not always safe have led to changes in the HHW characteristics (Gu et al., 2014). In another study, Laili and Kristanto (2021) found that household hazardous waste accounts for 530% (rural areas) and 8.22% (urban areas) of the municipal solid waste stream. Household hazardous waste in the rural area is dominated by sanitation (35.97%) and household cleaning products (18.3%). In comparison, the authors found that, household hazardous waste in urban areas dominated by sanitation (64.80%) and household cleaning products waste (15.81%). Economic factors and lifestyle are factors that influence a different household hazardous waste generation in urban and rural areas (Laili & Kristanto, 2021).

The study area is rapidly expanding and thus the distribution of the observed HHW. Under the current era as observed by Gutberlet (2017), industrial production of consumer goods is characterized by a reduction in product life spans, growing product variety, material component diversity, and increased packaging. All these characteristics are drivers for increased use of natural resources and are responsible for generating

waste and producing water, soil and air contaminants. Study has linked municipal solid waste generation to urban development (Liu et al., 2019) including the problem of inappropriate or inefficient waste disposal methods (Babayemi & Dauda, 2009). Population growth comes with an increase in consumption and waste. More affluent segments of the population consume more and generally their consumption also produces a larger environmental impact (Gutberlet, 2017). The urban lifestyle contributes to higher waste generation not only in people's homes but also outside. Particularly the food service industry thrives on disposables. Today, people consume more in the streets and their consumption leaves more disposable waste in public waste bins (Hoornweg & Bhada-Tata, 2012). Figures 4-13, illustrate percentages of the distribution of HHW in each layout. In Abakpa, paints and other paint-related products are the least HHW generated, followed by motoring products, while garden chemicals, E-waste and medicine are moderately generated. Batteries, household glasses, and home cleaning are highly generated. Abakpa accounted for 9.9% of HHW frequently generated in the study area (Figure 2). In Achara Layout, paints were the least generated HHW; others were e-waste, medicine, and motoring products. Batteries and glasses are moderately generated, while the others are highly generated respectively. Achara Layout accounted for the least (8%) of the HHW generated in the study area (Figure 3).

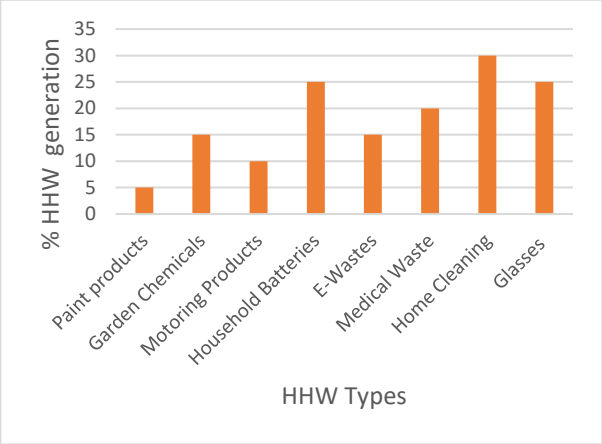

Figure 4*:* Frequency of HHW generated quarterly in Abakpa Layout.

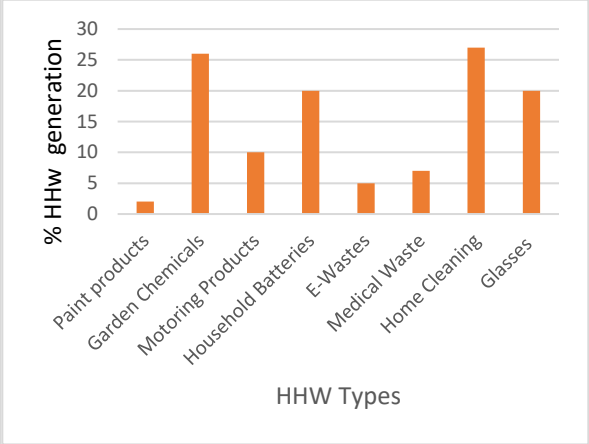

Figure 5*:* Frequency of HHW generated quarterly in Achara Layout.

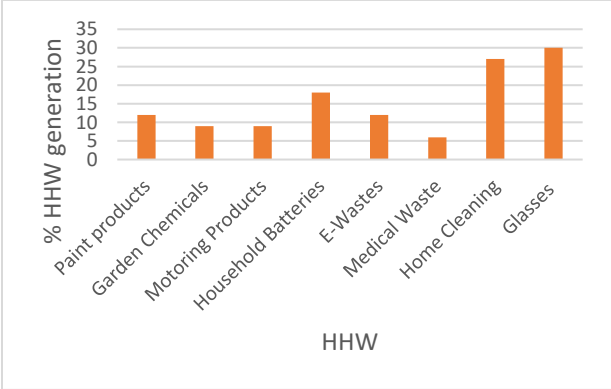

Figure 6*:* Frequency of HHW generated quarterly in Asata Layout.

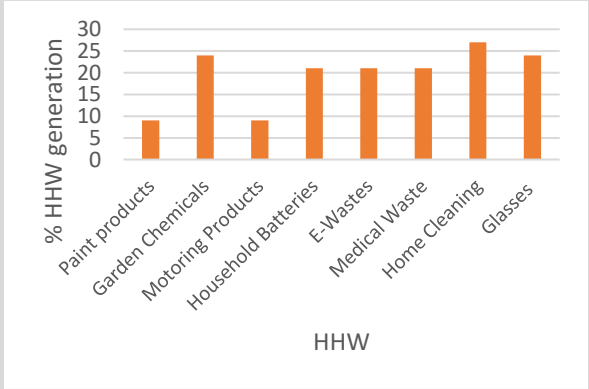

Figure 7*:* Frequency of HHW generated quarterly in Iva- Valley.

Asata contributed 8.4% of HHW generated in the study area in terms of frequency, the least HHW generated were medical waste, garden chemicals and motoring products. Paints, E-waste and batteries were moderately generated, and the others; home cleaning and glasses were the most generated as shown in Fig 6. In Iva-Valley, HHW generated is 10.6% of the total in the study area. With the exception of paints and motoring products which are least generated, the other HHW are highly generated as shown in Figure 7.

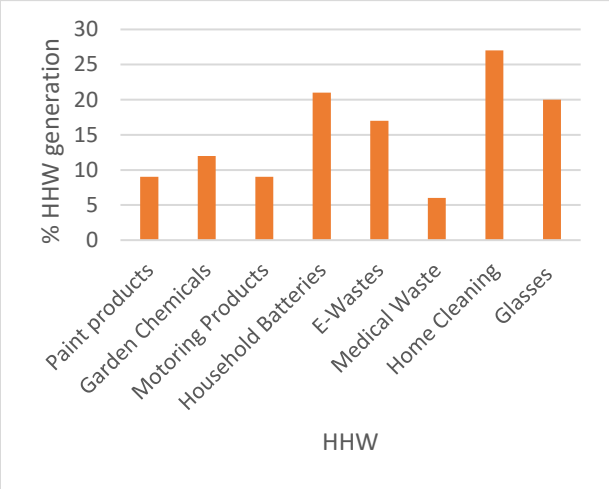

Figure 8*:* Frequency of HHW generated quarterly in Awkunanaw.

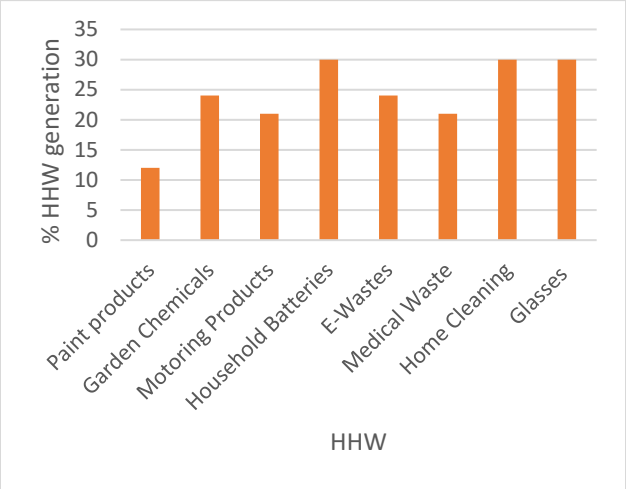

Figure 9*:* Frequency of HHW generated quarterly in GRA.

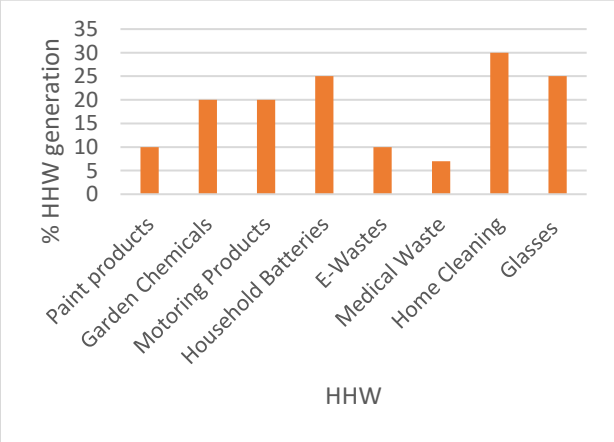

Figure 10*:* Frequency of HHW generated quarterly in Independence Layout.

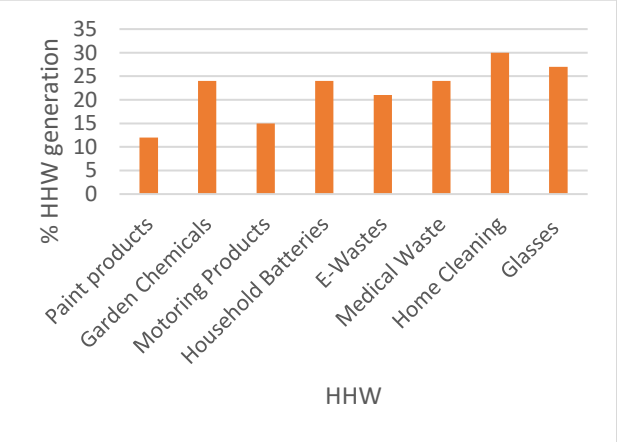

Figure 11*:* Frequency of HHW generated quarterly in New Haven.

In Awkunanaw, medicine, paints and motoring are the least frequently generated, while garden chemicals E-waste and glasses were moderately generated. Batteries and home cleaning products were the most generated as shown in Figure 8. Awkunanaw accounted for 8.3% of HHW generated in the study area. In G.R.A, with the exception of paints which are moderately generated, all other HHW are highly generated in this layout as shown in Figure 9.

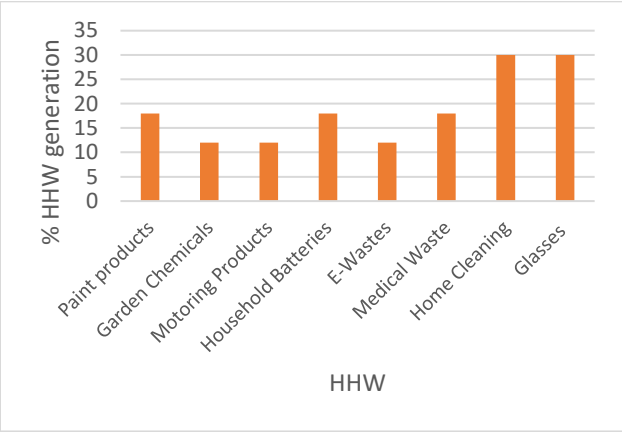

Figure 12*:* Frequency of HHW generated quarterly in Ogui Layout.

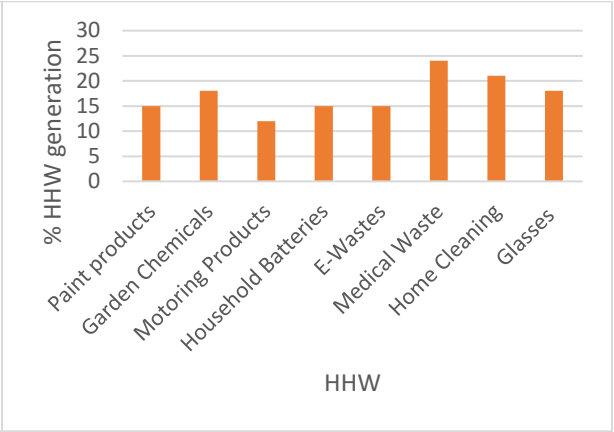

Figure 13*:* Frequency of HHW generated quarterly in Uwani Layout.

In Figure 10, the least frequently generated HHW are medical waste, paints and e-waste in Independence Layout. Garden chemicals and motoring products are moderately generated, while batteries and glasses and home cleaning are the highest HHW generated for the layout, respectively. Independence Layout accounted for 10% of HHW generated in the study area. In New Haven, apart from paints and motoring products that were moderately generated, the other HHW are most frequently generated, as shown in Figure 11. The generation of HHW in this layout accounted for 12.7% of the study area. In Ogui, with the exception of glasses and home cleaning products that were the most frequently generated, other HHW showed moderate frequency of generation (Figure 12). Ogui accounted for 10.2% of HHW generated in the study area. In Uwani, with the exception of medical waste and home cleaning products that were highly generated, the other HHW were moderately generated, as shown in Figure 13. Uwani accounted for 9.4% of HHW generated in the study area.

Improper management of HHW poses unpredictable negative impacts at the source of generation, at the waste collection points, during transportation and after disposal in landfills and/or incineration sites, with significant negative impacts to the environment and public health (Christensen et al., 2001; Slack et al., 2004; Zhu et al., 2009). Other harmful effects of HHW include air pollution, which may be caused by the release of mercury, lead, cadmium and nickel into the atmosphere from burning batteries (Gu et al., 2014). Waste, and in particular hazardous waste, is one of the priority areas for the Member States of the World Health Organization (WHO) Regional Office for Europe and was on the agenda of the Sixth Ministerial Conference on Environment and Health (WHO, 2016) due to arising health and environmental issues. The study has also shown that the burden of diseases of waste-related exposures in middle-low income countries is increasing (Landrigan et al., 2015). In 2000, a review of hazardous waste reported that the evidence of a causal relationship with cancers "is still weak", especially with regard to specific cancers reported in more than one study: leukemia, bladder, lung and stomach cancers (Vrijheid, 2000). A relationship was suggested with adverse pregnancy outcomes, *i.e.* low birth weight, total birth defects and cardiac, musculoskeletal and central nervous system defects (Vrijheid, 2000).

In Europe, in 2014, 342,000 contaminated sites were identified (5.7 per 10,000 inhabitants) (Fazzo et al., 2017). On the basis of the data provided by 33 countries, in 2011, the activities which contributed most to soil and groundwater contamination were HHW disposal, including municipal and industrial waste (about 38% of the sites), and industrial and commercial activities (mining, oil extraction and production, power plants - about 34% of the contaminated sites) (Van Liedekerke et al., 2014). In seven Asian countries, 679 areas were identified as contaminated by hazardous waste (Fazzo et al., 2017). Of these, 169 sites were polluted by lead resulting in an estimated 245,949 0–4-year-old children exposed to lead. The estimated levels of exposure might be sufficient to generate acute and chronic adverse effects, such as

a decrease in Intelligence Quotient (IQ) (Caravanos et al., 2013). Chatman-Stephens et al,. (2013) analyzed 373 hazardous waste sites in three Asian countries (India, Indonesia, Philippines) and estimated approximately 9 million people to be at risk; adding another estimated 43 million people at risk from unscreened sites to the exposed population, 4 million DALYs (disability-adjusted life years) associated with hazardous waste sites were estimated as the impact (Chatman-Stephens et al., 2013). In Africa, where WHO estimates that 1/3 of the burden of disease is attributable to environmental risk factors, hazardous waste has been included among the first three main such factors (McCormack & Schuz, 2011); domestic and hazardous waste management is of particular concern (Nweke & Sanders, 2009).

Effects of socio-economic factors on household hazardous waste (HHW) generation

Results of the effects of socio-economic factors such as dwelling type, income, household size, sex, etc on HHW generation are presented in Table 3. It can be deduced from Table 3 that

Table 3: Relationship between HHW and Dwelling types in Enugu Metropolis

Dwelling type	Abapka	Achara	Iva-Valley	Asata	Awkunanaw	G.R..A	Ind layout	New Haven	Ogui	Uwani	Total %
Multiple Rooms	10 (33.3%)	10 (33.3%)	9 (26.7%)	9 (26.7%)	0 (0.0)	3 (10%)	1 (3.3%)	15 (50%)	13 (43.3%)	18 (60%)	93 (31%)
Multiple Storey	5 (16.7%)	6 (20%)	7 (23.3%)	7 (23.3%)	0 (0.0)	0 (0.0)	1 (3.3%)	3 (10%)	0 (0.0)	6 (20%)	35 (11.7%)
Two Bedroom	0.0	2 (6.7%)	6 (20%)	3 (10%)	16 (53.3%)	0.0	0.0	3 (10%)	5 (16.7%)	3 (10%)	35 (11.7%)
Three Bedroom	15 (50%)	9 (26.7%)	3 (10%)	7 (23.3%)	14 (46.7%)	12 (40%)	4 (13.3%)	7 (23.3%)	12 (40%)	3 (10%)	85 (28.3%)
Duplex	0.0	4 (13.3%)	0.0	4 (13.3%)	0.0	15 (50%)	24 (80%)	2 (6.7%)	0.0	0.0	52 (17.3%)

households live in multiple rooms generated the most HHW 31%, followed by three-bedroom flats 28.3% and Duplex 17.3%. Households that live in multiple-storey and two-bedroom flats had generated the least HHW 11.7%. Income is a key determinant of any household expenditure, such as the purchase of household hazardous products (Figure 14). As shown in Table 4 the estimated per capita income per month ranges from 5,000 naira to 250,000 naira and above monthly.

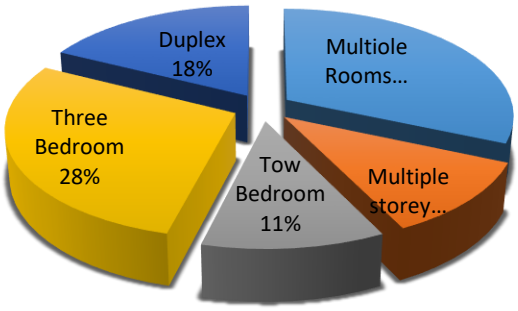

Figure 14: Dwelling types and % of HHW Generation

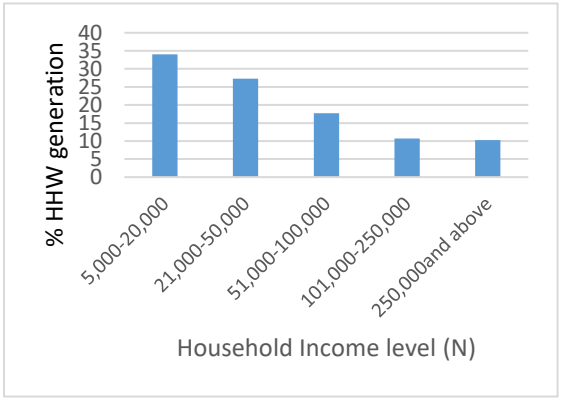

Figure 15: Mean monthly Income and % of HHW Generation

Table 4: Relationship between HHW Generation and Income in the Study Area (Monthly)

Income	Abakpa	Achara	Asata	Iva-Valley	Awkunanaw	G.R.A	Ind. layout	New Haven	Ogui	Uwani	Total (%)
5,000 - 20,000	15 (50)	2 (6.7)	12 (40)	12 (40)	11 (36.7)	3 (10)	0.0	18 (60)	12 (60)	11 (36.7)	102 (34)
21,000 - 50,000	10 (33.3)	4 (13.3)	6 (20)	12 (40)	9 (30)	9 (30)	4 (13.3)	6 (20)	12 (40)	10 (33.3)	82 (27.3)
51,000 - 100,000	5 (16.7)	12 (40)	7 (23.3)	3 (10)	7 (23.3)	3 (10)	7 (23.3)	6 (20)	0.0	3 (10)	53 (17.7)
101,000 - 250,000	0.0	8 (26.7)	5 (16.7)	0.0	3 (10)	9 (30)	4 (13.3)	0.0	0.0	10 (33.3)	32 (10.7)
250,000 and above	0.0	4 (13.3)	0.0	3 (10)	0.0	6 (20)	15 (50)	0.0	0.0	11 (36.7)	31 (10.3)

From Table 4 and Figure 15, we can deduce that HHW was generated most by those households that earn between, 5,000 naira-20,000 naira 34%, followed by 21,000-50,000 naira 27.3% and 51,000-100,000 naira 17.7%. While the HHW was least generated by those that earn between 101,000-250,000 10.7% and 250,000 and above 10.3%. The impact of household size on HHW generation is such that it determines the rate of consumption of household hazardous products. The distribution of the number of people living in a household is shown in Table 5.

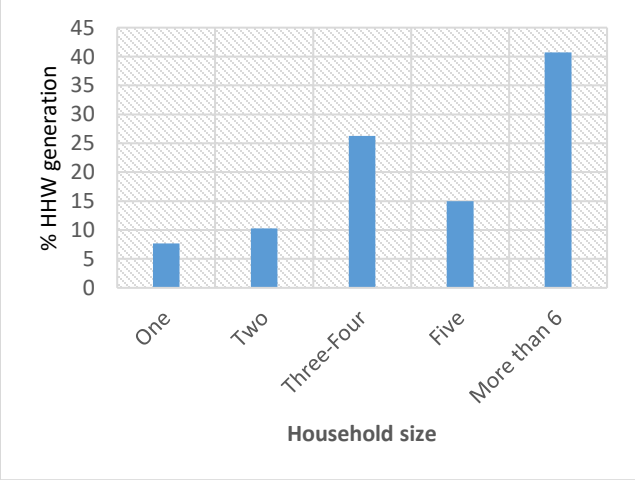

Figure 16: Household size and % of HHW Generation

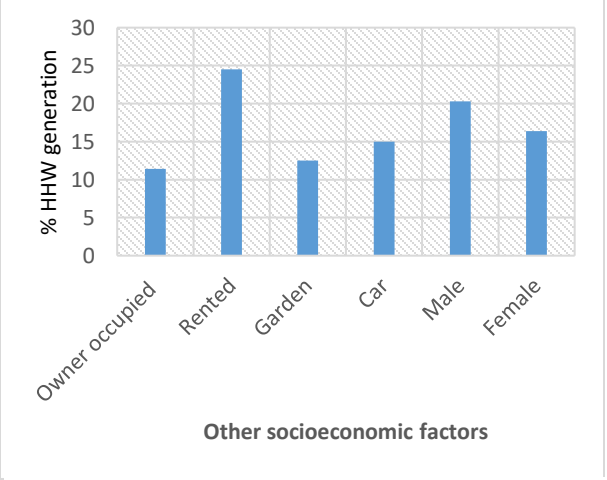

Figure 17: Other socio-economic factors and % of HHW Generation

Table 5: Relationship between HHW and Household Size Distribution in the Study Area

No of people in the household	Abakpa	Achara	Asata	Iva-Valley	Awkunanaw	G R A	Ind layout	New Haven	Ogui	Uwani	Total (%)
One	5 (21.7)	5 (21.7)	3 (13.0)	6 (26.1)	4 (17.4)	0.0	0.0	0.0	0.0	0.0	23 (7.7%)
Two	5 (16.7)	4 (13.3)	3 (10)	3 (10)	0.0	3 (10)	2 (6.7)	3 (10)	5 (16.7)	3 (10)	31 (10.3%)
3-4	15 (50)	6 (20)	9 (30)	9 30	8 (26.7)	3 (10)	8 (26.7)	3 (10)	12 (40)	6 (20)	79 (26.3%)
Five	0.0	9 (30)	3 (10)	2 (6.7)	8 (26.7)	9 (30)	2 (6.7)	6 (20)	0.0	6 (20)	45 (15%)
More than 6	5 (16.7)	6 (20)	12 (40)	10 (33.3)	10 (33.3)	15 (50)	18 (60)	15 (50)	13 (43.3)	15 (50)	119 (40.7%)

In Table 5 and Figure 16, households that have more than six people living in their household generate the highest frequency of HHW 40.7%, followed by 3-4 persons per household 26.7%. The least HHW were generated by households having one person 7.7%. Other socio- economic parameters that influence HHW generation in the study area include ownership of building the household occupied, if they own cars and gardens and their gender. These are shown in Table 6 and Figure 17.

Table 6: Influence of other Socio- Economic Parameters on HHW generation

Parameters	Abakpa	Achara	Asata	Iva-Valley	Awkanana w	G R A	Ind Layout	New Haven	Ogui	Uwani	Total %
Owner occupied	10 (10.8)	13 (43.3)	6 (20)	9 (30)	4 (13.3)	9 (30)	18 (60)	6 (20)	8 (16.7)	10 (33.3)	93 (11.4%)
Rented	20 (66.7)	17 (56.7)	18 (60)	21 (70)	26 (86.7)	21 (70)	12 (40)	24 (80)	22 83.3	20 (66.7)	201 (24.5%)
Garden	10 (33.3)	6 (20)	12 (40)	12 (40)	15 (50)	18 (60)	14 (46.7)	3 (10)	12 (40)	0.0	102 (12.5%)
Car	10 (33.3)	10 (33.3)	12 (40)	9 (30)	9 (30)	21 (70)	22 (73.3)	6 (20)	12 (40)	12 (40)	123 (15.0%)
Male	15 (50)	16 (53.3)	12 (40)	21 (70)	15 (50)	18 (60)	18 (60)	21 (70)	12 (40)	18 (60)	166 (20.3%)
Female	15 (50)	14 (46.6)	18 (60)	9 (30)	15 (50)	12 (40)	12 (40)	9 (30)	18 (60)	12 (40)	134 (16.4%)

From Table 6 households sampled that live in rented buildings, generated more HHW 24.5% than 11.4% of households who own the buildings they occupy. Two of the main groups of HHW *i.e.* motoring products and household garden chemicals are largely influenced by the number of households that possess a car and a garden. Households that have gardens generated 12.5% of HHW, while households that have cars generated 41% of HHW in the study area. Most people that have gardens are located at G.R.A while most people with cars are found in Independence Layout. These layouts from

our spatial analysis generated the most HHW. Finally 20.3% of the sampled households were males while the females were 16.4% that generated HHW.

Table 7 and Figure 18 shows, the temporal frequency of HHW generation among the different layouts in the study area. It can be observed from the table that the household generated and disposed HHW highest in less than three months (79.3%) against more than three months (13%), and unknown (6.7%). This implies that the temporal frequency of generation of HHW in the study area is very high. Therefore there is an urgent need to properly manage HHW in the study area. The frequency of disposal methods of HHW in Enugu Metropolis were also analysed and is as shown in Table 8 and Figure 19.

Table 7*:* No. of Respondents on HHW Generation Frequency in Enugu Metropolis

Temporal frequency	Abakpa	Achara	Asata	Iva-Valley	Awkunanaw	G.R.A	Ind. Layout	New Haven	Ogui	Uwani	Total (%)
< 3months	14	24	30	22	22	24	30	26	20	26	238(79.3%)
> 3months	7	2	0	5	6	6	0	3	6	4	39(13%)
Unknown	9	3	0	3	2	1	1	1	2	1	23(7.7%)

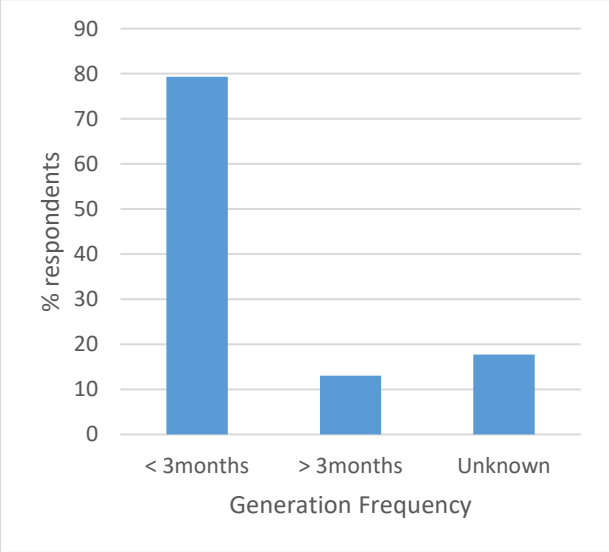

Figure 18: Frequency of HHW Generation

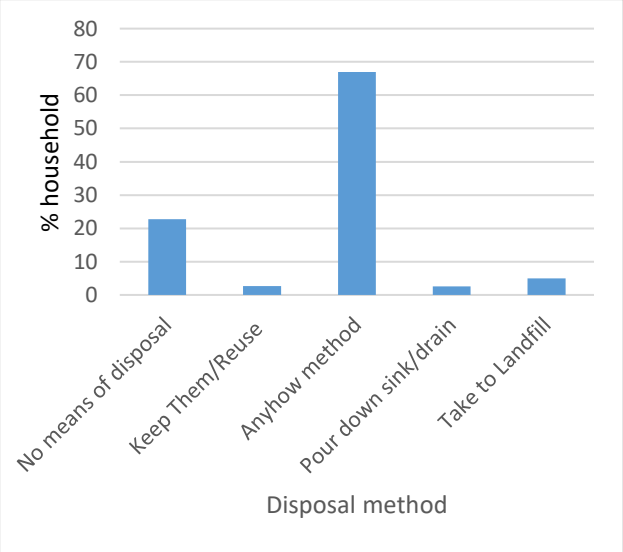

Figure 19: Household HHW disposal methods

Methods of household hazardous waste (HHW) disposal

From our analysis, 22.7% of the households indicated that they do not have means of disposal, 2.7% indicated that they keep them/reuse and this can pose a problem to their health and the environment, 2.6% pour liquid HHW down their sinks or drains, 5% take them to a landfill site, the remaining 67% dispose of them in any available space (Figure 19). In similar studies, Achankeng (2017) and Fazzo et al., (2017) reported that in most African cities, less than 20% of urban waste is disposed of in landfills, while the remaining waste ends up in illegal dumps.

Table 8: Frequency of Disposal Methods in Enugu Metropolis

Frequency of Disposal Methods	Abakpa	Achara	Asata	Iva-Valley	Awkunanaw	G.R.A	Ind. Layout	New Haven	Ogui	Uwani	Total (%)
Do not have means of disposal	10	5	7	10	8	3	2	10	5	8	68 (22.7%)
Keep Them/Reuse	0	0	0	2	5	0	1	0	0	0	8 (2.7%)
Anywhere/anyhow disposal	15	20	20	18	15	25	26	20	20	22	201 (67%)
Pour down sink/drain	5	0	3	0	0	0	0	0	0	0	8 (2.6%)
Take to landfill site	0	5	0	0	2	2	1	0	5	0	15 (5%)

A variety of studies have reported on the environmental effects of the use of open-air burns to control waste levels at disposal sites (Omran & Gavrilescu, 2008; Al-Khatib et al., 2010; Taboada-Gonzalez et al., 2010; Vuai, 2010). This practice promotes the harmful effects of HHWs and other materials, which by themselves do not substantially affect the environment upon disposal. One case was presented by Nnorom and Osibanjo (2009), who indicated that if the plastic casing of mobile phones is adequately treated, it is possible to avoid all immediate dangers associated with the end of its lifespan. However, considering the large quantity generated and inadequate management practices (such as open-air burns), a genuine concern is present regarding environmental contamination and human toxicity. The result in Table 8 also indicates that the awareness and usage of dust bins were the highest while keeping them was the lowest. Although in Enugu Metropolis there are no facilities for handling HHW, it is therefore a contributing factor to the low awareness of HHW management in Enugu Metropolis.

In Enugu Metropolis, the current HHW disposal methods are bagging of wastes, use of Dump-stars and the landfill. Bagging of waste involves throwing the waste into bags before they are put into the dump- stars. The dump-stars are big metal buckets with lids and the bagged wastes are thrown into them, (Plate 1). Dump stars are found around major streets and roads in the Enugu Metropolis. Areas that are densely populated usually have more than two dump-stars. ESWAMA has no separate disposal facilities for handling HHW. ESWAMA collects the HHW together with other household wastes and throws them into the dump-stars. The dump stars, when filled with waste, are then emptied into tippers that would transport them to the landfill and dispose of them there. Presently, only one municipal solid waste landfill exists in Enugu Metropolis and it is sited at Ugwuaji, off the Enugu-Port Harcourt expressway (Plate 2).

Plate 1: ESWAMA Dump-stars in Enugu Metropolis

Plate 2: The Ugwuaji Landfill Site for Enugu Metropolis

From our study, it was discovered that Enugu State has no hazardous waste landfill. The available landfill does not possess features of a modern landfill like natural and synthetic liner systems, monitoring programmes, leachates, etc. At Ugwuaji landfill, the wastes are being sorted and recyclable

materials such as plastics, bottles, metals etc, are recovered by scavengers for recycling. They are transported to Lagos, Onitsha and Nnewi towns for recycling. The above finding conforms to another study by Mmereki et al., (2014) that in most African countries, inadequacies of the policy frameworks include a lack of capacity and governance; fewer resources available to deal with environmental health issues arising, limited expertise and knowledge on HHW management technologies, inappropriate HHW classification and characterization and municipalities have not created their own HHW database. On the other hand, developed countries have dedicated substantial economic resources to regulate the production, treatment and disposal of HHW (Kummer, 2000).

Problems of Household Hazardous Waste (HHW) Disposal and Handling

From our survey on problems of improper disposal and handling of HHW, we can deduce from Table 9, that the major problem that households face is a lack of knowledge of HHW (44.3%). Most people do not even know they are hazardous and need to be handled with care and not disposed of with other household wastes. Some respondents (24.3%) adduced it to poor awareness and attitude to HHW; 19.3% blame the problem on the use of inappropriate dustbins, while 15.3% believe that lack of time to sort out the wastes, is part of the problem.

Table 9: Problems of HHW Disposal and Handling in Enugu Metropolis

Problems of HHW disposal	% respondents
Poor awareness and attitude	24.3
Lack of knowledge	44.3
Lack of time to sort	15.3
Inappropriate waste bins	19.3

Source:Field Work, (2019)

This above observation is in agreement with the findings of Egwu (2008) who stated that the problem with the management of HHW in Enugu Metropolis can be adduced to low level of public awareness and co-operation, and lack of recycling activities in the state. In another study, Ojeda-Benitez, (2013) found that the generation of HHW has grown more in urban areas which is recognized by high population growth. This increases the difficulties encountered in handling, collecting and final disposal because of the shortage of financial resources, administrative capacities, infrastructure, and necessary equipment. An alarming increase in MSW with its HHW component associated with the ineffectiveness of SWM accompanied by a change in purchasing habits will make a serious problem and risk. Mmereki et al., (2016), also confirmed that in the African context, the management of household hazardous waste (HHW) is becoming a major cause of concern in the twenty-first century. Currently, there is no segregation of household hazardous wastes and a consistent policy framework specifically dealing with HHW regulation in Africa and a significant proportion of these wastes are generated from daily residential life (Mmereki et al., 2016). In Nigeria, Agumbnwamba, et al., (1998) found that many Local Government Areas lack the capacity to meet infrastructural services for waste generation in rapidly growing areas.

Conclusions

The HHW generated in Enugu Metropolis were classified into eight, they include paints, garden chemicals, batteries, motoring products, medicines, home cleaning products, e-waste and household glasses. Results of spatial distribution of HHW show that G.R.A generated highest quantity of HHW, followed by New Haven. While Asata, Awkunanaw, and Achara Layout, generated the least quantities. Home cleaning products was commonly generated among the different sampled HHW types, followed by household glasses. The least frequently generated HHW were motoring products and paints. Similarly, buildings with multiple rooms generated the highest, followed by three-bedroom apartments. This coincides with household size, which has a household size of above six generating the highest quantity. More so, lowest income earners were known to generate the highest quantity. The above finding depicts the general low level of awareness of the impact of HHW. The study showed that 33% of the

households do not have a means of disposing of HHW, while the remaining 67% dispose of them in anyhow, any available space.

Conflicts of interest

The authors declare no conflicts of interest.

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