BIO-MECHANICAL TREATMENT PLANTS AND ENVIRONMENTAL IMPACT FROM INDUCED TRAFFIC

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SUMMARY: In the frame of municipal solid waste management, one of the aspects to be taken into account for comparative analyses is the role of traffic for waste transportation. To this concern the waste pre-treatment could change the environmental and cost balances compared with the conventional scenario based on burning on grate system. The present paper gives a contribution to the understanding of advantages and disadvantages of the strategies based on bio-mechanical municipal solid waste pre-treatment, in particular bio-drying, referring to the traffic aspects.

1. INTRODUCTION

In the latest years it can be seen that in some European countries waste pre-treatment plants before waste combustion have been adopted extensively. The refuse derived fuel (RDF) from municipal solid waste (MSW) and its utilization is viewed in those countries as a component of an integrated waste management policy because in this way the quantity of the biodegradable materials that could arrive in a landfill is reduced as requested from the Landfill Directive from 1999/31/EC. The younger MSW pre-treatment process can be considered bio-drying. For that reason in the present paper the developed balanced have been assessed referring to this process.

The European Union has developed and published a document (EC, 2003) which presents the situation of the use of RDF in Europe and indicates also the way for developing and using it. In this frame MSW bio-drying is shown as one of the available options (EC, 2003): bio-drying treatment is a short-time process of aerobic bioconversion, applied mainly to MSW as is and to MSW residual of selective collection. The aim of this process is the exploitation of the exothermic reactions for the evaporation of the highest part of the humidity in the waste with the lowest conversion of organic carbon. No water addition is required (and must be avoided). Bio-drying is conceptually different from thermal drying (widely adopted in the field of sewage sludge management): the first exploits the heat from the bio-chemical oxidation of a part of the volatile solids; the second uses only heat externally supplied. Bio-dried material is the product obtained after bio-drying process and which can be used to obtain RDF (Refuse Derived Fuel) after inert separation. An additional refining stage can increase the quality of the obtainable

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RDF, but can generate a secondary stream of wasted material to be landfilled. RDF can be sent to co-incineration if its characteristics comply with Dir. 2000/76/CE.

To this concern, the recent literature gave contributions on process understanding, energy aspects, emissions, etc. but has not yet faced in details with the role of traffic when bio-drying is adopted. The present work wants to give a contribution on it.

The effects of bio-drying on waste transportation are controversial. If bio-drying is proposed for a decentralized treatment before the exploitation in a centralized Waste to Energy plant built in the same region, the advantages can be related to the lower amount of waste to be moved. On the contrary, if bio-drying is proposed as a way to produce RDF for decentralized industrial use, the role of transportation can be significantly different. In this case we could have a local generation of RDF and a long distance transport. From the economical point of view the additional costs of transport could be counter-balanced by the activation of favorable contracts on RDF disposal, but it is clear that this solution is affected from the market conditions (that can vary from year to year).We remember that the process weight loss in case of MSW suitable for bio-drying (with high organic matter content) can be even higher than 25%. That does not mean that bio-drying can save a proportional cost of transportation as the density of bio-dried waste can be lower than the one of MSW as is. The reason is related to the fact that the process loss is mainly water and than its evaporation can free interstitial space without affecting the initial volume. The volume balance could be improved by compression of the bio-dried material but this option must be carefully taken into account as it can increase the costs. A decrease in the amount of tracks that go towards the centralized plant can be related to the decentralized inert separation as post-refining (glass, metals, etc.). This option causes an additional cost that can be counter-balanced by the selling of the materials and the saving in transport costs. The economical effects change case to case.

If the basin of waste to be serviced is small, this solution can exploit its flexibility, but in case of big amount of RDF generated, the instability of the market of RDF could be a problem.

A question related to the transportation is: can the environmental balance change strongly because of the introduction of additional emissions from transportation? In practice, we should choose between a centralized emission with centralization of emissions from transport (centralized plant) and a decentralized emission with possibly additional emissions from transportation but spread in a wider territory. The present paper wants to give a contribution to the understanding of these environmental aspects.

2. MATERIALS AND METHODS

In this paper three scenarios have been selected in order to study the role of bio-drying in relation to the different traffic environmental balances:

- The first one is the traditional one: the collected waste is transported to a centralised grate system.
- The second scenario takes into account the bio-drying process applied to MSW with the production of RDF (assumed 65% of the treated MSW). The combustion unit is considered located 500 km far.
- The third scenario is a combination of the other two scenarios, taking into account the bio-drying process applied to MSW, with RDF production send to an incineration plant built at a distance of about 50 km.

The three scenarios are schematised in Figure 1. Bio-drying emissions are assumed negligible. For all the scenarios some local and global balance aspects have been assessed, also taking into account the accident risk from the traffic increase.

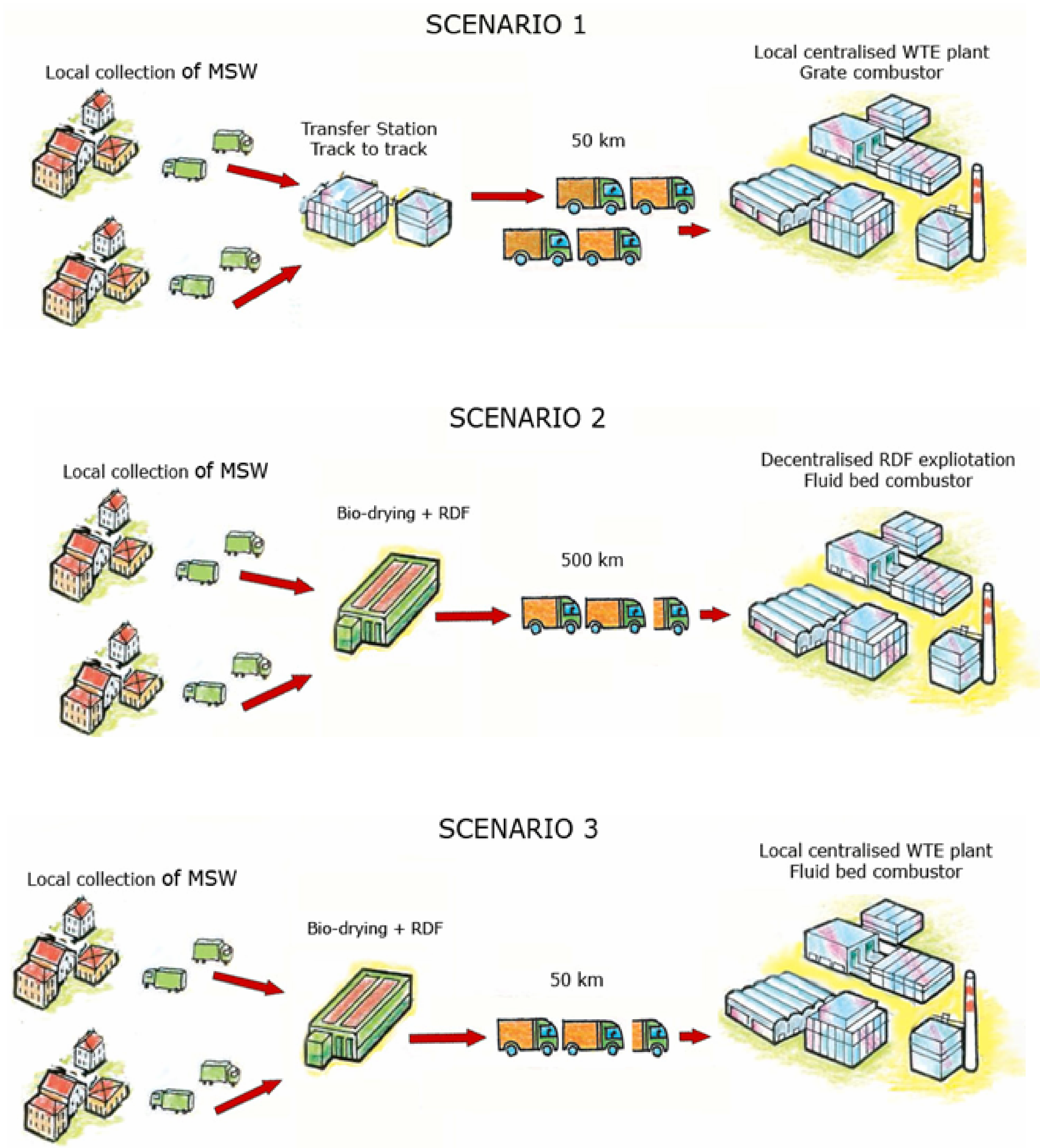

Figure 1. Scheme of the three considered scenarios

For the analysis of these different scenarios the following pollutants that result from the combustion of waste will be taken into account:

- Dioxin
- NO_x
- Particulate matter
- SO_x

Table 1. Emission factors from transport (ref: 1 kg_{MSW})

	Emission factor 20 t truck Euro 4 diesel	MSW transport 50 km drive/return	RDF (50% of MSW) 500 km drive/return
PCDD/F	10.9 $pg_{I\text{-}Teq}$/km	0.054 $pg_{I\text{-}Teq}$	0.272 $pg_{I\text{-}Teq}$
NO_x	1.67 g/km	83.5 mg	417 mg
PM_{10}	16 mg/km	0.8 mg	4.0 mg
SO_X	23.074 mg/km	0.11537 mg	0.57685 mg

Table 2. Emission factors from waste to energy plants

	Emission factor Centralised plant - Grate Ref: 1 kg_{MSW} (ex. Spittelau)	Emission factor Decentralised plant - Fluid bed Ref: 1 kg_{MSW} (ex. AVE-RVL Lenzing Adapted)
PCDD/F	91 $pg_{I\text{-}Teq}$/kg	175 $pg_{I\text{-}Teq}$/kg
NO_x	104.1 mg/kg	51.1 mg/kg
PM_{10}	3.6 mg/kg	2.1 mg/kg
SOx	9.4 mg/kg	14.35 mg/kg

These pollutants result also from the waste transport on road through diesel equipments. Emissions from local transport of slag and fly ash have been assumed equal to the local emissions of separated inert and refuse from RDF generation and transport. Some 20 t trucks (euro 4) have been taken into account. Emissions for the first three parameters have been assessed through the COPERT methodology (Ntziachristos et al., 2000) supposing an average speed as 80 km/h. Concerning S content, a value of 50 ppm in the fuel has been assumed. Emission data have been calculated taking into account the kms done according to its strategy of collection; each value is reported to 1 kg of MSW as shown in Table 1.

The value of km travelled in the average in one year from an Italian citizen has been assessed thanks *(ENEA, 2004)*: it resulted 8,140 km. Concerning MSW generation, a value of 1.44 kg inh^{-1} d^{-1} has been assumed from *(APAT, 2004)* with a selective collection efficiency as 50%. A ratio RDF / MSW equal to 0.65 has been assumed, as a scenario of simplified post-refinement after bio-drying as been considered.

Data from MSW and RDF combustion are presented in Table 2 *(Stubenvoll et al.,2002)*.

Referring to traffic data, Italian statistics of accidents has been adopted from *(ACI, 2005)*. An accident risk for the single citizen has been assessed as $5{,}8E^{-3}$ to be compared to a mortal accident risk as $1{,}2E^{-4}$. The present paper assumed a more detailed information, that is the mortal risk related to accidents involving the kind of truck used for transporting waste: $8{,}6E^{-6}$.

This value must be compared with the acceptable risk from the waste to energy option: 10^{-6}, according to *(Ministero dell'Ambiente, 1999)*.

3. RESULTS AND DISCUSSION

Results concerning emissions from transportation in the case of the three scenarios are reported in the following paragraphs referring to global and local balances.

3.1 Global balance n.1

The ratio between kms related to the waste management and kms travelled by can both referred to an inhabitant are presented in Table 3. In the same Table 3, the ratio between kms related to the waste management and kms travelled by trucks are shown too (Italian data are used for the calculations).

Table 3. Incidence of kms done for the three scenarios

	Scenario 1	Scenario 2	Scenario 3
Absolute responsibility in km	1.31 km inh^{-1} y^{-1}	8.52 km inh^{-1} y^{-1}	0.85 km inh^{-1} y^{-1}
Inhabitant responsibility of kms referred to one inhabitant (ref. cars)	0.0161 %	0.1046 %	0.0105 %
Inhabitant responsibility of kms referred to one inhabitant (ref. trucks)	0.0423 %	0.2749 %	0.0275 %

3.2 Global balance n.2

Another global balance concerns the assessment of the emissions globally generated from a waste management system. Data referred to the three scenarios are reported in Table 4. An additional calculation can be made in order to know the distance of equilibrium between the scenario 2 and the scenario 1. The referred area concerns 150,000 inhabitants giving 39,300,000 kg_{MSW}/year and 25,545,000 kg_{RDF}/year. Data are reported in Table 5.

Table 4. Transport plus combustion emissions for each scenario

	Scenario 1	Scenario 2	Scenario 3	Units
PCDD/F	23 856,28	29 895,31	29 811,78	$pg_{I\text{-}Teq}$ inh^{-1} y^{-1}
NO_x	29 461,90	22 922,38	10 124,34	mg inh^{-1} y^{-1}
PM_{10}	964,16	493,87	371,25	mg inh^{-1} y^{-1}
SO_x	2 493,03	2 640,28	2 463,45	mg inh^{-1} y^{-1}

Table 5. Distances of equilibrium between scenarios 1 and 2

	Pollutant			
	PCDD/F	NO_x	PM_{10}	SO_x
Limit distance (km)	< 0	730	2226	125

3.3 Global balance n.3

Another interesting balance concerns the limit distance to have emissions from transport equal to emissions from combustion. Data are reported in Table 6.

Table 6. Distances of equilibrium between transport and centralised combustion

	Pollutant			
	PCDD/F	NO_x	PM_{10}	SO_x
Limit distance [km]	160550	306	1313	6219

3.4 Local balance n.1

A local balanced referred to a radius of 2 km from the source has been implemented. A residual MSW generation basin equal to 100,000 t/y has been assumed. For the assessment of the deposit to the ground in the reported area it has been assumed a value of 7.5% of the total amount of pollutants emitted. Transport has been considered referring to the number of truck travels. In this case the scenario 2 and 3 are the same as the local scale is considered. Data are reported in Tables 7 and 8.

Table 7. Scenario 1 – Local depositions

	MSW combustion depositions (radius 2 km)	Transport Emissions	Units	Deposition ratio transport/combustion
PCDD/F	682,500,000	218,000	$pg_{I\text{-}Teq}/y$	0.03 %
NO_x	780,750,000	33,400,000	mg/y	4.28 %
PM_{10}	27,000,000	320,000	mg/y	1.19 %
SO_x	70,500,000	461,480	mg/y	0.66 %

Table 8. Scenario 2 or 3 – Local depositions

	MSW combustion depositions (radius 2 km)	Transport Emissions	Units	Deposition ratio transport/combustion
PCDD/F	853,125,000	141,700	$pg_{I\text{-}Teq}/y$	0.02 %
NO_x	249,112,500	21,710,000	mg/y	8.79 %
PM_{10}	10,237,500	208,000	mg/y	2.03 %
SO_x	69,956,250	299,962	mg/y	0.43 %

3.5 Local balance n.2

The inhabitants of the area has a risk related both to the emission from combustion and to the waste trucks traffic. Known the number of deaths for road accidents and the average mileage of trucks, the risk per km can be assessed to be used to calculate the incremental risk. The individual risk related to waste transport resulted some $1E^{-7}$ that is it can be considered negligible (a 15 year life time for the plant activities has been assumed).

3.6 Considerations on other bio-mechanical plants

Some considerations can be made referring to scenarios with different bio-mechanical plants.

First of all, the presented calculations assumed zero the emissions from bio-drying. In reality its emissions can vary strongly depending on the treated waste and the kind of process air treatment. For instance, the choice of e thermal oxidation at high temperature gives some emissions of NO_x that can be significant (Consonni, 2002).

The adoption of a two stream RDF plant, with an initial screening can change the balances as the amount of RDF can be lower than the one considered, but the role of landfilling must be assessed in details.

Anaerobic digestion can affect the balance referring to the two stream option and concerning the non-RDF stream.

4. CONCLUSIONS

Some consideration can be made based on the calculations previously presented:

- The amount of km driven by the truck-drivers is negligible compared to the typical distance done from the inhabitant generating the considered MSW.
- Results related to emission decrease thanks to decentralised options are controversial. Some pollutants can increase some other can decrease.
- The options based on RDF generation can be interesting but it must be taken into consideration that long distances of transport could give emissions higher that the one related to the combustion of the transported waste.
- The local risk from trucks (accident risk) can be considered acceptable.

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