# Municipal solid waste management problems in Morocco and evaluation of fuels fractions- case study of the province of Khenifra

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

[1]*Laboratory of Spectro-Chiemistry Applied and Environment University Sultan Moulay Slimane, Beni Mellal.*
[2] *Laboratory of Environment and Valorization d of Agro-Resources University Sultan Moulay Slimane, Beni Mellal*
[3]*Transdisciplinary Team of Analytical Sciences for Sustainable Development, University Sultan Moulay Slimane, Beni Mellal*
[4]*Laboratory of Geosciences and Environment, University Sultan Moulay Slimane, Béni Mellal.*

**For correspondence: Email: azhasib@yahoo.fr ouigmaneabdellah@gmail.com*

***Abstract***

The management of municipal solid waste (MSW) is an obstacle in several local communities, seen the socio-economic and environmental impacts that may be related to this sector. Waste generation is usually related to changing demographic figures and the improvement of living standards. The aim of this study is to search the problems of waste management in the province of Khenifra located in Morocco and to initiate a feasibility study in order to produce solid recovery fuels (SRF) from MSW. The results of the surveys have shown that waste management in the province has several disruptions. Indeed, the final destination of waste is dumping, despite the programming of a provincial landfill and recovery center. In addition, waste characterization during the winter and summer months showed no difference between the fuel fractions during the two seasons.

**Words keys:** MSW, environmental impacts, landfill, SRF, Waste characterization.

*Introduction*

The evolution of the demographic figures and the improvement of the standard of living are the cause of a non-stop of production of municipal solid waste. The impacts that may be linked to dumping have pushed nations to search valorization and recovery solutions. Sustainable waste management remains one of the main thrusts of the 21 century for environmental protection [1]. To date, landfills constitute the most widely used method of disposing of garbage [2], despite the negative impacts of this type of management and the high cost of environmental degradation [3]. Developing countries have serious problems in the waste management chain. Indeed, in some countries the collection rate of waste can reach values below 50% and the sorting sector remains informal in several cities [4]. In this context, the life cycle of a waste starts with production that differs qualitatively and quantitatively according to several parameters (socio-economic level, seasons, urban and rural areas, etc.). Efficient waste management starts with a sorting at the source by the population, a collective selection by the municipalities and a final disposal with exploiting much as possible our waste following hierarchy: reduce, reuse, recycling, recovery and disposal intended as a final solution [5]. The quality of the treatment depends on the sorting of waste and lack of impurities in the sorted residues. To solve this problem, waste sorting technologies are well developed [6].

Converting waste to energy remains one of the sustainable solutions of a waste management policy [7-9]. This conversion can be demonstrated by the production of SRF. Several authors have studied the characteristics and quality of SRF. Actually, the use of SRF by energy-intensive industries makes it possible to minimize the purchasing cost of fossil fuels and minimize greenhouse gas emissions with the reduction of waste landfilled [10-15]. In Europe SRF is defined as a fuel derived from non-hazardous waste produced in accordance with the requirements of the European standards, specifically in accordance with EN15359. It can be prepared by several

types of waste: industrial, household, sludge of waste water [16-18]. Thus, different categories of waste and products can be mixed to improve the calorific value of the recovery fuel [19-21]. MSW production in Morocco is estimated at 5 million of tons per year. The country has made several efforts in waste management through the drafting of Law 28.00 and the implementation of a national waste management plan aimed at rehabilitating all waste dumps and upgrading 20% at the horizon of 2020 [22-23]. Despite these efforts, the majority of communes have a problem in the management of household waste as they do not have enough consciousness about the resources that can be linked to the valorization of the garbage.

This paper aims to make a diagnosis on the state of waste management in the province of Khenifra and look for the sources of failure of the system of solid waste management. Secondly, we will present the results of a characterization study of the combustible fractions contained in the MSW.

## *1. Material and methods*

### *1.1. Area of study*

Morocco is a developing country located in northwestern of Africa. This study was conducted in the province of Khenifra (Figure 1) which, consists of 22 municipalities with a total population of 370 178 Inhabitants according to population census 2014 [24]. The type of the climate in the province is Continental Mediterranean with a rainy and cold winter and a dry and warm summer. The minimum temperature is 4 ° C (January) and maximum 35 ° C (July and August) with an average rainfall of 550 mm per year. Table 1 shows the 22 municipalities in the studied province with the assigned codes.

**Table 1: The communes of the study area**

| Name of commune | Allocated code | Name of commune | Allocated code |
|---|---|---|---|
| Aguelmam Azegza | C1 | Moulay Bouazza | C12 |
| Aguelmous | C2 | Mrirt | C13 |
| Ait Ishak | C3 | Ouaoumana | C14 |
| El Borgj | C4 | Oum Errabia | C15 |
| El Hamam | C5 | Sebt Ait Rahou | C16 |
| Lekbab | C6 | Sidi Amar | C17 |
| Had Bouhsoussen | C7 | Kahf Nessour | C18 |
| Kerouchen | C8 | Sidi Lamine | C19 |
| Khenifra | C9 | Sidi Hya Ousad | C20 |
| Lehri | C10 | Tighassaline | C21 |
| Mouha Oumhou | C11 | Ait Saadlli | C22 |

The overall survey allowed us to choose 7 communes according to the waste production. The estimated waste production and selected municipalities are shown in Figure 2.

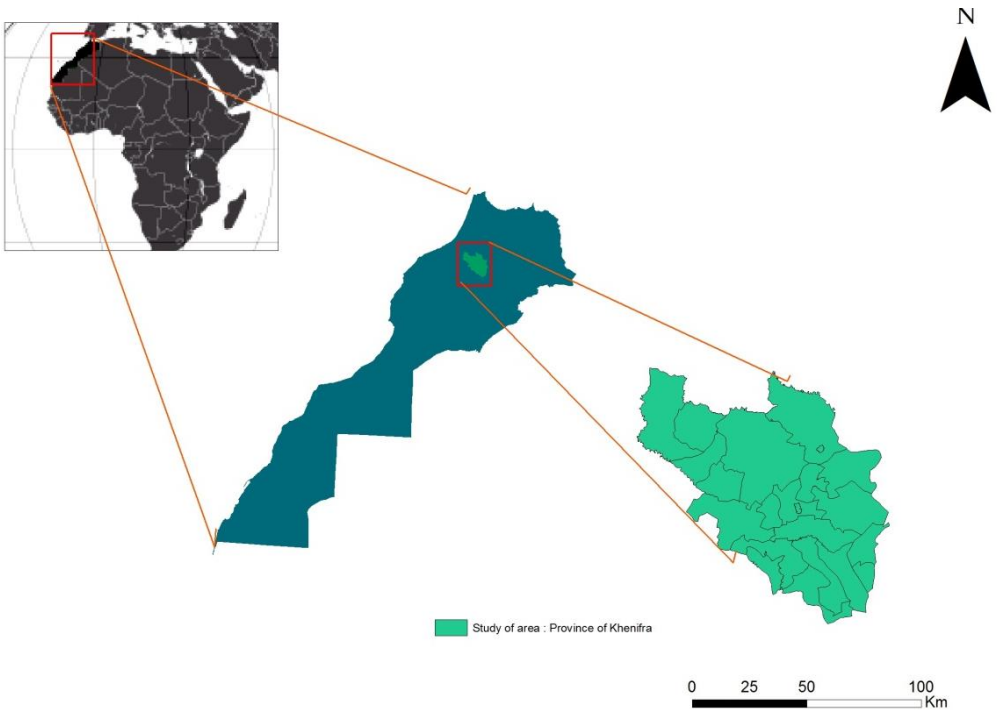


**Fig1. Map of the area of study**

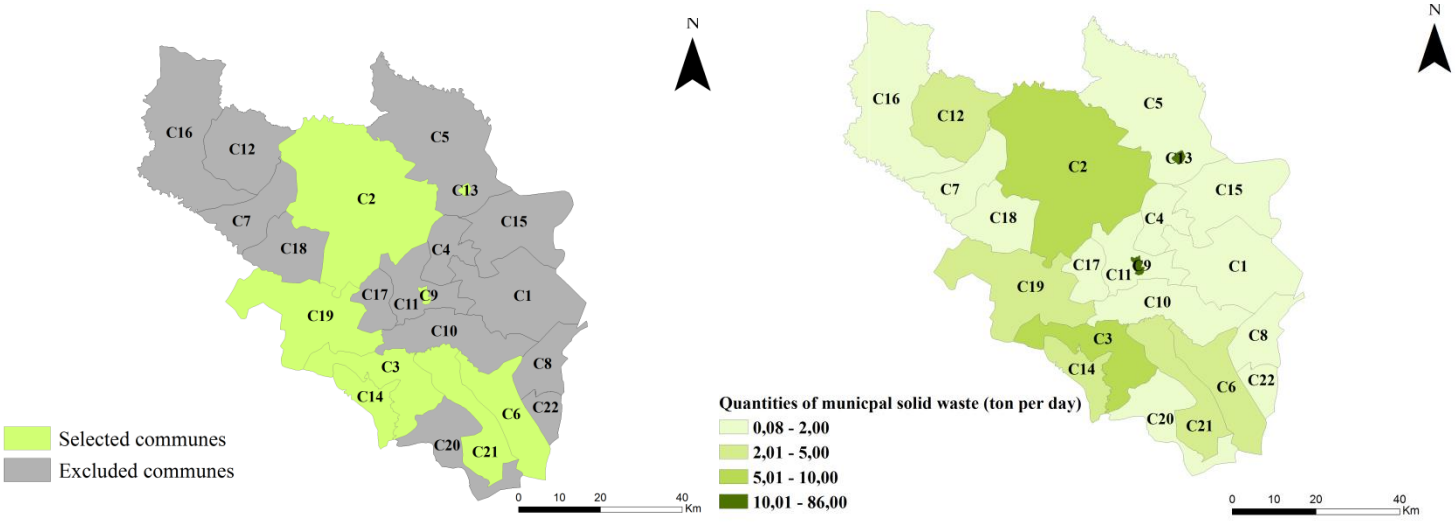


**Fig2. Waste production estimate (right map) and, location of selected municipalities (left map)**

1.2. *Inventory and surveys*

We developed two questionnaires, the first for the seven selected communes and the second for the population with a sample of 155 families distributed over the area of study as shown in figure 3. The questions are presented in the table 2.

### *1.3. Monitoring and evaluation of fuels fractions in MSW*

We decided to study the behavior of the qualitative aspect of the fuel fraction dependence of seasons in order to initiate a study of the production of solid waste fuels based on household refuse. The characterization concerned the fraction greater than 80 mm, because the fraction less than 80 mm consists mainly of the organic matter [25]. The sample is dried for one day, and then weighed and undergoes to a particle size sorting in order to eliminate the fraction less than 80 mm. After that, the fraction greater than 80 is sorted into non-combustible fractions and combustible fractions in four categories (Cat.1: Paper and cardboard, Cat.2: Plastics, Cat.3: Textiles and elastomer, Cat.4: Wood and other fuel). The used methodology is presented in Figure 4.

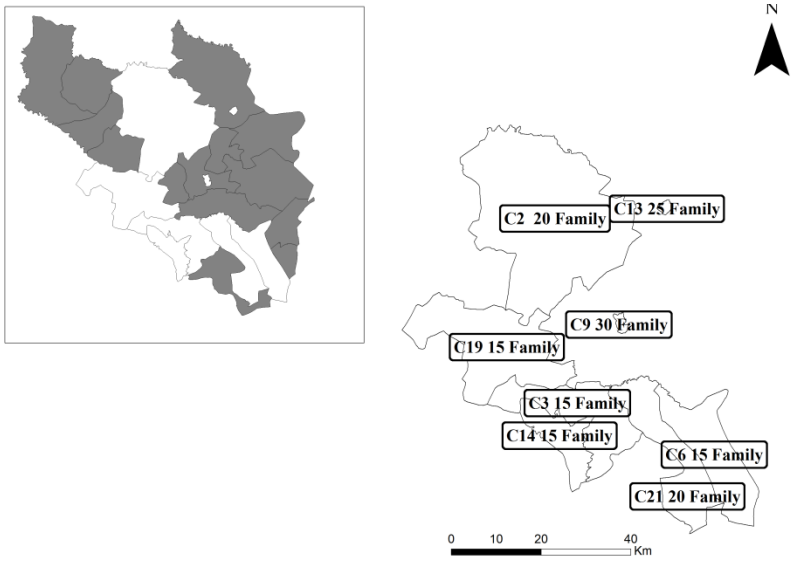


**Fig3. Distribution of surveyed families**

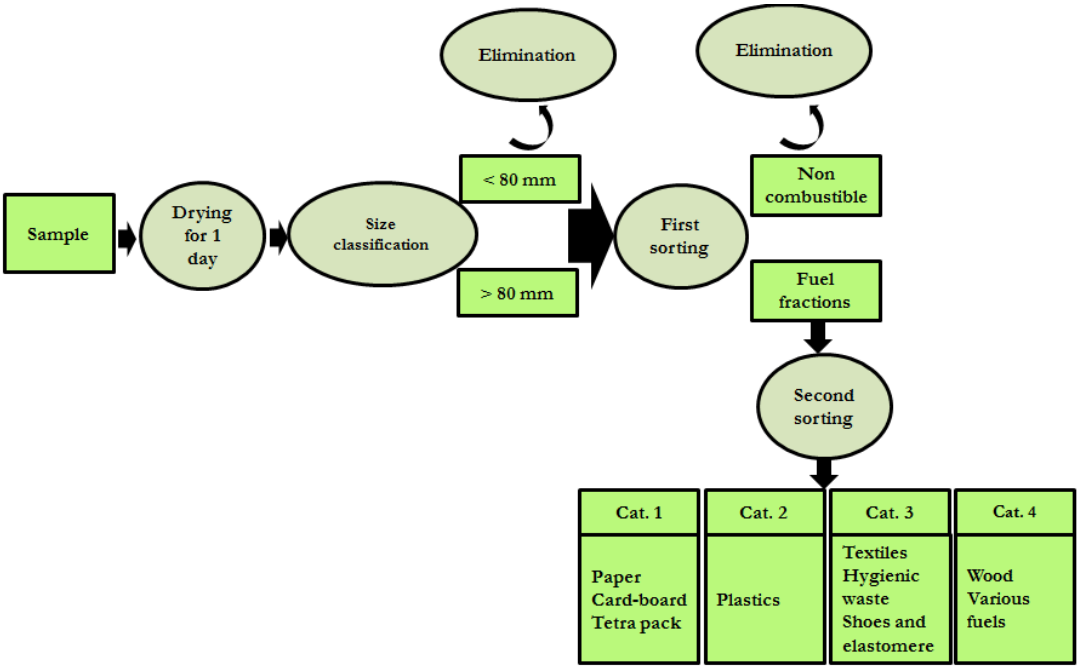


**Fig4. Methodology for the characterization of combustible fractions**

*2. Results and discussion*

*2.1. Waste Management Diagnostic Results*

The results of the survey showed that all municipalities had no any policies for the valorization of MSW. Municipalities which produce more than 2 tons per day throw their waste into landfills or in the nature. The other municipalities with low production do not have a collection and waste disposal service. The results of the questionnaires are presented in the tables 2.

**Table 2: Results of questionnaire of peoples**

| N° | Questions | Responses | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Number of persons per household? | 2/household | 3/ household | 4/ household | 5/ household | 6/ household | 7/ household |
| | | 6,45% | 17,42% | 22,52% | 32,90% | 14,84% | 5,81% |
| 2 | How do you get rid of your waste? | Door to Door | | Shared container | Dumping in nature | | Unspecified |
| | | 64.52% | | 25.16% | 4.52% | | 5.81% |
| 3 | How many times per day? | 1 time per day | | 1 time per 2 days | | 1 time per 3 days | |
| | | 40.65% | | 50.97% | | 8.39% | |
| 4 | What is the most abundant fraction in your trash? | Biodegradable materials ( B.M) | | | | | |
| | | 100% | | | | | |
| 5 | You know what sorting of waste? | Yes | | | No | | |
| | | 62.58% | | | 37.42% | | |
| | If YES, have you ever done a sort? | Yes | | No | _ | _ | _ |
| | | 44.33% | | 55.67% | _ | _ | _ |
| | If YES, what is the fraction you are sorting? | Dry bread | B.D. and dry bread | _ | _ | _ | _ |
| | | 30% | 70% | _ | _ | _ | _ |
| 6 | Do you practice composting? | No | | | | | |
| | | 100% | | | | | |
| 7 | Which collection method do you prefer? | Door to door | | Collection point | | Selective collection | |
| | | 25.80% | | 41.94% | | 32.26% | |
| 8 | Do you have an idea about the final destination of your waste? | Landfilling | | | | | |
| | | 100% | | | | | |
| 9 | Do you have an idea about the circular economy? | 2.50% | | | 97.50% | | |
| | | Yes | | | No | | |
| 10 | Can you engage in a waste sorting project? | Yes | | | No | | |
| | | 51.61% | | | 48.38% | | |
| | If YES, What is the number of fractions that you can sort? | 2 fractions | | 3 fractions | _ | _ | _ |
| | | 99% | | 1% | _ | _ | _ |

Almost half of the surveyed population showed their favorable reactions with the sorting of waste and their agreements to engage in a policy of sorting at the source of two fractions.

**Table 3: Results of questionnaires of communes**

| N° | Question | C2 | C3 | C6 | C9 | C13 | C14 | C18 | C21 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Do you know the law of waste management in Morocco | No | No | No | Yes | Yes | No | No | No |
| 2 | What types of waste do you collect? | All non-hazardous waste | All non-hazardous waste | All non-hazardous waste | All non-hazardous waste | All non-hazardous waste | All non-hazardous waste | All non-hazardous waste | All non-hazardous waste |
| 3 | What is the waste management method that you adapt? | Commune | Commune | Commune | Commune | Private | Commune | Commune | Commune |
| 4 | What is the waste production estimate in the municipal center ? | 10 tons/day | 6 tons/day | 4 tons/day | 85 tons/day | 25 tons/day | 3 tons/day | 4 tons/day | 7 tons/day |
| 5 | What is the mode of collection ? | Door to door | Door to door | Door to door | Both modes | Both modes | Door to door | Door to door | Door to door |
| 6 | Have you had a selective collection experience? | No | No | No | No | No | No | No | No |
| | If YES, What are the fractions collected? | - | - | - | - | - | - | - | - |
| 7 | What are the problems you found in the waste collection service? | Failure to respect trucking time | Failure to respect trucking time | Failure to respect trucking time | Non-conscious population | Non-conscious population | Failure to respect trucking time | Failure to respect trucking time | Failure to respect trucking time |
| 8 | What is the disposal method for your waste? | Landfill | Landfill | Landfill | Landfill | Landfill | Landfill | dumping ground | Landfill |
| 9 | Do you have an idea about composting? | No | No | No | Yes | Yes | Yes | No | Yes |
| | If YES, Have you ever done a pilot project? | - | - | - | No | No | No | - | No |
| | If YES, the project was successful? | - | - | - | - | - | - | - | - |
| | If NO, What problems have you encountered? | - | - | - | - | - | - | - | - |
| 10 | Do you have an idea about solid fuel recovery? | No | No | No | No | No | No | No | No |
| | If YES, Are you planning to set up a project like this? | No | - | - | - | - | - | - | - |

The survey shows that municipalities do not have enough consciousness about waste management, which is proved by the lack of knowledge of the law of waste, dumping of waste without any recovery and lack of experience in the selective collection. Municipalities, on the other hand, do not collect hazardous waste because of the risks associated with this service.

*2.2. Results of characterization of the fuel part*

The result of the monitoring of the fuel fraction during the winter and summer periods are presented in table 4. Figure 5 shows the distribution of fuel fractions according to the communes and the seasons.

**Table 4: Results of characterization of fuel fractions**

| | Summer 2016 | | | | | | | | | Winter 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cat1. | | | Cat.2 | Cat.3 | | | Cat.4 | | Cat1. | | | Cat. 2 | Cat.3 | | | Cat.4 | |
| Kind of waste | Paper | Cardboard | Tetra pak | Plastic | Textiles | Shoes/elsatomer | Hygienic waste | Wood | Various fuel | Paper | Cardboard | Tetra pak | Plastic | Textiles | Shoes/elsatomer | Hygienic waste | Wood | Various fuel |
| C2 | 8 | 15 | 5 | 18 | 18 | 3 | 27 | 4 | 2 | 10 | 13 | 7 | 18 | 21 | 4 | 25 | 1 | 1 |
| C3 | 7 | 16 | 4 | 17 | 15 | 6 | 25 | 7 | 3 | 12 | 15 | 8 | 17 | 10 | 11 | 17 | 4 | 6 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C6 | 5 | 18 | 3 | 15 | 16 | 7 | 24 | 5 | 7 | - | - | - | - | - | - | - | - | - |
| C9 | 8 | 11 | 9 | 20 | 14 | 4 | 25 | 3 | 6 | 12 | 14 | 12 | 17 | 13 | 2 | 20 | 2 | 8 |
| C13 | 7 | 12 | 7 | 18 | 16 | 7 | 28 | 2 | 3 | 13 | 10 | 10 | 15 | 17 | 5 | 28 | 1 | 1 |
| C14 | 7 | 16 | 4 | 13 | 14 | 4 | 29 | 6 | 7 | 17 | 13 | 4 | 17 | 20 | 2 | 18 | 4 | 5 |
| C18 | 3 | 17 | 5 | 18 | 19 | 4 | 27 | 4 | 3 | - | - | - | - | - | - | - | - | - |
| C21 | 9 | 15 | 3 | 17 | 13 | 6 | 27 | 3 | 7 | 15 | 12 | 8 | 13 | 14 | 6 | 22 | 4 | 6 |
| Average % | 7 | 15 | 5 | 17 | 16 | 5 | 27 | 4 | 5 | 13 | 13 | 8 | 16 | 16 | 5 | 22 | 3 | 5 |
| Average by category % | 27 | | | 17 | 47 | | | 9 | | 34 | | | 16 | 43 | | | 8 | |

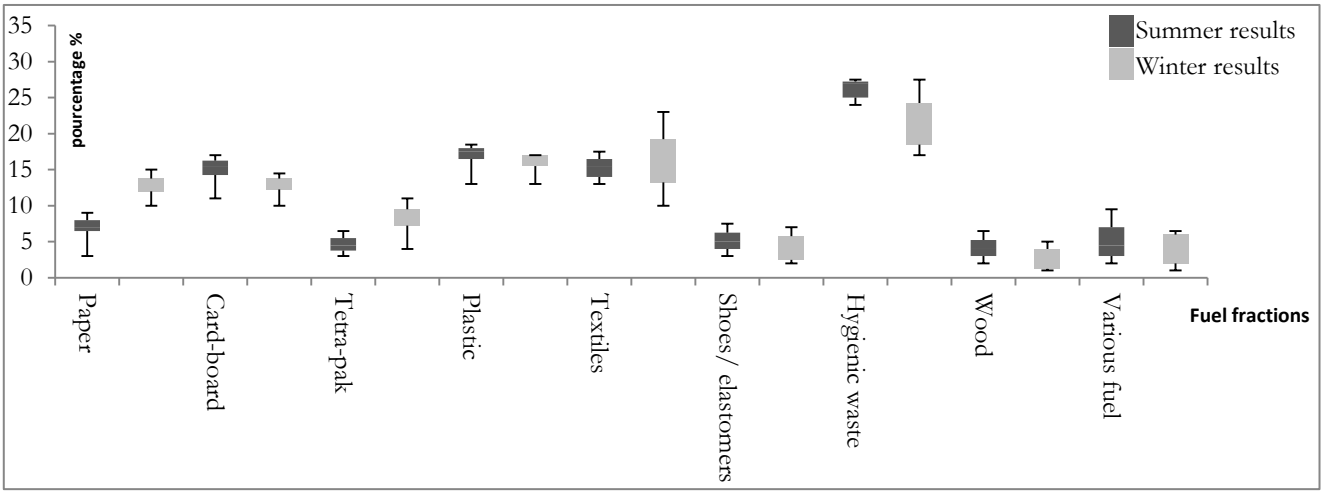


**Fig5. Distribution of fuel fractions by category and season**

We find that the Cat.3 is most abundant during both seasons with the presence of large amounts of baby layers, followed by Cat.1 by 27% in summer and 34% in winter period.

As shown in Figure 5, the co-fueled fractions constitute about 38% initial waste stream

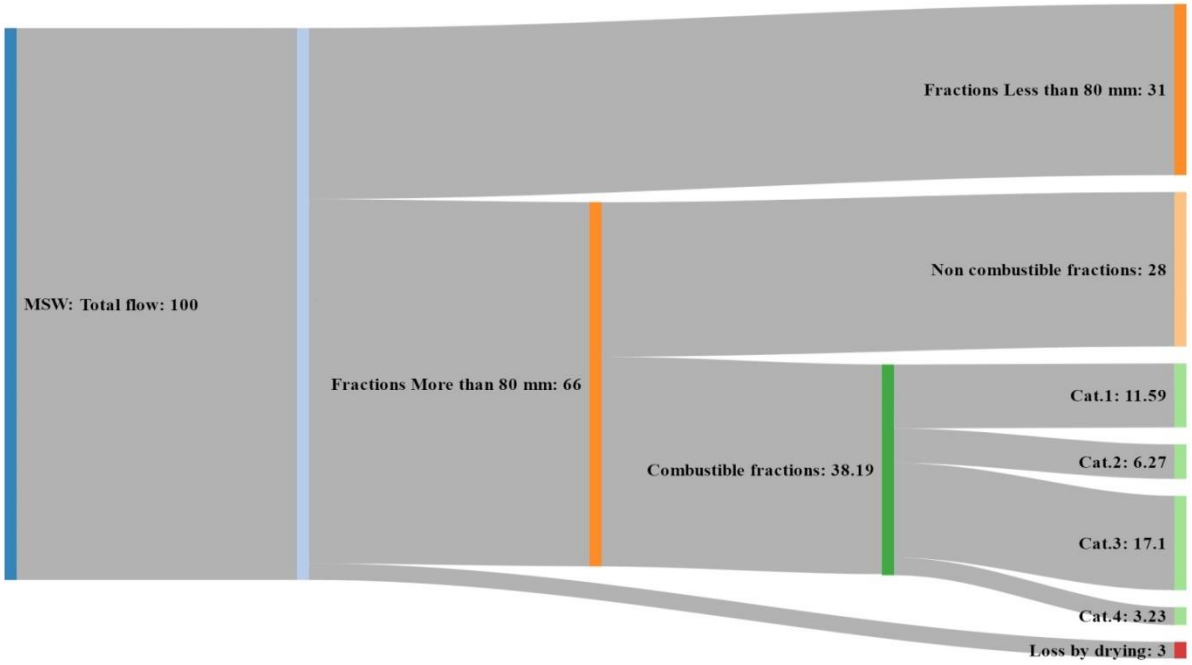


**Fig6. Flow diagram of the characterization study**

*2.3. Discussion of results*

The results of the survey can be explained by the lack of an awareness of the sustainable management of waste. Although the municipality is primarily responsible for the collection and disposal of MSW, we found that 6 communes had no idea about the law of waste management in Morocco. In addition, the municipalities have never tried to pilot a selective collection or compost because of the heterogeneity of the waste and the difficulty of sorting. This may explain the orientation of municipalities to landfilling method, although this mode can have adverse impacts on health and the environment. In the other part, the population survey shows that citizens are fairly aware of waste management and in particular sorting, which can positively influence the MSW management sector. Indeed, 52% of respondents show their interest in sorting the waste into two fractions and 30% of the respondents prefer a selective collection instead of ordinary collection. It can be inferred therefore that waste management can be improved if the municipalities put in place a communication and awareness-raising policy with the population because sorting at the source is the key to a sustainable solid waste management.
The results of the fuel portion show that it represents 38% of the initial flow. Regarding the variation of the fuel fractions depending the seasons, we did not find much difference except for the hygienic waste that is more abundant during the summer period, which can be explained by the frequency of changes of the baby layers by the mothers. The quantities of paper decrease during summertime which can be linked to summer vacation, since the main source of papers is printing sector. The comparison of results of these studies with those we have already done in city of Beni Mellal in summer times (figure 7) showed that waste is almost similar for paper, textiles and wood. On the other hand, this study showed that the plastics knew a decrease in amount thanks to the stop of production and using plastic bags in Morocco since June 2016[25-26].

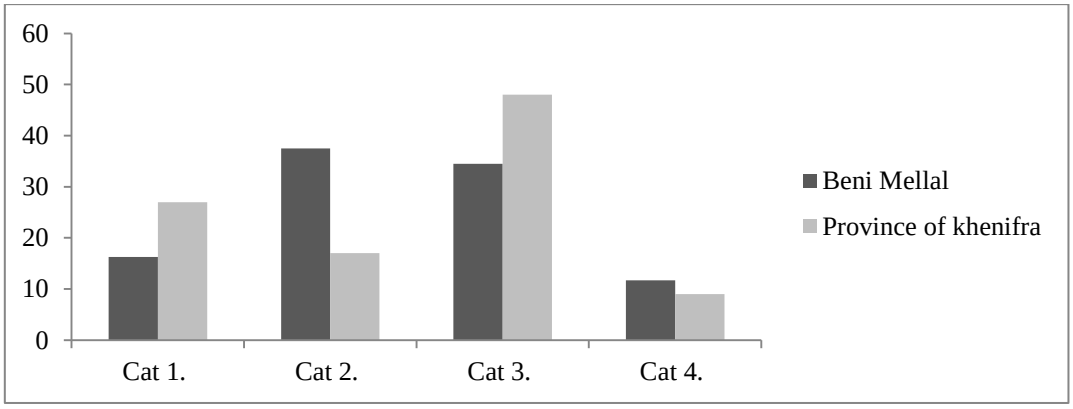


**Fig.7: Comparison of fuel fractions during the summer season of Beni Mellal and the study area**

*Conclusion*

It can therefore be shown that SRF production can be considered as a sustainable solution of MSW in the study area. In addition, the population has shown their interest to contribute to sorting waste into two fractions. Hence, the municipalities can organize itself with the associations to distribute two garbage cans per house, one for combustible fraction and the second for non-combustible fractions.

***Acknowledgement:*** We thank association Eco Atbir for environment and sustainable development for assistance in characterization of waste and we thank Ms. Layati EL Houcein , Abid Younes and Hajir Salah for their assistance during the investigation campaign.

***References***

**[1]** UNEP, 21 Issues for the 21 st Century: Results of the UNEP Foresight Procession Emerging Environmental Issues. Available at http://www.unep.org/pdf/Foresight Report-21 Issues for the 21st Century.pdf (2012)
**[2]** Hoornweg D., Bhada-Tata P.: What a Waste: a Global Review of Solid Waste Management, Urban Development & Local Government Unit. World Bank,Washington, DC. (2012)
**[3]** Eriksson O., Carlsson Reich M., Frostell B., Björklund A., Assefa G., Sundqvist J.O.,Granath J., Baky A., Thyselius L.: Municipal solid waste management from a systems perspective. J. Clean. Prod. 13, 241–252 (2005).

**[4]** Jayarama R.: Municipal Solid Waste Management: Processing, Energy Recovery, Global Examples. BS Publications. (2011)
**[5]** Massarini P., Muraro P.: RDF: from waste to resource – the Italian case. Energy Procedia 81, 569 – 584 (2015)
**[6]** Sathish P. F., Subrata H., Atul T.: A review on automated sorting of source-separated municipal solid waste for recycling. Waste Manage. xxx, xxx–xxx (2016)
**[7]** Porteous A.: Why energy from waste incineration is an essential component of environmentally responsible waste management. Waste Manage. 25, 451–459 (2005)
**[8]** Psomopoulos C.S., Bourka A., Themelis N.J.: Waste-to-energy: a review of the status and benefits in USA. Waste Manage. 29, 1718–1724 (2009)
**[9]** Ouda O.K.M., Raza S.A., Nizami A.S., Rehan M., Al waked R., Korres N.E.: Waste to energy potential : A case study of Saudi Arabia. Renewable Sustainable Energy Rev. 61, 328-340 (2016)
Massarini P., Muraro P. : RDF: from waste to resource – the Italian case. Energy Procedia 81, 569 – 584 ( 2015 )
**[10]** Abu-Qudais M., Abu-Qdais K.: Energy content of municipal solid waste in Jordan and its potential utilization. Energy Conversion & Management 41, 983-991 (2000)
**[11]** Kara.M.: Environmental and economic advantages associated with the use of RDF in cement kilns. Resour. Conserv.Recyc. 68, 21–28 (2012)
**[12]** Chakraborty M., Shrma C., Paney J., Gupta PK.: Assessment of energy generation potentials MSW in Delhi under different technological option. Energie Convers Mang. 45:249-95 (2013)
**[13]** Kathiravale S., Yunus M.N.M., Sopian K., Samsuddin A.H., Rahman R.A., Modeling the heating value of municipal solid waste. Fuel 82, 1119-1125 (2003)
**[14]** Velis C., Wagland, S., Longhurst P., Robson B., Sinfield K., Wise S., Pollard S.: Solid recovered fuel: influence of waste streams composition and processing on chlorine content and fuel quality. Environ. Sci. Technol. 46, 1923–1931 (2012)
**[15]** P. Vounatsos M. Agraniotis P., Grammelis E., Kakaras O., Skiadi T., Zarmpoutis: Refuse-derived fuel classification in a mechanical–biological treatment plant and its valorization with techno-economic criteria. Int. J. Environ. Sci. Technol. (2014). DOI 10.1007/s13762-014-0509-z
**[16]** Rada E.C., Ragazzi M., Apostol T. Role of refuse derived fuel in the Romanian industrial sector after the entrance in EU. WIT Trans. Ecol. Environ. 109, 89–96 (2008)
**[17]** Ragazzi M., Rada E.C.: RDF/SRF evolution and MSW bio-drying. WIT Trans. Ecol. Environ. 163, 199–208 (2012)
**[18]** Nasrullah M., Vainikka P., Janne H., Markku H.: Elemental balance of SRF production process: Solid recovered fuel produced from commercial and industrial waste. Fuel 145, 1–11(2015)
**[19]** Tezanou J., Koulidiati J., Rogaump T, Andzi B.T., Jabouille F., Sougot M., Kafando P., Bere A., Segdal B.G. Contribution à l'étude du traitement thermique des ordures ménagères des pays en voie de développement (PED). Rev. CAMES - Série A,Vol. 03, (2005)
**[20]** Lei Z., Apostolos G., Wan-Yee L., Sheng-Xuan L., Ke Y.: Characterization of Singapore RDF resources and analysis of their heating value. Sustainable Environ. res. xxx 1-4, (2016)
**[21]** Raquel R. C., Rivera J.A., Garcia E.B., Cuardrado R.E., Llorente M.F., Sevillano R.B., Delgado A.P.: Classification and characterization of SRF produced from different flows of processed MSW in the Navarra region and its co-combustion performance with olive tree pruning residues. Waste Manage. 47, 206-216 (2016)
**[22]** Kousksou T., Allouhi A., Belattar M., Jamil A., Elrhafiki T., Arid A., Zeraouli Y.: Renewable energy potential and national policy directions for sustainable development in Morocco. Renewable Sustainable Energy Rev. 47, 46–57 (2015)
**[23]** Naimi Y., Saghir M., Cherqaoui A., Chatre B.: Energetic recovery of biomass in the region of Rabat, Morocco. Intern. j. of hydrogen energy xxx 1 -7 (2016)
**[24]** Haut-commissariat au plan Maroc, http://rgphentableaux.hcp.ma/Default1/ (2014)
**[25]** Ouigmane A., Boudouch O., Berkani M., Hasib A., Aadraoui M., Dhairi E.: 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. J., Mater. Environ. Sci., 8, 2729-2737 (2017)
**[26]** http://www.artemis.ma/pdf/veille/2016/12/Bo6526fr9.pdf