THE ACTUAL IMPACT OF WASTE-TO-ENERGY PLANTS ON AIR QUALITY: CASE STUDY FOR THE DESIO PLANT

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This paper discusses on the local scale impact of the actual atmospheric emissions of criteria pollutants (PM10 and NOx) and toxic pollutants (cadmium (Cd) and dioxins and furans (PCDD/F)), from the Waste-To-Energy (WTE) plant located in the municipality of Desio (15 km North of Milan in the Lombardy region).

Waste incineration plants frequently face strong protests from local communities where they are situated because of the concern about possible adverse health effects due to their emissions of organic and inorganic toxic pollutants. Health risk assessment studies for WTE plants are usually performed with a very precautionary approach, based maximum waste throughput and concentration limits fixed by regulations for the pollutants in the stack gas. This approach leads to upper bound estimates for the impact on air quality (i.e.: maximum ambient air concentrations); in turn, these concentration levels, when used in dose-response functions for health assessment studies, lead to upper bound estimates of the health impacts. However, in spite of such a precautionary approach, health risk assessment studies indicate acceptable incremental risk for the population exposed to plant emissions to the atmosphere.

Risk perception in most of the public opinion is biased by a number of factors (Ren et al., 2015), essentially because both risk knowledge and awareness are still scarce; thus, proper communication of the real impact of WTE plants on air quality, and of the ensuing health risk, is required to reduce overpriced risk perception (Petts, 1992). Additionally, the comparison of the WTE plants impact on local air quality (i.e.: the contribution to ambient concentration levels of atmospheric pollutants) with the impact of "common" sources, like road traffic and domestic heating, that are not usually perceived as a threat for human health, can help putting in context and correctly understanding the actual role of these plants.

Focusing on the case study the WTE plant run by Brianza Energia Ambiente SpA in Desio, this work is intended to:

i) assess the impact of the plant on local air quality based on its real emission data; in fact, the actual pollutant concentrations in the stack gas are always well below the limit values, even up to orders of magnitude smaller for some pollutants.
ii) assess the impact of 2016 plant retrofit (when a Selective Catalytic Removal (SCR) unit for NO_X emission control was installed) on its emissions and on local air quality.
iii) compare the impact on air quality of the retrofitted plant emissions with the impact of ground-level road traffic emissions from the main roads (i.e.: national and highly-trafficked local roads) crossing the municipality of Desio.

CALPUFF air quality model was used to estimate the time series of 1-hr ground-level concentrations at the grid nodes of a 10 x 10 km^2 computational domain (100 m grid step) over Desio municipality for calendar year 2016. Raw data were then processed by the CALPOST module in order to obtain annual average concentrations and short-term values (daily averages/high percentiles) for graphical representation through maps showing isoconcentration contour lines.

Real emissions for the WTE plant were calculated based on data from the continuous emission monitoring system for stack gas temperature and speed, and for PM10 and NO2 concentrations; Cd and PCDD/F concentrations were taken from discontinuous sampling data. In order to evaluate the benefits of the 2016 plant retrofit, air quality model simulations separately considered two different scenarios: the former based on emission data for year 2015 (before retrofit), the latter based on 2017 data (after retrofit). Road traffic emissions from the main roads in Desio municipality were estimated based on the length of the road segments, traffic flow rates on any segment, and emission factors for each vehicle type. Traffic flow rates along the road segments have been evaluated through a dedicated study which assessed the hourly passages of three main classes of vehicles (cars, vans and trucks) on workday's rush-hour. Emission factors for road traffic were taken from the Air Emissions Inventory of Regione Lombardia (INEMAR - ARPA Lombardia, 2018) from the traffic emissions factors database in Italy (ISPRA, 2017), and from the EMEP/EEA air pollutant emission inventory guidebook 2016 (EMEP, 2016).

Summary statistics for the time series of the hourly mass flow rates of the pollutants considered in this work are reported in Table 1. In both 2015 and 2017 the maximum flow rates have been well below the emission limits for PCDD/F and Cd (two orders of magnitude less for PCDD/F and even more for Cd), five times below the emission limit in 2015 and two orders of magnitude less in 2017 for PM10, 58% of the authorized flow rate in 2015 and 68% in 2017 for NO_X. On the average, NO_X and PCDD/F flow rates were lower in 2017 than in 2015, Cd and PM10 flow rates were higher in 2017 than in 2015.

Table 1. Comparison between actual (Scenario 2015 and Scenario 2017) and authorized hourly flow rates of PM10, NO_X, Cd, PCDD/F from WTE plant

Parameter	PM10 (g h^{-1})		NOx (kg h^{-1})		Cd (mg h^{-1})		PCDD/F (ng_{TEQ} h^{-1})	
	2015	2017	2015	2017	2015	2017	2015	2017
Average	15.5	20.9	7.38	4.00	11.4	22.2	69.1	39.9
Median	10.8	21.6	7.38	4.00	11.6	23.3	64.8	40.7
Minimum	0.4	1.4	0.07	0.22	0.6	4.5	3.2	1.8
Maximum	205.6	72.7	12.82	14.54	15.4	29.4	202.7	110.2
Max Authorized	1,100		22		5,500		11,000	

Additionally, the comparison between 2015 and 2017 stack data points out that the retrofit of the plant resulted in both higher flue gas temperature (162 °C vs. 144 °C) and speed (11.4 m s^{-1} vs. 9.4 m s^{-1}) in 2017 than in 2015, thus leading to better plume rise conditions and pollutants dispersion.

Hourly average emissions from traffic along the main roads crossing the municipality of Desio were estimated as 32.3 kg h^{-1} for NO_X, 2.6 kg h^{-1} for PM10, 40 mg h^{-1} for Cd, and 600 ng_{TEQ} h^{-1} for PCDD/F. Thus, road traffic and WTE plant emissions were comparable only for Cd; conversely, road traffic emissions largely exceeded those from the WTE plant for the other three pollutants. These estimated emissions provided an underestimation of the total emission from road traffic in Desio because the emissions from minor roads and from the urban road network were not considered in this work. Actually, the comparison between the traffic emissions used for this study and the emission inventory data for road traffic in the municipality of Desio in 2014 showed a 30% emission underestimation for this study.

Contour plots for the contribution of WTE plant and road traffic emissions to NO_2 annual average concentration are reported in Figure 1 and 2, respectively. In agreement with the local wind field, WTE plant emissions did affect the residential area of Desio. Traffic emissions impact was higher in correspondence with the main roads, with strong concentration gradients locally; however, the impact of road traffic emissions affected the whole urban area of Desio. Coherently with the higher emission rate and the close-to-ground emission location, road traffic resulted in a stronger impact on air quality in Desio, not only for PM10 and NO_X but also for toxic pollutants (Table 2). Actually, the impact of road traffic in the residential area of Desio was from two to four orders of magnitude higher than the WTE plant impact: namely, the estimated contribution from road traffic was three orders of magnitude higher for PCDD/F and two orders of magnitude higher for Cd.

Table 2. Annual average concentration range within the residential area of Desio and air quality limits for PM10, NO_2, Cd (Italian D.Lgs. n. 155/2010) and PCDD/F (German guidelines on air quality: LAI-Laenderausschuss fur Immissiosschutz).

Parameter	PM10 (µg m^{-3})	NO_2 (µg m^{-3})	Cd (ng m^{-3})	PCDD/F (fg_{TEQ} m^{-3})
WTE plant (before retrofit)	$3\text{-}4.5\cdot10^{-4}$	0.12-0.18	$2\text{-}3\cdot10^{-4}$	$1.2\text{-}1.8\cdot10^{-3}$
WTE plant (after retrofit)	$2\text{-}3.5\cdot10^{-4}$	0.05-0.07	$3\text{-}4\cdot10^{-4}$	$5\text{-}7\cdot10^{-4}$
Road Traffic	2-3	6-10	0.02-0.03	0.5-1
Air quality limits (annual average value)	40	40	1	150

These results gave that WTE plant emissions have a very low impact on local air quality, both for the main pollutants, like PM10 and NO_2, and for organic micro contaminants and inorganic persistent toxic pollutants, like dioxins and Cadmium.

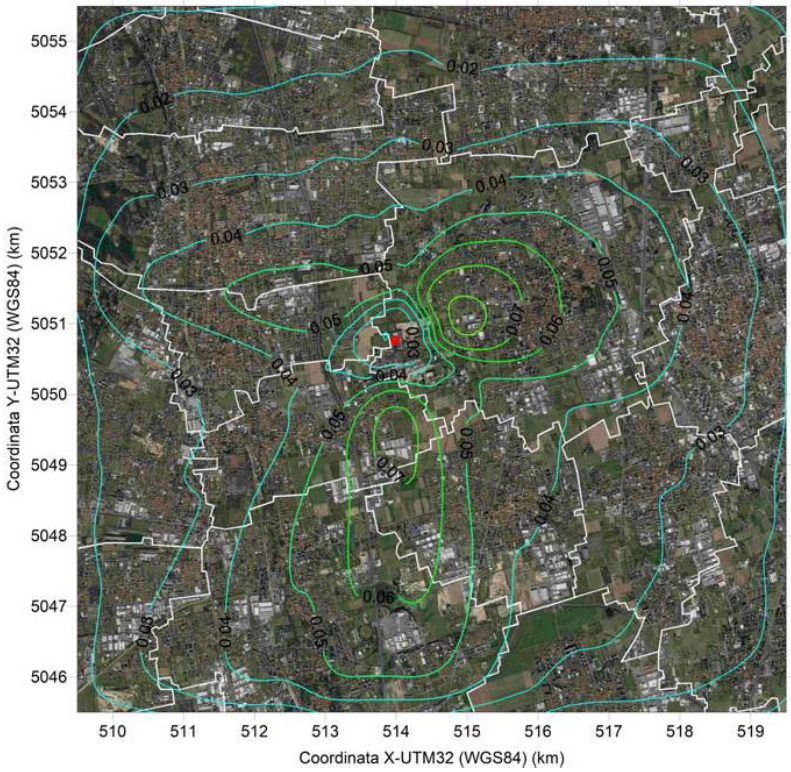

Figure 1 - Contribution of WTE plant emissions (after retrofit) to NO_2 annual average concentration (µg m^{-3})

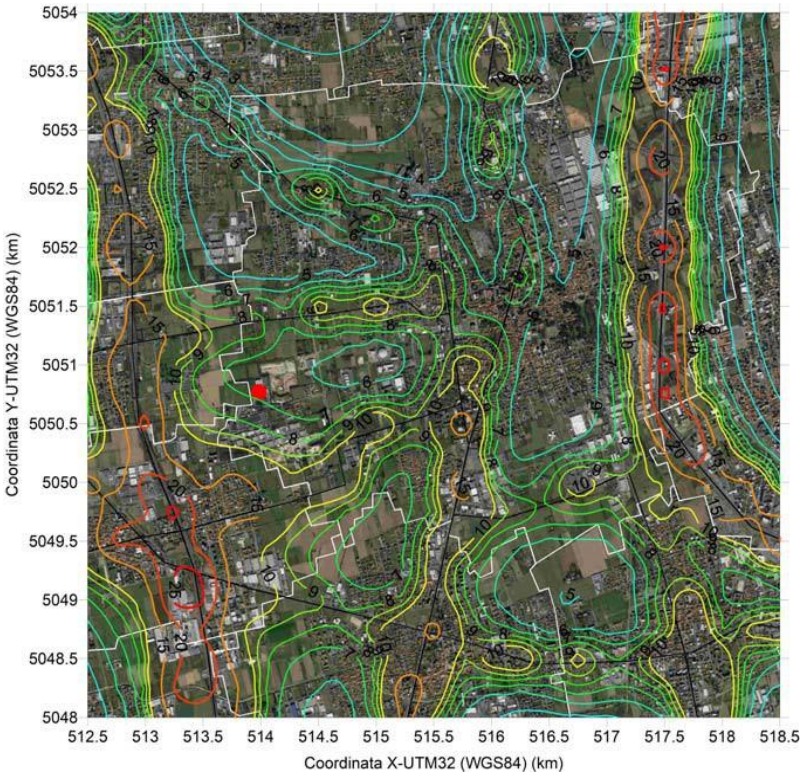

Figure 2 - Contribution of traffic emissions to NO_2 annual average concentration (µg m^{-3})

The very low impact of the WTE emissions is furtherly highlighted by the comparison with the estimated the impact of the traffic in the same area: actually, as an average, the contribution of traffic in the residential area of Desio has been from two to four orders of magnitude higher than the WTE plant impact, both for criteria and toxic pollutants. However, the role of traffic is likely underestimated, especially in Desio city centre, because this study has considered only the traffic along the main roads, neglecting the contribution of the low speed-high emission factor, stop-and-go traffic coming from the minor streets network.

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