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The size effect in the distribution of combustible components in the municipal solid waste produced in the summertime. Case of the city of Beni Mellal-Morocco.

A. Ouigmane[1,2], O. Boudouch[2], A. Hasib[3*], M. Berkani[1], M. Aadraoui[4], E. Dhairi[1]

[1]*Laboratory of Spectro-Chemistry Applied and Environment, University Sultan MoulaySlimane, Beni Mellal.*
[2]*Transdisciplinary Team of Analytical Sciences for Sustainable Development, University Sultan MoulaySlimane, Beni Mellal*
[3] *Laboratory Environment and Valorization of Agro-Resources University Sultan MoulaySlimane, BeniMellal*
[4]*Laboratory of Geosciences and Environment, Faculty of sciences and technics, University Sultan Moulay Slimane, BeniMellal.*

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A.HASIB
azhasib@yahoo.fr
Phone: (+212)6 61386902

Abstract

The total waste generated in Moroccan urban areas is about 5.3 million tons per year, which means 0.76 kg per capita per day, and 1.47 million tons in rural areas, which means 0.28 kg per capita per day. Landfilling is the most popularly used method of waste disposal used today in Morocco, which leads to a considerable energy loss. Converting waste to energy can be considered as a substitution of fossil energy. Solid recovered fuel (SRF) is a high quality alternative to fossil fuel. SRF is mainly composed of fractions with high calorific value which is produced from municipal solid waste including paper, wood, textiles and plastic. SRF is used in cement plant or factories which use fossil energy. This study is concerned with the count and inventory of fuels existing in household waste in BeniMellal city, and this in order to encourage development of energetic valorization of solid waste. The methodology used in this study is based on the MODECOM approach with characterization of 10% of waste produced in 9 sectors per day. The unloading of trucks is followed by the quartering operation, we take 10% per tour and then the sample is transferred to the sorting site. Before the sorting operation comes the screening and sorting process which distinguishes three fractions distribution size: less than 80 mm, between 80 and 250 mm, and more than 250 mm. The first category (less than 80 mm) is not sorted since it's composed essentially of organic materials, while sorting the other categories shows that they contain combustible materials at the rate of 42.2% and 10.4 % for the categories ''between 80 and 250 mm" and "more than 250 mm'' in a successive manner. The results of this study encourage the production of SRF as a substitute to fuel energy or to produce energy.

1. Introduction

The quantities of household waste don't stop increasing and that's due to the increased population figures and improvement of the standard of living [1-3]. Despite the variety of treatment and recovery of waste processes (composting, incineration, recycling and bio-methane), in developing countries the main destiny of waste is almost landfills.The reason behind that is the low costs in lower mid income countriesthat request this method of disposal(3 to 10 US$ / tonne), even it has serious impacts on environment. In the other hand, the treatment by composting or incineration request from 10 to 100 US$ / tonneand those according a study by the World Bank [4, 5]. There are two types of recovery:i) Material recycling by composting [6], recycling [7] or even the substitution of some building materials by plastic granulates to ensure their rigidity [8]. ii) The energy recovery through bio-methanation [9, 10], pyrolysis, incineration, gasification or production of SRF [10]. Therefore the goal of this paper is to initiate the study of SRF in a developing country as Morocco.SRF is a fuel derived from non-hazardous waste produced in accordance with the requirements of the European standards for SRF, specifically in accordance with EN15359. There are no studies in the developing countries concerning SRF despite the economic and environmental benefits of this sector. In fact, the use of SRF in cement plants minimizes costs and reduces greenhouse gas emissions [11, 12]. In contrast, this sector is developed in European countries with the establishment by European Committee for Standardizationof CEN standard 15359 which classifies the SRF into five categories according to three parameters (lower calorific value (LCV), Mercury and chloride) [13, 14]. This paper will set out the results of the first step concerning the quantification of fuel fractions contained in the household waste. Indeed, dysfunctional methods of treating and sorting waste which are defined by the US Agency for environmental protection as: (i) source reduction, (ii) recycling and composting, (iii) incineration and (iv) the landfilling [15], are primarilydue to the lack of characterization of waste in developing countries [16]. Hence, the quantitative and qualitative characterization of waste is necessary to choose the suitable treatment or recovery. Characterization studies have already been made in some developing countries, such asLome (Togo) [17], Tunisia [16, 18], Algeria [1, 3], Nouakchott (Mauritania) [19], Dar Salam [20] and Ghana [21]. The results of characterization studies indicate that the waste differs from one area to another even in the same country. Our study will review the fuel fractions in household waste in the region of BéniMellal in Morocco.

Firstly, we started with the delineation of collection sectors in the city thanks to the geographic information system (GIS) tool [22], the characterization was made 24hours/24 and 6 days/7, 10% of total municipal waste generated is characterized each day. The characterization method follows the MODECOM approach, where we did sort three size fractions; less than 80 mm, between 80 and 250 mm and more than 250 mm[23].

2. Materials and methods

2.1. *Study area*

The city of BeniMellal is part of the region of BeniMellal-Khenifra according to the new regional division admitted in Morocco in 2015, it covers a territory with an area of 39 km^2 and had approximately 192 676 inhabitants according to the 2014 census[24]. It is located in the center of Morocco to the border of the western high Atlas Mountains. The city is characterized by a continental climate: cold winters with hot summers [25] and an average temperature of 18 °C [25]. The following figure shows the geographical situation of the city of BeniMellal, the target of this study:

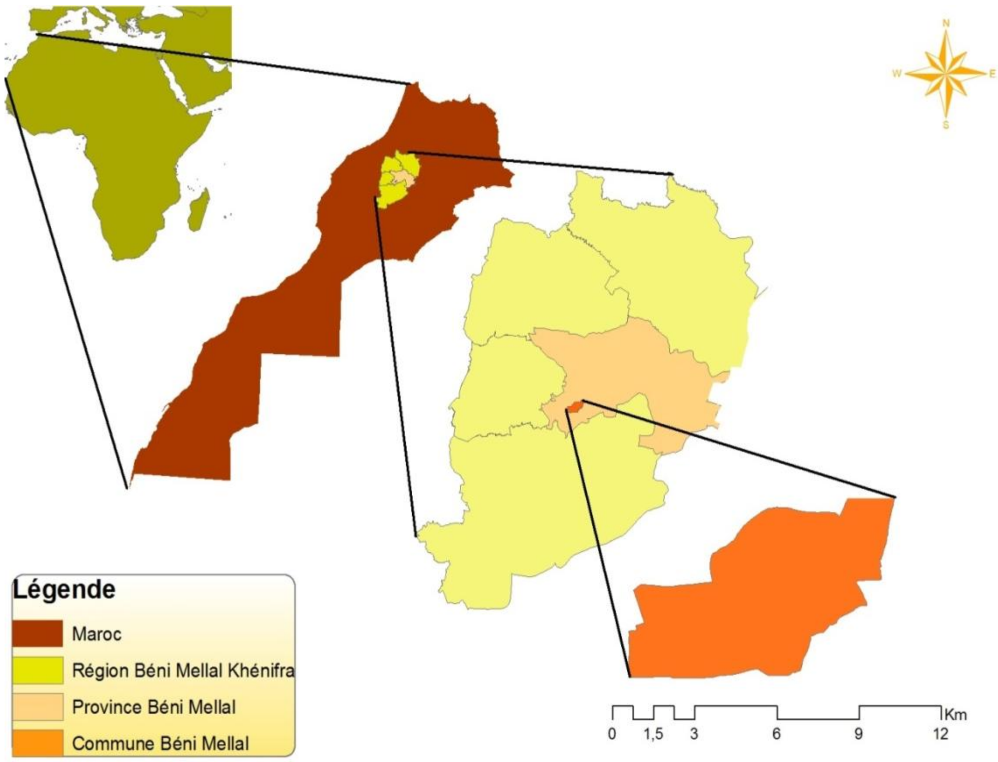


Figure 1: Geographical location of the study area

2.2. *Sampling and characterization*

In this study, we followed the MODECOM method of the characterization of municipal solid waste. The territory of BeniMellal city is divided into nine sectors, the latter goes through a collection frequency during the seven days of the week. The trash truck does two tours per sector per day. The average tonnage registered is 152 tons per day [22]. The campaign of characterization was realized during six days in June, with characterizing 10% of each collection tour per sector per day, and this waste is collected from heterogeneous neighborhoods (Table 1).

Table 1: Habitat type characterizing each sector

Sector	Housingtypology	Parasite Area
S1	Traditional houses, apartments (*F+3 and F+2)	Industrial Area + Weekly Souk
S2	Apartments (F+5, F+4, F+2 and F+3) and villa area	None
S3	Traditional houses, apartments (F+3 and F+2)	None
S4	Apartments (F+5, F+4, F+3 and F+2)	Provincial hospital + Clinics + Administrative Distric
S5	Apartments (F+3 and F+2)	Souika 7j/7 j (Old Madina)
S6	Traditional houses, apartments (F+5, RF4, F+3 and F+2)	Faculty Print shops
S7	Apartments (F+4, F+3 and F+2)	Industrial Area
S8	Apartments (F+4, F+3 and F+2)	None
S9	Traditional houses, apartments (F+3 and F+2)	Faculty + University campus

*F: Floor or ground floor

At the end of each round, the waste truck goes into the weighbridge, and then it discharges the waste, so that it can be homogenized by mixing and quartering. 10% of the weight of the waste of one round per sector is taken and transferred to another platform to be characterized.

The sample taken from each sector undergoes a granulometry characterization and this is thanks to the particle size table (Figure 2). The MODECOM approach defines the granulometric sizes as follows: small fraction less than 20 mm, middle fraction between 20 and 100 mm and the long fraction more than 100 mm. In our case, we took three fractions: i) fraction less than 80 mm (G1); ii) fraction between 80 and 250 mm (G2) and iii) fraction more than 250 mm (G3). This choice is justified by the fact that the majority of small-sized waste products are made of organic materials.

The following operation is the sorting of the two fractions G2 and G3 in 20 categories: Plastic, PET, HDPE, PP, LDPE (plastic bags), PVC, Polystyrene, sanitary waste, wood, textiles, cardboard, cardboard tetra pack, cardboard and paper, aluminum or iron, glass, Waste of electrical and electronic equipment (WEEE), Medical Pathological Waste (MPW), ceramic and waste demolition, shoes and elastomers, various fuels and fermentable materials. In contrast, the G1 fraction with particle size less than 80 mm was not sorted since we found that it almost consists of organic materials. The methodology followed during the characterization is presented in figure 3.

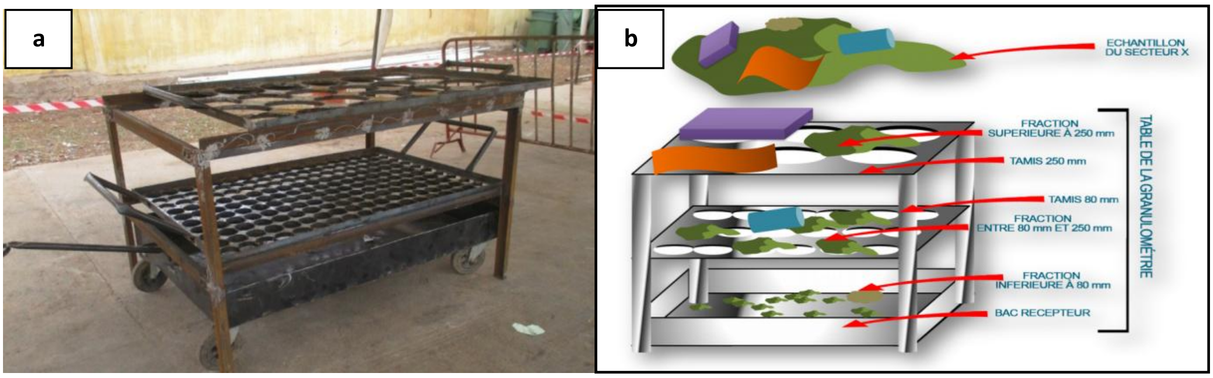


Figure2: Particle size table (a), particle size classification scheme (b)

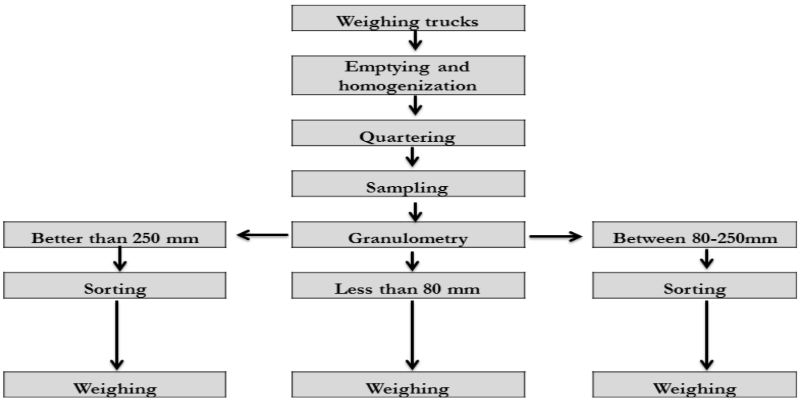


Figure 3: Summary of the adopted method for the characterization of waste

3. Results and discussion

3.1.*Granulometric aspects of waste*

After taking 10% of each collecting tour, a particle size study is made to see the distribution of initial flow concerning the size (table 2).

Table 2: The weight of the three fractions in Kg

Granulometry	Sector	Day1	Day 2	Day 3	Day 4	Day 5	Day 6	Average
G1	S1	374.57	313.8	312.58	423.4	375.14	227.21	337.78
	S2	284.62	286.7	185.24	147.47	124.12	166.28	199.07
	S3	120.88	99.5	124.36	73.53	120.87	184.38	120.59
	S4	133.65	175.2	113.10	184.26	121.01	158.24	147.58
	S5	547.3	437.2	688.2	748.21	545.32	601.36	594.60
	S6	97.21	226.4	158.6	218.32	169.30	249.5	186.56
	S7	324.08	312.5	493.28	316.21	416.2	398.12	376.73
	S8	114.36	227.27	268.21	201.87	191.07	262.64	210.90
	S9	354.57	327.95	259.36	198.25	184.34	199.47	253.99
G2	S1	472.67	264.2	399.51	403.4	393.09	372.54	384.24
	S2	324.68	356.8	198.93	279.45	128.1	157.6	240.93
	S3	58.91	47.7	34.4	32.12	46.98	33.58	42.28
	S4	498.27	372.7	211.25	483.85	491.07	157.09	369.04
	S5	354.98	184.26	216.7	214.11	189.14	245.21	234.07
	S6	174.25	454.76	469.32	641.02	658.35	697.39	515.85
	S7	182.67	346.4	183.6	142.59	194.08	176.84	204.36
	S8	391.95	542.01	536.84	478.08	431.54	688.69	511.52
	S9	571.27	428.69	426.36	301.57	417.21	438.84	430.66
G3	S1	280.69	198.25	219.1	190.45	245.68	197.57	221.96
	S2	247.98	230.14	154.67	181.63	112.11	181.24	184.63
	S3	31.62	21.2	5.21	33.78	62.14	46.95	41.65
	S4	167.87	170.1	130.6	314.85	278.14	143.92	200.91
	S5	185.72	111.54	177.4	178.25	159.2	168.36	163.41
	S6	94.36	167.22	205.2	14.26	127.2	190.36	133.10
	S7	91.67	95.6	68.3	47.82	74.94	81.84	76.70
	S8	161.06	183.8	216.2	222.36	224.07	287.51	215.83
	S9	144.95	184.36	214.69	192.32	321.82	241.3	216.57
Total samples Kg / day		**6786.81**	**6766.25**	**6720.21**	**6863.43**	**6802.23**	**6954.03**	**6815.49**

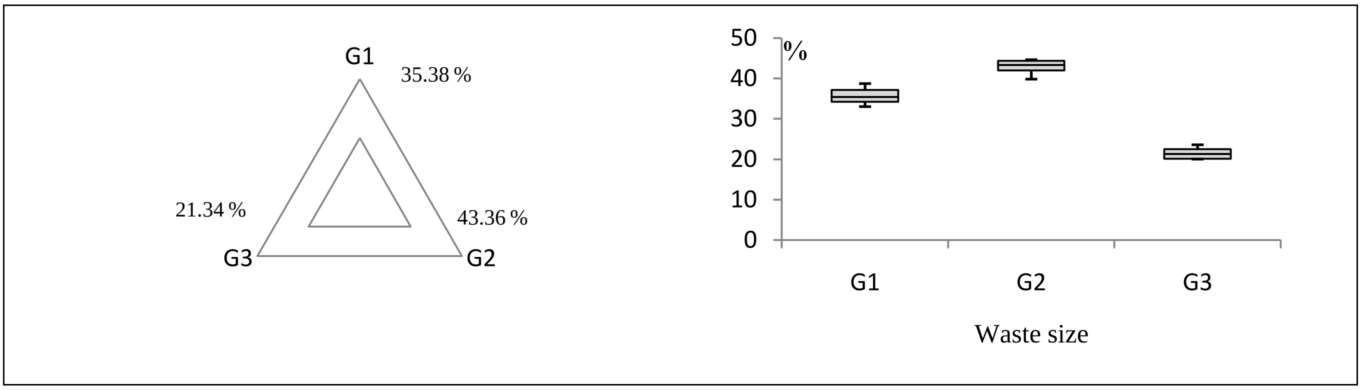
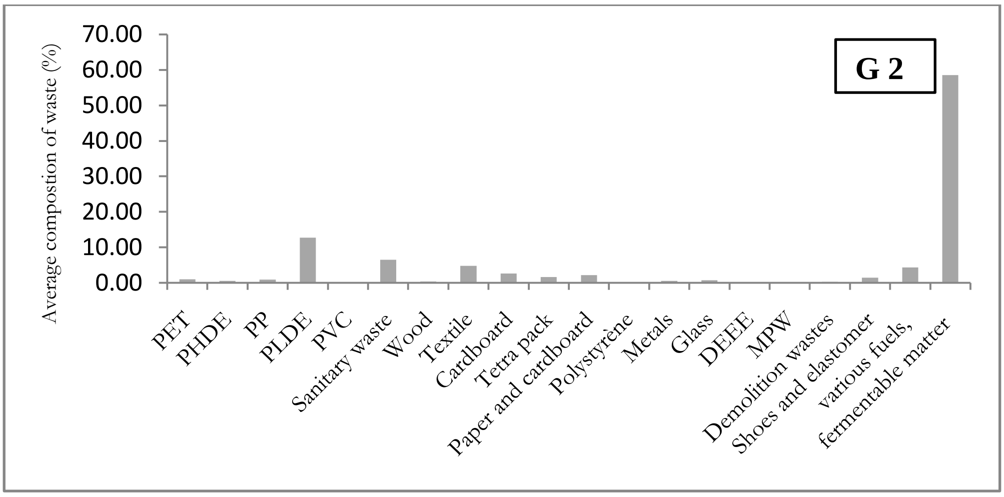


Figure 4: Distribution of the fraction sizes in terms of weight

The following graphs (figure 4) show the distribution of waste based on the three fractions size that we have chosen for this study. The most abundant waste granulometry is the G2.Thus, the dispersion diagram shows the homogeneity of the nine sectors.

3.2. Qualitative aspect of waste

For the analysis of the detailed composition of household waste in the city of Beni Mellal, we sorted fractions between 80 and 250 mm and more than 250 mm. However, the waste with fraction less than 80 mm has not undergone sorting since it consists mainly of the biodegradable materials. Waste composition more than 250 mm and the 80-250 mm is presented in graphs (figure 5).



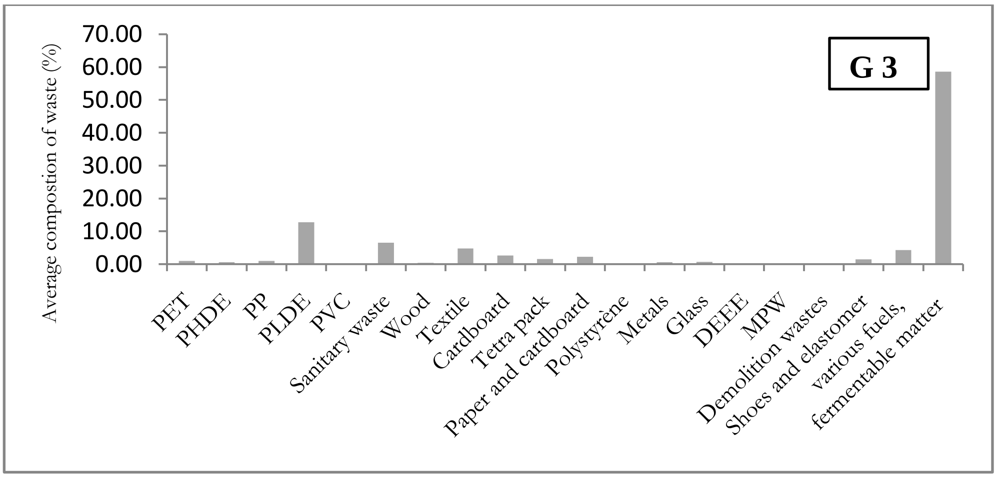


Figure 5: Wastes composition: (G2) Fraction between 80-250mm (G3) fraction better than 250 mm

The results presented in figure 5 show that the biodegradable fraction is the most abundant with a percentages of 57% and 59% successively for G2 and G3. Concerningfuel fractions in waste, it is found that the PLDEs, textiles and hygienic waste are the most important.

3.3. *Fuel fractions in waste*
The distribution of waste of all categories 1, 2, 3 and 4 is homogenous in the nine sectors as shown in figure 6 and which can be explained by the heterogeneity of the establishments and habitats in each sector (table1).

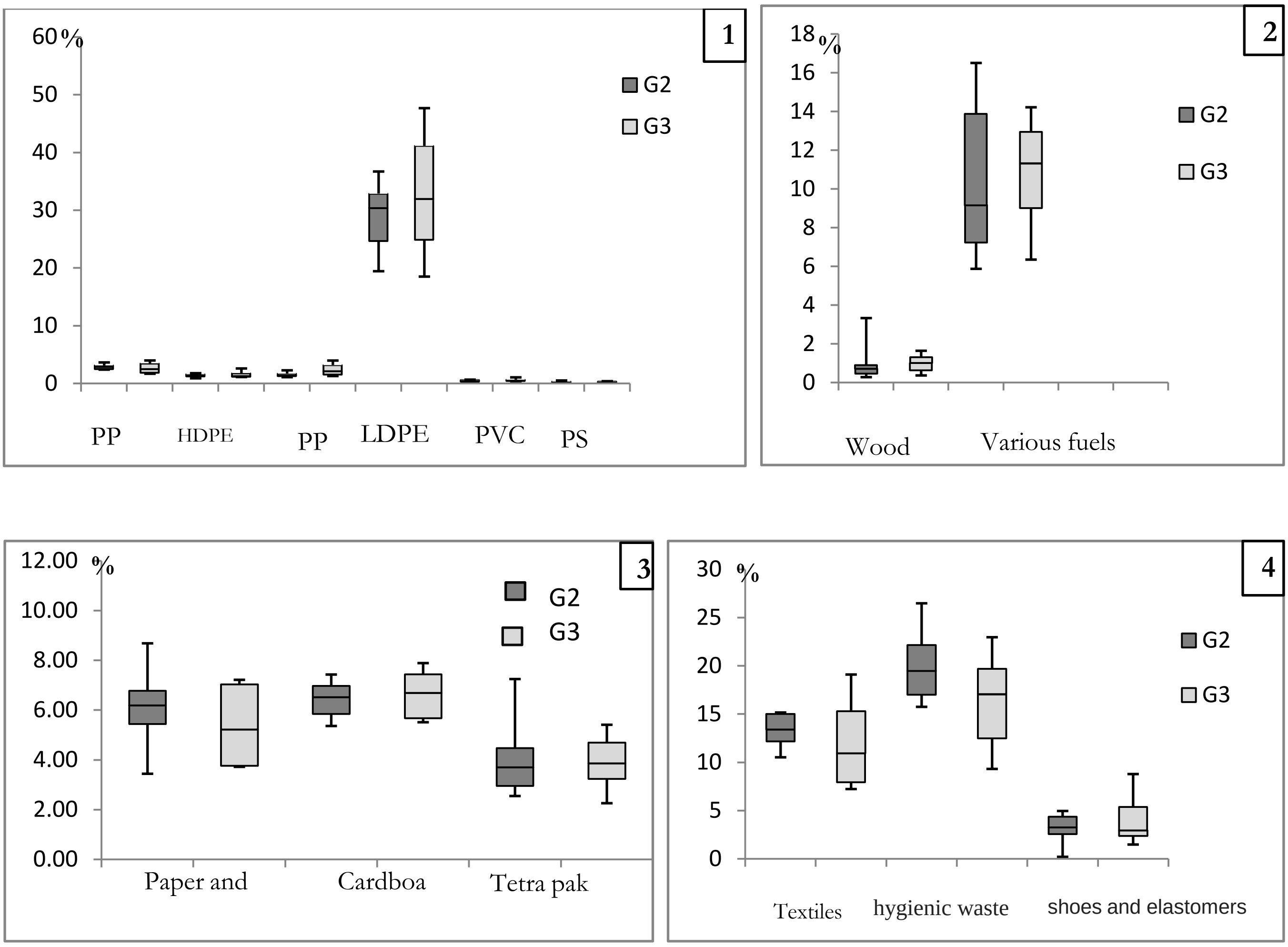


Figure 6: Diagrams of the dispersion of combustible fractions according to the sectors

The distribution of fuel fractions (textiles, cardboard, plastic...) that can constitute the composition of solid recovered fuels is shown in the following charts (figure 7) based on the particle sizes G2 and G3 (Chart A: plastic distribution, B: cardboard and paper distribution, C: textile and waste sanitary distribution, D: wood and other fuels distribution).
The graphics in figure 7 has showed that the distribution of different categories of waste has not been influenced by the size. The difference goes from 0.17% for cardboard until 2.46% for textiles. This proves the homogeneity of waste in both G2 and G3 as far as the granulometry is concerned. Hygienic waste and PLDE have the highest percentages. We also noticed that the mass percentage of PVC that can be considered as a source of chlorides [26] is small and does not exceed 1%.

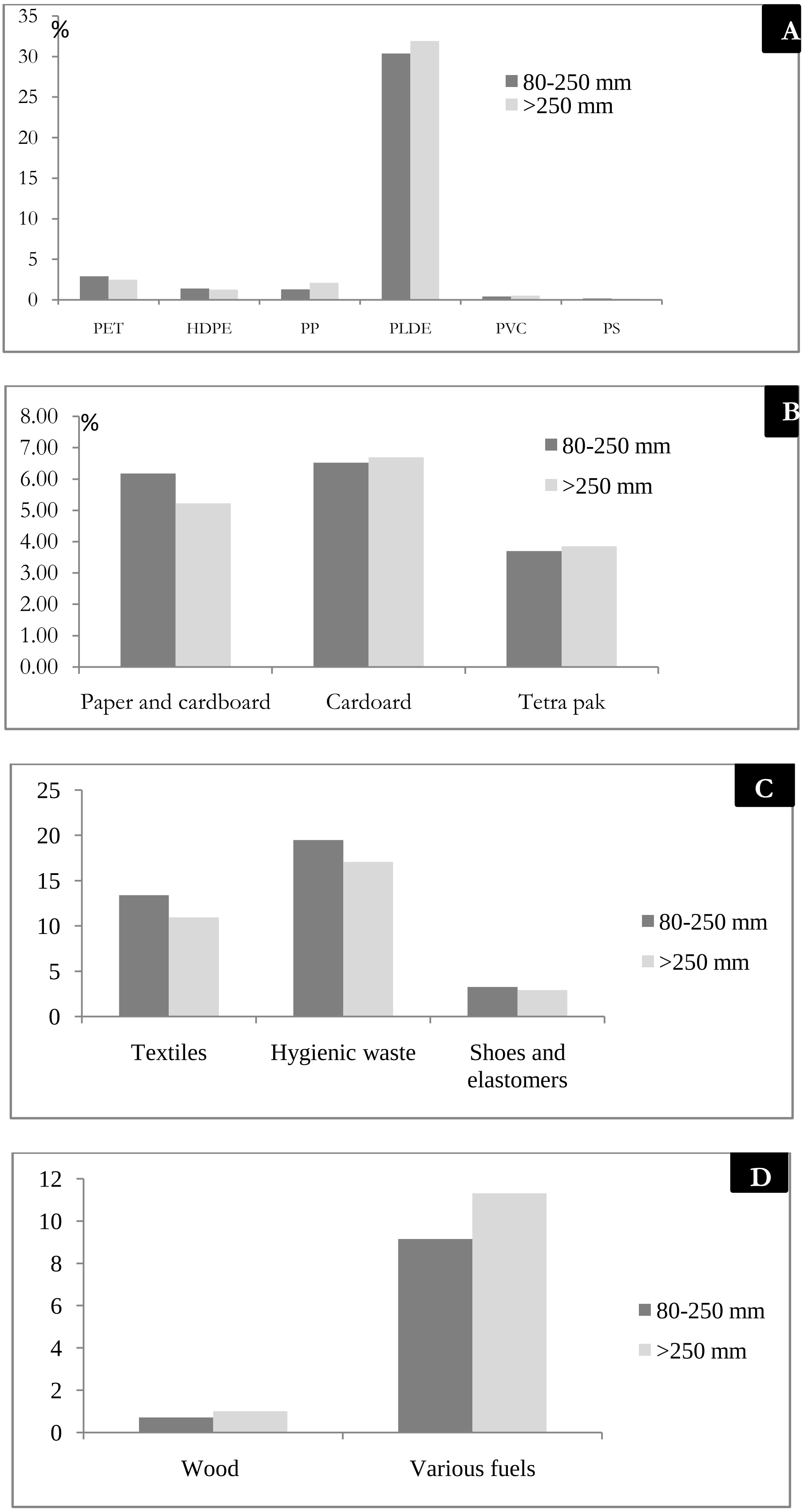


Figure7: Combustiles fractions distribution depending on the particle size
A : Plastics, B : Paper, C : Textiles, D : Various fuels

3.2. *Discussion of results*

The size separation showed that the G2 size fraction is the most abundant with a percentage of 43%, followed by G1 with 36%,whichconsists of biodegradable materials. However, fraction G3 represents 21% of the initial flow.

The waste of the G2 consists mainly of biodegradable materials(57%), and the combustible (textile, cardboard and paper, plastics, sanitary waste...) has 42%, while the rest of the waste (demolition waste, WEEE, MPW) does not have more than 1%. For fraction G3, the rate of the biodegradable materials was 58% and 40% for the combustible portion while the rest of the flow is 1%.

The fuel component consists mainly of; LDPE plastic with percentages of 30.39 % and 31.93% for G2 and G3, as we noticed that waste hygienic constitutes 19.49% and 17.05% for G2 and G3 that consists mainly by babies diapers.The presence of large amounts of plastic, which is characterized by a high calorific value of 22.88 MJ / Kg on wet and 30.94 MJ / Kg on dry, gives the SRF an energy value [27].Thus, the estimation of the fuel part is 40 tonnes per day if a trammel of80 mm size is installed in theupstream of the production unit. Indeed, converting this tonnage to SRF minimizes landfill costs and makes other recovery operations fairly easy.

Table 3: Comparison of the results with those of other studies in some developing countries

Study area	Granulometry mm	Plastic %	Paper and cardboard %	Textiles %	Various fuels %
Lome [17]	>100 mm	46,5	17,13	21	15,38
Nouakchout [19]	>100 mm	46,92	25 ,77	25	2,07
Ghana [21]	All flow	63,16	22	9	6
Naama (Algeria) [3]	>100 mm	20	25,07	53,83	1,32
The present study	> 80 mm	37,6	16,28	34,43	11,71

The results show that plastic is still the most abundant fuel, and this value is quite high in Ghana, Nouakchout and Lome. However, there are significant quantities of textiles for the Maghreb countries in Algeria and in this study.

Conclusion

The results of this study allowed us to extract precious information about the physical aspect of household waste in the city of BeniMellal. Therefore, a preliminary screening can be installed on the upstream of a production unit of the solid recovered fuel, and in order to recover the fraction of size less than 80 mm which may be used for composting or anaerobic digestion. Moreover, the analysis of other granulometric sizes G2 and G3 shows that the combustible fraction has almost the same percentage. Thus, a fuel model from raw waste which is larger than 80 mm may bemade through the results of this study (37% Plastic, paper and cardboard 16%, textile and other fuels 44%).

In the coming study, we are going to carry out chemical and physical analysis in order to investigate the characteristic of SRF generated by waste in a developing country as Morocco.

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