# DIOXIN HEALTH RISK ASSESSMENT FOR MUNICIPAL SOLID WASTE AND RDF COMBUSTION: A COMPARISON

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## Introduction

Health and environmental effects arising from application of different waste management strategies are becoming primary concerns when drawing up waste management plans(1). The European Union has proposed a community waste management strategy which addresses management towards a sustainable development. The incineration of MSW without any pre-treatment and the MSW pre-treatment coupled with RDF combustion are two strategies for the implementation of the EU waste-to-energy option in the waste management plans. In general thermal treatment is often favoured for its ability to decrease the waste volume to be landfilled and for energy recovery(2). The health problems associated with incineration have been well document especially the effect of toxic organic compounds such as dioxin. Dioxin toxicity in humans has been associated with a number of diseases ranging from wasting syndrome, immune system and haematopoiesis, digestive system, renal functions, reproductive systems, neurobehavioral effect and carcinogenity. A number of countries have put recommended allowable daily intake values with the hope of reducing cancer cases and other dioxin related diseases. In Europe, France recommends ADI of 1 pg TEQ/kg b.w., Germany recommends 1-10 pg TEQ/kg b.w., Italy, The Netherlands and UK propose 10 pg TEQ/kg b.w(3). The United States adopts the same level as the one recommended by the WHO which is 1-4 pg TEQ/kg b.w.

The fate of the emissions from thermal treatment plants is deposition in different environmental compartments with soil, crops and sediments as the main receivers. Human exposure takes place through inhalation, dermal contact, soil ingestion and food consumption. It has been estimated that human exposure to dioxin through food is about 90%(4). However, soil ingestion has been shown to contribute significantly to dioxin exposure especially for children(5). This paper focuses on studying the health effects from MSW and RDF management supposing a modern MSW incinerator is substituted by a RDF combustor. Real measured data have been used for these calculations.

## Materials and Methods

The considered MSWI treats about 250t $d^{-1}$ supplied from a community which has source separation in place (paper, glass, biodegradable fraction and hazardous waste). The plant operates with an air-cooled grate furnace and a chimney height of 60 meters. The PCDD/F analysis in flue gas was conducted following the CEN (1996) method(6).

The studied area is occupied by a population of 111 841 and covers a surface area of 121km$^2$ with the land use classification given in Table 1 below.

Table 1: Land use classification of the area studied

| Land Use | Percentage occupied (%) |
|---|---|
| Urban structures | 16 |
| Non-irrigated agriculture | 2 |
| Irrigated agriculture | 40 |
| Grassland and grazing pasture | 3 |
| Forest | 39 |

Dioxin concentration at ground level and deposition flux were calculated using the USEPA Industrial Source Complex model version 3(11). The study of health impact was conducted with the collaboration between the University of Trento and the Technical University of Milan (Italy).

The equation used for calculating soil concentration is given below (USEPA, 1998)(7).

$$C_s = \frac{F_d\left[1 - e^{-k_s T}\right]}{k_s \rho_s z} \tag{1}$$

Where $C_s$ is the contaminant mass fraction in soil (mg kg$^{-1}$) and $F_d$ is the deposition flux (mg m$^{-2}$ year$^{-1}$).

The calculation of health exposure from soil ingestion and inhalation was done using the following equations taken from the USEPA (1996)(7) and some parameters used in this study are given in Table 2:

$$I_{Inh} = \frac{C_{AIR} \cdot IR_{air} \cdot EF \cdot ED}{BW \cdot AT} \tag{2}$$

$$I_{soil} = \frac{C_S \cdot IR_{soil} \cdot EF \cdot AF \cdot ED}{BW \cdot AD} \tag{3}$$

$I_{Inh}$ and $I_{soil}$ are the exposure concentrations from inhalation and soil ingestion, respectively.

Table 2: Parameters and legend used in the study on MSWI

| Parameter | Value |
|---|---|
| Emission period - T | 30 years |
| Soil bulk density - $\rho_s$ | 1500 kg m$^{-3}$ |
| Soil mixing depth- z | 0.1 m |
| Dioxin decay rate - $k_s$ | 0.06 year$^{-1}$ |
| Adult inhalation rate- $IR_{air}$ | 0.22 m$^3$ kg $^{-1}$d$^{-1}$ |
| Child inhalation rate- $IR_{air}$ | 0.45 m$^3$ kg $^{-1}$d$^{-1}$ |
| Soil ingestion rate by adults- $IR_{soil}$ | 50 mg d$^{-1}$ |
| Soil ingestion rate by child- $IR_{soil}$ | 85 mg d$^{-1}$ |
| Adult body weight- BW | 70 kg |
| Child body weight-BW | 30 kg |

Dermal contact and diet were also calculated starting from equation 2 and 3. The dermal contact was calculated considering 0.0489 m$^2$ kg$^{-1}$ exposed surface.

The RDF combustion facility chosen for the comparison receives about 120 000 t y$^{-1}$ of which 36% ends up on the RDF combustion stream and the rejected 64% is sent to landfill. The RDF preparation involves mechanical pre-treatment by size reduction, sieving and bulking. The produced RDF has a calorific value of about 3200 kcal kg$^{-1}$, 23% humidity and 200 kg m$^{-3}$ density.

The plant operates with a fluidized bed furnace and has a chimney height of 60 meters. The most significant difference between the off-gas treatment line between the two plants is the presence of a Selective Catalytic Reactor in the case of MSWI and a Selective Non Catalytic Reactor in the case of RDF combustion. This explains the significant difference in terms of dioxin emission factors.

Considering pre-treatment (in case of RDF), off-gas flow-rates, PCDD/F concentration at the stack, the emission factors are 48 $pg_{teq}\ kg_{msw}^{-1}$ and 150 $pg_{teq}\ kg_{msw}^{-1}$ for MSWI and RDF combustion, respectively.

**Results and Discussions**

The results obtained for the MSWI are given in Table3. The ground level concentration from the MSWI does not significantly affect the background dioxin air concentration owing to the adopted SCR technology. The lower ground air concentration is supported by the values reported by the DETR (1999) on their survey in European countries and Fiedler (1995)(8) in Germany. DETR found air concentrations between 0.001-0.810 $pg_{teq}\ Nm^{-3}$ while Fiedler found concentrations between 0.07–0.35 $pg_{teq}\ Nm^{-3}$. The difference between the results reported by Fiedler and DETR arises partly from the year of sampling. Fiedler measured the air concentration in the early 90s while DETR did theirs in the late 90s. The decrease in MSWI emissions resulted in the decrease in air concentrations, which has been reported by a number of researchers, is confirmed by the lower dioxin emission found in this study. Less than 1% of the MSWI emitted dioxin ended up in the air at ground level. Also, the deposition flux did not significantly affect the previous soil condition. The deposition flux varies from season to season as found by Halsal et al. (1997)(9). They found deposition flux in Manchester to be $6x10^{-6}$ mg $m^{-2}$ $day^{-1}$ in winter and $9.9x10^{-7}$ mg $m^{-2}$ $day^{-1}$ in summer while Cardiff had $5.6x10^{-6}$ mg $m^{-2}$ $day^{-1}$ in winter and $1x10^{-6}$ mg $m^{-2}$ $day^{-1}$ in summer. As shown in Table 3, the deposition flux from the modern MSWI should not significantly affect the background value.

Table 3: Environmental compartments concentrations and Individual cancer risk probability(11)

| Measured Parameter | MSW Thermal Treatment plant |
|---|---|
| Emission rate at stack level ($ng_{teq}\ Nm^{-3}$) | $9x10^{-3}$ |
| Ground level air concentration (pg $Nm^{-3}$) | $3.8x10^{-5}$ |
| Maximum deposition Flux (mg $m^{-2}$ $yr^{-1}$) | $1.3x10^{-8}$ |
| Maximum soil concentration (mg $kg^{-1}$) | $1.1x10^{-8}$ |
| Risk through inhalation | $1.2x10^{-11}$ (15.9%) |
| Risk though soil ingestion | $2.5x10^{-12}$ (3.4%) |
| Risk through dermal contact | $1.9x10^{-12}$ (2.6%) |
| Risk through food ingestion | $5.9x10^{-11}$ (78.1%) |
| Maximum individual health risk | $1.8x10^{-9}$ |

Now assume the MSWI is replaced by the RDF combustion facility presented above. The dioxin emitted by the RDF is higher than the MSWI at stack height by a factor of three (48 $pg_{teq}\ kg_{msw}^{-1}$ and 150 $pg_{teq}\ kg_{msw}^{-1}$ for MSWI and RDF combustion, respectively). This relatively high dioxin amount from RDF combustion facility is caused by the fact that SCR is not adopted to clean the off-gas. The emissions from the RDF combustion need to be controlled as done in MSWIs. The deposition flux and soil concentrations follow the same trend as the ground level air concentration with RDF yielding higher concentration compared to MSWI. The dioxin concentration and the deposition flux at ground level are thus expected to be higher than the MSWI with the factor of three.

The daily exposure levels obtainable in this study are relatively lower than the proposed WHO 1-4 pg $kg^{-1}$ $day^{-1}$ limit. This does not mean that care should not be taken in combustion facilities. The higher contribution of food ingestion, Table 3, to dioxin exposure has been confirmed by other researchers who found as high as 90% contribution(4). Looking at the higher RDF emission rate care should be taken to correctly treat the off-gas. A typical fault could be be the construction of a RDF combustion plant with a low stack height and without SCR.

In the RDF option, the contribution of dioxin emissions related to the pre-treatment plant should also be considered. Emissions from MSW biological pre-treatments reported in the literature ranges from 0-7 $pg_{Teq}$ $m^{-3}$ which disagrees with the negligible emission factor often assumed(10). Suppose a MSW biological treatment plant has an average emission value of 2 $pg_{Teq}$ $m^{-3}$ and a specific process air flow-rate of 3 $m^3$ $kg_{MSW}^{-1}$. The resulting emission factor will be 6 pg I-TEQ $kg_{MSW}^{-1}$. This is lower than MSWI but considering the height of release, often about 10m from ground level, it could have a significant role in contributing to the local dioxin concentration because of the lower dilution factor available. In short, the health risk from the RDF option could be higher than that of a modern MSWI. In order to avoid this contradiction, it is important to improve the dioxin removal from biological mechanical pre-treatment and/or fractionate the pre-treatment activities in many smaller plants.

## Conclusions

The results obtained in this study confirm two things: Firstly, the recent 0.1ngTEQ $m^{-3}$ limit will yield lower air concentrations at ground level and secondly, the RDF combustion facilities are to be treated and regulated with the same criteria used for modern MSWIs in order to minimize health risk in waste-to-energy plants. A SCR should be adopted also for RDF combustion plants. On the contrary, the common opinion that RDF combustion is always better than MSW combustion resulted in the negligence for the need to treat off-gas with SCR. Finally, the possible additional emission of dioxin from biological mechanical pre-treatment plants in the case of the RDF option must be considered carefully as the local impact on human health could be worsen.

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