PCDD/F EMISSIONS FROM MUNICIPAL SOLID WASTE AND RDF COMBUSTION FACILITIES: A COMPARISON

Marco Ragazzi, Nonjabulo Sibisi

University of Trento, Department of Civil and Environmental Engineering, Via Messiano 77, Trento 38100, Italy
e-mail: nonjabulo.sibisi@ing.unitn.it

Introduction

Thermal treatment involves the oxidation of waste at high temperature with the aim of producing inerts, reducing the waste volume and recovering energy. Thermal treatment is one of the waste management strategies proposed by the European Union in the community waste management strategy(1) which aims to establish an integrated waste management policy. This community waste management strategy addresses the integration of waste management technologies into a strategy for sustainable development, where the prevention of waste generation, re-use and recycling, energy recovery are given top places in the hierarchy. Thermal treatment aids in recovering energy from waste with about 10 million MWh recovered in 2000 only in Germany(2). However, emissions of toxic carcinogenic compounds, such as polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), discredit this waste management system. In UK about 14-38 g I-TEQ yr^{-1} is released to land from new MSW incineration plants(3). Waste thermal treatment with energy recovery includes processes such as incineration, gasification and pyrolysis. The plants in operation today in Europe are mainly incinerators.

The main objective of this paper is to compare the polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) emission from two waste management options. The first one is the mass burning of waste in a modern municipal solid waste incinerator (MSWI). The second option is the thermal treatment of refused derived fuel (RDF) in a facility designed for only this input. The RDF studied here is derived from mechanical pre-treatment which involves sorting, sieving and removal of inerts and putrescibles.

Materials and Methods

The RDF combustion facility chosen for this study receives about 120 000 t yr^{-1} of residual waste (a source separation is present in the region). About 36% of the initial mass ends up on the RDF combustion stream and the residual 64% is sent to the 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 fluidised bed furnace and has a chimney height of 60 meters. In 2001 it produced about 24 000 MWh. The configuration of the treatment line bases the removal of dioxin on good combustion conditions, inhibition of formation with a Selective Non Catalytic Reduction (SNCR) system, high efficiency filtration with a bag filter (with preliminary addition of lime and activated carbon), final wet scrubber. The purified gas is released to the atmosphere through the chimney at 115 °C.

The MSWI treats about 250 t d^{-1} supplied from a community which has source separation in place. Considering the generated waste, a significant percentage of paper, glass, biodegradable fraction and hazardous waste does not reach the incineration plant. The plant operates with a grate furnace and a chimney height of 60 meters. The configuration of the treatment line bases the removal of dioxin on good combustion conditions, high efficiency filtration with a bag filter, wet scrubber and Selective Catalytic Reduction (SCR).

The PCDD/F analysis in flues gas, slag and fly ash were performed following the CEN (1996)[(4)] method. For the MSWI working at the maximum load, PCDD/Fs concentrations were performed in the flue gas, fly ash and slag. For the RDF plant, five samples of flue gas were taken under maximum waste loading conditions and were taken at different times of the year. In order to comlete the RDF mass balance an assumption that the concentration in fly ash and slag is the same as that of the MSWI was made. This is due to the fact that there is no literature data available to the public to give an idea on the difference in slag and ash concentrations. The draw back of this is the uncertainty of the real dioxin balance in RDF plants.

Results and Discussions

The results obtained from the MSWI are given in Table 1. The dioxin emission to the atmosphere obtained in this study was 0.009 ng I-TEQ Nm^{-3} which is below the 0.1 ng I-TEQ Nm^{-3} proposed limit. This confirms the findings of a number of authors that dioxin emission from incinerators has significantly decreased compared to 15 years ago[(5)]. Potreous (2001) reported a 99% decrease in dioxin emitted to air in the UK between 1991 and 2000. In 1991 the amount of dioxin emitted to the air was about 225 ng I-TEQ Nm^{-3} and $6{\cdot}10^3$ ng I-TEQ Nm^{-3} found in 2000.

Table 1: PCDD/F emissionfactors and concentrations from the MSWI (ng_{teq} $kg_{\text{treated msw}}^{-1}$)

	Atmospheric emissions		Bottom Ash	Fly Ash	Slag (sludge)	Residuals Total
	Gasphase	Particulate				
Total PCDD	0.8	0.4	48	212	7.1	268
Total PCDF	2.4	0.1	69	211	3.9	286
PCDD/F I-TEQ	0.043 0.005		1.8	5.1	0.1	7

It can be noted from the table above that the highest concentration is on the fly ash and atmospheric emission contribution is significantly lower compared to the incinerator residues. Abad et al. (2000)[(6)] on their study of dioxin mass balance in incinerator also found higher dioxin concentration between 370-650 ng I-TEQ kg_{MSW}^{-1} on fly ash and between 13-60 ng I-TEQ kg_{MSW}^{-1} on slag compared to 0.004 ng I-TEQ Nm^{-3}.

The relatively lower dioxin concentration in the flue gas can be partly attributed to the fact that they use selective catalytic reduction (SCR). SCR has been proven to be a good technique for the removal and decrease of formation of dioxin in the afterburning zone of incinerator with over 93% removal efficiency[(7)]. The Austrian Federal Environment Agency confirmed the removal of PCDD/F in flue gas from MSWI with the use of the SCR[(8)]. They found that using a SCR can reduce dioxin emissions to levels between 0.00079-0.009 ng I-TEQ Nm^{-3}.

In summing up the balance and the cycle of PCDD/Fs within the incinerator the input, the dioxin concentration in the incoming waste, and the output, the dioxin emission on flue gas and the residues, should be balanced. In this study the incoming waste was not analyzed for PCDD/Fs concentration. However, if considering the waste concentration values between 6.3-250 ng I-TEQ kg_{MSW}^{-1} reported in the literature[6,9,10] and the output, Table 1, was 7 ng I-TEQ kg_{MSW}^{-1} from this study, one can conclude that that incinerator played a role of dioxin destruction not formation. There is a lot of discussion regarding the formation and destruction of dioxin during incineration and that will not be dealt with in this paper.

The average (five sampling periods) emission from the RDF treatment plant was 0.072 ng I-TEQ Nm^{-3} which is also lower than the 0.1 ng I-TEQ Nm^{-3} limit value, but higher than 0.03 ng I-TEQ Nm^{-3} found by Tagashira et al. (1999)[11]. They found PCDD/F emissions from RDF combustion between 0.01-0.03 ng I-TEQ Nm^{-3}. It can be noted that the concentration emitted by the RDF combustion is about eight times higher than that emitted by the MSWI. This significant difference in emission might be caused by the fact that in MSWI there is a SCR to treat the flue gas while in RDF combustion this is often said to be unnecessary. This highlights the fact that combustion facilities should be treated as same with the criteria applied to MSWI also applied to RDF combustion. Combustion plants either MSWI or RDF should seriously consider adopting SCR for flue gas cleaning if they want to minimize the risk from dioxin. The 0.072 ng I-TEQ Nm^{-3} concentration found in this study is relatively close to the limit and the risk of exceeding the limit exists (a maximum value of 0.095 ng I-TEQ Nm^{-3} was measured). The dioxin mass balance of RDF would be 0.15 ng kg_{MSW}^{-1} at the flue gas plus 7 ng kg_{MSW}^{-1} from the residuals. However, the weakness of this balance is that the concentration in residuals is not real and therefore the confrontation between the two waste combustion emissions is not fully feasible. It should also be brought to attention that the RDF combustion plant treats only 36% of the incoming solid waste while the MSWI treats almost 100% and the amount of off-gas generated is different. If we consider these aspects we can compare the emission factors from the MSW before any treatment. In the case of MSWI the specific off-gas generation was 5.4 Nm^3 kg_{MSW}^{-1} giving an emission factor of 48 pg I-TEQ kg_{msw}^{-1}. For the RDF combustor, considering a specific off-gas generation equal to 5.7 Nm^3 kg_{MSW}^{-1} and a ratio RDF/MSW equal to 0.36 the resulting emission factor is 150 pg I-TEQ kg_{msw}^{-1}. It is clear that the optimization of PCDD/F emissions is not dependent on the technology of combustion. On the contrary the minimization of the dioxin emissions depends strongly on the adoption of a SCR.

When dealing with RDF a comprehensive approach should consider also the PCDD/F emission factor from waste pre-treatment especially for bio-mechanical plants. Zeschmar (1997)[12] reported dioxin emissions from a bio-mechanical treatment (BMT) plant in Germany of about 0.007 ng_{teq} m^{-3} after air treatment. If this value was representative of this kind of pre-treatment, it could have an emission factor similar to the one of a small MSWI. In general the specific flow of process air in BMTs is in the range of 3 – 5 m^3 kg_{MSW}^{-1} giving an emission factor up to 35 pg I-TEQ kg_{msw}^{-1}. The literature on BMT dioxin emission lacks in details useful to understand if the release is in form of fine particulate or gas due to volatilization (a generation can be excluded, but a loss from the initial dioxin content in the treated MSW can explain the phenomenon). Moreover it is generally difficult to understand that the few values available depends on peak of release or can be considered as average values. Thus dioxin emissions from BMTs need to be intensively studied to look and confront the feasibility and health effects of different waste management studies. This is of relative importance because the concentration is emitted almost at ground level, depending on the plant type, thus excluding the possibility of higher dilution factor available for MSWI emissions which have elevated chimney. For this concern, the Austrian federal agency reported that in Austria there is a new guideline which requires careful treatment of the process gas. In order to understand the full dynamics for dioxin release processes the University of Trento has built a pilot MBT plant which will allow to assess the emission factor for the local MSW. It should also be brought forward that the emission factor is strongly depend on the characteristics of the treated waste. This study will give light to the complete dioxin balance for the RDF option.

Conclusions

The results from the study show that RDF combustion emits higher dioxin concentration compared to MSWI and this might be caused by the fact that SCR is not used in RDF thermal treatment facilities.

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