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THE ACTUAL CONTRIBUTION OF WTE PLANTS EMISSIONS TO AIR QUALITY: A CASE STUDY FROM NORTHERN ITALY

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ABSTRACT: In the last decades there has been a lot of debate about the impact of WTE plants emissions on air quality, and therefore on public health. Emissions inventories data are currently available, showing the negligible impact of waste incineration on air quality, but they refer to large areas. A number of impact assessment studies are currently available too. Few of them are site specific, but none of them makes a direct comparison between the impact of the emissions coming from the WTE plant and the emissions coming from other sources (e.g. traffic) on that specific site. In this paper, the contribution to air quality from the Desio WTE plant has been investigated. A site specific approach has been carried out. The dispersion of the main air pollutants measured from the stack of the plant has been mapped making use of CALPUFF model. With the same model, the diffusion of the same pollutants emitted by the traffic in the main roads around the plant has been mapped. The actual contribution of the plant to the air quality in the area around the plant has thus been quantified, being three (NO_X) to four (PM_{10} and dioxins) orders of magnitude less than the contribution coming from the traffic.

Keywords: WTE emissions, traffic emissions, air quality, impact assessment

1. INTRODUCTION

In spite of the stricter and stricter emission limits set by regulations on atmospheric emissions from waste incineration plant and of the technological improvements in flue gas treatment (Passarini et al., 2014), there is still considerable concern in the public opinion about possible adverse health effects associated with waste incineration. Significant positive relationships with broad groups of congenital anomalies in populations living near waste incinerators have been reported in some epidemiological studies, but results from these studies remain inconclusive due to limitations on exposure assessment, possible confounding risk factors and lack of statistical power (Ashworth et al., 2014).

Waste incinerators and state-of-the-art Waste to Energy (WTE) facilities frequently face strong protests from local communities where they are situated and the location of new plants is an ongoing concern. Health risk assessment studies for new plants, usually based on both maximum plant throughput and stack concentrations (i.e. estimating upper bound impact on air quality), indicate acceptable incremental risk. Nevertheless, risk perception in most of the public opinion is biased by a number of factors (Ren et al., 2015), because proper environmental education (i.e.: levels of risk awareness and knowledge) is still scarce. Risk communication and public involvement are ways to reduce overpriced risk perception (Petts, 1992). Finally, studies comparing the impact on local air quality due to emissions from WTE plants and other common sources (e.g.: road traffic, domestic heating through biomass burning) are rare and limited to emission inventory data comparison, thus neglecting the features of flue gas release into the atmosphere.

Considering as case study the WTE plant run by Brianza Energia Ambiente SpA (BEA SpA) in Desio (Northern Italy – Lombardia Region), this work focuses on the following three issues:

- assess the actual impact of the plant on local air quality based on its real emission data, in order to have a deeper understanding of the plant impact also for communication purpose;
- assess the impact on plant's emissions and air quality impact of the latest retrofit in 2016, which involved a 40% increase in the incineration capacity, the installation of a new steam turbine, and the repowering of the flue gas treatment system with a new SCR (Selective Catalytic Removal) unit for NOx. In order to evaluate the benefits of the 2016 retrofit, emission data for year 2015 (before) and 2017 (after retrofit) have been compared and used for air quality model simulations;
- compare the impact on air quality of the plant's stack 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. Traffic emissions from minor roads and from the urban road network have not been considered in this work.

The whole study has considered two criteria pollutants, PM_{10} and NO_X, whose concentrations are particularly high in Northern Italy, and two toxic pollutants, Cadmium (Cd) and dioxins and furans (PCDD/F), typically emitted by waste incineration plants.

2. MATERIALS AND METHODS

2.1 Air quality model

The study has been carried out by means of the CALPUFF model, a tri-dimensional air quality model particularly suitable in complex meteorological conditions with slow winds and calms, which frequently occur in the Po valley area. CALPUFF calculates the time series of 1-hr ground-level concentrations at each grid node of the computational domain. Raw data are then processed by the CALPOST module in order to obtain summary statistical data (e.g.: average annual concentration, hourly maximum/daily average/percentiles values) for graphical representation through isoconcentration maps. The computational domain was a 10 x 10 km^2 square grid around the WTE plant with 100 m grid step, leading to a total of 10,201 grid points.

Meteorological data have been supplied by the Regional Environmental Protection Agency (ARPA) and from LAMA database (Limited Area Meteorological Analysis), which has been generated using COSMO meteorological model and GTS data. COSMO is the Italian model for short term weather forecasts. In order to make the comparison easier, same meteorological data (year 2016 data) has been used for both 2015 and 2017 cases.

2.2 Emission data

2.2.1 WTE plant

Hourly values for flue gas temperature and speed, dust (considered as PM_{10}) and NO_X (as NO_2) concentrations were taken from the continuous monitoring system (SME) data of the WTE plant. Cd and PCDD/F concentrations from discontinuous sampling data: for Cd the maximum concentration among the three analyses available per year was used (0.000193 mg m^{-3} in 2015 and 0.000323 mg m^{-3} in 2017); for PCDD/F the sets of monthly data available per year were used.

The comparison between 2015 and 2017 emissions data points out that the revamping 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, leading to better plume rise conditions and pollutants dispersion.

In both years (2015 and 2017) pollutant concentrations and mass low rates were always lower than regulatory limits and authorized flow rates (Table 1). PCDD/F and Cd maximum flow rates have been well below the emission limits (two orders of magnitude less for PCDD/F and even more for Cd), five times below the emission limits in 2015 and two orders of magnitude less in 2017 for PM_{10}, 58% of the authorized flow rate in 2015 and 68% in 2017 for NO_X. However, as NOx and PCDD/F average flow rates were lower in 2017 than in 2015, Cd and PM_{10} flow rates were higher in 2017 than in 2015.

Table 1. Comparison between actual and authorized pollutant flow rates 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	

2.2.2 Road traffic

Hourly emissions from traffic on the main roads around the plant was estimated based on the length of the road segments, traffic volumes 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 were taken from the Air Emissions Inventory of Regione Lombardia (INEMAR - ARPA Lombardia 2018) form the traffic emissions factors database in Italy, and from the EMEP/EEA air pollutant emission inventory guidebook 2016.

The estimated daily emission pattern has been applied for the whole year, without any seasonal or weekly variation. Though this approach could lead to an overestimation of the contribution coming from the traffic on main roads, it partially compensates the emissions from the minor roads and local streets not considered in the calculations. 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 shows a 30% emission underestimation for the study.

3. RESULTS AND DISCUSSION

3.1 WTE plant contribution

Isoconcentration maps for the estimated contribution of WTE plant emission to NO_2 annual average concentrations are presented in Figure 3.1 for year 2015 and 2017. Spatial distribution of the concentration levels is similar for all the pollutants in the two years, because the input meteorological data were the same. Actually, differences in the concentration levels are due to emissions regime only.

The distribution pattern shows three lobes, extending North-West, North-East and South of the plant, according to the most frequent wind directions in the area. The highest impact area (i.e.: where the maximum contribution is estimated) concentration is located at about 1 km East-North, on the outskirts of the urbanized area of Desio; however, the plant's emissions also affect the air quality in the centre of the town. Table 2 summarises the values at maximum fallout point and annual average concentration of pollutants at ground level within the residential area of Desio before (2015) and after (2017) WTE plant retrofit. Comparison with air quality regulatory limits is also shown. Plant emission results to have a very limited impact on air quality, both before and after retrofit. After retrofit the plant contribution accounts for 0.001% of PM_{10} acceptance limit, for 0.2% of NO_2, for 0.05% of Cd and for 0.0005% of PCDD/F acceptance limit of German regulation. The impact of the WTE plant emission is also negligible as far as regulatory short-term concentrations for PM_{10} and NO_2 are concerned.

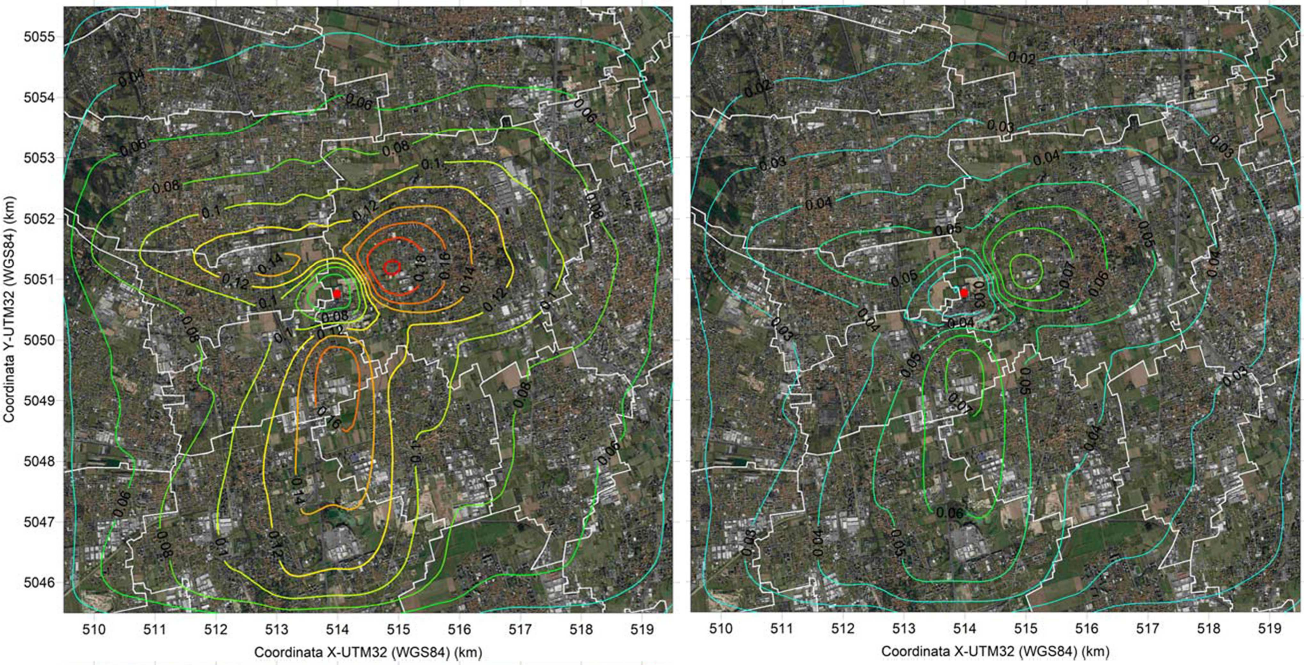

Figure 1. Contribution of WTE plant emissions to NO_2 annual average concentration (μg m^{-3}): before (2015, left) and after (2017, right) plant retrofit.

Table 2. Annual average concentration at the maximum fallout point, 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).

Year	Parameter	PM10 (μg m^{-3})	NO_2 (μg m^{-3})	Cd (ng m^{-3})	PCDD/F (fg_{TEQ} m^{-3})
2015	Maximum value	$5.2 \cdot 10^{-4}$	0.20	$3.3 \cdot 10^{-4}$	$2.3 \cdot 10^{-3}$
2015	Desio residential area (range)	$3\text{-}4.5 \cdot 10^{-4}$	0.12-0.18	$2\text{-}3 \cdot 10^{-4}$	$1.2\text{-}1.8 \cdot 10^{-3}$
2017	Maximum value	$4.4 \cdot 10^{-4}$	0.08	$4.8 \cdot 10^{-4}$	$8.1 \cdot 10^{-4}$
2017	Desio residential area (range)	$2\text{-}3.5 \cdot 10^{-4}$	0.05-0.07	$3\text{-}4 \cdot 10^{-4}$	$5\text{-}7 \cdot 10^{-4}$
Air quality limits (annual average value)		40	40	1	150

3.2 Traffic contribution

Isoconcentration map for the estimated contribution of road traffic to NO_2 annual average concentration is presented in Figure 2. Because traffic has been modelled considering the main roads only and due to its ground-level emission, the resulting spatial distribution is a less regular pattern than the one obtained for the WTE plant and essentially driven by the layout of the considered road network. Maximum pollutant concentrations occur in the proximity of the road axes and sharply decrease as we move away. In particular, the impact of emission from the national roads n. 35 and 36 are clearly visible with their N-S alignment on the left and the right side of the map, bordering the Municipality of Desio.

Highest annual average values are about 5-6 µg m^{-3} for PM_{10}, 15-20 µg m^{-3} for NO_2, 0.08-0.1 ng m^{-3} for Cd and 2-3 fg_{TEQ} m^{-3} for the PCDD/F. For the residential area of Desio, far from the main roads, model results show pollutant concentrations ranging between 2-3 µg m^{-3} for PM_{10}, 6-10 µg m^{-3} for NO_2, 0.02-0.03 ng m^{-3} for Cd, and between 0.5-1 fg_{TEQ} m^{-3} for PCDD/F (Table 3). Highest short-term concentrations are in the 3-6 µg m^{-3} for 24-hr PM_{10} and in the 100-150 µg m^{-3} for 1-hr NO_2, roughly about 10% and 50-70% of the corresponding air quality limits (50 µg m^{-3} for PM_{10}, 200 µg m^{-3} for NO_2).

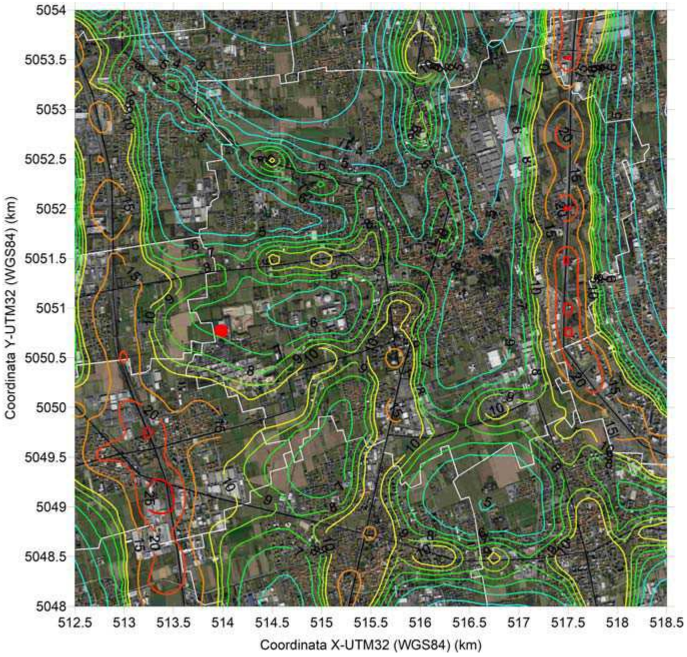

Figure 2. Contribution of road traffic emissions to NO_2 annual average concentration (µg m^{-3}).

3.3 Comparison between source contributions

The comparison between the estimated annual average concentrations due to the emissions of WTE plant and of the traffic in the main roads crossing Desio municipality shows the much higher role of traffic on local scale air pollution. This is true both for the contribution estimated at the point of maximum fallout and within the residential area of Desio. The contribution from the traffic on any of the investigated pollutants is at least two orders of magnitude higher than the contribution coming from the WTE plant in the residential area of Desio (Table 3). PM_{10} emissions from traffic are four orders of magnitude higher (10,000 times) than the emissions from Desio WTE, PCDD/Fs are three orders of magnitude (1,000 times) higher and NO_2 and Cd are two orders of magnitude higher (100 times) than the emissions coming from the plant. Even in case of short term concentrations, the impact of traffic is far higher than the impact of the WTE plant in the residential area of Desio: the contribution for PM_{10} and NO_2 emissions from traffic are about 1,000 times and 40-50 times higher than from the WTE plant, respectively. Similar considerations hold for the point where the maximum fallout due the WTE plant is expected, even though located rather far from the main roads and thus less affected by traffic emissions.

Table 3. Range of estimated contributions from WTE plant and road traffic emissions to the annual average concentrations of PM10, NO_2, Cd, PCDD/F in the residential area of Desio.

Source	**PM10 ($\mu g\ m^{-3}$)**	**NO_2 ($\mu g\ m^{-3}$)**	**Cd ($ng\ m^{-3}$)**	**PCDD/F ($fg_{TEQ}\ m^{-3}$)**
WTE plant (2017 data)	0.0002-0.00035	0.05-0.07	0.0003-0.0004	0.0005-0.0007
Traffic	2-3	6-10	0.02-0.03	0.5-1

4. CONCLUSIONS

Model results gave evidence of the positive effects of the flue gas treatment retrofitting of the Desio WTE plant on NO_X and PCDD/F, whose emissions have been halved. Additionally, the higher temperature and velocity of the effluents after retrofit have increased pollutants dispersion, reducing the average annual pollutant concentrations by 60%. Thus, in spite of the increased incineration capacity, the impact on air quality is decreased. Generally speaking, WTE plant emissions have a very low impact on local air quality, both in terms of annual and hourly averaged concentrations and for the main pollutants like PM_{10} and NO_2 and for organic micro contaminants and inorganic persistent toxic pollutants like dioxins and Cadmium.

The very low impact of the WTE emissions is highlighted by the comparison with the estimated the impact of the traffic in the same area, likely underestimated because the study has considered main roads only, neglecting the diffused, low speed-high emission factor, stop-and-go traffic coming from the minor streets network. 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. Considering average annual values, the contribution from traffic is four orders of magnitude higher than the WTE plant for PM_{10}, three orders of magnitude higher for dioxins, and two orders of magnitude higher for NO_2 and Cadmium. The impact of traffic is even higher when short-term concentration values for PM_{10} and for NO_2 are considered.

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