IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 10, Issue 2 Ver. I (Feb. 2016), PP 34-43
www.iosrjournals.org

Residential solid waste management in cities with developing economies: case study of Yaoundé, Cameroon.

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Abstract: *Rural exodus together with high birth rates and migration brings about a significant increase of urban population. Rapid urban population growth and urban development usually lead to environmental challenges, as increase in population density eventually causes major increase in quantity of waste produced. The management of waste has always been a tremendous challenge, especially in developing nations, where there is usually inadequate data on the quantity and quality of waste produced. The production and the management of solid domestic waste were studied in Yaoundé (Cameroon). The waste collected from the study site by the waste management company and at household levels were analysed, its quantification was done by collecting, sorting and weighing various categories.*

It was found that the per capita daily production of solid wastes varied from 0.36 Kg in poorer (unplanned settlements), to 0.56 Kg in well laid out areas (planned). About 77 % of the total waste produced is biodegradable.

Due to the poor accessibility of some parts of the town, about 33 % of waste generated in the study area is not collected by the waste collection company and is dumped into streams and canals then leads to clogging.

Keywords: *Characterization, Developing economies, Generation, Management, Waste*

I. Introduction

The rapid urbanization observed over the last century, has virtually transformed the world into communities of cities and towns that face similar challenges of waste management [1]. [2] Identified two major factors making waste management challenging. Firstly, waste management involves a large number of different stakeholders, with different conflicting interests. Often, waste management is the sole responsibility of the municipal authorities and hence most stakeholders are not involved in waste management. Secondly, solid waste management is a multi-dimensional issue. An effective system is not only based on technological solutions but also on environmental, socio-cultural, legal, institutional and economic linkages that should be present to enable the overall system to function. The lack of participatory management and holistic considerations most often result in ineffective systems of waste management.

According to [3], as long as humans are living in settled communities, solid domestic waste generation will always be an unavoidable and decisive issue both in developed and developing nations. Waste is a pejorative term for unwanted materials. According to [4] "waste" can be defined as any residue from a production, processing or utilization process, any movable or immovable good abandoned or intended to be abandoned. Despite the existence of waste collection companies in developing countries, the issue of waste management in towns most often remains the concern of households in municipalities. As this becomes an individual's problem, people seek individual options, making use of limited, short term and most often inadequate solutions. The most common practices are, the evacuating or dumping of waste in drains before or during rain events [5], open dumping, dumping in valleys, night dumping... Some reasons that lead to such practices are: little or no availability as well as poor distribution of skips, poor road infrastructure and poor settlement configuration.

Some studies have been carried out in the town of Yaoundé, mainly in the bulk production of wastes by [6], [7], and [8]. They found that Yaoundé produces about 840 tons of solid domestic waste daily. According to [9], households produce most (86%) of these wastes in Yaoundé. However, these bulk values are not very useful in waste management planning, as the specific household production is not known. Neither is the composition of the waste nor the waste management practices of producers. In order to determine the capacity of solid waste management facilities, it is important to determine the per capita production. More accurate assessment of the quantity will be obtained if data is available on the per capita waste generation as a function of settlement types. Knowing the proportion of different settlement types and the per capita waste produced will result in a more

accurate assessment of the quantity of waste generated and hence this will facilitate planning. The composition or characterization of waste is important in determining the appropriate waste management alternatives. The aim of this paper is to analyse household waste production and management in Yaoundé as a contribution to the development of a sustainable solid waste management plan. More specifically it will be to:
a) Determine the daily per capita waste generated as a function of settlement types in Yaoundé;
b) Assess the composition of wastes produced in the various settlement types and
c) Analyse the waste disposal behaviour of the households.
This study will as such permit to bring forth more information on elements necessary for an effective waste management planning.

II. Methodology

Presentation Of The Area Of Study

Yaoundé is the administrative and political capital of Cameroon, located between latitudes 3^o 47'-3^o 56' North and longitudes 11^o 10'-11^o 45' East (Fig 1). The study site selected in Yaoundé is one of the sub-drainage basins in Yaoundé called Abiergué. The hydrography of this basin (Fig 2) shows a stream of the third order on Strälher-horton classification with an average bifurcation ratio of 3.7 and drainage density of 1.58km/km^2 [10]. The stream flows south – west, on a distance of about 8 km, towards the Mefou River that it joins at the Nkolbisson district [11], [12].This area was chosen because it contains all the different settlement patterns found in the city and encloses as well residential, commercial and administrative districts. The relief of the study area also has the main features found in Yaoundé which is that of hills, low lying areas with swamps etc. The population of the study area is estimated to be 201 677 inhabitants, with a growth rate of about 3.1% [13]. This rapid increase in population pushes people to seek and occupy land, in risky areas (steep slopes, valleys) of existing districts. Yaoundé is a highly cosmopolitan city regrouping most of the ethnic groups of Cameroon.
The average altitude of the city is estimated at 726 m with a surface area estimated in 2012 at 136.14 km^2. Yaoundé has witnessed a very rapid growth estimated at over 3 % a year with a population estimated at 1 881 876 inhabitants [14].

Source: adapted from [15] Source: [10]
Figure 1: location of the study zone

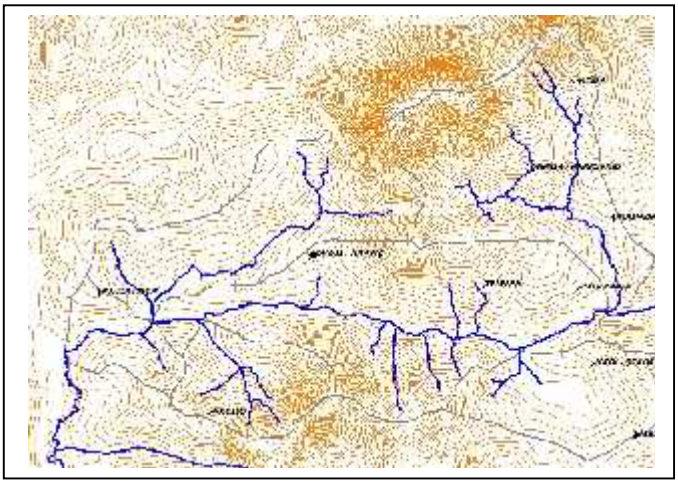

Figure 2: drainage pattern in the study area

The rainfall pattern in Yaoundé is bimodal with two dry seasons and two wet seasons. The average annual precipitations are about 1600 mm [16]. The inter-annual average monthly temperatures vary from 22.4 ^{o}C and 25.7 ^{o}C with 1500 – 1750 hours of annual sunshine [17]. The hydrographic network of the city is very dense with numerous drainage sub-basins. These ensure that the natural drainage of the city is very good [16], especially as the city has been built on seven hills.

Households And Housing Structure

Just like the majority of the towns of tropical Africa, Yaoundé for the past four decades has known a rapid growth [18]. Unfortunately, the absence of a coherent urban policy has led to uncontrolled urbanization.

Yaoundé is characterized by the presence of structured and spontaneous settlements [13]. Spontaneous districts are characterized by poorly constructed houses which are much closed one from the others and relatively average road conditions. The density in these districts varies but could be as high as 320 pers/ha.
Structured districts have a moderate population density of about 200 inhabitants/ha. These districts are usually characterized by buildings of very good quality (with permanent construction material being used for the construction purpose) and good road configurations (nature and size). The study area is drained by the principal stream from which its name was derived: "*Abiergué*"...

Data Collection And Analysis

Household Level

Three hundred and seven households were selected from the various districts within the study area, based on a stratified random sampling scheme and interviewed on various aspects of the production, transport and disposal of solid domestic wastes. The technique consisted of dividing the population in homogenous groups called strata that were mutually exclusive from which independent samples were chosen [19]. It is a probabilistic sampling which gives every member of the population within each stratum, equal chances of being selected, hence increasing objectivity and reducing bias. The sample size allocations for each neighborhood during the survey were done with respect to the population size of these respective neighborhoods. The sampling strategy is as presented on TABLE 1

Table 1: Sample strategy in the study area

District	**Population in 2013**	**Number of HH district^{-1}**	**Redistribution of the SS district^{-1}**
Cite Verte	21312	9	7
Nkolbisson	4082	3	6
Oyomabang	21913	9	8
Total for Structured HH	47307	21	21
Madagascar	13853	6	6
Melen	24601	10	8
Messa	29793	12	10
Mokolo	17773	7	8
Nkolbikok	10673	4	6
Carriere	29890	12	10
Nkolso	1497	1	6
Etetack	26290	11	9
Total for Spontaneous HH	154370	63	63
Total	201677	84	84

Note : HH = household.

The districts were selected based on two principal criteria: household density and state of the road, following the sampling procedure proposed by [9].

Households from the various strata and aimed for interview were selected randomly. A questionnaire was administered to each household together with a pair of plastic bags (capacity 50 liters) of two different colors for the sorting and collection of biodegradable and non-biodegradable wastes The plastic bags were coded to match with the corresponding questionnaire from the household under investigation. In order to improve the return rate according to [9], it was made anonymous and self-administered. To ensure the reliability of the data collected on the field, preliminary meetings were held with the local administrators of the questionnaires to clarify the work to be done and recall the objectives. The administrators were multi-lingual (English, French, Pidgin English and even local languages) to ensure the effectiveness of the quantification together with the data gathering from questionnaire, and considering the high number of household to monitor the questionnaires and the waste bags were both collected after three days. According to [9], this period corresponds to the maximum duration a household could tolerate keeping domestic waste. After collection, the biodegradable and non-biodegradable wastes were weighed separately. The non-biodegradable wastes were sorted and the various components weighed with a high precision electronic spring balance. The data collected were analyzed with Microsoft *Office Excel 2007*.

Basin and City Level

The waste produced from individual households was extrapolated to obtain the total waste generated in the study site. In order to assess the amount of solid domestic waste dumped in nature, the quantity collected by the waste collection company (HYSACAM) was determined and deducted from the total production. To get the amount of waste collected by the waste collection company, their trucks were monitored over a period of three

weeks. The truck weights were obtained from the weighbridge station at the entrance of the dumping site. The mean value was used to determine the daily weight of solid domestic waste disposed out of skips.

III. Results and Discussion

The Settlement Pattern In Yaoundé

The study area comprises of 11 districts characterized by two main types of settlements structured or planned settlement and spontaneous or unplanned. In the first type of settlement, the houses are well laid out and is characterised by, presence of drainage canals, accessibility by road and relatively low house density. The second type is characterized by haphazard construction of houses, few or no drains, poor accessibility by road and a relatively high house density. The variations in the house density and road accessibility are presented in TABLE 2.

Table 2: Settlement characteristics of the districts found within the study area

District	District type	(Household per ha)	House density	Road accessibility
Cité-Verte	Structured	15	(Low)	Good
Nkolbisson	Structured	19	(Average)	Good
Oyomabang	Structured	24	(Average)	Average
Average	*Structured*	*19*	Low to average	Average to good
Etetack	Spontaneous	30	(High)	Poor
Melen	Spontaneous	35	(High)	Average
Messa	Spontaneous	32	(High)	Poor
Nkolso	Spontaneous	13	(Low)	Poor
Nkolbikok	Spontaneous	14	(Low)	Average
Mokolo	Spontaneous	33	(High)	Average
Carrière	Spontaneous	32	(High)	Average
Madagascar	Spontaneous	37	(High)	Average
Average	*Spontaneous*	*28*	Low to high	Poor to average
Average	*Both district type*	*26*		

The area of study was as such grouped into: 1) structured low house density; 2) structured medium house density; 3) spontaneous high house density and 4) spontaneous low house density and it is on this basis that the methodology, results and discussions were carried out.

TABLE 1 show that the study area is composed of mostly spontaneous districts (73%) of high density (more than 30 households per hectare) with average to poor road accessibility. Nkolso and Nkolbikok where the density is low, corresponds respectively to hilly and wetland areas in the area. The difficulty in accessing the different districts by roads by the waste collection companies justify the high rate of unauthorised dumping of domestic wastes.

Waste Generation

Waste production in the basin varies with: types of settlement and population density (TABLE 3). The household daily production in structured settlements varies from 2.08 kg per day in Nkolbisson to 3.61 kg per day in Cité Verte with an average of 2.70 kg per day. In spontaneous districts the production varies from 1.71 and 2.87 kg per day with an average value of 2.30. This difference in amount produced per household could be justified by the socio-economic context. Indeed, in structured districts the purchasing power is significant compared to spontaneous districts.

Despite the fact that the specific production as illustrated on TABLE 3 is smaller than the mean value (0.75) in Yaoundé [7], these values show that inhabitants in structured districts produce 50% more wastes than those in poor spontaneous districts.

Table 3: Amount of waste produced per capita in Yaoundé

District	Total production (kg per day)	BD	NBD	Specific production (kg per capita per day)	Household production (kg per household)	Total Production in study area (kg)
Carrière	10 462	239	64	0.35	2.20	**80 867**
Cite Verte	13 000	275.2	82.3	0.61	3.61	
Etetack	8 939	209.4	77.9	0.34	2.39	
Madagascar	5 126	137.9	43.1	0.37	2.87	
Melen	9 840	202.4	55.6	0.40	2.32	
Messa	10 130	187	43.3	0.34	1.71	
Mokolo	7 109	133.7	53.7	0.40	2.31	
Nkolbikok	4 162	86.8	28.3	0.39	2.40	
Nkolbisson	1 918	33.3	10.1	0.47	2.41	
Nkolso	539	11	2	0.36	2.17	
Oyomabang	9 642	161.5	50.2	0.44	2.08	
Total	80867	1677.2	510.5			
Proportion (%)		**77%**	**23%**			
Average for spontaneous settlements	**7038.38**			0.37	2.30	
Average for structured settlements	**8186.67**			**0.51**	**2.70**	
Average for the basin	**7 351**			**0.41**	**2.41**	

Note : BD = biodegradable NBD= non-biodegradable

Globally, the household production in the study area is about 81 tons per day. From this amount, just about 32 tons (40%) of solid domestic waste are collected daily by the waste collection company (HYSACAM). This implies that 60% are left in nature.

Characterization Of Wastes

As it is shown on TABLE 3, 77% of wastes produced in the area of study is essentially organic, mostly constituted of food remains and green wastes (leaves of trees and plants). The rest (approximately 19 tons), is non-biodegradable.

An analysis of the non-biodegradable components obtained by weighing and converting the results as percentages of the entire non-biodegradable (Fig 3) revealed dominance of plastic materials (35%), glass (17%) and paper (14%). This plastic fraction is made up of plastic sheets, bottles, bags and buckets. These distributions are consistent with the findings of [20].

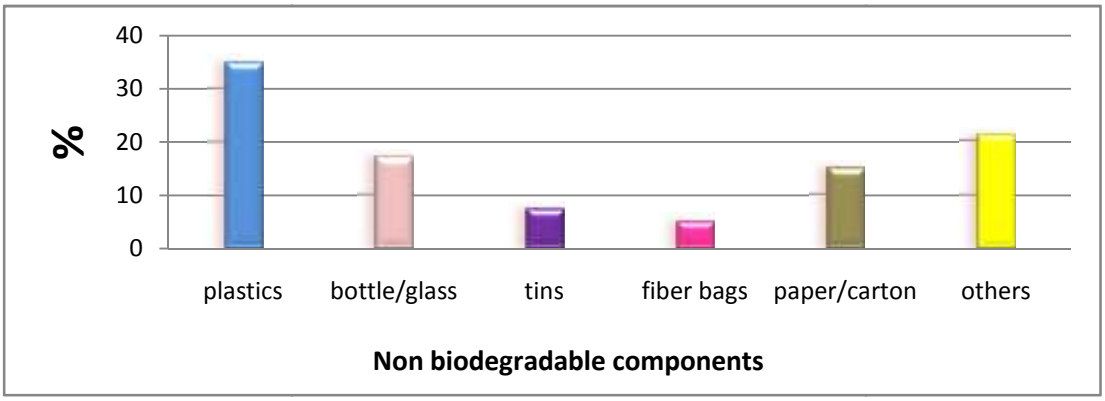

Figure 3: Composition and proportion of non-biodegradable wastes in Yaoundé

The **s**patial analysis of these non-biodegradable fraction illustrated in Fig 4, indicates that the plastic component is high in all the districts of the study area, with Mokolo, Nkolbisson, Madagascar, Oyomabang, and Nkolso being the highest producers (more than 40% plastic). These districts are mainly characterised by high population density and low road accessibility. The amount of bottles, glass, paper and cardboard are also high in all the districts. Fibre bags constitute the least dumped material meanwhile the high presence of plastic could be

justified by their low-cost in markets. From Fig 4, it is observed that the proportion of the different types of non-biodegradable waste is essentially the same irrespective of the type of settlement.

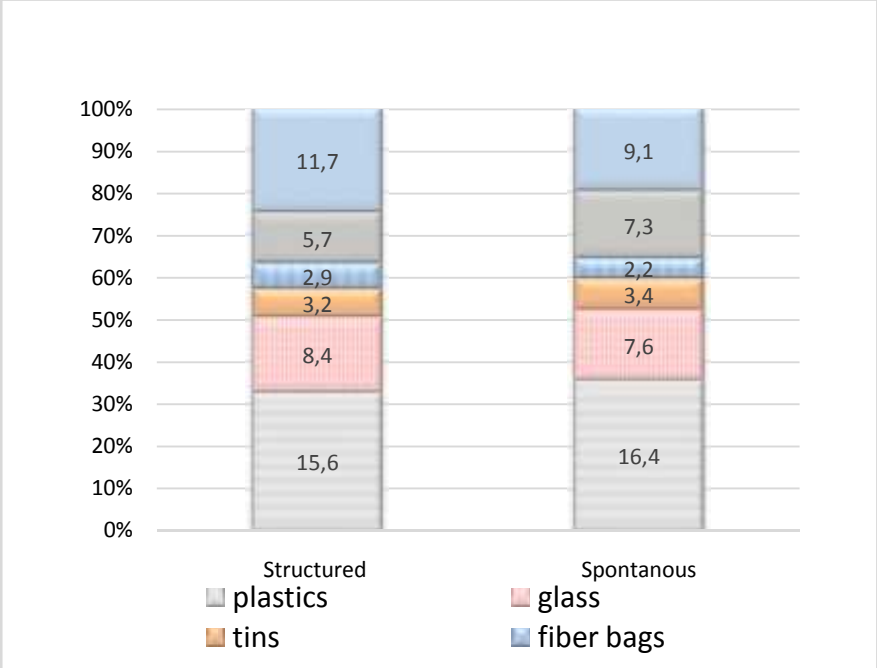

Figure 4: composition of non-biodegradable wastes in structured and spontaneous areas

Waste Handling And Transportation

At the household level, the management of waste mainly consist of disposing the wastes in a bin and after a certain period of time, it is either dumped in the HYSACAM's waste skips or at areas relatively far from their homes.

The collection of waste in the household is done with various materials, depending on its availability and durability. The materials used (as shown on TABLE 4), are plastics buckets (41.18%), fibre bags (28.91%), plastic bags (17.81%), cartons (6%) and metallic buckets (6%). The preference for plastic containers is due mainly to its affordability, availability, durability and ease of cleaning. Low risk of getting hurt when manipulating it is also a reason from the household point of view.

Table 4: Waste handling systems in different housing types

District	Plastic bag (%)	Plastic bucket (%)	Metal bucket or can (%)	Fiber bags (%)	Carton (%)
Carrière	26	28	7	30	9
Cite Verte	27	33	3	15	21
Etetack	16	42	0	39	3
Madagascar	15	25	15	35	10
Melen	26	26	17	31	0
Messa	12	31	12	40	5
Mokolo	13	43	9	30	4
Nkolbikok	13	44	0	44	0
Nkolbisson	20	60	0	20	0
Nkolso	0	100	0	0	0
Oyomabang	28	21	3	34	14
Average StS	25	38	2	23	11.67
Average SpS	15,13	42.38	7.5	31.12	3.87
Average for the basin	17.81	41.18	6	28.91	6

Where StS= structured settlements; SpS = Spontaneous settlements

On the other hand, households prefer using plastic bags, because they could discard the bags altogether with its content when wastes start to decompose. More-over, the closeness of the houses both in structured areas and spontaneous ones oblige the households to keep waste for the shorter period possible. Another reason for the choice of this material as trash cans was the fact that the materials are abundant in local markets and could as such be replaced easily and rapidly because of their availability and accessibility [21]. Within the study area, it

is observed that the structured districts prefer the use of plastic bags (25%) compared to the unplanned settlements (15.13%). The plastic containers are light weight and hence easier to use to transport waste, they are durable and less expensive compared to metal buckets.

This notwithstanding, the choice of the rubbish bin (material of the bin) used for collecting the domestic waste is greatly influenced by the frequency of waste collection, storing and discarding.

Waste Removal Frequency

Different factors generally influence the rate of disposal of waste from households: the maximum capacity of the container; the distance from the skips; the nuisance from waste accumulation (smell, aesthetics and animals), biodegradability and the daily production. Households instinctively decide on the frequency based on those parameters. Fig 5 shows the waste disposal frequency in the study area.

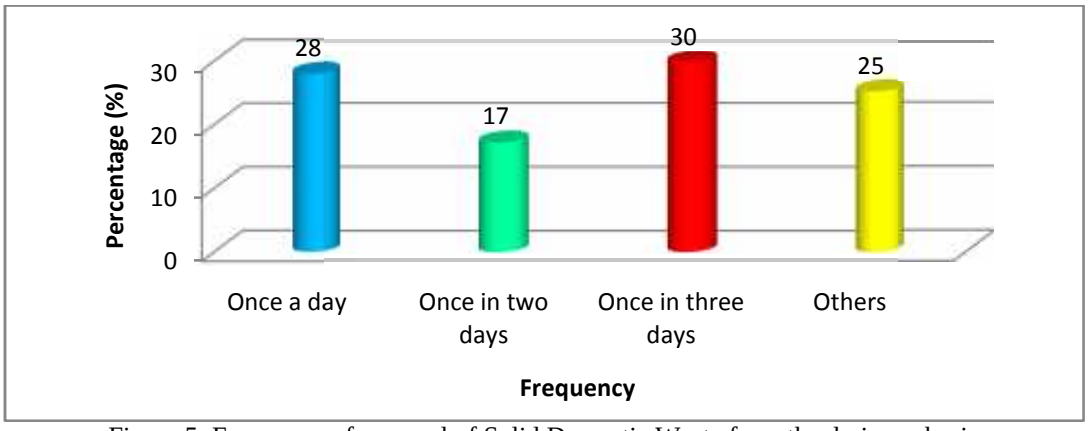

Figure 5: Frequency of removal of Solid Domestic Waste from the drainage basin

The term 'Others' represent those who had no specific period for dumping their waste

As far as waste discarding is concerned, it was observed that most of the districts in the area of study usually get rid of their waste generally once after every three days (Fig 6). It was observed that the most household that gets rid of their waste on daily basis where those found in structured districts. However some households in spontaneous districts equally got rid of their water on daily basis. These households in both structured and spontaneous districts were found to be in areas where the road condition (accessible) was pretty good. The districts concerned were: Cité Verte, Nkolbisson, Oyomabang, Melen, and Carrière.

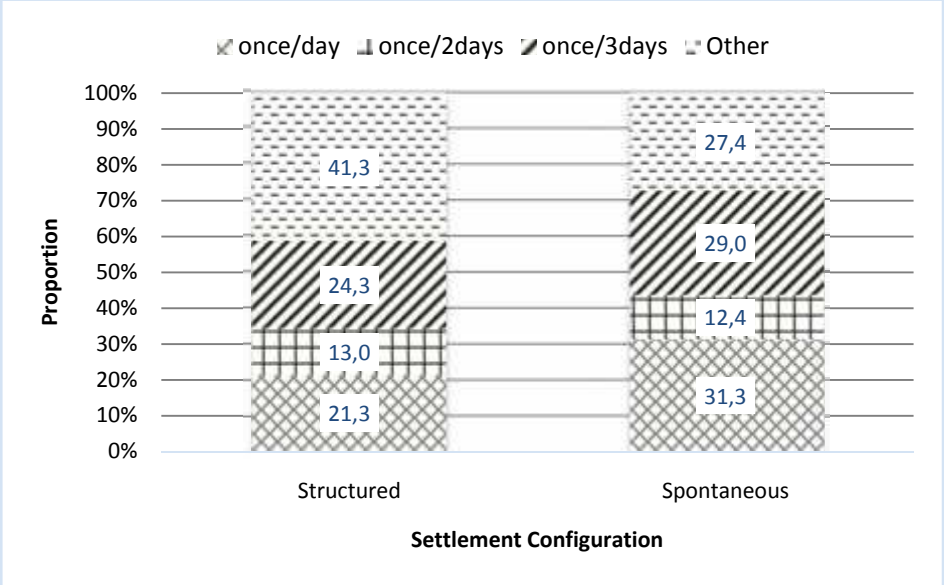

Figure 6: Frequency of removal of waste with respect to the settlement configuration

According to [9], the population of Yaoundé getting most often get rid of their waste once a day (54.1%), which differs from the situation in the study area, where just 26% of the population get rid of their waste once a day. This drop could be justified by the frequency of waste collection of the trucks of and the HYSACAM *door to door* operation. Indeed, the trucks of collect HYSACAM waste on a three day interval and

the door to door operation might have encourage some household to keep their waste waiting for the HYSACAM agents during this operation.

Disposal Of Uncollected Wastes

Though it is against law to dispose of waste improperly, the study revealed that about 60% of the households practise unauthorized dumping (most of which practice night dumping as the main way of getting rid of their waste). Analysis of these practices in the various districts revealed that most of these households (who practice unauthorised dumping) were living nearby the storm drainage system. So it was easier for them to discard their wastes in nature especially during rain events. Fig 7 shows the proportion of the population in various settlement configuration and district that dispose their wastes either in nature or place them at the disposal of HYSACAM

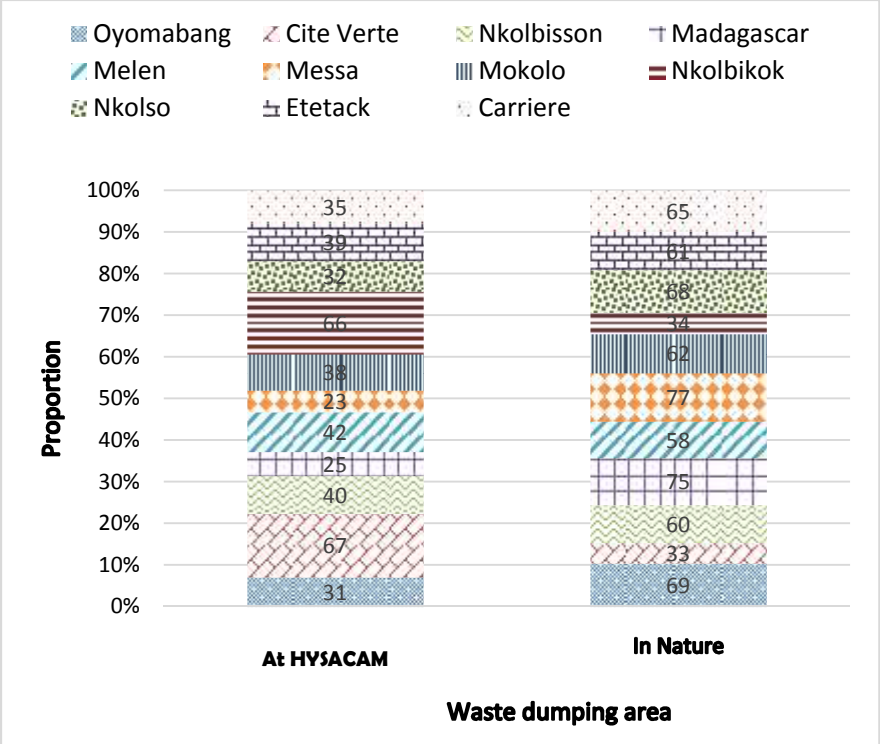

Figure 7: Waste disposal preferences of the population

In most of the districts of the study area, more than 60% of the households dispose their waste in nature, except Melen, Cité Verte, Nkolbikok where the uncontrolled waste discarding phenomenon is less. This is due to the good road network which provides adequate accessibility to the trucks of HYSACAM to go through and collect the various wastes. It was observed that the spontaneous districts were those with the higher proportion of unauthorised dumping, Madagascar, Oyomabang and Messa being the worst cases (more than 70 %), meanwhile on the other hand, Cité Verte was the district practicing the least. There could be as such a high potential in pre-collecting wastes in the spontaneous districts, particularly those with poor state of road infrastructure. In fact, most inhabitants that practice unauthorized dumping tend to justify their act by the distance of the various dumping sites and especially the weight of the waste they have to carry. As the biodegradable fraction of these wastes occupies more than ¾ of the total waste, a simple way to reduce the load to carry to the skips could be via pre-sorting of wastes at household levels, re-use of some materials if possible, and composting of the organic fraction. The used compost should be used to sensitize people on the valorisation of organic waste.

From Fig 8, the main disposals sites of unauthorized dumping were: valleys (32%), nearby bushes (25%), streams or lakesides (23%), open spaces (13%), and holes dug close to households (7%). Dug holes are classified here as being illegal because the waste dumped might contain heavy metals (from batteries or other sources) that might pollute the environment.

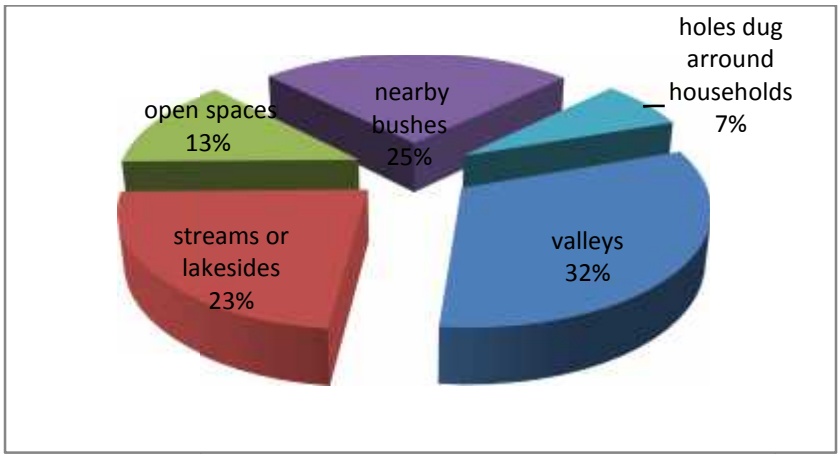

Figure 8: Dumping sites for unauthorized solid wastes in Yaoundé

Bushes, streams and valleys are the sites which are preferred by households to dump their wastes most often at night (night dumping). Wastes from unauthorized dumping sites usually end up in drainage channels which clog the canals and facilitate flooding in low lying areas of the city.

IV. Conclusion

Developing countries suffer from poor waste management systems which are worsened by rapid urban growth, slums settlements and poor road infrastructures. In order to resolve this, local governments often rely on sanitation companies who provide trucks for the collection of wastes.

However, there is usually inadequate data on the specific house production, which makes estimation of waste generation very difficult. As such sanitation companies most often rely on poor information for planning. At the end of this study, it was found that the daily per capita solid waste produced varied from 0.36 kg in unplanned areas to 0.56 kg in more to do and better structured districts.

Globally, households in the basin produce 81 tons of solid domestic waste daily, most of which (49 tons) is discarded in nature into the drainage system of the basin, leading to their clogging. This practice is widespread despite the action of the waste collection company in the basin. The waste discarding frequency is once per day or once each three days, depending on the purchasing power and household size. These wastes are mostly organic (77%) in nature, but the remaining fraction is made essentially of plastic, paper and glass material. The continuous act of dumping waste in nature encourages the growth of such materials in the environment thus contributing in degrading the environment and increases potential risks of flood events.

In order to minimize unauthorized dumping and improve waste collection and management, actions have to be taken by local government towards sound and appropriate environmental education and sensitization, as well as provision of local composting or pre-collecting services.

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