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MSW BIO-DRYING: DESIGN CRITERIA FROM A 10 YEARS RESEARCH

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A multi-year research developed since 2003 between the University of Trento, Italy, and the Politehnica University of Bucharest, Romania, allowed defining a few design criteria useful for the optimization of the energy balance and for the minimization of the environmental impact. The design parameters for the biological process are related to the varying food waste content of the input. Values come from pilot scale runs. The design criteria for the environmental impact management refer to the underestimated role of odor and PCDD/F emissions.

Keywords: bio-drying, MSW, odor, PCDD/F, SRF.

1. Introduction

The latest European Union (EU) policy on waste management recommends municipal solid waste (MSW) source reduction, recycling of materials, energy recovery and waste treatment before landfilling. In the last decades, in the EU, the growth of MSW generation depended on the urbanization, on the population increase, and also on the higher consumer demand.

In the framework of the EU Directives, the member states have encouraged integrated systems for MSW management taking into account the availability of plants, of the landfilling volume and of the economic scenario [1,2,3,4,5].

Mechanical Biological Treatments (MBT) can be a viable option in emerging countries that must face with the optimization of a MSW management starting from landfills based scenarios [6,7]. Indeed MBT can treat waste with variable composition and can comply with the EU request regarding the minimization of the biodegradable materials landfilling and energy recovery through Solid Recovered Fuel (SRF). The activation of the selective collection (SC) can be compatible in most of the scenarios [8,9].

MBT plants can be configured in a variety of ways to achieve the required treatment and separation of MSW. Bio-drying is a unique-flow MBT process that

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comply with the EU targets for MSW management. This process can be applied to MSW, to residual MSW after the SC and to other biomasses alone ore mixed [10,11]. The aim of this process is to exploit the biochemical exothermic reactions for the evaporation of most of the initial moisture of the treated waste, with the lowest consumption of volatile solids (VS). The obtained material can be easily converted in SRF [12].

The water exiting or formed by the reaction of hydrogen (from the oxidized organic compounds) with oxygen, is removed in bio-drying thanks to the exothermic aerobic process [13,14,15]. The temperature of the output air is much bigger than the one of input air and in this way a maximized quantity of water is removed. Winter conditions are less favorable then the summer ones in allowing removal of water from waste crossed by an air flow.

In the present paper design criteria are proposed and discussed as a result of a multi-years research developed thanks to the collaboration between two universities: Politehnica University of Bucharest and University of Trento [16].

2. Process considerations

A pilot scale research [18] allowed the generation of data useful for the description of the bio-drying process. In Tables 1 and 2, some parameters useful for a deeper understanding of bio-drying are reported. The role of the selective collection was taken into account.

The very high values of the ratio $m^3_{AIR}/kg_{\Delta VS}$ demonstrate that the process is not oxygen limited. Indeed the management of the process is based on the regulation of air flow-rate for keeping the temperature lower than 60°C. The ratio m^3_{AIR}/kg_{VSinit} allows making a few considerations:

- the case of 100% organic fraction (OF) shows values double than a typical composting process; the reason is related to the absence, in the studied case, of bulky agent usually added to guarantee an adequate porosity, the bulky agents contributes to the VS amount with slowly biodegradabile materials;
- the remaining cases show values lower than the one of a composting plant; this is a consequence of the lower amount of putrescible volatile solids available in case of MSW bio-drying.

The ratio m^3_{AIR}/kg_{OF} gives an idea of the specific effects of the exothermy of the process: the cases 100% OF, 50% OF and 29% OF show values the same order of magnitude. On the contrary the case of 8% OF was characterised by the highest value. This does not depend on the heat generated from the biochemical oxidation, but to the need of increasing the air flow to see some effects of water removal: the risk of bio-drying MSW with very low OF content is to operate the plant similarly to a thermal drying with a high air-flow rate (dewatering the waste by physical phenomena and not biological ones).

Table 1

Experimental parameters characterizing bio-drying : air

OF	**100%**	**50%**	**29%**	**8%**
m^3_{AIR}/kg_{MSW}	15.4	10.9	6.4	7.1
$kg_{\Delta VS}/kg_{MSW}$	0.037	0.033	0.018	0.008
$m^3_{AIR}/kg_{\Delta VS}$	412.7	330.8	361.7	921.0
kg_{VSinit}/kg_{MSW}	0.168	0.452	0.452	0.537
m^3_{AIR}/kg_{OF}	15.42	21.80	22.24	88.87
kg_{VSinit}/kg_{MSW}	0.168	0.384	0.452	0.537
m^3_{AIR}/kg_{VSinit}	91.94	28.42	14.26	13.24
$kg_{VSp\ init}/kg_{MSW}$	0.168	0.084	0.049	0.013
kg_{VSinit}/kg_{MSW}	91.94	129.98	132.48	541.45

Table 2

Experimental parameters characterizing bio-drying : energy

OF	**100%**	**50%**	**29%**	**8%**
SC [%]	only for OF	0	35	65
T_{max} [°C]	46.4	63.5	52.2	31.6
LHV_{MSW} [kJ/kg_{MSW}]	1,972	8,616	9,678	13,495
$LHV_{biodried\_mat}$ [kJ/kg_{MSW}]	2,114	11,327	11,665	14,593
LHV_{SRF} [kJ/kg_{MSW}]	2,114	12,556	13,741	18,516

The presented parameters can be used for a preliminary design of the process air requirement in scenarios where the local selective collection give variable results in term of percentage of OF in the residual MSW. The same data were used for the development of a bio-drying process [19] and a detailed energy balance [14].

The approach must be completed with a post-treatment line in order to generated Solid Recovered Fuel [20, 21, 22]. The efficiency of non-combustible materials separation takes advantage from the characteristics of the bio-dried waste [23].

Taking into account the chlorine and mercury content of MSW [24], some considerations on the three classes that characterize SRF [12] can be made as summarized in Table 3.

Table 3

Expected classification for SRF generated from bio-drying

	SRF : 100%OF	**SRF : 50%OF**	**SRF : 29%OF**	**SRF : 8%OF**
LHV	Not suitable for SRF generation	Class 5 expected	Class 5 expected	Class 4 expected
Cl	Classification not affected by the biological process			
Hg	Classification not affected by the biological process			

3. Environmental impact considerations

Two main environmental concerns have been pointed out by the multi-year research. One refers to the underestimation of the odor impact on the territory. The other refers to the potential loss of PCDD/F already present in the residual MSW to be treated.

In the sector of mechanical–biological plants, odor is not related to the presence of only one compound [25,26]. Thus, the management of the related problems is not easy. In some countries the odor impact from this kind of plants is often under-estimated, also because, during the design step, the consequences of a few design decisions are not fully understood.

A recent contribution from the multi-year research on bio-drying concerned the knowledge of the different results, in term of odor impact, related to three solutions of process air management: biofilter at ground level, biofilter on the roof of the plant, thermal regenerative oxidation (RTO) with release from a stack [27]. Results obtained from a case-study demonstrated that the design choice can have significant consequences on the acceptability of the plant in an area. The Gaussian model AERMOD was used [27]. Before performing the simulation, it was necessary to know the orography of the area, the meteorological values characterizing the atmospheric boundary layer and the quantity of MSW to be treated, in order to estimate the odor flow. A map with isoconcentration lines (step = 1 OU_E/m^3) is presented in Fig. 1 [27] for the case of bio-filer at ground level. It must be pointed out that at the borders of the studied area the values are at least equal to 1. That means that the impact of the plant is not negligible according to the most stringent regulations.

In case of biofilter at roof level, the impact is much smaller than in the first case, with maximum values, close to the plant, slightly lower than 20 OU_E/m^3 compared to 160 OU_E/m^3 of the previous configuration. An overview of the phenomenon is given in Fig. 2 [27]. In spite of a significant decrease of the impact close to the plant, at the borders of the studied area the odor concentration is still not optimized as odor concentrations are still higher than 1.

In the case of RTO the maximum values are lower of orders of magnitude, slightly above 0.12 OU_E/m^3. According to these results, the best option for odor minimization is the adoption of a conveyed stream of process air and the construction of a stack, even if no combustion concerns the process.

The release of dioxin (PCDD/F) from mechanical-biological treatment of MSW is one of the most unexplored topics in the sector of MSW management, even if this phenomenon is known since 1998 [28] before the recent insights [29,30,31,32,33].

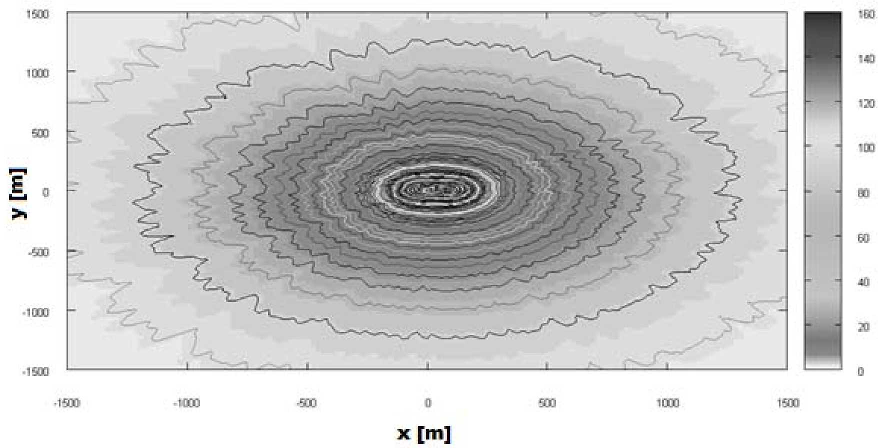

Fig. 1. Isoconcentration of maximum hourly values (yearly basis; biofilter at ground level)

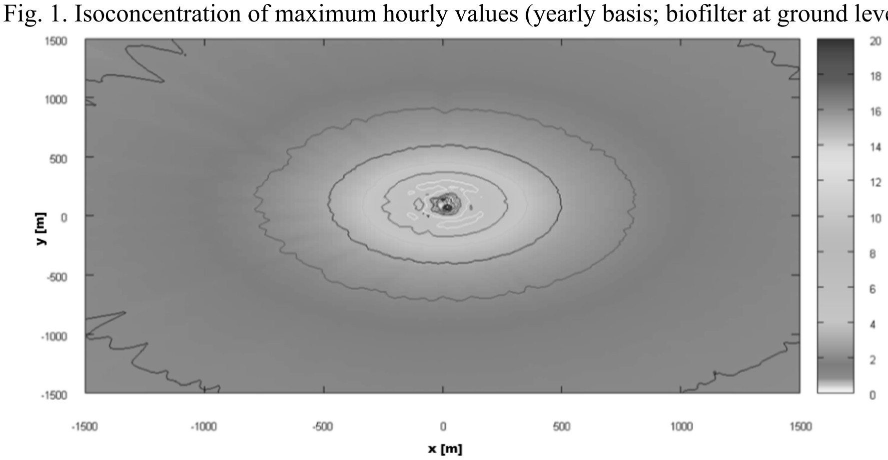

Fig. 2. Isoconcentration of maximum hourly values (yearly basis; biofilter on the roof)

The PCDD/F emission into the atmosphere from MBTs is a phenomenon recognized also from MBT forwarders with a proposed emission factor as 13.5 $pg_{TEQ}\ kg^{-1}$[34]. A confirmation of this phenomenon can be found in DEFRA [34] with a proposed emission factor of 40 $pg_{TEQ}\ kg^{-1}$ [35]. As the residual MSW is collected as is, micro-pollutants like PCDD/F are not immobilized in the waste matrix and they can have a mobility; so, it is reasonable to assume that a fraction of the PCDD/F contained in the waste can have sufficient mobility to be stripped, for example, by an air flow blown into the waste.

The release from bio-drying is net (output higher than input) as related to values higher than the background level of PCDD/F in ambient air [31]. The measured release is generally low, but the impact on health may be not negligible if the dispersion is not optimized.

As for the odor case, the PCDD/F concentrations and respectively deposition dynamics form bio-drying have been analyzed in a case-study during the research years. The same systems for the air treatment of the (large) plant were considered [33]:

- biofilter at ground level resulted also for PCDD/F the worst solution: a maximum concentration value near the source equal to 118 fg_{TEQ} m^{-3} was assessed, rural area concentrations are generally lower, being in the order of tens of fg_{TEQ} m^{-3}. However this value decreases, in the case-study, of about 2 orders of magnitude in the first 200 m and to 0.2 fg_{TEQ} m^{-3} at about 1 km;
- biofilter on the roof of the plant building improves the environmental impact: the values of pollution near the plant are reduced by two orders of magnitude, but the impact at around 1 km away from the plant is similar to the one from the biofilter at ground level;
- RTO solution optimizes the PCDD/F impact, guaranteeing values lower than 0.1 fg_{TEQ} m^{-3} in the surrounding area, compatible with the presence of a rural area.

4. Criteria for bio-drying design

The above considerations allow proposing some criteria for bio-drying design:

- as the ***mass loss*** depends on the quantity of putrescible materials present in the input waste, bio-drying can be correctly designed only if the future scenario of selective collection is clear; data generated during the overviewed research allows choosing the mass loss value and the optimum lasting of the process;
- the ***VS consumption*** is minimized thanks to the avoidance of water addition; by this way the presence of carbon in the output can be maximized, giving interesting results in term of specific ***LHV increase***; this result is a concentration of the initial energy in a lower mass of waste (there is no energy generation); the mass loss can be related to the OF content;
- the importance of the ***specific air flow-rate*** is related to the necessity of data availability for design criteria; the choice of the blower for the aeration of the waste depends also on the overall amount of air when the lasting of the process is known; flow-rate variations depend on the management of the temperature process; the set of runs performed during the multi-year research gives important information to this concern;
- the ***temperature*** of the process is regulated through the air-flow control; the temperature in the core of the waste can go over 55°C for 3 days if the OF is enough and the air flow is optimized;
- the optimum solution for minimization of the ***odor and PCDD/F*** impacts resulted the one with RTO option applied for air treatment; biofilter costs less

but the impact of a plant adopting this option could not comply with the quality targets of modern regulations; the design strategy of placing a biofilter on the roof of the plant could guarantee a lower impact mainly in the surroundings of the plant.

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