Biodrying for Mechanical Biological Treatment of mixed municipal solid waste and potential for RDF production.

A. Elnaas[1], A. Belherazem[2], W. Müller[3], A. Nassour[1] and M. Nelles[1]

[1]Department Waste Management and Material Flow, University of Rostock, Rostock, 18051, Germany.

[2] GKW Consult GmbH, Mannheim, 68165, Germany.

[3]Institute of Infrastructure, University of Innsbruck, Innsbruck, 6020, Austria

Presenting author email: Ayman.Elnaas@uni-rostock.de

Abstract: In recent years some Arab countries have introduced the integrated solid waste management concept. Collection, composting, incineration of medical wastes and sanitary landfills are starting to be implemented, while recycling, reuse and resource recovery are still at the initial stages. Considering the poor compost quality produced from mixed MSW and the unfeasibility of a segregated collection in most the Arab region other practical alternatives for the management of mixed MSW should be evaluated and considered. The aim of this paper is to investigate the potential for RDF production by using the biodrying process, within a pilot project supported by the German Financial Cooperation via KfW. Furthermore, the economic feasibility and financial risk of the project proposal is evaluated by carrying out a capacity analysis. The biodrying process increased the waste calorific vale by about 20%. Chlorine content, in the RDF, ranges betweem 0.66-1.30 % w/w. The RDF has a high concentration of heavy metals, this could be explained by the high content of

organic material and fine particles in the product. RDF became one of the interesting alternatives to solve both, global warming and MSWM problems. Furthermore, it was important to point out that other benefits could be achieved in terms of improved quality of life, reduced health damage, as well as environmental benefits associated with reduced pollution and preserved landfill.

Key words: Municipal solid waste (MSW), mechanical-biological-treatment (MBT), biodrying, rrefuse-derived fuel (RDF), composting, waste composition, heavy metals, heating value, cost analysis.

Introduction: The effective management of solid waste involves the application of various treatment methods, technologies and practices to ensure the protection of the public health and the environment. There is a wide range of alternative waste management options and strategies available for dealing with mixed municipal solid waste (MSW) to limit the residual amount left for disposal to landfill (Adani et al. 2002). Population growth in urban centers, lack of strategic planning, lack of proper disposal, limited collection service, use of inappropriate technology and inadequate financing are considered the main problems facing solid waste management (Diaz et al. 1999). Disposal of MSW is challenging in many areas, mainly because that landfill space is becoming scarce and growing public environmental awareness. Therefore, the recent MSW management strategies encourage material recycling, energy recovery and stabilization of MSW before landfill. Thus, the combustion and biological processes, yielding thermal power, refuse-derived fuel (RDF), compost and stabilized product, have drawn increasing attention. With proper MSW management and the right control of its polluting effects on the environment and climate change, MSW has the opportunity to become a precious resource and fuel for a future sustainable energy.

In recent years some Arab countries have introduced the integrated solid waste management concept. Collection and sorting, composting, incineration of medical wastes and sanitary landfills are starting to be implemented, while recycling, reuse and resource recovery are still at the initial stages. Recyclable materials such as plastic, glass, paper, metals and textiles are not separately collected, and household waste is mixed with other types of waste when it is collected. About 2-5% of material are recovered as recyclable materials, these materials are sorted by informal sector (Nassour 2008). Waste management in Arab countries is characterized by a high percentage of uncollected waste, with most of the waste directed to open or controlled dumpsites. Sorting and composting facilities are being operated with limited capacity, most of them are not operating anymore and some of them are even closed before they start to operate. Their failure was due to the mismanagement of the plants, the selection of inappropriate technology for the local conditions, which results in high operating costs and frequent mechanical breakdowns through poor maintenance, lack of understanding of the composting process and training of personnel for the operational procedures (Nassour et al. 2011).

A previous study carried out in the region to evaluate the situation of SWM practices in the Arab region and to examine the compost produced from mixed MSW in the region (Elnaas et al. 2014). Samples were collected from different cities in different countries in the region (Egypt, Syria, Iraq, Turkey and UAE). The main samples are MSW compost, and the raw material to produce the compost was mixed municipal solid waste. Generally, most compost samples tested in this study had poor quality and are not recommended to be used as soil fertilizers. This is due to the risk from heavy metals and organic pollutants alongside the physical risks from sharp objects, glass and the aesthetical problem of plastic scraps that remain highly visible even after composting. The heavy metal concentration, in the compost sample analysed for this study, was compared with the German standards (BioAbfV), the results show that 56% of the samples have three or more elements of the heavy metals more than the proposed limit and 12% have two elements more than the proposed limit (Fig. 1), while only 32% have one element more than the proposed limit. Only one of the 16 tested samples fulfil the (BioAbfV) requirements and are considered as stable compost of class (A) due to high concentration of Ni which is higher than the limit set by (BioAbfV). (Fig. 1 here)

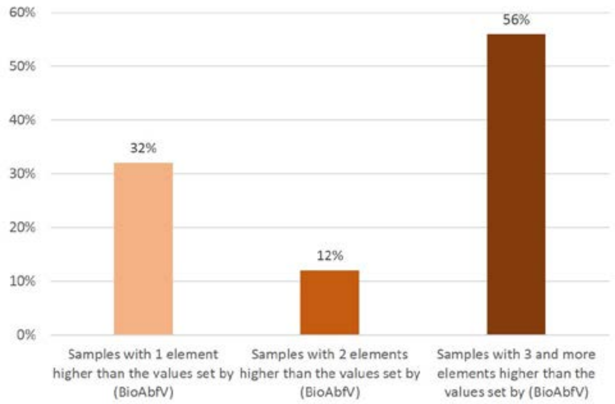


Figure 1. Results of heavy metals concentrations in the compost samples compared with the German standard (BioAbfV)

It is clear that the production of compost from mixed MSW widely exists in many countries in the Arab region, and it needs sustainable method for its disposal. Almost all composts derived from MSW, tested in this study remain wastes rather than compost, even after successful processing to stabilize the organic matter. The absence of local standards, monitoring system and the legal barrier prevent the commercialisation and selling of MSW compost and its application to agricultural/horticultural land. Although, there is a risk that the application of MSW compost will increase the heavy metals content of agricultural soils.

Considering the poor quality compost produced from mixed MSW, and the unfeasibility of a segregated collection in most developing countries and the Arab region other practical alternatives for the management of mixed MSW should be evaluated and considered for the region (Nassour et al 2011, Rechberger 2011 & Rotter 2011).

The aim of this paper is to investigate the potential for RDF production and to quantify RDF that would be produced by using the biological drying/stabilization process. The performance of Biological drying process of solid waste, by aerated windrow composting/stabilization, was investigated within a pilot project supported by the German Financial Cooperation via KfW (2014-2015) to transfer a low cost mechanical biological pretreatment technique of MSW to the conditions in Tunisia. Furthermore, the economic feasibility and financial risk of the project proposal is evaluated by carrying out a capacity analysis.

Materials and methods:

Input material (MSW): The waste, under study, has a typical characteristics of most waste developing countries, such as high moisture contents and large organic fraction Both will contribute to the production of leachate and landfill gasses with the presence of odour problem. The results of the waste characterization are shown in (Fig. 2)**.** (Fig. 2 here)

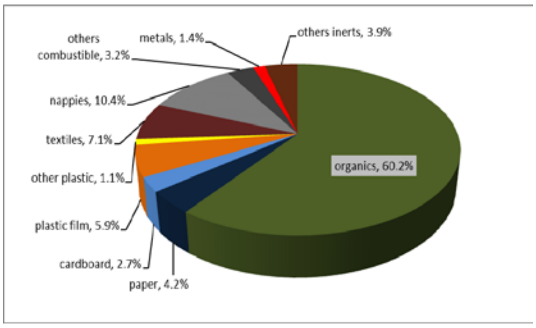


Figure 2. Composition of household waste from Beja, average of total analyses during both seasons (June, 2014- Jan, 2015).

Organic material represents the highest portion in waste stream, about 60.2%. It contributes to the high moisture content, and hence leads to low calorific value. Textiles represented 7.1 %, nappies 10.4% and plastic film 5.9%, which is mainly plastic bag, due to people usually disposing their wastes in plastic bag. Paper and cardboard, combined, contribute to 6.9 % of the waste composition.

Experimental setup and operation: For each test trial, the waste was subjected to biodrying phase (self-draining of waste) for 3 weeks period, to enable an effective screening of waste to separate recyclable materials and high calorific value components from the fine organic fraction. The activities during the projects included the following tasks:

- Waste delivery, it was planned that the facility should receive about 100t for each trial/windrow.

- Shredding of the total waste received using the existing compost-shredder at the site was not possible. Therefore, the windrow turner was used to at least open the waste bags and mix the waste.

- Formation of windrows with 5m wide, 2m high and along the whole length of the aeration pipes (about 40m).

- To maintain optimum composting/biodrying conditions, the piles were turned and mixed once a week using a composting turner.

- After 3 weeks, the process should be finished and the waste should be dried. The waste was screened at 80 mm with the drum screen.

- Determination of the split between > 80 and < 80 mm on the site. Afterword the total RDF was weighed with the weighbridge in the close dumping site it order to estimate and calculate the mass balance.

Sampling was carried out during the different steps of the process as follows:

- Sampling for the characterization of received waste at the site,

- Sampling the dry waste while screening (at 80mm), after 3 weeks (output), and

- Sampling during the weekly turning of waste for monitoring biological reactions.

All the samples went, three times, through preparation and shredding at 20mm to reduced their size before analysis. The main parameters are: the dry matter content, ash content, chlorine content, heavy metals and calorific value.

Experimental monitoring

The biodrying process of the formed windrows was monitored by an automatic temperature control system which continuously measures the windrow temperature. A forced aeration system was installed to ensure that sufficient air is blown into the waste which is necessary to provide optimum conditions for composting. The aeration system, illustrated in (Fig. 3), was set to maintain an average compost temperature at around 40˚C to 70˚C. Turning of the waste, with the compost turning machine, was conducted weekly to avoid poor air distribution and uneven composting of the waste in the windrow, and also to maintain a good structure in order to maintain porosity throughout the entire composting period. (Fig. 3 here)

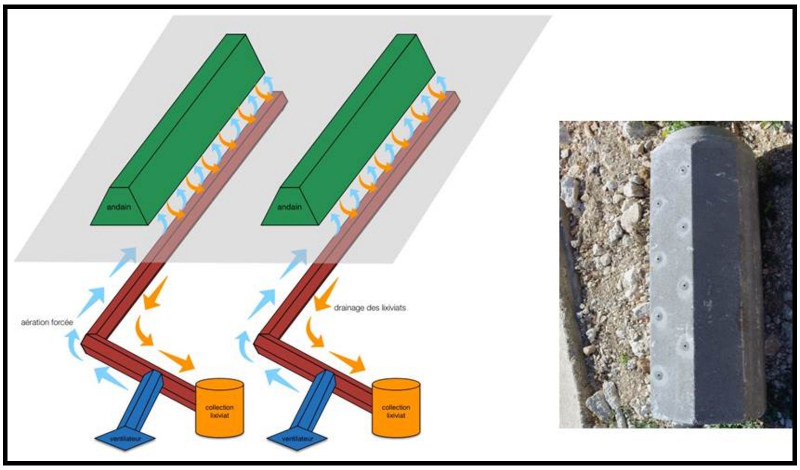


Figure 3. Ventilation system installed on the pilot site (source: intrim unpublisched report of the pilot project)

In addition to the evaporation of water, the forced aeration helps to establish optimum composting conditions and to reduce the production of odorous substances. To further reduce the emission of odour, to the environment the windrows were covered with a membrane. The other purpose of the membrane is the protection of the composting windrows against sun and rain.

As shown in (Fig. 4) the temperature of the windrows during the biodrying process was maintained at 40-70^{0}C most of the duration of the biodrying process. After three weeks of composting, the waste was fairly dry with a moisture content between 30 and 45 %, the dry matter of the final product increased from the initial 44-53% to 53-72%. (Fig. 4 here)

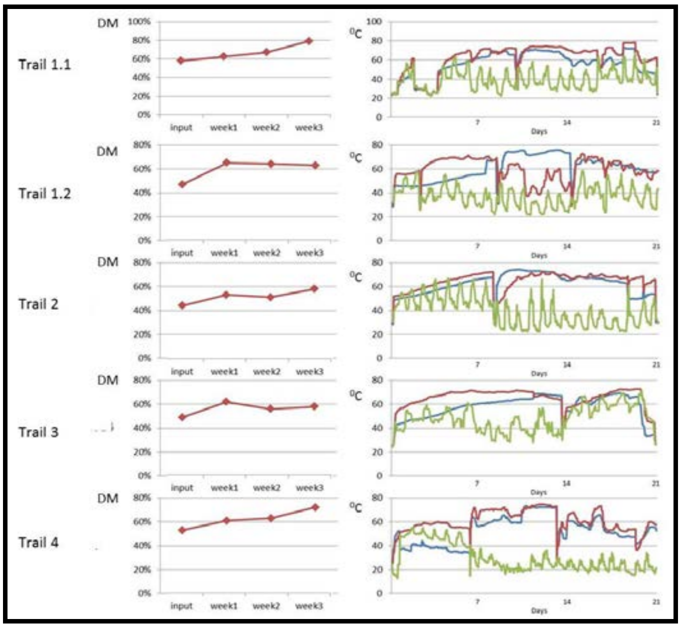


Figure 4. Monitoring of temperature and water evaporation during the biodrying process (June, 2014-Jan, 2015).

Results and discussion:

Bodrying concept:

The principle of aerobic bio-drying is to drive evaporation with energy/heat from organic matter degradation. Thus the capacity for water removal is limited by the amount of biodegraded organics. The air supply was controlled automatically, the control mechanism was managed by the temperature probe sensor. The temperature was the key parameter for water evaporation and organics degradation during biodrying. The aeration of waste is critical for biodrying. It provides mass and energy flow media, enabling water content removal, heat-transfer redistribution, removing excessive heat, adjusting the windrow temperature and ensures O_2 suplly for aerobic decomposition. Air blowers were set to maintain an average compost temperature at around 40˚C to 70˚C. Turning of the waste with the compost turning machine, was conducted weekly to avoid poor air distribution and uneven composting of the waste in the windrow, and also to maintain a good structure in order to maintain porosity throughout the entire composting period (Tambone et al. 2011, Velis et al. 2009, Adani et al. 2002 & Sugni et al. 2005).

The resulting dry material is, afterwards ,screened in order to separate the oversize fraction characterised by high net heating value from the smaller fraction.

Screening at 80mm and mass balance:

After three weeks of composting and drying, the waste can be screened efficiently into a coarse fraction with high calorific value, which can be used as a basis for the production of substitute fuel. The results of screening splits and mass balance of all trials during summer and winter seasons are illustrated in (Fig. 5). (Fig. 5 here)

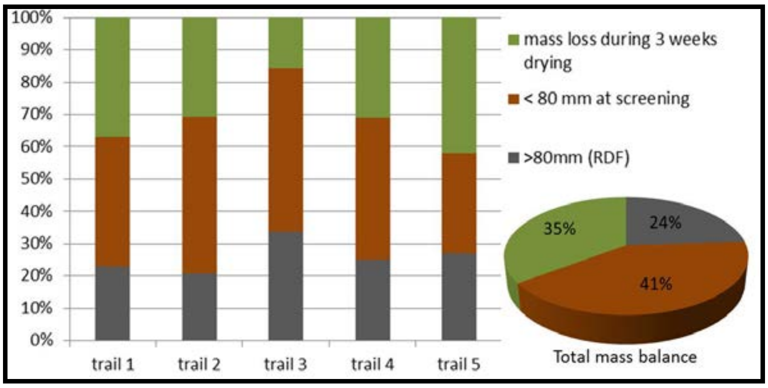


Figure 5. the percentage of output fractions after screening at 80mm for the total and each trial (June, 2014- Jan, 2015).

In average, through biodrying of waste, 24% of water was removed and 9% of solid waste mass was lost from the input material weight as shown in (Table. 1). In total, the weight of MSW decreased by 29% during summer and 35% during winter. The

RDF utilization has not beenconsidered in these figures of mass reduction. (Table. 1 here)

Table 1. Mass balance after the biodrying process during the pilot test.

trial	% Input material		%output of Biodrying 3 weeks					%Mass loss	
	dry matter	water content	RDF		<80mm		water	Dry matter	water
			fresh	dry	fresh	dry			
summer	47	53	26	16	46	29	27	3	26
winter	51	49	26	14	37	21	28	14	21
total	49	51	26	15	42	25	28	9	24

By the end of the biodrying process, the mass of waste was reduced by approx. 33 % when the dried waste is directed to landfill without the recovery of material (Fig. 6). In the case of RDF utilisation from the dried waste, the mass of waste to be landfilled is reduced by approx. 60%. Furthermore, by dumping the dried waste in the landfill leachate, would not be produced if the landfill was carefully covered be protected from rainfall. (Fig. 6 here)

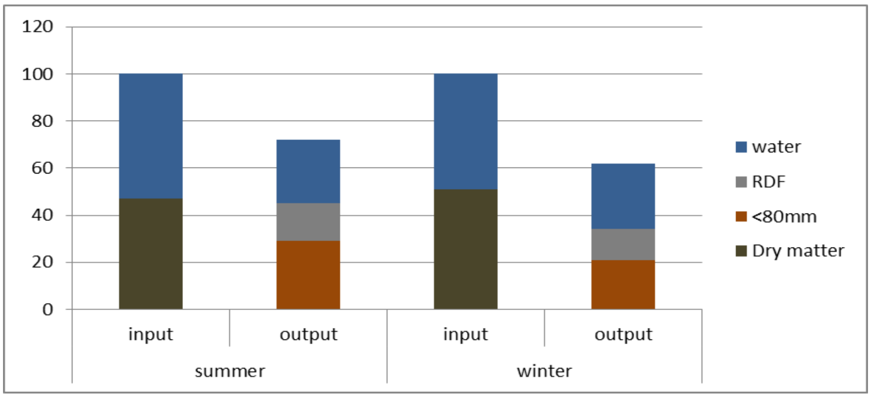


Figure 6. The mass balance after the biodrying process for the summer and winter trial.

Characterization of the coarse fraction:

A 80 mm drum screen was used to separate the coarse fraction (> 80 mm) from the fines fraction (< 80 mm). As an average of both seasons, shown in (Fig. 7). The major components of RDF are textile (21.2%), plastics films (19.7%), nappies (10.5%) and cardboard (6.4%). Other combustible materials present, include paper (15.4%), other plastics (4.5%) and organics (14.5%). (Fig. 7 here)

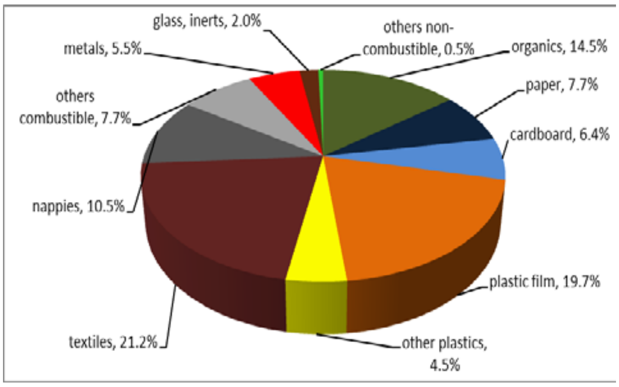


Figure 7. Average total composition of coarse fraction characteristics (June, 2014- Jan, 2015).

The proportion of plastics, textiles, nappies and paper/cardboard are higher compared to the fresh waste composition as shown in figure (5-19). There is still some organics in the coarse fraction, but this can be further reduced by optimisation measures. Impurities in the RDF consist of non- combustible materials, namely metals (5.5%) and glass and inert material (2%)

Chemical properties of the RDF:

The results on the basic chemical features of RDF are presented in table 2, which includethe heating value, other important fuel properties such as the moisture content, the chlorine content and the ash content. (table 2 here)

Table 2. The basic chemical features of RDF produced in the study area.

Parameter		summer trial			winter trial	Average
		1	2	3	4	
DM $_{Input}$ (%)		47	44	54	47	48
LHV $_{Input}$ (MJ/Kg)		16.04	16.79	17.94	15.56	16.24
DM $_{output/RDF}$ (%)		75	69	50	67	66
LHV $_{output/RDF}$ (MJ/Kg)		12.87	20.61	19.96	18.87	19.58
Ash$_{output/RDF}$ (%)		31.9	17.6	20.3	23.8	24
Chlorine$_{output/RDF}$ (% w/w)		0.84	0.66	1.30	0.94	0.94
Heavy metals$_{output/RDF}$ (mg/Kg)	Cd	0.76	0.45	4.18	0.62	1.21
	Cr	89	74.7	96	142	114.28
	Ni	71.1	34.9	45.6	70.2	60.37
	Hg	0.45	0.34	0.27	0.55	0.45
	Zn	262	141	140	229	205.00
	As	3.5	2.3	4.5	3	3.22

Moisture content shows great variability ranging from 25% to 50 %. The high moisture content lowers the fuel value significantly, as when moisture content increases, there is lower combustible material per unit. In addition, a significant amount of high heat energy is used to heat and evaporate the water in the waste (Rhyner et al 1995).

The biodrying process, studied in this work, increased of the waste calorific vale of about 20% (from 16.79 and 15.56 MJ/kg for the untreated waste to 20.61 and 18.87 56 MJ/kg for the dried material), as consequence of the waste moisture reduction. The calorific value of unprocessed MSW range between 15.56-17.94 MJ/Kg. Whereas the calorific value of the RDF, produced from the pilot project, ranges between12.87-20.61MJ/kg, which makes it appropriate as a fuel.

The ash content of the RDF produced in Beja appears to be high ranges between 20-31%. Chlorine is also a limiting factor for RDF quality, not only for ecological reason but also technical reason. It was in the range of 0.66 to 1.30 % w/w. Chlorine concentration, which is related to the content of plastics in the RDF, requires much attention because it is considered a source of acidic pollutants and important reactive element in the formation of dioxins (Watanabe et al. 2004)

The results on heavy metal concentrations in the RDF samples showed high concentrations of heavy metals, This could be explained by the high content of organic material and fine particles in the RDF produced, which may have high heavy metal.

Proposed RDF Facilities for the Arab region:

Two strategies have been considered for RDF production facility.

The first is based on the recovery of RDF and recyclables after the biodrying of raw waste, while in the second strategy the raw waste is processed into RDF, recyclable material are recovered and the fine fraction is further stabilized before landfilling.

The main objectives of the chosen options are recovering recyclable material, diverting material from landfill and relevant factors: recovery efficiency, costs and time needed for treatment.

The assumptions made for the following strategies are based on the available results which were obtained during the summer trial from the pilot project in Beja.

Strategy 1. Biological drying of mixed MSW with RDF production and recyclables recovery.

The concept of this strategy is proposed for facilities with a capacity of (Option 1. with 50000 Mg/a and Option 2. with 100,000 Mg/a). The waste will be subjected to composting (biodrying) without adding any water for 2-4 weeks. At completion of the drying process the waste would be screened efficiently into a coarse fraction with high calorific value, which can be used as a basis for the production of substitute fuel (RDF), (Fig. 8).

Based on the results obtained for the pilot project in Beja, the mass of input waste will be reduced by approx. 60 %. This means that only 40% of the input material will be sent to the landfill and 60% will be diverted from landfill. (Fig. 8 here)

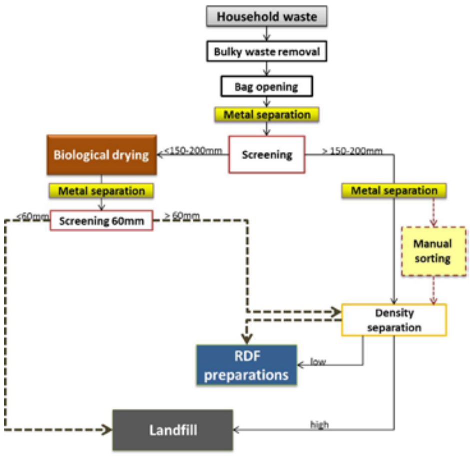


Figure 8. Strategy 1, biological drying, RDF production and recyclable material recovery.

Strategy 2. Biological drying of mixed MSW with RDF and metal recovery and stabilization of organic material before landfilling.

The concept of this strategy is the same as the concept of the previous strategy, except that at the end of the drying process the fines fraction, after screening would go through further composting/stabilization for further mass reduction. The composting period is about 6-8 weeks. Refer to (Fig.9). Two options will be studied for this strategy:

Option 3. Biodrying with RDF, recyclables recovery and stabilized material for landfilling.

Option 4. Biodrying with RDF, recyclables recovery, compost-like output (CLO) and inert material for landfilling.

Based on the stabilization results obtained from the pilot project in Beja, the mass of the stabilised portion will be reduced by approx. 87 %. This means that only 13% of the waste input will be sent to the landfill ,while the rest is recovered as RDF fuel, recyclable material (metals) and compost like product with moisture content loss as a result of the biodrying and stabilization process. (Fig.9 here)

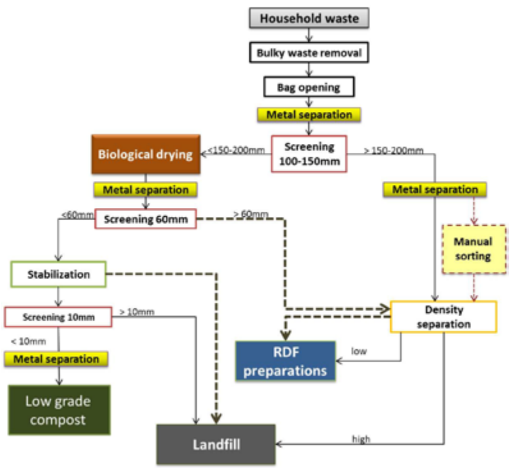
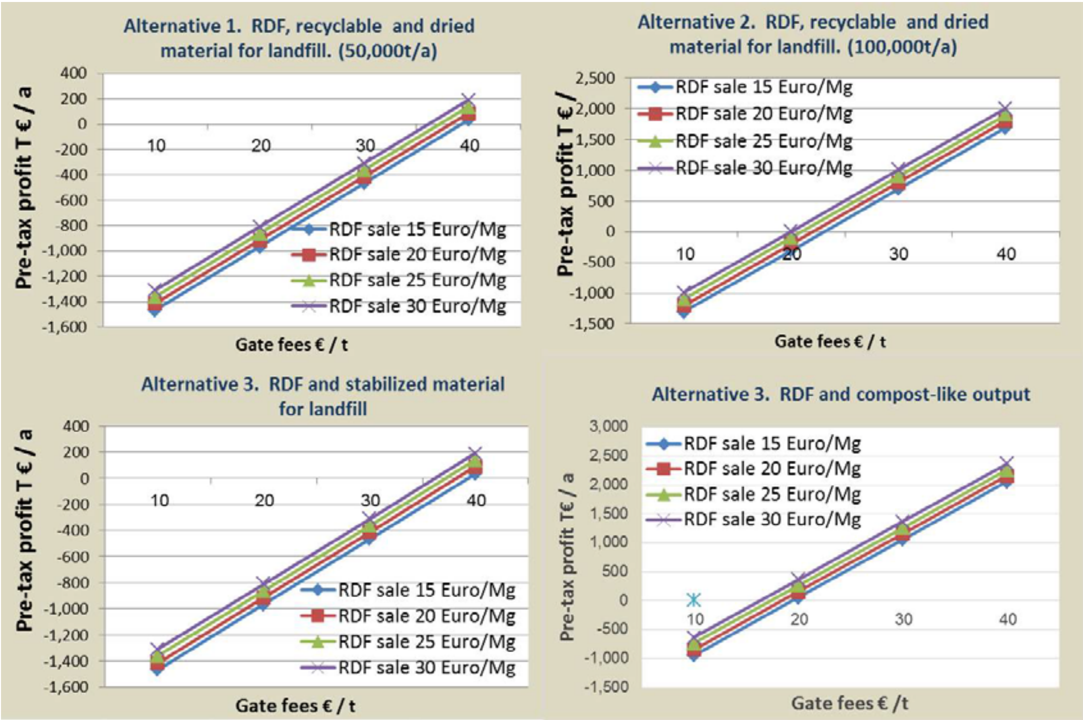


Figure 9. Strategy 2, biological drying, RDF and stabilized material production and recyclable material recovery.

Economic Feasibility Analysis for the suggested treatment alternatives for the Arab region:

Based on the availability of the RDF and its composition. It is useful to estimate the costs related to its production and management. The cost of each plant is included into two main components. Total capital investment, and operation and maintenance cost. Revenues come mainly from the sale of produced RDF, recycled materials, as well as from MSW gate fee. It was assumed that the plant will work for 4000 hour per year to treat the required quantity of waste, which means that the plant will work for 2 shifts daily each shift is 8 hours.

Moreover, the gate fees and RDF selling price have been studied in the analysis of the proposed facilities, (Fig. 10), to investigate the effect of change in these parameters upon investment return and to estimate the best reasonable price suitable for the Region. The results showed that a return of investment will be gained for option 2 for strategy 1, and option 4 for strategy2 , where the gate fees is 20€/t, the RDF sell price was assumed to be 30€/t. (Fig. 10 here)



Parameter :			Costs:		
Capital investment	8,12,14,14	MioEUR	Effective personnel costs	480,000	EUR/a
Net equity	30	%	Maintenance	100	EUR / Op hour
Useful economic life	15	years	Removal of residues	10	EUR / Mg
Interest (inflation adjusted)	5	% p.a.	Electricity consumption	80	EUR / MWh
			Sale of recyclables	50	EUR / Mg

Figure 10. The effect of change in gate fee and RDF price on investment return for the four suggested alternatives.

Cost analysis has been performed for different facilities and the assumptions were made for the different parameters involved in the cost calculation to suite the region situation, as shown in (Table. 3). (Table. 3 here)

Table (3). Assumption of different parameters for the cost calculation

net equity percentage	30	%
Useful economic life	15	years
Interest (inflation adjusted)	5	%p.a.
Insurance, Revisions	2	%p.a.
Expenses:		

removal costs for residues and transportation	10	EUR / Mg
maintenance costs	100	EUR / h
Electricity consumption costs	80	EUR / MWh
Personnel costs (1 man)	12000	€/a
number of necessary persons	40	
effective	480000	€/a
Revenues:		
Gate fee	20	EUR / Mg
Sale of RDF	30	EUR / MWh
Sale of recyclables	50	EUR / Mg
Sale of compost like output	10	EUR / Mg

As shown in (Table. 4), the cost of capital investment starts from 38% up to 50% of the total costs. The high percentage of the investment cost makes it hard to gain enough revenue fromthe sale of RDF and recycling material produced. For treatment cost per ton more than 30Eur/t there was no profit. Therefore, the cost of treatment per ton should be less than that. (Table. 4 here)

Table 4. The total capital investment, operation and maintenance cost and revenues for the four suggested alternatives

Alternative	1	2	3	4	unit
Capital Investment	8	12	14	14	MioEUR
waste quantity	50,000	100,000	100,000	100,000	t/a
Annual costs (operation and maintenance)					
Net debt service (Capital	859,517	1,289,275	1,504,154	1,504,154	EUR / a

investment)					
Personnel costs	480,000	480,000	480,000	480,000	EUR / a
Maintenance costs (abs)	400,000	400,000	400,000	400,000	EUR / a
Electricity consumption costs	320,000	320,000	320,000	320,000	EUR / a
Removal of residues	197,938	395,875	342,400	39,375	EUR / a
Sum costs	2,257,454	2,885,150	3,046,554	2,743,529	EUR / a
Operation cost	1,397,938	1,595,875	1,542,400	1,239,375	EUR / a
Capital investment /total cost	38%	45%	49%	55%	
Operation cost/t	28	16	15	12	EUR / t
total cost/t	45	29	30	27	EUR / t
Revenues					
Gate fee	1,000,000	2,000,000	2,000,000	2,000,000	EUR / a
Sale of recyclable material	136,563	273,125	273,125	273,125	EUR / a
Sale of RDF	310,500	621,000	621,000	621,000	EUR / a
Sale of CLO	0	0	0	212,118	EUR / a
Sum earnings	1,447,063	2,894,125	2,894,125	3,106,243	EUR / a
Pre-tax profit	-810,392	8,975	-152,429	362,713	EUR / a

From the cost analysis, it was clear that larger sized plant and machinery are required. Therefore, high capital investment is needed to set up an RDF plant. However, return on investment is not guaranteed to treat the designed waste quantity for all cases.

The most influential parameter appeared to be the capital cost, to overcome this obstacle, the involvement of the local municipalities and governments is recommended to take responsibilities of providing the initial capital cost. The public sector has better opportunities to gain grants and loans for such project more the private sector. As a result, the rate of return will increase and better economic performance can be achieved for all alternatives and also sustainability could be afforded for operating the facilities. Furthermore, it was important to point out that other benefits could be achieved in terms of improved quality of life, reduced health damage, as well as environmental benefits associated with reduced pollution and preserved landfill.

Conclusion:

A good alternative for the region is the waste to energy concept, where mixed MSW is converted to RDF. This alternative, mainly, contributes into the reduction of the moisture content of the waste leading to an increase in the calorific value of the resulting product and a decrease in the production of leachate from landfilled material, if no further stabilization of organic material is applied. The biodrying process dried the waste within 3 weeks. This enabled an efficient screening of the waste, to separate the recyclables and high calorific components from the organic fines fraction. RDF is becoming one of the interesting alternatives to solve both global warming and MSWM problems. However, due to high moisture content, low calorific value and high ash content of raw MSW, it is needed to segregate the raw MSW and produce RDF. The advantage of RDF over raw MSW is that RDF can be considered as homogeneous material, with little pollutants content and with a good calorific value, which can be used for energy production in different plants or for replacing the conventional fuels. A good quality RDF is that which has high calorific value and have low concentration of toxic chemicals, especially for heavy metals and chlorine. The results showed that an efficient waste treatment can be achieved with a fairly basic and low-cost MBT concept. This is by utilising the biological drying process to produce a substitute fuel for industrial processes and reduce the landfill areas required as well as reducing the air emissions from the landfill, in particular greenhouse gases. High capital investment is needed to set up a RDF plant. However, return on investment is not guaranteed to treat the designed waste quantity for all cases. Therefore, the success of SWM is based on the partnership and cooperation between different involved parties (politicians, private sector, consultant companies and public sector). Overall, every possible solution will still need a landfill as inert or stabilized material. The selection of the appropriate solution for MSW must be based on many factors, such as the availability of land for disposal, market for recyclable material and the need for energy production, and taking into account the economic and social aspects, with particular attention to environmental issues.

Acknowledgement:

The pilot project has been supported with grant funds allocated by the German Government / Federal Ministry for Economic Cooperation and Development (BMZ) in the frame of the German Financial Cooperation via KfW Development Bank. The project executing agency was the Tunisian National Agency for Waste Management (ANGed). Oher involved participant in the implementation of the project are University of Innsbruck, Austria; Lahmeyer GKW Consult GmbH; Germany; STE, Tunis, Tunisia; University of Tunis, Tunisia.

References:

- Adani, F., Baido, D., Calcaterra, E., & Genevini, P. (2002) The influence of biomass temperature on biostabilization-biodrying of municipal solid waste, Bioresource Technology, 83(3): 173- -179
- Diaz, L.F., Savage, G.M., & Eggerth, L.L. (1999). Overview of Solid Waste Management in Economically Developing Countries. In: Proceedings of Organic Recovery and Biological Treatment, ORBIT 99, Part 3, Rhombos, Berlin, pp. 759–765
- Elnaas, A., Nassour, A. & Nelles, M. (2014) Waste Generation and Disposal Methods in Emerging Countries. In: Thomè-Kozmiensky (Ed.): Book for the International Recycling and Recovery Congress, pp. 111-120, ISBN 978-944310-15-2, 8. and 9. September 2014 in Vienna
- Nassour, A., Al-Ahmad, M., Elnaas, A., & Nelles, M. (2011). Practice of waste management in the Arab region. In: kule-weidemeier, M.:(Editor), Water-to-resources 2011-4. International conference MBT and sorting systems, conference proceedings, 24-26 May 2011, pp. 81-91, ISBN 978-3-86955-747-2 (05/2011)
- Nassour, A., Majanny, A., & Nelles, M. (2008) Waste Management: Current Developments in the Arabic Countries, Tagungsband anlässlich der Asian-European Environmental Technology and Knowledge Transfer Conference vom 5.-6. Juni 2008 in Hefei, China, S. 14-23, ISBN 978-3-00-024606-7
- Rechberger, H. (2011). Incineration: Co-combustion in Solid waste technology & management. In: Rives, J., Rieradevall, J., & Gabarell, X.

(2010) LCA comparison of container systems in municipal solid waste management, Waste Management, 30, 949-957

- Rhyner, C.R., Schwarz, L.J., Wenger, R.B., & Kohrell, M.G. (1995) Waste Management and Resource Recovery, CRC Press, Lewis Publishers, Boca Raton, pp. 215-272
- Rotter, S. (2011). Incineration: RDF and SRF - Solid waste from fuels. In: Solid waste technology & management Tchobanoglous, George & Kreith, Frank, (2002). Handbook of Solid Waste Management, 2nd Edition, McGraw-Hill.
- Sugni, M., Calcaterra, E., & Adani, F. (2005) Biostabilization-biodrying of municipal solid waste by inverting air-flow, Bioresource Technology, 96(12): 1331--1337
- Tambone, F., Scaglia, B., Scotti, S., & Adani, F. (2011) Effects of biodrying process on municipal solid waste properties, Bioresource Technology, 102(16): pp.7443--7450.
- Velis, C. A., Longhurst, P. J., Drew, G. H., Smith, R., & Pollard, S. T. J. (2009) Biodrying for mechanical-biological treatment of wastes: A review of process science and engineering, Bioresource Technology, 100(11): 2747-2761
- Watanabe, N., Yamamoto, O., Sakai, M., & Fukuyama, J. (2004) Combustible and incombustible speciation of Cl and S in various components of municipal solid wastes, Waste Management, 24: pp 623–632.