TWO SOLUTIONS FOR MSW TREATMENT IN VIEW OF LANDFILL MINIMIZATION AND ENERGY RECOVERY MAXIMIZATION

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MSW management can be performed through many options. The bio-mechanical ones are interesting where the food waste content of MSW is high, like in Romania. The present paper analyses a few aspects of these processes applied to the MSW generated at national level. Energy and environmental balances are presented and discussed.

Keywords: bio-drying, bio-stabilization, energy, GWP, HTP, selective collection, SRF.

1. Introduction

The European Union's policy in the field of waste management is based on a concept called "***waste hierarchy***". Taking into account this concept different waste management solutions were proposed, from best to the worst respect to the environment: prevention, minimization, reuse, recycling, energy recovery and disposal [1, 2]. Although the waste hierarchy should not be regarded as a strict rule to follow, the aim of reaching a recycling and recovery society means the decrease of the waste sent to land filling [3, 4, 5]. This aspect is important not only at international level but also from the citizen point of view [6].

The definition of "waste" was originally derived from the European Community Waste Framework Directive (*75/442/EEC 1975*) as "any substance or object, which the holder/producer discards or intends to discard" [7]. The European Union produces more than 3 billion tons of waste every year [8]. The municipal solid waste (MSW) in general is waste collected by the municipality. In the last years based on the increasing amounts of MSW the selective collection (SC) followed by recycling and treatment/disposal is more and more implemented with good results [9, 10, 11, 12].

In Romania, the selective collection of recyclable materials that can be valued (paper, cardboard, glass, metal, plastic materials), is a limited waste management solution, adopted mainly at local level [13, 14], while the land filling

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is the most used solution for the waste management [15]. As required by EU legislation, the national policy for waste management in Romania is enforced by the Government Emergency Ordinance no. 78/2000 on waste [16, 17].

Energy recovery from waste and recycling represents one of the most important activities for the world's economy, considering that it is more and more obvious the decreasing of natural resources of raw materials. The benefits are connected to the positive environmental impact and to the saving of primary energy derived from fossil fuel [3, 18, 19, 20, 21].

The waste to energy concept can be applied in general using thermal or biological processes [22, 23, 24, 25]. Due to the MSW heterogeneity and high-risk induce by the potential pollutants, a waste pre-treatment before energy conversion could help. Waste pre-treatment could solve the problem of heterogeneity together with other technological issues by generation of Solid Recovered Fuels (SRF) [26, 27]. The SRF can be produced through mechanical biological processes (MBT) [28, 29]. The most used MBT process is the bio-drying one [30]. The process by-product is a bio-dried material that can be transformed into SRF of different quality after some post-treatments: metals, glass and inert separation mainly [22].

The paper presents two solutions for MSW treatment for the landfill minimization and energy recovery maximization. The mass, energy and environmental balances is reported and compared in this paper.

2. Materials and methods

Generally the Romanian waste contains not only domestic waste but also other fractions [31]. The largest share in the structure of MSW is the domestic waste (75-80%), followed by street waste (10-12%) and other waste such as construction and demolition (7-9%), excavations (3-4%). For 90% of these wastes the treatment used is land filling. Municipal waste represents almost 76% (5.24 million of tons per year) of the total quantities of waste collected, and approximately 56% of them are biodegradable fraction.

For the development of the research, the Romanian municipal solid waste composition is used, and is reported in Fig. 1.

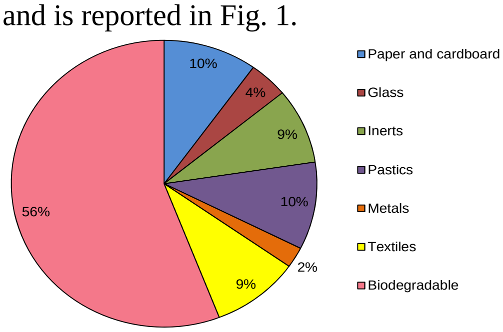

Fig. 1. Municipal solid waste composition in Romania

The scenarios proposed in this paper, are aimed to find a solution for the Romanian MSW management in order to minimize the waste land filling and maximize energy recovery. The quantity of initial MSW taken into account for all the scenarios was 1 kg_{MSW}.

The ***first scenario*** is presented in Fig. 2. In this scenario two solutions are proposed. In both solutions, selective collection (SC) with material recovery (only the sellable materials) is coupled with a pre-treatment stage (bio-mechanical treatment): bio-drying (solution 1) and bio-stabilization (solution 2).

All quantities of MSW will be subjected to a selective collection stage to recover only the sellable material (plastic, paper and cardboard), with an efficiency of 30%. The resulted material, named Residual Municipal Solid Waste (RMSW) will enter to a MBT stage process with the aim of environmental impact reduction. At the end the recovery of metals and, in some cases, energy will be taken into account.

The MBT combines mechanical processes to separate out the dry recyclables such as glass and metals, with biological processes for drying and stabilize with different efficiency the organic fraction of the RMSW

In the ***bio-stabilization*** process, the RMSW is submitted to a sieving process where the materials are sorted by their dimension (granulometry) in order to separate the dry fraction (*over sieve material*) from the wet one (*under sieve material*) [32]. The over sieve material enters to a de-ironing process in order to obtain first SRF (SRF_1). After this step, the obtained material will be subjected to an air aspiration stage (light fractions) in order to obtain a better SRF (SRF_2). The residues from this stage are sent to landfill.

Because of the high organic content, the under sieve material is subjected to an aerobic bioconversion treatment (bio-stabilization) in order to obtain stabilized organic fraction (SOF) that can be safety land filled.

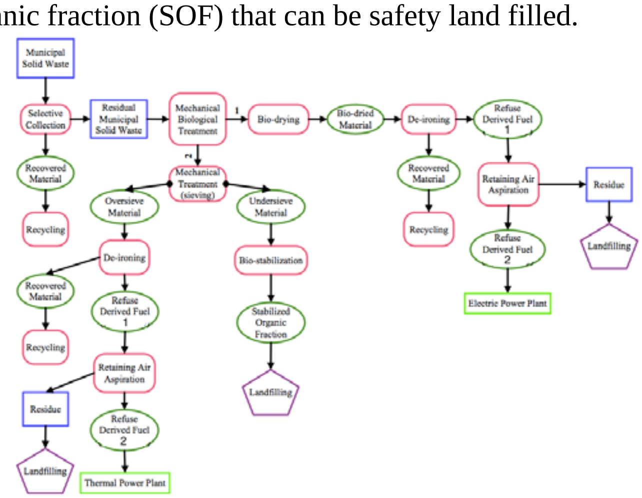

Fig. 2. Scenario no.1 (de-ironing can be integrated with glass extraction)

In the ***bio-drying*** process the RMSW decreases its moisture thanks to the exothermic reaction and a bio-dried material is generated [22, 30]. After de-ironing and glass removal a first SRF (SRF_1) is obtained. The efficiency of removal is high thanks to the characteristics of the bio-dried material. This SRF_1 is post-treated in a second mechanical stage, for obtaining the SRF_2. The remaining residues are land filled.

In the first scenario the final fuel obtained from waste after different treatments, the SRF_2, can be used in thermal power plants for energy conversion; two co-combustion cases in thermal power plants are considered in this paper: one with only electrical generation (case A) and one with co-generation (case B).

The ***second scenario*** is reported in Figure 3. The MSW stream undergoes a high selective collection with the efficiency: recycled material (74%), paper and cardboard and food waste (85%), plastic (60%) and glass and metals (90%). The resulted RMSW can be considered a SRF and can be used in Waste-To-Energy plants (WTE) [10].

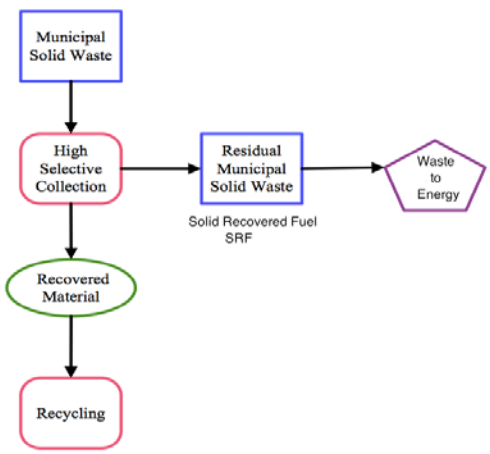

Fig. 3. Scenario n.2

A very important aspect for comparing the net electric energy produced in each scenario is represented by the energy consumption in the MSW pre-treatment stage. In the Table 1 the electric consumption in kWh per ton of treated waste for each considered stage of the mechanical and biological steps are reported [33].

Table 1

Details on specific electrical consumptions, kWh/t

Bio-drying process	35
Bio-stabilization process	65
Sieving	7
De-ironing process	0.3
Refining air aspiration	20

In Table 2 the efficiency of considered thermal treatments for SRF energy valorisation are reported. The conversion efficiencies were chosen as function of primary energy conversion stage. The thermodynamic cycle efficiency and the scale factor (power plant size that depends on waste feed-in flow) were also taken into account. The values refer to plants treating more than 200 tones per day [34].

Table 2

Efficiency of thermal treatment: net electrical generation [%]

RMSW combustion on grate + steam turbine co-generation	28.7
SRF co-combustion in thermal power plant + steam turbine electrical generation (case A)	40.0
SRF co-combustion in thermal power plant + steam turbine co-generation (case B)	35.9

Obtaining energy from waste requires, also, an analysis on the environmental performances of proposed solutions. Life Cycle Assessment (LCA) was applied by the authors for evaluating the environmental impact of each scenario considering only emissions of air pollutants. To this concern, two impacts indicators have been used: Global Warming Potential (GWP) and Human Toxicity Potential (HTP). Their equivalence values [35] are reported in Table 3.

Table 3

Equivalent factors

Emissions	Potential (kg 1.4 – dichlorobenzene eq. /kg)
Dioxins	1.90E+09
Cd	1.50E+05
Hg	6.00E+03
Pb	4.70E+02
NO_2	1.20E+00
HCl	5.00E-01
NH_3	1.00E-01
SO_2	3.10E-01
	GWP (kg CO2 eq/kg)
CO_2	1
CH_4	21

For evaluating the environmental impact, GWP was expressed as kg of CO_2 equivalent per kg of treated waste and HTP as kg of 1.4 - dichlorobenzene equivalent per kg of treated waste, respectively. In this paper the following atmospheric emissions have been considered [33, 34, 36]:

- Residual emissions from landfill;
- Emissions from the bio-stabilization and bio-drying process;
- Emissions from the stabilized organic fraction (SOF) landfilling;
- Emissions from the stack of a WTE;
- Emissions from the thermal and electric power plant.

GWP was calculated considering that the emissions of CH_4 is 60% of total quantity of biogas produced and the CO_2 emissions were assumed equal to zero, being considered biogenic.

3. Results and discussion

In this paper the MBT options are used for SRF production. The results are influenced by the initial MSW composition and by the efficiency of selective collection. For the development of the mass and energy balances the proximate and ultimate analysis of MSW and of its fractions, energy efficiency and consumptions for each step were used [18, 37, 38].

For the proposed scenario, the mass, energy balance and the low heating value (LHV) are presented in Table 4 and 5. The bio-drying and bio-stabilization processes have been treated separately.

Table 4

Mass and energy balance for Scenario 1

	Mass [g]	LHV [kJ/kg]	Available energy	
			kJ / kg	kWh / kg
RMSW	934	7,372	6,885	1.912
Bio-dried material	758	9,596	7,788	2.128
SRF_1	631	10,552	7,130	1.980
SRF_2	285	17,119	5,235	1.434
RMSW	934	7,372	6,885	1.912
Oversieve material	449	11,912	5,355	1.487
SRF_1	432	12,310	5,330	1.480
SRF_2	216	18,568	4,026	1.118
Undersieve material	485	3,014	1,462	0.406
SOF	396	877	348	0.096

Table 5

Mass and energy balance for Scenario 2

	Mass [g]	LHV [kJ/kg]	Available energy	
			kJ / kg	kWh / kg
RMSW (SRF)	265	9,411	2,494	0.693

From an energetic point of view, the LHV of the SRF obtained from the bio-drying process can be compared with the one from wood and lignite, respective 13.000 kJ/kg and 10.500 kJ/kg.

Taking into account the electrical efficiencies from Table 2 and the energy availability in the analysed scenarios, from Table 3 and 4, it can be demonstrated that the RMSW energy valorisation is highly influenced by the material diversion performed through the selective collection:

- the SRF option opens to co-combustion plants (possibly already existing) where the net electrical generation can take advantage of the large scale; in this frame, pre-treatment consumptions (Table 1) can be acceptable;
- an highly efficient selective collection significantly decreases the

energy available from RMSW; moreover direct combustion cannot reach the net electrical efficiency of large scale fossil fuel plants; thus, also in this case it could be interesting to see RMSW as a SRF-like product to be improved through simplified treatment in order to become a high quality SRF suitable for co-combustion in thermal power plants.

Concerning the environmental aspects, the GWP and HTP results are reported in Figs. 4 and 5.

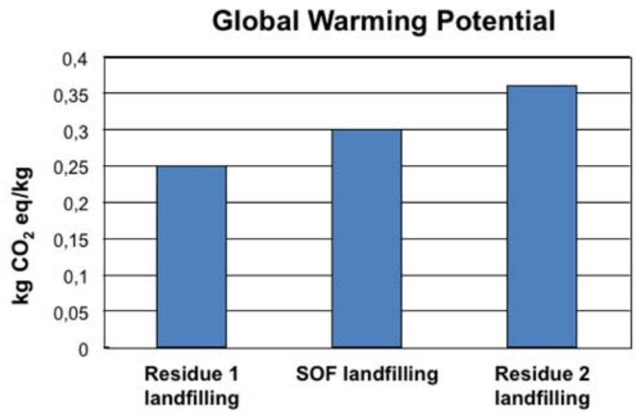

Fig. 4. Global Warming Potential

The HTP calculations were made considering a wide range of toxic substances, with an exposure and effects for an infinite time horizon. In the present paper the emissions generated from energy conversion processes, the materials and the infrastructure needed by the production process were considered. Results in Figure 5 confirm the advantages of the SRF option when compared with direct combustion of RMSW (WTE).

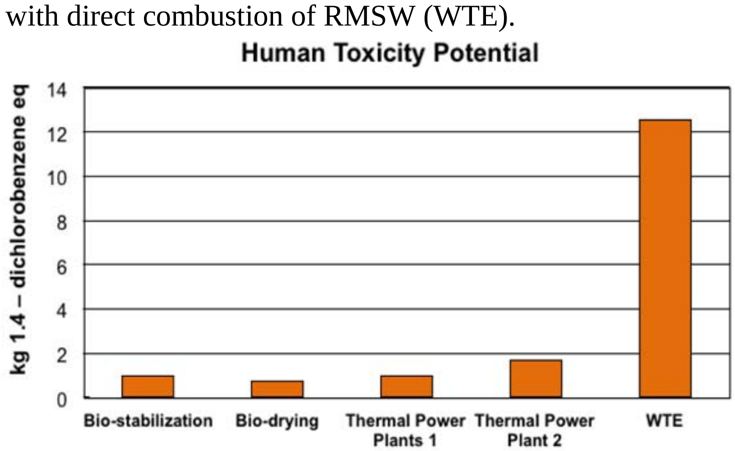

Fig. 5. Human Toxicity Potential (WTE = waste to energy)

4. Conclusions

The management of MSW depends on many parameters and a decision must be taken after an adequate preliminary study based on MSW composition, selective collection implementation and also on the existing industrial plants. The present paper shows a method useful for supporting decision makers comparing two different scenarios of waste management and energy conversion.

The MSW bio-drying seems a suitable solution for scenarios were the food waste percentage is high, but post-refining are requested for a better LHV in order to better its characteristics before energy conversion. Also the mixing of MSW with other waste fractions that have higher LHV could be a viable solution.

The pre-treatment processes decrease landfill need, because in this case only the residues will be landfilled. The use of biogas produced from the sustainable landfilling for electricity production can give advantages to the environmental balance.

For the first scenario landfilling volumes needs are different for the both solutions (bio-drying and bio-stabilization) because of the amounts of residues resulting from different steps; instead the environmental consequences are similar.

For the first scenario the environmental consequences are not worrying thanks to the use of BAT for the flue gas cleaning systems. Also the energetic recovery is good.

From the obtained results, the most suitable option for Romania seems to be the use of MBT with bio-drying process, because of the higher flexibility in producing energy, the lower environmental impact and the viable cost of operation. The use of SRF in a large thermal power plant as substitute of coal can give interesting balances in terms of mass and energy, but must be studied in details referring to the local impact of the plants burning SRF.

All the studied scenarios take into account the Waste Framework Directive, regarding the decrease of landfilling, in particular for biodegradable waste and the increase on material and energy recovery.

The final choice for the best solution for Romania must take into account also the local availability of industrial plants suitable for SRF because it is not reasonable to use it if it must be transported for a very long distance.

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