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Full Length Research Paper

Characterization of the household solid waste of the municipality of Abomey-Calavi in Benin

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Ever since the 1980-s the Municipality of Abomey-Calavi has known a strong population growth. This fast growth of its population engendered a number of problems in the field of management of household solid waste. This is proven by an increase accelerated by the production of this waste, the rarity of the free spaces and the absence of sites for final discharges of waste. From then on the study on the characterization of household solid waste of the municipality has become essential to put the bases for an effective management policy of this waste.We conducted a descriptive and analytical study. The method of sampling was of systematic random sampling. The size of the household sample was determined according to the daily average production of waste by household and by sector. The weight of waste to be sorted out was defined according to the standard recommended by MODECOM. The data collected were analyzed with the software SAS (Statistical Analysis System, 2006).The results from the characterization of the household solid waste showed that the waste production and the waste traits depend significantly on the sector of production and the season. The households of the municipality of Abomey-Calavi produce on average 0.71kg / inhabitant / day. The sorting was carried out on thirteen (13) categories recommended by the standard MODECOM. However some of them such as sanitary textiles, glass and sometimes hazardous waste are absent in rural areas. The most important categories of households waste in the municipality of Abomey-Calavi were in order: highly fine waste (70.57 %) the fine waste (14.38 %), putrescibles (10.18 %) and plastics (1.58 %).The study on the characterization of municipality waste also revealed it has a density of 0.36, average moisture of 16.13 % during the dry season and of 21.66 % during the rainy season, a calorific value lower than 1224.74kcal / kg and a C/N ratio which mostly varies between 8 and 9. From these results, the dumping processing coupled with the valuation of waste through recycling and composting would be the most adapted to the municipality of Abomey-Calavi for an effective and sustainable management of the household solid waste.

Keywords: Abomey-Calavi, characterization, household solid waste, waste management.

INTRODUCTION

Any inhabitant of the world who goes back a decade realizes that his consumption changed both from the quantitative as qualitative point of view. This increase in the consumption keeps pace with the production of waste. Actually the population growth coupled with an accelerated exploitation of the resources and the intensification of the human activities are several factors which explain the increase of the production of waste.

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According to Beede and Bloom (1995), every rise of 1 % in population growth triggers an increase of 1.04 % in production of waste.

With an exponential increase of the production of waste worldwide, the question of waste begins by firmly raising the awareness in front of environmental and sanitary problems. In the developed countries this issue is raised less. This is understandable by the fact that they have access to qualified financial and human resources which they dedicate to an effective management of waste (Gbinlo, 2010). In these countries, waste is transported towards wastage places for valuation. At the same time, in developing countries and especially those of sub-Saharan Africa, the situation is worrisome notably because of the considerable delay observed in this particular field. It is due to the lack of means and to the difficulties for these countries to approach the question in a manner suitable for their context (Ben Armmar, 2006).Their mode of management mostly remains traditional. Waste is evacuated on the wild garbage dumps. This way of managing waste entails enormous risks on the environment and consequently on the health of the populations.

As one of these countries, Benin presents similarities. In all its municipalities waste is evacuated in nature on garbage dumps installed near houses, in streets and on empty spaces. But starting a few years ago the municipalities of Cotonou and Porto-Novo have tried hard to implement a more effective management of their waste by creating centers of technical burying. Among the municipalities of Benin, the one that worries most is the municipality of Abomey-Calavi. This municipality which is second most populated after Cotonou does not still settle infrastructures (grouping points, garbage tanks, intermediate and final discharges), which have to allow it to face the issues connected to the management of waste and the instability spread in this municipality (Yêmadjè, 2009). Even if transitory, these devices will allow us to minimize the impacts of the anarchy discharges and to limit their harm on the public health and on the environment. Furthermore, at the moment when the waste management has to join from now perspective of a sustainable development – whose basic principles put forward a viable environment (costs of degradation of the environment), a preservation of the natural capital (ecocompatible discharges) and the biodiversity -measures for a better waste management did not have the upper hand over the practices of the traditional management means in the municipality of Abomey-Calavi. In this rapidly expanding demographic municipality, the totality of waste is evacuated on deserted garbage dumps created almost everywhere or by NGO-s of pre-collection which have no place where to discharge the garbage, or by the very populations (Dossou, 2005). Besides, the slums which are natural receptacles of rainwater are filled by waste, triggering floods (Yêmadjè, 2009). Also, the burning of waste and the traditional burying are common practices. These various practices represent sources of environmental and sanitary pollution. Facing this situation, the search for sustainable and adequate solutions for the management of domestic waste is necessary in the municipality of Abomey-Calavi.To meet a rational and sustainable management of the waste of this municipality it is then essential to have real data of characterization of waste. The present article aims at contributing to the adoption of a more effective management policy of waste in the municipality of Abomey-Calavi by supplying data on the production of domestic solid waste in this municipality and its characteristics.

Study area

Abomey-Calavi's municipality is situated in the southern part of Benin and in Atlantic Ocean department. It is limited in the North by Zè, in the South by Atlantic Ocean, in the East by Cotonou and So-Ava municipality (Coast), in the West by Ouidah and Tori-Bossito municipalities of (Figure1). It is the vastest municipality of Atlantic Ocean department with a surface of 539 km^2 that is nearly 20 % of the surperficies of the department and 0.48% of the national surficies. It comprises seventy one (71) villages and city districts distributed on nine (09) districts which are: Abomey Calavi, Godomey, Akassato, Zinvié, Ouèdo, Togba, Hêvié, Kpanroun and Golo-Djigbé. In the census of 2002, its population was of 307 745 inhabitants (INSAE/RGPH3, 2003)

MATERIALS AND METHODS

Sample of waste collected for characterization: 250kg of waste at the rate of 10 linear takings of 25kg each. This sampling method is recommended by SENES Consultants Limited (1999) for a study of characterization of waste from the source.

Identification of the households for the campaign of characterization

Identification of sectors and choice of districts for the campaign of characterization

With the aim of reducing at most the variability of the rate waste and their composition, the municipality was split in homogeneous sectors. On the basis of this division into sectors, nine districts which are part of the municipality were able to be grouped in three sectors: urban, outer-urban and rural. By means of the software of random

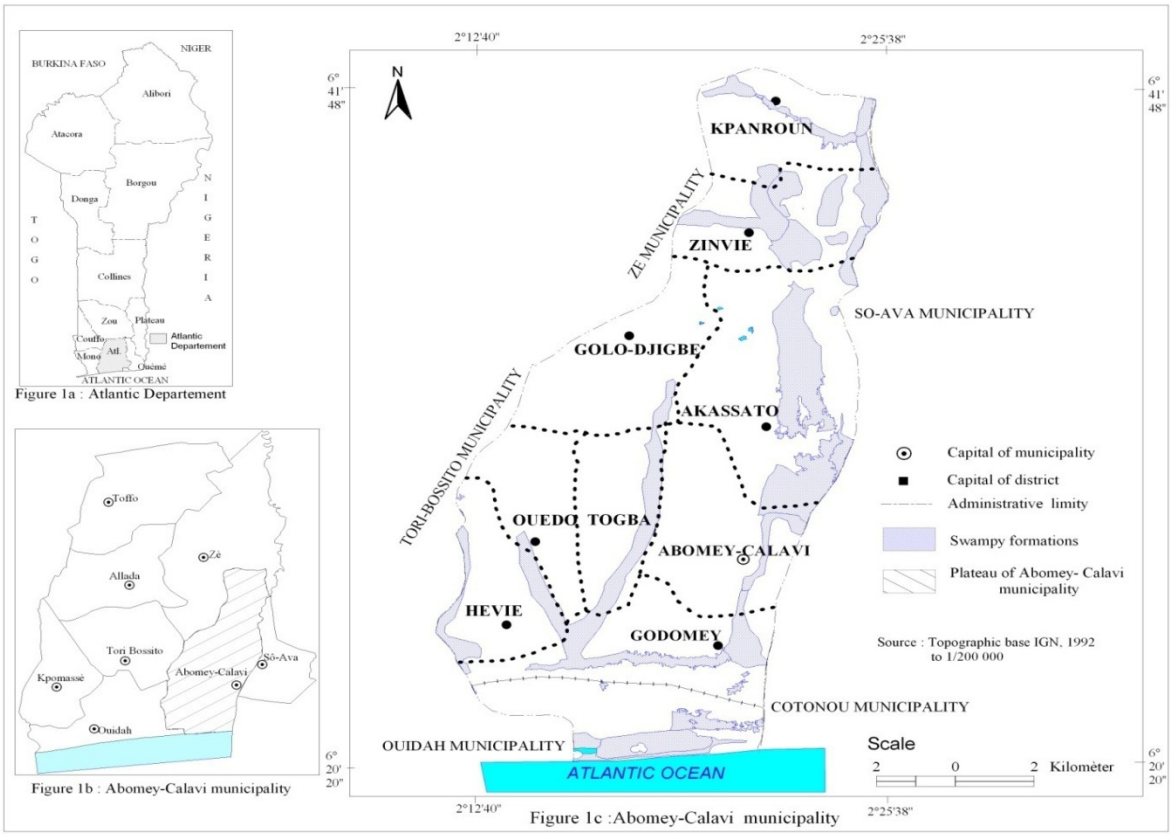

Figure1: Geographical location of the municipality of Abomey-Calavi

numbers, one neighborhood was selected per district (table1).

Size of the households sample for the campaign of characterization

Before identifying the size of the households which are going to participate in the study of the characterization, a pre-campaign was organized in every sector with six households for three days. A systematic weighing of the daily production of waste produced by these households and intended for the evacuation was made. This allowed us to determine the average quantity of waste produced by sector per day which is 1.2 kg, 1.3 kg and 1.8 kg respectively in the urban, outer-urban and rural sector. Then the number of necessary households which can produce the 250 kg of waste for three days of campaign was estimated at 70.65 and 47 households respectively in the urban, outer-urban and rural sector. For previsions in the case of refusals and abandonments, these samples are made to reach 76, 70, and respectively 52 and distributed by district or village (Table 1).

Choice of houses and households for the campaign

In every neighbour or village selected, the choice of the grouped houuseholds and the households was made in the following way:

In the center of household or village selected districts, we turned one bottle. According to its direction we began with the first house on the right. After this house, every time we selected the second house. Within the reserved houses, a number was allocated to every household. Among the numbers, one was picked at random. The household to which this number was allocated was chosen.

A single household by house In case the sample planned for the household or village was not reached the end of the taken direction, we continued in a clockwise direction till reaching the planned sampling.

Pre-campaign

It allowed us to get in touch with the chosen households, to explain them the goal and the method of the work then

Table 1: size of the households for the campaign of characterization by sector and by district

Sectors	Districts or selected	Number of households selected by district	Number of households selected by sector
Urban	Sèmè	38	76
	Togoudo	38	
Outer-urban	Yêkon-Aga	14	70
	Alassankomey	14	
	Adovié	14	
	Houeto	14	
	Houekèhonou	14	
Rural	Gbodjoko	26	52
	Kpaviédja	26	
Total		**198**	**198**

to communicate the launching date of the campaign to them.

Campaign of characterization

It took place for three days during two seasons (dry and rainy). On the eve of every day of collection, bags were distributed in the households. Waste was collected per day, forwarded and kept on the site of transit. At the end of every campaign of collection, the characterization by size and by category was launched.

Characterization of waste

The sorting by size and by category

The sorting by size was done according to the method of sorting adapted by MODECOM and to the NF XP X 30-408 standards. It consisted in sorting out the sliced waste grading from 100mm, 20mm, higher and lower than 8mm. As for the sorting by category, it was made according to thirteen (13) categories. These various categories were the ones used by ADEME in MODECOM (MODECOM, 1993) and resumed in the French XP X 30-408 standards AFNOR (French National Organization For Standardization, 1996).

The density

The density for waste directly from households was determined. Several measures were taken for the determination of the density. Ten (10) measurements were adopted by means of the 30 liter bucket and of the suitable scale.

Humidity

Sample for the determination of the humidity: 200g of reconstituted waste (size grading and composition) were put in the steam room at 105°C for 24 hours according to the NF M03-002 standards (MODECOM, 1993), until the mass of waste was constant. The moisture content was calculated as follow:

Moisture content according to category and the size of waste

$$Hg = \frac{1}{100}\sum \frac{Mcg - Mcgs}{Mcg} \times \% \, C$$

Hg: Moisture of the heavy waste;
Mcg: Moist mass of the heavy waste;
Mcgs: Mass of the heavy waste after drying in oven at 105°,
% C : Proportion of this category in a given size of waste;

Total moisture of the reconstitue sample per size

$$Hgl = [Hg \times \% \, G + Hm \times \% M + Hf \times F] \times \frac{1}{100}$$

With %G, %M and %F, the respective proportions of the heavier, middle and slim waste in the overall sample; and

Table 2: Ratio by sector and by season in the municipality of Abomey-Calavi

	Sectors	Number of households	Production (Kg)	Number of inhabitants	Ratio (kg/inhab/day)
Dry season	Urban	62	466.07a	291	0.53a
	Outer-urban	52	543.65b	286	0.63b
	Rural	31	420.56c	146	0.96c
Rainy season	Urban	30	267.62a	141	0.63a
	Outer-urban	52	521.72b	286	0.61a
	Rural	21	268.45a	99	0.90b

The means interclass of the same column followed by different letters differ significantly with the threshold of 5%.

Hg, Hm, Hf, the respective moisture content of the heavier, middle and slim waste.

Lower calorific value

The lower calorific value was calculated according to the content of all the categories of waste except for extra special waste. The used formula was the one of the conventional standard (Alouémine, 2006). It appears as follows:

$$PCI = 88 \times 2R + 40.5(P + G) - 6W$$

R = Plastic (in dry mass); P = % paper /cardboard (in dry mass); G = % rest of waste (in dry mass),
W = average moisture of waste (%).

Test of lixiviation

It was realized on the extra fine fractions (<8mm). The mass of waste used was 100g and the volume of distilled water was of 1000ml. The ratio distilled water / waste was equal to 10 optimized during the previous studies in the laboratory. The mixture of water and waste of the same sample was made in three different hermetically closed bottles and put under controlled agitation of 150 tours / minute for seventy two (72) hours. Measurement of the pH and rh were taken every 24 hours to identify stabilization time. The mixture obtained in three bottles containing the same sample was put in a plastic flask. This mixture of eluate obtained was used to determine:
- The total organic carbon (TOC). It was measured by the method of oxidation with the K2Cr2O7, in the presence of concentrated H2SO4 according to the NFT 90-101standards.

- The total Kjeldahl Nitrogen (TKN). It was determined by the Kjeldahl method according to the NFEN 25663 standards. The Kjeldahl nitrogen content (mg/L) is given as :

$$N = \frac{M \; x \; C \; x \; (V2 - V1)}{Ve}$$

N = Kjeldahl nitrogen content (mg/L) in the samples after lixiviation;
C = Concentration of HCl used for sample titration;
V2 = Volume of HCl used for sample titration;
V1 = Volume of HCl used for control sample (the white) titration;
Ve = Volume of sample used for titration;
$M = M_{(N)} = 14000$ mg/L

Statistical analysis

The data collected were analyzed with the software SAS (Statistical Analysis System, 2006). For the analysis of variance, a fixed linear model was adjusted to the waste production and waste characteristics. This model includes the fixed effects of zone and season. The F test was used to determine the significance of each effect in the model. Means were compared two by two by the Student's t test.

RESULTATS AND DISCUSSION

Ratio of waste by sector and by season in the municipality of Abomey-Calavi

Table 2 summarizes the results of three days of collection of the OM by sector in dry seasons and rainy then the quantity of waste generated per day and per capita. The results from the characterization of the household solid waste showed that the waste production depends significantly on the sector of production and the season.

It appears that the daily ratio in the municipality of Abomey-Calavi was of 0.71kg / inhab /day. This low rate of generation of waste observed lies in the range of the daily ratios of developing
countries (0.21-0.90 kg inhab-1.day-1) (Charnay, 2005). But this can be understandable by the valuation of the fermentable matter, especially the garden refuses and also the leftovers in this particular case in the rural areas, followed by plastics, metals, bottles in glasses mainly in the urban and outer-urban sectors. Some of this waste was valuable at the level of households as fertilizers in

Table 3: Density of wastes per sector and per season

Sectors \ seasons	Density		Effect of season
	Dry season	Rainy season	
Urban0	0.25a	0.47a	**
Outer-urban	0.39b	0.37b	NS
Rural	0.28c	0.36b	*
Average / standard deviation	0.31 / 0.07	0.40 / 0.06	

NS: No Significant; *: P<0.05; **: P<0.01. The means of the same line followed by different letters differ significantly with the threshold of 5%.

Table 4: Humidity of waste

	Dry season				
Sectors	**Coarse> 100**	**Average >20**	**fine >8**	**Extra fine <8**	**Global (%)**
Urban	25a	29.9a	18.8a	9a	18.25a
Outer-urban	25.45a	27.1b	19.55a	7.75ab	16.99ab
Rural	22.3b	29.85a	21.9b	6.25b	13.14a
Average / standard deviation	24.25	28.95	20.08	7.68	16.13 / 2.66
		Rainy season			
Urban	42a	43.75a	20.5a	9.5a	24.63a
Outer-urban	42a	36.75b	25.75b	8.33ab	20.38b
Rural	39.75b	43.75a	29.83c	7.17b	19.97c
Average / standard deviation	41.25	41.42	25.63		21.66 / 2.58
Season effect	**	**	*	NS	*

NS: No Significant; *: P<0.05; **: P<0.01. The means interclass of the same column followed by different letters differ significantly with the threshold of 5%.

fields, gardens or feed for animals either was reused in other purposes. On the other hand others were sold. The latter was used in the initial state or transformed. This valuation of waste was noticed in the characterization where we recorded low proportions of these categories of waste. This proves that these categories do not integrate in the circuit of the evacuated waste. This practice was already reported by Aloueimine (2006) in Nouakchott.

The production per day noted in the municipality varied according to the sectors of study and seasons. It was more substantial in rural areas (0.96 % and 0.90 %) respectively in dry season and rainy and lower (0.63 % and 0.53 %) respectively in the outer-urban and urban sectors in dry season. But during rainy season, it was the opposite in these two sectors (0.61 % and 0.63 %). The high rate of the daily production in the rural environment was connected to the big production of the extra fine fraction in this waste. Besides, the decrease of the ratio noticed in this environment and the outer-urban one during rainy season was due to the valuation of the fermentable matter in fields or gardens.

The increase of the ratio of waste in the urban sector during the rainy season was connected to the integration of farm produces as corn, fresh peanuts, vegetables and certain fruits in the food habits of consumption. The characterization of waste confirms this change of the diet of the inhabitants from this sector where we noted an increase of agricultural waste during this period.

Physico-chemical characteristics

Physical parameters

Density

The results of the density of wastes recorded in Abomey-Calavi municipality are presented in Table 3. It comes out from this study that the the waste traits depend significantly on the sector of production and the season.

The average density of the waste in the municipality of Abomey-Calavi was of 0.40 during the rainy season and of 0.31 during the dry season. It stays in the range of the values recorded in developing countries (0.25-0.5) according to Cointreau-Levine (1997). This averagely high density was connected to the importance of the extra fine fraction constituting in heavier waste.

Humidity

Humidity was determined after the sorting by size. Table 4 presents the humidity contents of the waste from households.

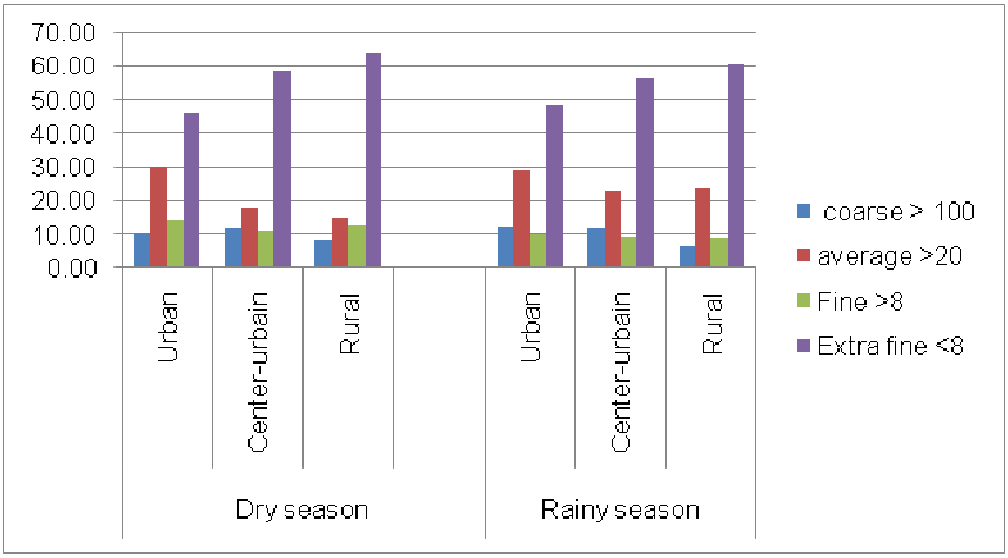

Figure 2: Distribution by size of the waste of Abomey-Calavi municipality

The average rate of moisture in the municipality of Abomey-calavi was of 16.13 % in dry season and of 21.66 % in rainy season. This rate was very low compared with those of the developing countries which can exceed 90 % with an average of 50 % (Charnay, 2005). This low rate of moisture determined in the municipality was understandable by the strong proportion of extra fine matter and the small proportion of the fermentable contained in waste. Actually the extra fine matter which was in important quantity has no capacity to retain water while fermentable matter containing a strong rate of humidity was in small quantity. These results were similar to those in Nouatchott (Alouemine, 2006), in Lomé (Koledzi, 2011) and in Yemen (Ben Ammar, 2006). The analysis of results showed that the highest rates of humidity were the ones of the urban sector and the lowest were the ones of the rural sector. This situation was connected to the fact that the urban environment presented a higher rate of putrescible waste and paper and a rate of the extra fine fraction lower than in the other sectors.

Composition of waste

Grading distribution

The separation of waste by size was made by means of riddles: coarse (> 100 mm), average (> 20mm), fine (> 8 mm), and extra fine <8mm. From the results of this separation by size, it emerged that the dominant fraction of waste was the extra fine one with percentages ranging between 45.92 % and 63.82 % during the dry season, and 48.47 % and 60.80 % in rainy season followed by averages with percentages situated between 15.13 % and 29.90 % during dry season whereas 22.98 % and 29.28 % during rainy season (Figure 2).

As figure 2 shows, the variations by size during both seasons were not significant. They were uniformly distributed in every sector during both seasons except in the urban sector where the fraction of coarse and that of the fine matter > 8mm had no uniform variation during the seasons. This situation can probably be due to the absence or to the rarity of agricultural waste such as: corn, stalks of vegetables in waste.

The important proportion of the extra fine fraction observed in all the sectors during both seasons can be understandable by the fact that waste resulting from households was essentially constituted of sand especially in the outer-urban and rural circles. Kolédzin (2011) remarked the same phenomenon in Lomé. According to him, the importance of the fraction of fine matter in waste is connected to the degradation of waste, especially fermentable one, due to the stay and the mixture of sand with this waste on the site of transit which is a sandy zone. By taking into account these reports, it is then necessary that action be taken in the waste management within the municipality of Abomey-Calavi and especially in suburbs and countryside for the reduction of the extra fine fraction from the very source in order to decrease the quantity of waste to be collected, evacuated, composted and consequently reducing the cost of transport and management.

Composition of waste

From the characterization of the waste from trash bins of households of the municipality that participated in the campaign, it emerged that the fraction of fine matter

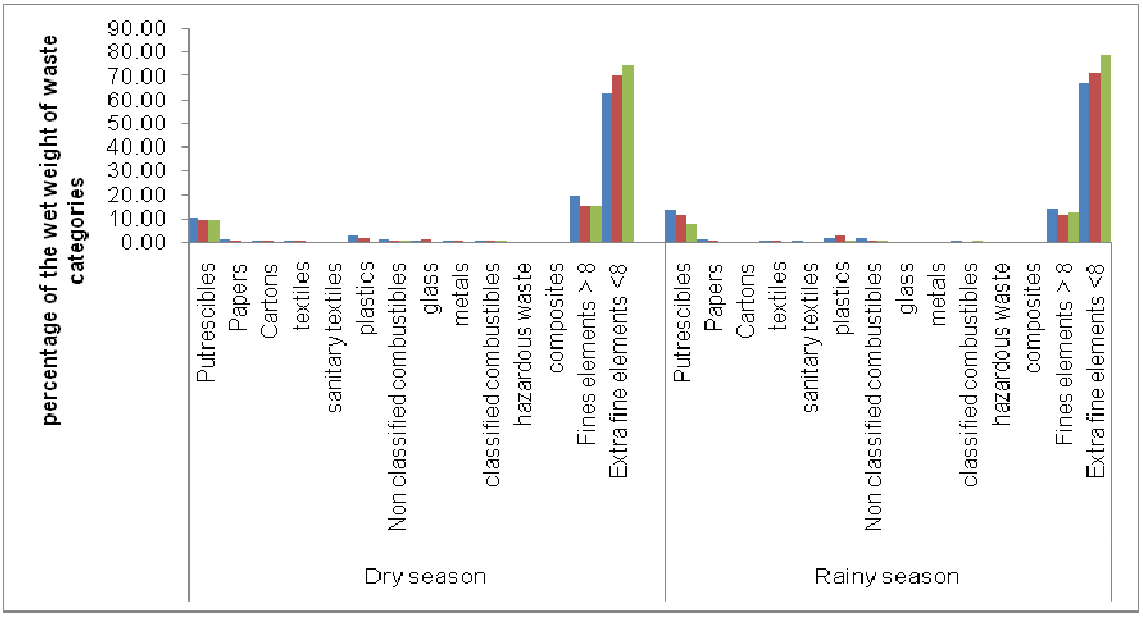

Figure 3: Composition of the domestic solid waste in Abomey-Calavi municipality

grading <8mm represents the most important fraction because of its wet weight during both seasons and in all the sectors. According to the rate this fraction was followed in the order of importance by five categories which are: the fine elements of size grading > 8mm, putrescibles, plastics and not classified combustibles. Figure 3 presents the categories of waste which compose the trash bins of the households by sector and by season in the municipality.

The observation of the figure 3 shows that the variation of the different categories of waste was similar during both seasons but differs from one sector to another. This variation of the categories between sectors is low. This non-significant difference between the categories of waste in sectors does not prevent us from noticing that the putrescible and fine elements in the urban sector and the fine fraction in the rural sector were the biggest proportions of waste. The high rate of putrescible can be understandable by the lack of valuation especially in the urban sector or the low valuation in the form of compost in the agricultural activities and gardens at the level of the rural and outer-urban sectors. It is then important to have an effective management of waste in the municipality, to envisage the valuation of putrescible waste by composting. The high rate of the fine fraction is connected to the technique of sweeping. Thus a raising awareness at the source on the manner of sweeping and the use of trash cans with stitches could help eliminate or reduce considerably the quantity of this category from the source. This will allow us to reduce the difficulties connected to the collection.

As regards to plastics, not classified combustibles and papers, they are in average proportion in waste. They are more present in the urban and outer-urban zones. It is observed that plastics essentially consist of packing bags as well as combustibles of locks in urban and outer-urban areas then of twigs of wood, charcoal and of residues of the palm tree in rural areas. At this level a policy must be implemented for the valuation packing bags or a raising awareness on the regulations of the use in daily activities.

As for the rest of the categories of waste, they are very low or sometimes absent in proportion. This absence is noticed in the rural environment where there are no sanitary textiles, hazardous waste, no glass and subcategories of putrescibles as waste from cooking and rests of food. The low rate or the absence of certain categories of waste in one environment or the other one can be connected to its valuation and to the level or the lifestyle of the households. It is the case of the waste from cooking and leftovers which were valued in the breeding especially in the rural sector where all the households are into this activity. In 2006, Alouémine reported the same fact in Nouachott. He stressed that these categories of waste were especially valued at the level of low and average status where the breeding of animals at home is practised almost every household. Added to this, is the activity of recycling practised in the entire municipality. The recycled categories are mainly metals, glasses and plastics.

Low calorific value of the domestic solid waste

Low calorific value of the domestic solid waste of Abomey-Calavi varies significantly according to the sector and season of collection table 4. It is observed that

Table 4: Calavi: Low calorific value of the domestic solid waste in the municipality of Abomey-Calavi

Seasons / Sectors	Dry season PCI	Rainy season PCI	Season effect
Urban area	1776.11a	1377.73a	**
Outer-urban area	1257.39b	1318.96b	*
Rural area	925.26c	691.16c	***
Average / standard deviation	**1319.58** / **428.82**	**1129.28** / **380.56**	

****: P<0.05; **: P<0.01 ; *** : P<0.001. The means of the same column followed by different letters differ significantly with the threshold of 5%.***

Table 5: ratio carbon / nitrogen according to the seasons and the sectors.

Seasons / Sectors	Dry season			Rainy season		
	Carbon	Nitrogen	C/N	Carbon	Nitrogen	C/N
Urban area	170.1a	18a	9.45a	103a	10.5a	9.81a
Outer-urban area	109.2b	12b	9.1a	152b	7.5b	20.27b
Rural area	161.4c	3.75c	43.04b	78.8c	9ab	8.76a

The means interclass of the same column followed by different letters differ significantly with the threshold of 5%.

the calorific value of the domestic solid is in the range of 1000Kcal / kg during dry season as well as in wet season except in the rural sector where its value is lower than 1000Kcal / kg (691.16 Kcal / kg and 925.26Kcal / kg). These low calorific values found in the rural area were understandable by the absence of certain categories (cardboards, textiles, sanitary products, glass and hazardous waste), the low rate of plastics (021 % and 0.40 %) and the low rate of humidity (13.14 and 19.97) respectively during the dry season and the rainy season. Altogether the values of this parameter were situated in the lower range of the calorific value of developing countries (800-1100Kcal / kg) (Cointreau-Levine, 1997). However, it could reach 1600 and even 2700Kcal/kg (Georgieva et Varma, 1999; Abu-Qudais, Abu-Qdais, Aloueimine et al., 2005).

It is the case of the urban zone in Abomey-Calavi municipality where the PCI is of 1776.11Kcal / kg during the dry season. This high PCI is favored by the important rate of plastics (3.02 %) and the low rate of moisture (18.25 and 24.63) respectively in dry season and in rainy season. The results of Alouémine are in concordance with our results. In 2006 he also found in Mauritania a higher PCI (2652Kcal / kg). According to this author, the high rate of the PCI in this country was connected to the low rate of humidity (11 %) and to a relatively important rate of plastics (20 %).

Also it is noted that almost all the values of the PCI were lower than 1500 Kcal / kg; this means that the option of the processing by incineration of waste in the municipality cannot be adapted. From then on, any action for the processing of domestic solid waste in the municipality had to undertake initiatives on the valuation and on the dumping

Ratio carbon / nitrogen (C/N)

Low calorific value of the domestic solid waste of Abomey-Calavi varies significantly according to the sector and season of collection. It is an important index in the production and the valuation of compost and the fertilizing soils favorable to the agricultural activities. Thus the capacity of the category of extra fine waste in Abomey-Calavi municipality was determined by the C/N ratio to serve as fertilizing or compost. This ratio was calculated in the various sectors (urban, outer-urban and rural) and seasons (Table 5).

From the results presented in the table 5, it appears that the recorded ratios C/N mostly range between 8 and 9 in the sectors of study. These low ratios, lower than ten (10), indicate a good biological activity of the ground. Out of the analysis of the table it can then be stated that the extra fine fractions of the categories of the domestic solid waste in Abomey-Calavi municipality present interesting indications which condition the evolution of organic matters and are satisfactory values to use this part of waste as a fertilizing in various activities.

However, the use of other indexes beside this ratio for a better appreciation of the quality of this part of waste is indicated. The values above 15 are very high values. They indicate a slowing down of the biological activity in the soil. So, they are connected with unfavorable conditions of evolution of organic matters. These values found in the rural and outer-urban zones respectively in dry season and rainy season can be connected to the composition of waste in these periods.

CONCLUSION

The management of domestic solid waste became more and more complex in Abomey-Calavi municipality. This is connected to the population growth coupled with the exaggerated increase of the production of waste. This situation created difficulties in the circuit of waste management. These difficulties arose in term of quantity of waste to be pre-collected and transported, to be evacuated and treated. One thorny question is added to these issues: where to pour them? Thus the characterization of the domestic solid waste of the municipality is a key element for the reorganization of the sector.

The campaign of characterization of the domestic solid waste made in Abomey-Calavi municipality allowed us to note that the average quantity of waste produced by the households per day was not unimportant. It was an average production of 0.71kg / inhab /day. The produced waste is rich in fine elements, in putrescible and plastics largely constituted by packing bags. Most of this waste can be recycled or valued in the form of compost. The recyclable waste is essentially done of packing bags which can be used to make toys, bags and pavements. With regard to extra fine waste, it can serve directly as some compost in gardens and farms. On the other hand, putrescible will be composted before their use. So the choice of the processing manner by incineration seems to be a possible option because of the average rate of 16.13 % moisture during the dry season and 21.66 % during the rainy season and of the PCI (1224,.74 kcal / kg) all included between the minimal thresholds required for the incineration. But the adoption of this mode of processing could be problematic because the PCI was very close to the minimal threshold and the low rate of humidity was especially connected to the high rate of the extra fine fraction. If we do not take into account this fraction, this rate reaches 30 and can get close to 50 - 60 if the rate of moisture is determined on the global sample. It would then be interesting for an effective management of waste in Abomey municipality to envisage the mode of processing by the dumping followed by the valuation of waste through recycling and composting.

REFERENCES

Abu QHA, Hamoda MF, newham J (1997). "Analysis of residential solid waste at generation sites", waste management & research, 15 (4) P.

ADEME (2006). choix des catégories et des sous-catégories pour l'analyse de la composition des déchets, rapport final, 55p.

Afroz R, Hanaki K, Kurisu KH (2009). "Willingness to pay for waste management improvement in dhaka city, bangladesh," journal of environmental management, 90:492-503p.

Agamuthu P, Khan N (1997). Solid waste characteristic and quantification in effective solid waste management, kuala lumpur: ecotone management 1-14p.

Aliyu BN (2010). An analysis of municipal solid waste in kano metropolis, nigeria j hum ecol, 31(2): 111-119p.

Aloueimine O (2006). Méthodologie de caractérisation des déchets ménagers à Nouakchott (Mauritanie) : contribution à la gestion des déchets et outils d'aide à la décision. thèse de doctorat. Université de Limoges, 195p.

Aouane E, Chbab Y, Jadal M, Berny E, Ouhssineel M (2010). Characteristics of household waste in a landfill Moroccan, bull. soc. pharm. bordeaux, 57-66p.

Attrassi B, Mrabet L, Douira A, Ounine K, El haloui N (2005). Study of the agricultural use of compost waste prominence. Biotechnol. about, 17(5):14-29p.

Awiplan S (2004) Etude sur la caractérisation des déchets ménagers dans le département de la somme, rapport, 17p.

Beede D, Bloom DE (1995). the economics of municipal solid waste, the world bank researh observer, 1995, 10(2):113-150pp.

Ben AS (2006). Les enjeux de la caractérisation des déchets ménagers pour le choix de traitements adaptés dans les pays en développement résultats de la caractérisation dans le grand tunis au point d'une méthode adaptée, Thèse de doctorat, Institut National Polytechnique de Lorraine, 326p

Benzakour A (2004). Impact of landfill on the environment of Kenitra and test biotransformation of household waste into a value-added ingredient. PhD thesis. State Sci. Biol. Kenitra, Morocco,222 p.

Charnay F (2005). Composting of municipal waste in the ped: Development of a methodological approach for a sustainable production of compost.PhD thesis. University of Limoges, 277p.

Cointreau LS (1997). "Occupational and environmental health issues ofsolid waste management". international occupational and environmental medicine. St. Louis (USA), 25p.

Dossou OV (2005). Contribution de l'évaluation environnementale stratégique à l'aménagement du territoire : cas du plan directeur d'aménagement du plateau d'Abomey-Calavi (République du Bénin).Mémoire de Thèse, FLASH/UAC, 348p

Epa United States Environmental Protection Agency Office of Solid Waste, 2010: Solid waste inthe united states, 189p www.epa.gov.

Francois V (2004) Détermination d'indicateurs d'accélération et de stabilisation de déchets ménagers enfouis. étude de l'impact de la recirculation de lixiviats sur colonnes de déchets. thèse de doctorat. Universite de Limoges, 197p + annexe.

GBINLO RE (2010). Organisation et financement de la gestion des déchets ménagers dans les villes de l'Afrique Sub-saharienne : Cas de la ville de Cotonou au Bénin, Thèse de doctorat, Université Orléans, 237p

Georgieva K, Varma K (1999). Municipal solid waste incineration; world bank technical guidance report; the international bank for reconstruction and development / the world bank; washington D.C, 103p.

Ghrabi A, R'houma A, Ennabli M, Picoud F (2000). characterization of municipal solid wastes in the sahel region in tunisia, proceedings of international symposium on environmental pollution control and waste management, 260-270p.

Gintaras D, Viktoras R, Ingrida R, Renata P (2006). An assessment of the current and future options for domestic waste management in kaunas, lithuania, 27-36p.

Girus S (1999). Quantification and characterization of waste tourist populations report 9p.

Hassan TI, Ibrahim B, Mohammad RM (2010). "The Practice and Challenges of Solid Waste Management in Damaturu, Yobe State, Nigeria," Journal of Environmental Protection, , 1, 384-388.

Koledzi Ek (2011). Valorisation des déchets solides urbains dans les quartiers de Lomé (Togo): approche méthodologique pour une production durable de compost. thèse de doctorat. université de limoges, 210p + annexe.

Lecomte c, et Bouda L (2010). Survey quantification and analysis of waste streams, report, 27p

Matejka G, Bouvet Y, Emmanuel E, Koulidiati J, Ngnikam E, Tanawa E, Vermande P (2005). Mastered management of municipal solid waste and sanitation in developing countries, the need for specific scientific and technical studies and adapted methodological tools, 11p.

Mohee R (2002). Assessing the recovery potential of solid waste inmauritius. - resour. conserv. recycl, 36(1):33-43p.

Ngnikam E (2002). The mastery of the collection and treatment of solid waste in developing countries and reducing emissions of greenhouse gas emissions, meeting the North-South technological cooperation for sustainable development and climate organized under pollution, Lyon 22 p.

Ngnikam E, Vermande P, Tanawa M, et Wethe J (1997). " Une démarche intégrée pour la maitrise de la gestion des déchets solides urbains au Cameroun", revue déchets sciences et techniques **5**: 22-34p.

RDC-Environnent SA (2010). Study of the composition of household waste in the Walloon region in 2009-2010, Final Report, 97p.

Yêmadjè AAS (2013). Basic Purification And Management Of Household Waste In The District Of Abomey-Calavi In Benin Republic: Case Of Agamadin, Gbodjo And Tokpa-Zoungo Areas, *International Research Journal of Environment Sciences* Vol. 2(3), 28-34p.

Yêmadjè AAS (2009). Problématique d'assainissement de base : Cas de l'arrondissement d'Abomey-Calavi, mémoire de DEA, FLASH/UAC, 71p.