PCDD/PCDF FROM MUNICIPAL SOLID WASTE INCINERATORS IN ITALY: AN INVENTORY OF AIR EMISSIONS

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Introduction

Incineration of municipal solid waste (MSW) has for about 20 years been considered one of the most important sources of dioxin emissions and pollution. National inventories of polychlorinated dibenzo-*p*-dioxin (PCDD) and polychlorinated dibenzofuran (PCDF) air emissions generally show quite great values of PCDD/F emissions from MSW incineration during the Eighties and a progressive reduction during the Nineties until the first decade of the new century due to the implementation of more advanced air pollution control devices (APCDs).
The U.S. EPA (1997) reports that MSW incinerators are the main PCDD/F sources of PCDD/F with a national annual air emission of 730,4 gI-TEQ y^{-1} (about 37% of total annual emission). The German UBA (De Stefanis *et al.*, 1997) has estimated a contribution of about 33% (400 gI-TEQ y^{-1}) for the years 1989-90 with a reduction under 2 gI-TEQ y^{-1} (3% of national air emission) for the years 1999-2000. The British HMIP and DoE (Eduljee & Dyke, 1996) have estimated a 1995 national annual air emission of 460-580 gI-TEQ y^{-1} (about 53-82% of total annual emission), with a reduction for the future to 15 gI-TEQ y^{-1} (about 4-14% of total annual emission). The Dutch RIVM (Danish EPA, 1997) has estimated a contribution of about 79% (382 gI-TEQ y^{-1}) for the year 1991 with a reduction to 2-4 gI-TEQ y^{-1} (3-7% of national air emission) for the year 2000. Finally, the Danish EPA (1997) has estimated a reduction of national annual air emission from MSW incinerators from 34 to 20 gI-TEQ y^{-1} during the period 1991-1995.
An Italian PCDD/F air emission inventory still lacks, but a careful evaluation of PCCD/F emission factors from seven MSW incinerators located in Regione Lombardia (Martines *et al.*, 1999), where 25% of total MSW incinerated is treated (see Table 1), allows to obtain a reasonable estimation of total annual air emission.

Materials and Methods

The annual quantity of PCDD/F released to the atmosphere (expressed as gI-TEQ y^{-1}) has been calculated multiplying an adequate air emission factor (expressed as μgI-TEQ $(tMSW)^{-1}$) by the weight of MSW annually incinerated (expressed as 10^6 tMSW y^{-1}) obtained from ANPA (1999), Beone *et al.* (1998), Morselli (1999) and Motawi (1998). Different emission factors (EFs) for MSW incineration in function of the combustion and APCDs technologies are summarised below (EFs 1, 2 and 5 from Martines *et al.*, 1999; EFs 3 and 4 from U.S. EPA, 1997):

Table 1 - PCDD/F emissions in 1997 from MSW incinerators.

Facility	Combustor (APCDs)	MSW 1997 [tMSW y^{-1}]	EFs [µg t^{-1}]	Emissions [mgI-TEQ y^{-1}]
1. Mergozzo (VB)	MG (SD+CI+FF+WS)	29,244	0.66	19
2. Vercelli	MG (ESP+WS)	41,131	6.80	280
3. Abbiategrasso (MI)	RK (ESP+WS)	12,240	19.90	244
4. Bergamo	MG (ESP+WS)	46,500	6.80	316
5. Busto Arsizio (VA)	MG (DSI+FF)	31,000	1.60	50
6. Como	MG (ESP+WS)	39,560	6.80	269
7. Cremona	MG (SNCR+SD+CI+FF+WS)	3,000	0.59	2
8. Desio (MI)	MG (ESP+WS)	64,678	6.80	440
9. Milano 1	MG (ESP+WS)	86,261	6.80	587
10. Milano 2	MG (ESP+WS)	77,952	6.80	530
11. Valmadrera (LC)	MG (ESP+WS)	77,650	6.80	528
12. Bolzano	MG (FF+WS+SCR)	58,000	0.59	34
13. Padova	MG (DSI+ESP+WS)	34,258	6.80	233
14. Schio (VI)	MG (ESP+WS)	37,000	6.80	252
15. Gorizia	RK (DSI+ESP)	12,400	19.90	247
16. Moraro (GO)	RK (DSI+ESP)	12,400	19.90	247
17. Trieste	RK (ESP+WS)	110,000	19.90	2,189
18. Coriano (RN)	MG (ESP+DSI+CI+FF)	99,200	0.59	59
19. Ferrara 1	MG (ESP+WS)	10,229	6.80	70
20. Ferrara 2	MG (SD+FF+WS)	37,308	0.66	25
21. Forlì	MG (ESP+WS)	52,589	6.80	358
22. Granarolo E. (BO)	MG (ESP+WS)	139,209	6.80	947
23. Modena	MG (ESP+WS)	120,000	6.80	816
24. Parma	RK (ESP+WS)	62,000	19.90	1,234
25. Reggio Emilia	MG (ESP+DSI+CI+FF)	45,496	0.59	27
26. Castelnuovo (LU)	MG (DSI+CI+FF)	9,600	0.59	6
27. Greve in Ch. (FI)	RDF-CFB (SD+FF)	33,150	0.66	22
28. Livorno	MG (DSI+FF)	41,400	1.60	66
29. Massa Maritt. (GR)	MG (DSI+FF)	15,500	1.60	25
30. Montale (PT)	RK (ESP+WS)	27,900	19.90	555
31. Pisa	MG (ESP+WS)	63,583	6.80	432
32. Poggibonsi (SI)	MG (DSI+CI+FF)	21,000	0.59	12
33. Pontassieve (FI)	MG (SD+FF)	9,920	0.66	7
34. Tolentino P. (MC)	MG (ESP+WS)	24,800	6.80	169
35. Rende (CS)	MG (ESP+WS)	20,150	6.80	137
36. Messina (ME)	MG (DSI+FF)	18,450	1.60	30
37. Capoterra (CA)	MG (SD+FF)	91,200	0.66	60
38. Macomer (NU)	FB (SD+FF)	43,500	0.66	29
TOTAL		1,759,458		11,548

1. 19.90 μgI-TEQ $(tMSW)^{-1}$ for rotary kiln (RK) incinerators independently from APCDs used (all based on elecrostatic precipitators);
2. 6.80 μgI-TEQ $(tMSW)^{-1}$ for moving grate (MG) incinerators equipped with APCDs mainly based on electrostatic precipitators (ESPs) and wet scrubbers (WSs);
3. 1.60 μgI-TEQ $(tMSW)^{-1}$ for moving grate incinerators equipped with APCDs based on dry sorbent injection (DSI) systems and fabric filters (FFs);
4. 0.66 μgI-TEQ $(tMSW)^{-1}$ for moving grate, circulating fluidised bed (CFB) and fluidised bed (FB) incinerators equipped with APCDs mainly based on spray dryers (SDs) and fabric filters;
5. 0,59 μgI-TEQ $(tMSW)^{-1}$ for moving grate (MG) incinerators able to comply with the strict European air emission standard of 0,1 ngI-TEQ Nm^{-3}, generally equipped with APCDs mainly based on spray dryers (SDs) or dry sorbent injection (DSI) systems combined with activated carbon injection (CI) systems and fabric filters (FFs), eventually with selective non catalytic reduction (SNCR) systems or based on fabric filters (FFs), wet scrubbers (WSs) and selective catalytic reduction (SCR) systems.

Results and Discussion

Italian inventory of PCDD/F air emissions has been calculated for three situation:

- "1997 scenario": is the reference year (see Table 1)
- "minimum" scenario: is the future scenario where MSW incineration of unsorted MSW, dry waste (no compostables) and RDF will increase from 7 to 30% (De Stefanis *et al.*, 1998);
- "maximum" scenario: is the future scenario where MSW incineration will increase from 7 to 47% (De Stefanis *et al.*, 1998).

Typical characteristics and combustion properties of unsorted MSW, dry waste and RDF are summarised in Table 2. Lower heating value (LHV), stoichiometric air requirement (SAR) and normalised flue gas factor (FGF) have been calculated using the same equations reported in Martines *et al.* (1999). Results (Table 3) show that, in the future, the use of more advanced combustion technologies and APCDs (able to comply with the European air emission standard of 0,1 ngI-TEQ Nm^{-3}) could reduce PCDD/F emissions also considering an increased consistency of incineration in integrated solid waste management.

Table 2 - Typical characteristics and combustion properties of unsorted MSW, dry waste and RDF.

Parameters		**Unsorted MSW**	**Dry waste**	**RDF**
Moisture content (W)	[%]	23.69	25.00	20.00
Inert matter (I)	[%]	23.16	12.50	12.20
C	[%]	28.09	36.81	41.90
H	[%]	3.72	4.81	5.83
O	[%]	21.18	20.69	20.00
S	[%]	0.16	0.19	0.07
LHV	[kcal $(kgMSW)^{-1}$]	2,258	3,289	4,054
	[kJ $(kgMSW)^{-1}$]	9,454	13,770	16,973
SAR	[Nm^3 $(kgMSW)^{-1}$]	2.81	3.91	4.66
FGF*	[Nm^3 $(kgMSW)^{-1}$]	5.85	8.03	9.49

* FGFs are corrected at the following conditions: dry gas, 273 K, 101.3 kPa, 11%O_2

Table 3 - Current and future scenarios of MSW incineration in Italy and corresponding PCDD/F annual emissions.

Parameters		**Unsorted MSW**	**Dry waste**	**RDF**	**TOTAL**
EF*	[μgI-TEQ $(tMSW)^{-1}$]	0.585	0.803	0.949	-
"1997" scenario	[%]	6.76	0.00	0.02	6.78
	[10^6 tMSW y^{-1}]	1,73	0.00	0.03	1.76
	[mgI-TEQ y^{-1}]	-	-	-	**11,548**
"Minimum" scenario	[%]	15.00	11.00	4.00	30.00
	[10^6 tMSW y^{-1}]	3.89	2.86	1.04	7.79
	[mgI-TEQ y^{-1}]	2,278	2,293	0,985	**5,556**
"Maximum" scenario	[%]	27.00	14.00	6.00	47.00
	[10^6 tMSW y^{-1}]	7.01	3.63	1.56	12.20
	[mgI-TEQ y^{-1}]	4,100	2,918	1,478	**8,496**

* EFs have been used only for "minimum" and "maximum" scenarios and take into account the compliance with the European air emission standard of 0,1 ngI-TEQ Nm^{-3}. Actual EFs could be lower, reflecting air emission concentrations well below 0,1 ngI-TEQ Nm^{-3} as experienced in new plants (e.g., Brescia incinerator, in operation since 1998)

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