ALTERNATIVE RESIDUAL MUNICIPAL SOLID WASTE MANAGEMENT SCENARIOS IN AREAS WITH DEFICIENCY OR ABSENCE OF INCINERATORS

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Abstract

An LCA (Life Cycle Analysis) was realized for different residual waste management scenarios in a given urban area. The analysis was performed by evaluating the environmental impacts and the potential of the conservation of the resources. The results show that the disposal of the residual waste in landfill, even if the waste has been biostabilized before, is always disadvantageous in comparison with the scenarios with energy recovery. The use of Solid Recovered Fuel in the cement plants, in substitution for coal, results to be advantageous. Recycling of metals, coming from mechanical selection, is a significant benefit for the environment.

Keywords: energy recovery, incineration, life cycle assessment, landfill, mechanical treatment, residual waste

1. Introduction

Waste management consists of three main activities: collection, treatment and disposal. Several possible solutions could be exploited for each activity, and also the combinations of them, in order to manage a single ton of Municipal Solid Waste (MSW), could be in great numbers. An efficient Source Segregation (SS) collection can contribute significantly to maximizing waste material recycling, but can represent up to 70% of the entire cost of MSW management (Di Maria and Micale, 2014).

∗Selection and peer-review under responsibility of the ECOMONDO
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Despite the recent directives of the European Council (2008/98 / EC) require the maximization of the MSW recovered and recycled, the fraction of the Residual Municipal Solid Waste (RMSW) to manage is still often substantial. The Mechanical-Biological Treatment (MBT) carried out before final disposal in landfill, entails the reduction of the pollutant emissions production (Di Maria et al., 2013) and the volume reduction, but also high energy consumption. The mechanical treatment of the RMSW is useful also for the extraction of recyclable materials mingled with the RMSW, like iron and aluminum.

Several authors have demonstrated that the incineration of the RMSW is more environmentally advantageous than the landfilling, even if this treatment solution involves high investment costs. Also the use of Solid Recovered Fuel (SRF), from mechanical selection in MBT facilities or Mechanical Biological Separation (MBS), could be a good alternative to the use of the coke in the cement plants (Ruth, 1998). The energy substitution plays a relevant role in terms of resource conservation and avoided emissions and strictly depends on the energy mix of the area to which the analysis is referred. Despite the studies about the best solution for waste management are quite numerous, there is a lack of information about the RMSW management strategy. In this study a Life Cycle Analysis (LCA) about the RMSW management options, for an urban area in central Italy with a SS intensity of 25% was carried out.

2. Materials and methods

The present LCA study was performed according to ISO 14040 (2006) methodology and also by following the indications of the ILCD Handbook guidelines (EC, JRC, IES, 2010). The LCA analysis carried out in this study intends to evaluate the more sustainable management solution in terms of environmental impact and can be a valuable contribution to the decision-making of local governments for the achievement of targets set by the European Union. The classic approach "cradle to grave" should be revised. The incoming material, in fact, becomes the waste that can be disposed of or may re-enter several times in the cycle as recycled material, thus avoiding the consumption of primary material.

The replacement of the raw material or energy involves an environmental benefit due to the production process and the material consumption avoided, but at the same time involves environmental loads due to the process of recycling or the energy production itself. The functional unit chosen to perform the LCA analysis is a ton of RMSW and it is also the reference flow used in the analysis. The Life Cycle Inventory (LCI) modeling framework chosen is attributional. The amount of the waste that enters the system and its features are fixed. Only the RMSW mass rate involved in the different treatment processes varies, depending on the scenarios. Fig. 1 describes the different analyzed scenarios. The background of the system is represented by RMSW, energy, ancillary materials and fuels used by the processes.

The energy mix assumed in the analysis is referred to the Italian situation on the basis of the data reported by TERNA (2013). Instead the foreground of the system is represented by the energy produced by incineration and Landfill Gas (LFG) combustion, by the emissions from processes, treatments and energy consumption and by the materials for recycling. The collection model was realized by referring to the collection routes of the reference area of about 24,000 inhabitants with a SS intensity of 25% (Di Maria and Micale, 2013). After collection the RMSW could be directly landfilled or conveyed to incinerator. The model of the landfill was realized by considering an energy recovery of 33-62 kWh/tonne, depending on the biostabilization of the waste before disposal.

Other data of the model are referred to the ELCD database (EC, JRC, IES, 2008). The model elaborated for the incinerator is mainly referred to the Ecoinvent database (Hischier et
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al., 2010) but was modified in regard to the mass balance of the outputs and energy production of 500kWh/tonne.

Fig. 1. System boundary

Two types of mechanical and biological treatments were considered in the scenarios: treatments aimed at maximizing the recovery of recyclable materials and bio-stabilization of the waste before landfilling, or treatments aimed at the production of SRF through a first bio-drying and a subsequent refining. Table 1 shows the main features of the treatments. Energy consumption of the treatments, mass balances and the production of LFG were defined on the basis of previous studies (Di Maria et al., 2013).

The model used for the co-combustion in cement plants, in substitution for coke, has been specially created by considering the combustion of each fraction present in the waste, the composition being fixed. The models used for recycling are referred to Ecoinvent database (Hischier et al., 2010). The indicators chosen, referred to the CML methodology (CML, 2001), are: Global Warming Potential at 100 years (GWP100), Acidification Potential (AP), Eutrophication Potential (EP); Photochemical, Ozone Creation Potential (POCP); Ozone Layer Depletion Potential, (OLDP), Abiotic Depletion Potential (ADP), Human Toxicity Potential, (HTP) and Terrestrial Ecotoxicity Potential (TEP).

Table 1. Main features of the mechanical treatment processes

<table>
<thead>
<tr>
<th></th>
<th>Losses</th>
<th>Metals</th>
<th>SRF</th>
<th>Disposal in landfill</th>
<th>Energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TMB</strong></td>
<td>25</td>
<td>$3^a$-$0.3^b$</td>
<td>-</td>
<td>71.0</td>
<td>33</td>
</tr>
<tr>
<td><strong>TMB and SRF</strong></td>
<td>25</td>
<td>$3^a$-$0.3^b$</td>
<td>40.7$^c$</td>
<td>31.0</td>
<td>45</td>
</tr>
<tr>
<td><strong>MBS</strong></td>
<td>30</td>
<td>$3^a$-$0.3^b$</td>
<td>57.0$^c$</td>
<td>9.40</td>
<td>45</td>
</tr>
</tbody>
</table>

3. Results and discussion

The assessment of impacts (Fig. 2) highlights that energy recovery of RMSW is very beneficial. Indeed scenarios 4 and 5 have negative values with regards to the GWP, HTP, POP, AP and ADP. The last indicator, in particular, is related to the consumption of resources and therefore the substitution for coal in the cement gives a benefit that grows if the SRF produced is higher. Also in the other indicators, the benefit derives from the avoided emissions by substituting SRF for coal. Scenario 5 has a negative impact with regard to EP and OLDP, while this does not happen for the scenario 4.
This happens because in the scenario 5, compared to the scenario 4, a greater production of SRF takes place and the quantity of waste which is sent to the landfill is reduced. The landfilling of RMSW in fact, as shown in scenario 1, involves in all indicators, except HTP, a load on the environment. Regarding the indicator TEP, both scenarios 4 and 5 show a load of the environment, which is due to the emissions resulted in iron recycling process. However, the impact is reduced by increasing the production of SRF, while it remains still high in scenario 3 where the benefit due to the substitution of energy is limited to the combustion of LFG.

Instead in the other indicators the primary materials substitution contributes to a significant environmental benefit. Scenario 3 for indicators GWP, ADP, POP, HTP, AP and EP turns out to be better than the direct landfilling. The benefit, however, is mainly due to the avoided emissions due to recycling of metals separated by mechanical selection. In this scenario all other processes involve only loads, except for the energy recovery from the landfill, but this is a benefit much lower than the one related to recycling. Scenario 2 instead shows a benefit on the environment relative to the indicators ADP, OLDP, POP, AP, and this is due to the substitution of energy from fossil fuels.

The indicators GWP, HTP, TEP, EP instead present a burden on the environment and largely depend on the emissions generated by the process itself. The impacts related to collection activities appear to be marginal compared to those of the treatments or subsequent processes.

![Fig. 2. Impact assessment for the scenarios 1 - 5](image)

4. Concluding remarks

An LCA analysis was performed on different Residual Waste Management scenarios referring to an urban area in central Italy. The scenarios with the energetic exploitation of the waste, through the production of Solid Recovered Fuel or incineration, turn out to be the best environmental solutions. The Mechanical-Biological Treatment of RMSW before landfilling implies limited environmental benefits.

The benefit from recycling of materials, commingled with the RMSW, extracted by mechanical selection, is high. An important role is played by the substitution of energy, and impacts are highly dependent on the energy mix of the area to which the analysis is referred.

References


