PCDD/F enviromental impact from municipal solid waste bio-drying plant

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The present work indetifies some environmental and health impacts of a municipal solid waste bio-drying plant taking into account the PCDD/F release into the atmosphere, its concentration at ground level and its deposition. Four scenarios are presented for the process air treatment and management: bio-filter or regenerative thermal oxidation treatment, at two different heights. A Gaussian dispersion model, AERMOD, was used in order to model the dispersion and deposition of the PCDD/F emissions into the atmosphere. Considerations on health risk, from different exposure pathways are presented using an original approach. The case of biofilter at ground level resulted the most critical, depending on the low dispersion of the pollutants. Suggestions on technical solutions for the optimization of the impact are presented.

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1. Introduction

The release of dioxin (PCDD/F) from mechanical–biological treatment (MBT) of municipal solid waste (MSW) is one of the most unexplored topics in the sector of MSW management, even if this phenomenon is known since 1998 (Lahl et al., 1998). In general the role of PCDD/F in the MSW management was analyzed only in relation with combustion processes. Anyway 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 pgTEQ kg \(^{-1}\) (GET, 2003). A confirmation of this phenomenon can be found in DEFRA (DEFRA, 2004) with a proposed emission factor of 40 pgTEQ kg \(^{-1}\). As the residual MSW (the waste not source separated) 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 enrichment of PCDD/F in the process air during an aerobic processes applied to waste was pointed out already in 2001 (UNEP, 2001), but an explanation of this PCDD/F release from the bio-drying treatment was provided only recently (Rada et al., 2007a). The release is net (output higher than input) as related to values higher than the background level of PCDD/F in ambient air. The measured release is generally low but the impact on health may be not negligible if the dispersion is not optimized. In order to assess the role of this release, in the present paper some considerations on the human exposure from PCDD/F intake have been developed. To this concern, the tolerable daily intake (TDI) of dioxin established by the World Health Organization (WHO) and individual countries, based on scientific knowledge was used.

In 1990, WHO proposed for the first time an acceptable daily intake of 10 pgTEQ kg \(^{-1}\) d \(^{-1}\) for 2,3,7,8-TCDD based on information and studies available at the time (Kociba et al., 1978; Kimbrough et al., 1984). In 1998, taking into account the United State Environmental Protection Agency (EPA) research and the OSWER Directive 9200.4.26 WHO recommended a Total Daily Intake (TDI) in the range 1–4 pgTEQ kg \(^{-1}\) d \(^{-1}\) as “maximal tolerable intake on a provisional basis” but it stressed that the ultimate goal should be to reduce human intake levels to less than 1 pgTEQ kg \(^{-1}\) d \(^{-1}\).

The Toxic Equivalency Factor (TEF) concept for polychlorinated dibenzo-p-dioxins and dibenzofurans and dioxin-like polychlorinated biphenyls (PCBs) for human, fish, and wildlife assessment was introduced in 1998 (van den Berg et al., 1998), as the most “plausible and feasible approach for risk assessment of halogenated aromatic hydrocarbons with dioxin-like properties. In 2005, the Total Toxic Equivalency (TEQ) was introduced by WHO for abiotic matrices as soil, sediments, etc. for direct application in human risk assessment.

In 2010, after six years of research and studies developed with the National Academy of Science (NAS), EPA has released a draft report entitled EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments and established a cancer slope factor of 1.0 × 10\(^{8}\) (mg kg \(^{-1}\) d \(^{-1}\)) \(^{-1}\) based on a linear dose–response model.
In this frame also the knowledge on PCDD/F releases into the atmosphere was developed in the last decades. One of the original contributions to this development concerned MBTs, until the 1990s belonging to a PCDD/F zero emission sector.

Bio-drying is a MBT process, an aerobic bioconversion treatment that can be applied to MSW as is, to MSW residual of selective collection, or to contaminated organic fractions (under-sieve from mechanical selection, etc.). The most widely used configuration is one based on the one-stream concept: all the waste enters into the biological stage. After an inert post-separation, the final product is aimed to be used as Refuse Derived Fuel (RDF) or disposed in landfills, or incinerated (in a PCDD/F oxidation system for process air treatment, options with not well available technologies for PCDD/F prevention and reduction; in many countries, occurring in the area where dispersion takes place, is a mandatory requirement in order to obtain precise scenarios of air quality and fall-out mapping. For this reason advanced numerical models for simulation of pollutant dispersion require as an input a series of meteorological measurements from both surface stations and upper soundings. Often the sites proposed for the implementation of a bio-drying plant have no specific data concerning this aspect.

### 2. Materials and methods

In this paper, in order to assess the PCDD/F dispersion from a bio-drying plant, the Gaussian model AERMOD was used. The AERMOD Modeling System is a software implementing the calculation of concentration and deposition of pollutants (emitted from either surface or elevated sources) at ground level, over both simple and slightly complex terrain. Dispersion processes are reproduced by means of suitable parameterization of atmospheric structure and planetary boundary layer turbulence (EPA, 2004a).

AERMOD has been developed by EPA in conjunction with the American Meteorological Society (AMS). This model requires a pre-processor that organizes and processes meteorological data and estimates the necessary boundary layer parameters for dispersion calculations in AERMOD. The meteorological preprocessor that serves to this purpose, and was used for the present calculations, is AERMET. AERMET uses available meteorological measurements, representing of the modeling domain, to compute atmospheric boundary layer parameters used by AERMOD to estimate profiles of wind, turbulence and temperature. AERMOD is based on the Meteorological Processor for Regulatory Models (MPRM) (Irwin et al., 1988), but the actual processing of the meteorological data is similar to that done for the CTDMP (Perry, 1992) and HPDM (Hanna and Chang, 1993) models. In particular the growth and structure of the atmospheric boundary layer is driven by heat and momentum fluxes, which in turn depend upon surface effects (Stull, 1988). The depth of this layer, as well as the dispersion of pollutants within it, are influenced on a local scale by surface characteristics, such as surface roughness, reflectivity (albedo), and the availability of surface moisture. The surface parameters provided by AERMET are the Monin–Obukhov length, surface friction velocity, surface roughness length, surface heat flux and the convective scaling velocity (Venkatram, 1980; Panofsky and Dutton, 1984). AERMET also provides estimates of the convective and mechanical mixed layer heights (Weil and Brower, 1983). AERMET uses available meteorological data and estimates the necessary boundary layer parameters for dispersion calculations in AERMOD. The meteorological preprocessor that serves to this purpose, and was used for the present calculations, is AERMET. AERMET uses available meteorological measurements, representing of the modeling domain, to compute atmospheric boundary layer parameters used by AERMOD to estimate profiles of wind, turbulence and temperature. AERMOD is based on the Meteorological Processor for Regulatory Models (MPRM) (Irwin et al., 1988), but the actual processing of the meteorological data is similar to that done for the CTDMP (Perry, 1992) and HPDM (Hanna and Chang, 1993) models. In particular the growth and structure of the atmospheric boundary layer is driven by heat and momentum fluxes, which in turn depend upon surface effects (Stull, 1988). The depth of this layer, as well as the dispersion of pollutants within it, are influenced on a local scale by surface characteristics, such as surface roughness, reflectivity (albedo), and the availability of surface moisture. The surface parameters provided by AERMET are the Monin–Obukhov length, surface friction velocity, surface roughness length, surface heat flux and the convective scaling velocity (Venkatram, 1980; Panofsky and Dutton, 1984). AERMET also provides estimates of the convective and mechanical mixed layer heights (Weil and Brower, 1983). AERMET defines the stability of the PBL by the sign of the surface heat flux (convective for a positive flux and stable for a negative flux).

### Table 1

<table>
<thead>
<tr>
<th>Plant</th>
<th>t/y</th>
<th>Air treatment</th>
<th>m³ kg⁻¹ MSW</th>
<th>Concentration pgTEQ m⁻³</th>
<th>FE pgTEQ kg⁻¹ MSW</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rennerod  (D)</td>
<td>100 000</td>
<td>RTO</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>0.53</td>
</tr>
<tr>
<td>Aßlar (D)</td>
<td>140 000</td>
<td>RTO</td>
<td>5.3</td>
<td>0.1</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>Fusina (I)</td>
<td>125 000</td>
<td>RTO</td>
<td>3</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oberpullendorf (A)</td>
<td>44 000</td>
<td>Biofilter</td>
<td>6</td>
<td>0.5</td>
<td>3</td>
<td>Lahl et al., 1998</td>
</tr>
</tbody>
</table>

The concentration in the process air of bio-driers are re-analyzed below. In this paper some environmental and health impacts of a MSW bio-drying plant, taking into account the PCDD/F release into the atmosphere, the induced concentration at ground level and its deposition, are presented. In order to determine the health risk associated with the PCDD/F emissions from MSW bio-drying plants, the emission phenomenon and the emission factors are analyzed below.

In the literature variable data regarding PCDD/F emission factors or PCDD/F concentration in the process air of bio-driers are reported, as summarized in Table 1. These variations are caused, in addition to the various operational strategies adopted or to different air treatment technologies, by the fact that the amount of dioxins in present in the MSW may differ significantly from case to case, and the fraction of MSW can be characterized by a different mobility. For example, in England the average concentration of PCDD/F in MSW was found to be of approximately 6.3 ngTEQ kg⁻¹ MSW, in Germany 73 ngTEQ kg⁻¹ MSW, while in Italy approximately 20 ngTEQ kg⁻¹ MSW (Rada et al., 2006). However these values cannot be generalized: variations must be expected also in the same country depending on the year of characterization and the level of contamination of MSW. Concerning concentrations measured in the bio-drying process air at the outlet, the detected values alone could seem negligible, but when combined with the specific air flow (from a bio-drying plant generally about 3–10 m³ kg⁻¹ MSW), the resulting release into the atmosphere may become important. Although the MBT does not have a specific EU directive, in some regulations in European countries we can find both enhanced approaches (BMLFUW, 2002 and BMU, 2001), and soft approaches. For example, in Italy specific regional regulations have been established only in a few areas, but not concerning PCDD/F (D.G.R., 2003). Regarding PCDD/F, only the German regulation imposes a limit of 0.1 ngTEQ m⁻³, the same imposed in EU for the MSW incineration plant. However it must be taken into account that a modern incineration plant typically adopts as air treatment the best available technologies for PCDD/F prevention and reduction; instead a MBT plant can have a biofilter or a regenerative thermal oxidation system for process air treatment, options with not well studied effects on PCDD/F removal. For this reason and also taking into account that one of the two systems generally used for the MBT air treatment releases at ground level, at low temperature and with low velocity, it could be interesting to compare the PCDD/F impact from a MBT plant with the one from an incineration plant; the present paper gives a contribution to this concern.

Atmospheric conditions play a crucial role in determining the fate of pollutants emitted into the atmosphere. Wind strength and direction, turbulence intensity, thermal structure, relative humidity, precipitation and solar radiation are all factors which can strongly affect the transport of pollutants and their modifications. As a consequence, a precise knowledge of weather and climate, occurring in the area where dispersion takes place, is a mandatory requirement in order to obtain precise scenarios of air quality and fall-out mapping. For this reason advanced numerical models for simulation of pollutant dispersion require as an input a series of meteorological measurements from both surface stations and upper soundings. Often the sites proposed for the implementation of a bio-drying plant have no specific data concerning this aspect.
MOD is capable of estimating meteorological profiles with data from as little as one measurement height, it use as much data as the user can provide for defining the vertical structure of the boundary layer. In addition to Planetary Boundary Layer parameters, AEROMET passes all measurements of wind, temperature, and turbulence in the format required by AERMOD (Cimorelli et al., 2004). AEROMET is designed to be run as a three-stage process and operate on three types of data: hourly surface observations, twice-daily upper air soundings, and data collected from an on-site measurement program such as from an instrumented tower. The first stage retrieves data and assesses data quality. The second stage combines the available data for 24-h periods and writes these data to an intermediate file. The third and final stage reads the merged data file and develops the necessary boundary layer parameters for dispersion calculations by AERMOD.

The model requires, as minimum meteorological input data, hourly surface observations of wind speed and direction, ambient temperature, opaque sky cover (in the absence of opaque sky cover, total sky cover). Station pressure is recommended, but not required, since it is used only to calculate the density of dry air, whereas AEROMET will use a default value of 1013.25 h Pa (sea level pressure) in the absence of station pressure. Also an upper air sounding taken in the morning is required (EPA, 2004b).

In the present work hourly observations of air temperature, wind speed and direction (at 10 m above the ground level), precipitation, relative humidity and solar radiation were provided at a weather station operated at Legnaro (Padua) by the Environmental Protection Agency of Veneto region. As a case study a flat zone in the North of Italy was chosen having about 500,000 inhabitants producing 268,000 t MSW y\(^{-1}\), and a MSW selective collection well implemented (about 65% of efficiency); about one third of the produced MSW will be treated in the bio-drying plant, having about 23% of organic fraction in the input. Bio-drying has no effect on inert in MSW, but affects moisture and volatile solid content. In the case-study, the total input of the plant is 95,071 t MSW y\(^{-1}\). Comparing this value with the ones in Table 1, the studied plant can be classified as of average capacity. According to an available energy model (Rada et al., 2007b) and the MSW characteristics of the case-study, the process allows extracting about 10,885 t y\(^{-1}\) of water, with a volatile solid collection assessment as 14.1 g kg\(^{-1}\)MSW. This consumption can be related to the release of PCDD/F into the atmosphere assuming a level of contamination of the volatile solids (VS), according to the PCDD/F bio-drying model (Rada et al., 2007a). In the present paper the emission factor has been assumed 20 pgTEQ kg\(^{-1}\)MSW, taking into account the range proposed in the literature (Rada et al., 2005).

For the bio-drying plant two systems for the process air treatment were chosen for a comparison:

- A biofilter at ground level (height of release: 2 m) or on the roof of the plant building (height of release: 17 m).
- A regenerative thermal oxidation treatment, RTO (height of release: 25 m or 35 m).

Taking into account the above considerations, in Table 2, the most important characteristics of the bio-drying plant, of the biofilter and of the RTO system are presented.

For the chosen scenarios a Cartesian grid square having the source located in the center was used. For the biofilter emissions the considered area had the size 3 km \(\times\) 3 km, with receptors spaced 20 m, while in the case of point source, a survey area of 4 km \(\times\) 4 km and 40 m mesh was used.

In this paper, the behavior of PCDD/F during deposition was assumed as the one of passive tracers. For the deposition rate the velocity formulas proposed by Wesely et al. (2002) were used. Through the combined results of these depositions, it can be deduced which air treatment is less impacting from the environmental point of view.

For the estimation of carcinogenic risk in case of ingestion and respectively inhalation of the slope factor (slope of the linear dose–response curve) and respectively the cancer potency, the daily amount of inhaled air (20 m\(^3\)) and body weight (70 kg) were used. In order to assess the risk related to the emitted PCDD/F, the deposition data were compared with the standards proposed from the Flemish Guide Lines (van Lieshout et al., 2001) using the EPA slope factor and unit risk.

In this paper for the impact of PCDD/F emission from the studied bio-drying plant two deposition limits (DL) were adopted:

- DL\(_{TDI,100}\%\): assuming zero the background deposition, when the deposition from the plant corresponds to this value, the plants alone is responsible for the highest tolerable deposition according to the Flanders Guide Lines;
- DL\(_{TDI,5\%}\): assuming zero the background deposition, when the deposition from the plant corresponds to this value, the plants is responsible for 5% of the highest tolerable deposition according to the Flanders Guide Lines; when this deposition is below this limit, the impact of the plant can be considered not significant.

Taking into account the trend of the WHO’s vision regarding the TDI, in this paper the proposed lower value of 1 pgTEQ kg\(^{-1}\) d\(^{-1}\), was used for safety reasons. The adopted value in Germany confirms that the assumption in this paper is the most stringent: the German TDI is 4 pgTEQ kg\(^{-1}\) d\(^{-1}\) with a deposition of 15 pgTEQ m\(^{-2}\) d\(^{-1}\) (LAI, 2000) similar to the Flemish less stringent one: 14 pgTEQ m\(^{-2}\) d\(^{-1}\) (van Lieshout et al., 2001).

The calculation of the deposition critical value is related to concentrations of PCDD/F in food products. The PCDD/F flow before reaching the human body through ingestion, takes into account the various levels of concentration in the atmosphere, the deposition in the grass and soil and also the transfer of the PCDD/F congeners in the chain of fish, animals farm, milk, eggs and meat. This approach was used also in the Flanders in order to propose the deposition limit.

For the risk assessments of dioxins, in this paper a linear dose–response relationship for dioxin-induced cancer was assumed; the one in a million cancer risk was calculated for an exposure of 0.006 pgTEQ kg\(^{-1}\) body weight d\(^{-1}\) (Buckley-Golder et al., 1999a,b).

### Table 2

<table>
<thead>
<tr>
<th>Bio-drying plant</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>t y(^{-1})</td>
<td>95 000</td>
</tr>
<tr>
<td>Operating time</td>
<td>d y(^{-1})</td>
<td>350</td>
</tr>
<tr>
<td>Process timing</td>
<td>h d(^{-1})</td>
<td>24</td>
</tr>
<tr>
<td>Process air</td>
<td>m(^2) kg(_{MSW}) d(^{-1})</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biofilter</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission factor</td>
<td>pgTEQ kg(^{-1})</td>
<td>20</td>
</tr>
<tr>
<td>Mass flow</td>
<td>pgTEQ s(^{-1})</td>
<td>63</td>
</tr>
<tr>
<td>Optimal volumetric flow</td>
<td>m(^3) h(^{-1})</td>
<td>80</td>
</tr>
<tr>
<td>Volume</td>
<td>m(^3)</td>
<td>1425 (15 m (\times) 95 m (\times) 1 m)</td>
</tr>
<tr>
<td>Specific mass flow</td>
<td>pgTEQ m(^{-2}) s(^{-1})</td>
<td>45</td>
</tr>
<tr>
<td>Emission velocity</td>
<td>m s(^{-1})</td>
<td>2.2 (\times) 10(^{-2})</td>
</tr>
<tr>
<td>Temperature (out)</td>
<td>°C</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RTO</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>pgTEQ m(^{-3})</td>
<td>2</td>
</tr>
<tr>
<td>Mass flow</td>
<td>pgTEQ s(^{-1})</td>
<td>63</td>
</tr>
<tr>
<td>Emission velocity</td>
<td>m s(^{-1})</td>
<td>10</td>
</tr>
<tr>
<td>Temperature (out)</td>
<td>°C</td>
<td>47</td>
</tr>
<tr>
<td>Diameter</td>
<td>m</td>
<td>1.2</td>
</tr>
</tbody>
</table>
3. Results and discussions

In Fig. 1 the PCDD/F concentrations and respectively deposition dynamics taking into account the chosen air treatment system, in the South direction are presented.

The use of biofilter at ground level is the worst solution: taking into account the mass flow (63 pgTEQ s⁻¹) it results a maximum concentration value near the source equal to 118 fgTEQ m⁻³; from Hovmand et al., 2007, rural area concentrations are generally lower, being in the order of tens of fgTEQ m⁻³. However this value decreases of about 2 orders of magnitude in the first 200 m, arriving to a value of about 5 fgTEQ m⁻³. At about 1 km away from the biofilter, the PCDD/F concentrations are around 0.2 fgTEQ m⁻³.

The PCDD/F depositions have the same dynamics moving away from the source of pollution, with a peak of 14 ngTEQ m⁻² y⁻¹ at 5 m away from the biofilter, value that decreases to 100 pgTEQ m⁻² y⁻¹ at about 500 m from the plant.

The solution with the 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: the maximum concentration arriving at 1.2 fgTEQ m⁻³, while the peak of deposition is about 820 pgTEQ m⁻² y⁻¹. However, the impact at around 1 km away from the plant is similar for both solutions. The peak deposition is anyway high. Indeed in a Belgian case-study (Nouwen et al., 2001) referred to two incinerators located in the same area, modeling results gave a maximum deposition value of 1.2 ngTEQ m⁻² y⁻¹ near the two incinerators. These incinerators exceeded respectively of one and two orders of magnitude of the present EU standard (0.1 ngTEQ Nm⁻³).

The situation improves in the case of RTO solutions. In the case of RTO outlet placed at 25 m the values are reduced by an additional order of magnitude, with maximum values of 0.1 fgTEQ m⁻³ and a deposition of 74 pgTEQ m⁻² y⁻¹. The PCDD/F from the stack are more sensitive to the preferred direction of the wind but the deposition values, however, are less affected by the vertical wind profile. In the case of RTO placed at 35 m the impact is not comparatively reduced substantially, because the situation is already good with heights of 25 m.

In order to facilitate the interpretation of the results, in Figs. 2 and 3 the concentrations and depositions are presented in logarithmic scale for the case of biofilter at ground level (the worst case) and RTO at 25 m (the already suitable case), in order to give an overall information on the impact in the plant surroundings. The climatologic characteristics of the area do not give a prevailing direction of the impact.

For the evaluation of the risk for human health from PCDD/F ingestion and inhalation, the PCDD/F dose and cancer potency and slope parameters factor were used. Taking into account the PCDD/F deposition 3.4 pgTEQ m⁻² d⁻¹ for the TDI = 1 pgTEQ kg⁻¹ d⁻¹ (van Lieshout et al., 2001) and the slope factor of 150 pgTEQ kg⁻¹ d⁻¹ adopted in the Flemish Guide Lines, in our case the tolerable risk results 1.5 × 10⁻⁴.

In the case of a good management of waste, in this paper a limit for the dioxin emission in order to comply with a maximum individual risk of developing a tumor effect was set as 10⁻⁶. This is the standard value used for human health risk evaluation in the case of incineration. Taking into account the target risk (10⁻⁶) and in our case the tolerable risk, the target deposition (DL_{TDI, 10⁻⁶}) results...
In Fig. 4 the isodeposition curves related to DLTDI_100%, DLTDI_5% and DLTDI_10 are reported for the case of the bio-drying plant with biofilter at 2 m, 17 m and respectively for the same bio-drying plant with RTO at 25 m and 35 m.

The isoline in red (DLTDI_100%) represents the critical value of limit exposure, the one in green (DLTDI_5%) is the limit for relevant impact and the blue one (DLTDI_10) is the limit for the target impact.
The worst solution is the one of bio-drying with biofilter at ground level, having a PCDD/F critical environmental impact. The critical value of 1.24 ngTEQ m\(^{-2}\) y\(^{-1}\) \((D_{LTDI_{100\%}})\) is confirmed in an area out of a distance of about 100 m from the source. In the case of the more stringent \(D_{LTDI_{5\%}}\), this value is not respected in an area as far as a distance of about 500 m in the North–South direction and about 300 in West-East direction; instead the \(D_{LTDI_{10^{-6}}}\) is not complied with at less than 1.5 km. The meaning of these results is that the population is not protected according to the WHO criteria required for one source of pollution.

For the second case (bio-drying with biofilter at 17 m) the PCDD/F environmental impact improves. The \(D_{LTDI_{100\%}}\) is always respected, the \(D_{LTDI_{5\%}}\) is not respected with in a small area with a maximum diameter of 300 m but for the \(D_{LTDI_{10^{-6}}}\) the situation does not change significantly, the limit exposure distance remains at about 1.5 km in the North–South direction and at about 1 km in the West-East direction. One of the reasons is that the deposition dynamics is not affected by the release height at distance greater than 1 km.

For the last two proposed cases (bio-drying with RTO at 25 m and 35 m) the overall PCDD/F environmental impact improves significantly, and the involved population living near the plant is further protected. The \(D_{LTDI_{100\%}}\) is respected in both cases, the \(D_{LTDI_{5\%}}\) is not complied with in a small area (with a limit distance of 100 m only in the case of RTO at 25 m). Even for these two cases the \(D_{LTDI_{10^{-6}}}\) is not guaranteed, there is indeed still an exposed zone with a radius of up to about 600 m.

A change to the RTO height from 25 m to 35 m, gives higher capital costs, slightly higher operation costs (because of the higher energy demand for the blowers) and a higher impact on the landscape, but does not give a significant improvement from the environmental point of view.

For a better understanding of the PCDD/F environmental impact resulting from a bio-drying plant that treats MSW, in Table 3 the minimum and maximum critical distances for the four proposed cases are reported.

<table>
<thead>
<tr>
<th>Distance from Source (m)</th>
<th>(D_{LTDI_{100%}})</th>
<th>(D_{LTDI_{5%}})</th>
<th>(D_{LTDI_{10^{-6}}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biofilter 2 m</td>
<td>63.2</td>
<td>107.7</td>
<td>577.2</td>
</tr>
<tr>
<td>Biofilter 17 m</td>
<td>170.9</td>
<td>316.2</td>
<td>693.1</td>
</tr>
<tr>
<td>RTO 25 m</td>
<td>89.4</td>
<td>126.5</td>
<td>288.4</td>
</tr>
<tr>
<td>RTO 35 m</td>
<td></td>
<td></td>
<td>282.8</td>
</tr>
</tbody>
</table>

The environmental impact from municipal solid waste bio-drying treatment cannot be neglected. As demonstrated the worst case is the one with the biofilter at ground level, which is the most adopted in the sector of MBTs. Of course the biofilter on the roof improves the impact in the surroundings, and it should be adopted as compulsory, while ground level biofilters should not be authorized any more. A visible change can be obtained by the implementation of the RTO system. This option is widely used in Germany, and has the only disadvantage of its high cost. The present study demonstrates that the stack height for the RTO is not the core issue of the optimization: good results can already be obtained with average heights.

This paper demonstrates that an environmental impact assessment should be requested also in the case of aerobic mechanical–biological treatments, as it is currently required in the case of incineration plants. For a detailed investigation on the PCDD/F dynamics, generally mathematical and numerical models requiring appropriate meteorological data are widely used.

Three problems can be pointed out: (1) the present regulation does not require a specific study on the emissions of PCDD/F from bio-drying; (2) often there is a lack of site-specific meteorological data; (3) there is not a universally-valid model for the evaluation of pollutant dispersion/deposition processes. In the first case, the limits of the present regulations depend either on the limited knowledge of the phenomena, or on the underestimate of its effects: in Germany the measurement of PCDD/F emissions from BMTs is required, but the imposed limit concentration is the same as for incineration, without any attention to the emission factor and on its role in terms of the different conditions under which dispersion may occur. Human exposure is crucial, thus the prevention that a regulation must guarantee cannot be based only on conventional approaches. The second problem, related to meteorological analyses, is often underestimated; the best solution could be installing a meteorological station in the site proposed for a new plant, thus allowing one year of measurements.

The last problem regards the limitation of the mathematical model applicability. AERMOD has been originally developed for flat or slightly complex terrain, and cannot simply be extended to cases of strongly complex terrain, such as within deep mountain valleys (Rotach and Zardi, 2007). The MSW treatment plants are constructed in all the orographic conditions. For example the vertical extent and structure of both wind and temperature fields in complex areas are very different from those occurring over flat terrain (de Franceschi et al., 2003, 2009; de Franceschi and Zardi, 2009; Serafin and Zardi, 2010a,b); thus the model must be specifically chosen case by case.

Summing up, the present work points out the need of specific studies related to the role of PCDD/F in MBTs. These studies should take into account waste contamination, dioxin removal by process air treatment, ways in which pollutants are released into the atmosphere, meteorological characteristics of the area, land use in the surroundings, resident population presence and location.

### References


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