

The Physical Characterization of Household Waste in the City of Mohammedia- Morocco-and the Evaluation of the Financial Impact of its Current Management

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Abstract---This study focuses on the physical characterization of household waste of the city of Mohammedia. It is based on an adequate sampling protocol. A quantity greater than 500 kg was sorted for each housing type in the city, according to 13 components of household waste during the winter, spring and summer of 2014. Results of this characterization work show variations according to season and housing type for all components. Also, the ratio of output per capita varies by season and the maximum was recorded for the summer season with a significant increase on exceptional occasions. The assessment of the financial impact of the value enhancement of fermentable components and some recyclable components shows the enormous potential that source sorting can generate.

Keywords—household waste, waste management, waste characterization, Mohammedia.

I. INTRODUCTION

Rational and environmentally sound and sustainable waste management is one of the major challenges that humanity should face today and in the future. With a trend of increasingly larger and more diversified worldwide consumption, but with the obvious gap between the North and the South, waste production is increasing in quantity and quality and generating enormous risks to the health of the environment and consequently to the health of populations [1, 2, 3]. This situation is much more serious in developing countries, particularly because of their lack of resources and the difficulty in addressing the issue with an approach suitable to their own context.

Thus, in view of the seriousness of the problem of waste and its important stakes in Morocco on the political, social, cultural and environmental levels, there appears to be in recent years a new momentum and a political will expressed by the government, to set up a comprehensive strategy for waste management throughout the national territory. The Ministry of the Interior provides the hierarchical supervision of the cities for which the 2002 Municipal Charter specifies the responsibility for the management of household solid and similar. In addition, the Ministry of Spatial Planning, Water and Environment is primarily responsible for the making of laws, regulations and standards governing the service. On the other hand, the Moroccan legal arsenal is enriched by recently enacted laws, mainly: Law No. 28-00 relating to waste management and disposal, the law N° 12-03 on studies of the impacts on the environment and the law N° 11-03 on the protection and enhancement of the environment [4]. This study is a meant

to be contribution toward aiding decision-makers by providing them with reference data on the composition of household waste in the city of Mohammedia, for which the cost of the management of Municipal waste amounts to approximately 2.72 million euros, and their treatment is limited to simple burying which generates major nuisance in terms of air, water and soil pollution. Good use of these results will allow decision-makers to work out an adequate valuation method and a program that could help solve the problem of waste in the city [5, 6, 7, 8, 9].

A. Study zone



Fig. (1): Geographical situation of the city Mohammedia

Mohammedia, formerly Fedala, is a port city on the Atlantic coast, between two of the most important cities of Morocco: Casablanca, the economic Capital (25 km east), and Rabat, the administrative Capital (65 kilometers west). The city of Mohammedia stretches out over 34.03 Km² and has a population of 235,400, according to the 2004 census. Based on the annual rate of population growth in Morocco [10], the population of the city in 2013 is estimated at 266376.

B. Current household waste management analysis

Household waste Management remains a problem for the city of Mohammedia as is the case with other local communities in Morocco. Significant amounts of waste produced, financial failure, deficiencies on organizational, institutional and managerial levels, the deficit in trained

staff, poor infrastructure and the low level of environmental education –all these are important elements of the problem [11].

The disposal of solid waste takes place in two stages: (1) the collection of household and similar waste and then (2) dumping it in the inter municipal rubbish dump for burial. Lack of information on the part of managers and communities on the other options for recycling and composting and on potential customers seeking products of these operations leads to the adoption of such a very simplistic, unvisionary approach. In addition to this lack of information, we do not take into account criteria that may help in the choice of options for the disposal, treatment and value enhancement of waste. Among the determining criteria, stand out the nature and composition of the waste, the local socio-economic situation and the environmental cost.

II. MATERIALS AND METHODS

It is established that the reliability of the measurement protocol depends on the purpose of the study and the accuracy of expected results.

Two approaches are generally used for the physical characterization of waste, the first of which is the source sampling from households, and the second is sampling from dump trucks or transit sites. This latter approach enables us to obtain detailed results with respect to the composition of the waste; that is why we chose this approach for the collection of our samples during the winter, spring and summer of 2014.

Also research conducted in developing countries has shown that household waste varies in quality and quantity according to the socio-economic level [12, 13, 14]. In the absence of a socio-economic study on the city of Mohammedia, housing is the only criterion considered as an indicator of standard of living.

A. Target population

The target populations are households with different levels of socio-economic life. There are five types of housing that cover the entire territory of the city. Several areas for each housing class were chosen at random, as is summarized in Table 1.

B. Sample size of household waste to sort

Waste from each housing type is studied on a sample of 500Kg, which will allow us to have a high degree of accuracy, particularly for the most minority components in the waste stream [8].The masses of the samples are shown in Table 2.

C. Operating Method

Preliminary investigation

A preliminary survey was conducted to collect all the data necessary to identify the various representative classes among the components of the waste. Indeed, a sorting of an amount of about 500 kg allowed us to identify the categories shown in Table 3.

Table 1: Classification of districts according to type of housing

Housing Type	Code	Areas
Promotional Individual Housing	P.I.H	Behira – Eucalyptus - Hay Chams – Lacoline - LacolineSghira – Lassiesta - Mander Jamil – Manisman – Marsa – Monika - Sablette
Individual Housing	Ind.H	Derbchabab - Derb Marrakech - Hassania 1 - Hassania 2 - Hay El Amal - Hay Falah – Houria – Lakrette – Mourabitin – Nahda - Riadsalam
Collective Housing	C. H	Anfa – Fajer – Florian - IbnKhalidoun – Irmitage – Kaoutar – Litorale – Louma – Manisman – Nassim – Panorama – Rachid – Rokia – Sallam – Tahra - Zainab
Popular Housing	P. H	Derb Meknes - Dyourlakraai - DyourLakrem - Hay Ennasser – Kasbah – Labita – Nikola – Hay El Qods - Rachidia
Informal Housing	Inf. H	Bradaa - Chantijdid - Ch’hawta - DouarCherif - DouarFabrika - DouarLach’heb - Massira - Mesbahiyat - DouarZaimat

Table 2: Masses of samples sorted by housing type (in Kg)

	Inf.H	Ind.H	P.H	C.H	P.I.H
Winter	651,5	748,6	547,5	695,3	623,8
Spring	1136	1098,5	914,5	889	810
Summer	780	778,8	557,5	836,5	722,3

Table 3: Sorting nomenclature corresponding to household waste

Index	Waste classes	Qualitative Description
1	Fermentable materials	Vegetable and fruit peelings, corpses...
2	Cardboard	Cardboard packaging, ...
3	Flexible Plastic	Film, receptacle cover, plastic food packaging bags, ...
4	Metal	Iron, aluminum cans, ...
5	Paper	Newspapers, leaves, ...
6	Plastic	Plastic bottles and cans, ...
7	Plastic Bags	
8	Textile	Remains of cotton and nylon clothes, ...
9	Hygienic textile	Sanitary napkins and diapers, ...
10	Glass	Broken bottles and glass, ...
11	Wood	
12	Green waste	
13	Minority waste	Pebbles, composite, pottery, ...

Sample collection

A driver of a satellite dump truck and his aid were asked to collect samples in a tank with a capacity of 360 liters from each pre-selected area. Once on the sorting site, the tank was emptied into a plastic bag and ticked (date, provenance).

Sample sorting

Once the bags arrived at the waste sorting center, an initial weighing is carried out and the result is recorded. Then, the bags are scattered on the sorting table. Trained personnel begin to classify waste by predefined category. Each type of waste is put into a plastic bag and weighed separately. The analysis of acquired data will allow us to evaluate the deposit of household waste produced by the city of Mohammedia.

III. RESULTS AND DISCUSSION

A. Quantity of household waste produced by the city of Mohammedia

Analysis of Table 4 confirms the seasonal effect on household waste generation, hence the significant increase in daily production during the summer season.

Table 4: Ratios of waste generation per month for the years 2012 and 2013 (in kg /Hab. /Day)

	2012	2013
January	0,732	0,747
February	0,622	0,726
March	0,7	0,784
April	0,75	0,772
May	0,844	0,784
June	0,844	0,875
July	0,85	0,965
August	0,845	0,878
September	0,743	0,73
October	0,907	0,994
November	0,766	0,718
December	0,701	0,717
Average	0,775	0,808

An increase in the tonnage of about 4.2% is noticed. This increase is mainly due to population growth, rapid urbanization and changing consumption patterns.

The ratio of average waste generation per capita per day is close to that of Greater Casablanca, i.e., 0.89 kg /inhab. / Day [9]. On the other hand, it is higher than the average ratio of Morocco, estimated at 0.75 kg /inhab. / Day in urban areas. This can be explained by the high population density in this region (characterized by the verticality of its buildings) and the collection is done at a high rate compared

to other cities of Morocco. Secondly, there are two ‘peak periods’ where waste generation is very important: The month of Ramadan (July) and the Feast of Sacrifice (October).

Table 5: Ratios of waste generation in some cities and countries of the Maghreb

Country	City	Waste production (kg / inhab. / day)	References
Algeria	-	1,20	(Mate, 2005) [16]
	Mostaganem	0,62	(Guermoud, 2008) [17]
	Biskra	0,55	(Mezouari, 2011) [18]
	Alger	0,75	
Morocco	-	0,75	Secretary of State for Environment, 1999
	Casablanca	0,89	(Ben Amar, 2006) [9]
	Mohammedia	0,80	Current study
Tunisia	Tunis	0,80	(Ben Amar, 2006) [9]
Mauritania	Nouakchott	0,21	(SidiOuld, 2006) [19]

B. Results of the sorting work

Results of the sorting work were ranked in increasing order according to their importance in wet mass.

Table 6: Variation by housing type in the composition of waste during the winter of 2014

Component	C.H	P.I. H	Ind. H	Inf. H	P.H
Fermentable materials	38,98%	42,96%	43,35%	50,50%	46,03%
Glass	13,38%	9,83%	11,09%	6,29%	8,31%
Hygienic textile	9,56%	7,21%	6,95%	6,14%	7,40%
Plastic bags	8,34%	8,74%	8,35%	6,91%	8,49%
Plastic	7,33%	5,61%	6,61%	6,45%	6,48%
Paper	5,61%	5,21%	6,14%	5,83%	6,58%
Cardboard	4,31%	6,81%	4,54%	4,91%	5,21%
Textile	2,88%	0,56%	3,81%	4,91%	3,11%
Wood	1,94%	0,96%	3,81%	3,15%	2,56%
Metals	2,73%	1,92%	1,84%	2,15%	2,10%
Thin plastic	2,73%	2,05%	1,67%	1,23%	1,83%
Minority waste	2,20%	3,64%	1,84%	1,53%	1,92%
Green waste	0,00%	4,49%	0,00%	0,00%	0,00%

Table 7: Variation by housing type in the composition of waste during the spring of 2014

Component	C.H	P.I. H	Ind. H	Inf. H	P.H
Fermentable materials	51,63%	48,09%	49,07%	48,59%	52,10%
Glass	8,44%	10,62%	7,60%	6,07%	7,76%
Hygienic textile	9,06%	8,77%	7,87%	5,46%	7,60%
Plastic bags	6,92%	7,47%	7,65%	7,35%	7,76%
Plastic	6,07%	6,91%	5,92%	6,38%	6,56%
Paper	4,16%	5,06%	5,69%	6,43%	4,92%
Cardboard	3,15%	2,72%	3,96%	4,71%	3,88%
Textile	2,64%	1,98%	3,64%	4,93%	1,80%
Wood	2,19%	1,23%	2,82%	6,07%	2,19%
Metals	2,47%	3,09%	2,55%	1,94%	2,13%
Thin plastic	1,91%	2,47%	2,05%	0,79%	2,02%
Minority waste	1,35%	1,60%	1,18%	1,28%	1,26%
Green waste	0,00%	0,00%	0,00%	0,00%	0,00%

Table 8: Variation by housing type in the composition of waste during the summer of 2014

Component	C.H	P.I. H	Ind. H	Inf. H	P.H
Fermentable materials	55,95%	50,05%	53,54%	47,69%	49,84%
Glass	8,37%	9,14%	7,77%	5,83%	8,09%
Hygienic textile	8,43%	9,00%	8,22%	6,73%	10,27%
Plastic bags	7,29%	7,61%	8,54%	7,50%	7,87%
Plastic	5,32%	6,09%	4,17%	5,77%	6,78%
Paper	4,48%	4,57%	4,43%	4,23%	4,59%
Cardboard	2,81%	5,12%	3,98%	5,32%	3,17%
Textile	1,49%	1,38%	1,67%	5,90%	3,39%
Wood	1,20%	0,69%	2,70%	6,15%	0,66%
Metals	1,79%	2,01%	1,80%	2,05%	1,75%
Thin plastic	1,43%	1,59%	1,67%	1,28%	1,86%
Minority waste	1,43%	1,63%	1,52%	1,54%	1,75%
Green waste	0,00%	1,11%	0,00%	0,00%	0,00%

The results suggest that organic matter is the most important fraction, which reflects the diet of Morocco, a fruit-and-vegetable-based diet. Second, glass remains the most widely used for packaging several products (drinks, tinned foods ...). Plastic bags are the most common means of packaging, hence its major portion. Given the changing lifestyle, hygienic textile is increasingly used. The plastic portion is 6.50%, explained by the development of the petrochemical industry in Morocco.

On the other hand, we note that informal settlements produce more organic and textile materials, however a little less than other components. For collective housing, they produce less organic waste, given the lifestyle of households that tend to eat outdoors, while they produce more hygienic textiles. Apart from some exceptions, such as the presence of small shops, that affects the cardboard and paper rate, the majority of components reflects a certain homogeneity of waste components despite the change in the remaining housing types.

It has been shown [20] that the exploitation of this household waste deposit in the city of Mohammedia, as is the case with to cities in developing countries, can have positive impacts on the entire comprehensive management and beyond, on employment and financial resources generation and on improving the quality of life.

C. Estimated recoverable components by fermentation and recycling

The physical characterization of household waste in the city of Mohammedia is motivated by the need to estimate the fractions that can be recovered by fermentation and to assess the possibility of recycling certain components of its waste. In 2013, the amount of collected and processed waste is around 78,608 tons. The management of one ton costs 34 euros /a ton.

The variation of the components relative to the total quantity for each season is shown in Table 9.

D. Estimated fermentable components

Organic waste has the characteristic of being completely biodegradable. It is fermentable, that is to say, it may be treated by composting [21] or methanation.

Organic matter represents about 48.57% of the waste produced by the city of Mohammedia. Indeed, the annual amount is about 38,180 tons. It is not subject to a specific treatment and its management costs 1.29 Millioneuros, while it is 100% recyclable. Solutions for organic waste treatment are varied, and can be performed by individuals or by the communities.

E. Estimated recyclable components

The main components recoverable by recycling correspond to the following categories: glass, plastic, paper, cardboard and metals [22].

Based on our study, the introduction of a selective waste collection will help retrieve 6,720 tons / year of glass, 4,810

tons / year of plastic, 7,499 tons / year of cardboard and paper and 1,690 tons / year of metals [23, 24, 25]. The annual treatment of this waste costs about 0.70 million euros. However, the recovery of this type of waste has become, in Morocco, an important income-generating economic activity, mostly informal. Informal waste collectors resell the recyclables, which they collect from

bins to intermediaries who transport them to recycling industries.

Formalizing this branch of industry can make it more profitable due to the reduction of intermediaries working in this field and the industrialization of the recycling process. This study shows the enormous potential that sorting and recovery of such wastes (whose overall sale price is about 1.31 million euros) can generate.

Table 9: Components of solid waste in the city of Mohammedia according to season

Component	Winter	Spring	Summer	Average
Fermentable materials	44,22%	49,83%	51,65%	48,57%
Glass	9,91%	7,93%	7,80%	8,55%
Hygienic textile	7,47%	7,62%	8,36%	7,82%
Plastic bags	8,16%	7,44%	7,75%	7,78%
Plastic	6,52%	6,34%	5,51%	6,12%
Paper	5,86%	5,33%	4,45%	5,21%
Cardboard	5,11%	3,76%	4,13%	4,33%
Textile	3,09%	3,14%	2,71%	2,98%
Wood	2,53%	3,08%	2,43%	2,68%
Metals	2,15%	2,40%	1,89%	2,15%
Thin plastic	1,91%	1,79%	1,54%	1,75%
Minority waste	2,21%	1,32%	1,56%	1,70%
Green waste	0,86%	0,00%	0,22%	0,36%

Table 10: Prices/cots of recyclable waste processing and resale in Morocco –Case of Mohammedia

Category	Deposit in 2013 (in tons)	Management Cost (Euro / ton)	price of sales in the informal sector (Euro / ton)	overall management costs (Euro)	Total price of Sales in the informal sector (Euro)
Glass	6720,984	34	45,45	228513,456	305468,723
Plastic	4810,8096	34	90,9	163567,526	437302,593
Cardboard & Paper	7499,2032	34	45,45	254972,909	340838,785
Metals	1690,072	34	136,13	57462,448	230069,501

IV. CONCLUSION

The almost single approach adopted so far for the disposal of municipal waste is very simplistic and somewhat unvisionary. In the best case, it involves the improvement and organization of waste collection only to dump the waste afterwards for burial. The choice of such an approach is based on different criteria, primarily the lack of information on the part of managers and communities on the other recovery options, on the nature and composition of the

waste, on the local socio-economic reality and on the environmental cost

At the end of this first measurement work in the city of Mohammedia, it emerges that the quantity and composition of generated household waste vary according to season and housing type. The fermentable proportion suggests composting as the most promising technique compared to other methods of waste disposal (such as incineration). Nevertheless, a chemical waste characterization is crucial for a better decision. The recoverable fraction by recycling is interesting and could be the second segment in the

management of household waste. To this end, a selective sorting system is justified.

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