ASSESSMENT OF HEALTH IMPACTS FROM THE INCINERATION OF MUNICIPAL SOLID WASTE IN THESSALONIKI, GREECE

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ABSTRACT

Sustainable environmental management has become an issue of critical concern over the past decades. Due to the population growth and changing consuming habits and patterns of communities in developed countries, solid waste represents nowadays a significant pressure on the environment. Besides cement production, Municipal Solid Waste (MSW) correspond to the largest volume that is produced worldwide. At the same time, citizens' demand for environmentally sound management of MSW has significantly increased during the last years. Having realized at an international level that one single waste management option cannot provide a universal solution for all different kinds of waste generated and populations with different customs and habits, a concatenation of different processes and technologies is beginning to take shape to manage waste. In this light, efforts internationally are focalized towards the emerging concept of integrated waste management, taking into account the following alternatives' order of priority; (i) prevention of waste production, (ii) reuse of products and/or materials, (iii) recycling of materials, (iv) energy recovery in Waste-To-Energy (WtE) plants and (v) environmentally sound disposal in sanitary landfills.

Due to economic and efficiency rates of alternative MSW management strategies, WtE is considered in most cases to be the only “competitor” to disposal MSW in landfills. However, public health and safety issues represent the main concerns of local communities against the development of WtE facilities. The aim of this work is to assess the health impacts attributed to air pollution from mass burning of MSW in Thessaloniki, Greece. Up to now, landfilling is exclusively adopted for waste management in the Greater Thessaloniki Area. However an integrated waste management scheme is examined. In this framework, a facility mass burning plant is under consideration as a future perspective in hypothetical scenarios. The facility is planned to be developed in the suburban area of the city of Thessaloniki.

In the work herein presented, three different alternative locations are considered. The concentrations of the chemical stressors from the installation of the incinerator are estimated with the use of air quality modelling computational tools.

Keywords: Health impacts, air pollution, incineration, waste-to-energy, Years of Life Lost.

1. Introduction

Municipal Solid Waste (MSW) management is considered as one of the most critical issues towards urban sustainability. This is triggered by the fact that urban population constantly grows over the past decades, as well as due to consumers' lifestyles, habits and behavioral patterns that continually change globally. In many real life cases, Waste-to-Energy (WtE) is considered to be the main “competitor” –if not the only realistic alternative– of sanitary landfill, considering that emerging waste management technologies are not cost-effective and still relatively immature for commercial and industrial use (Porteous, 2005). According to relevant studies (e.g. Achillas *et al*., 2011; Kikuchi and Gerardo, 2009; Contreras *et al*., 2008), public health and safety are considered as the major concerns of local communities against the development of a WtE facility. Low social acceptance becomes even lower when such facilities are located close to densely populated areas. Nevertheless, WtE plants need to be located in a relatively short distance from domestic or industrial consumers so as to exploit also the co-generated heat from the thermal treatment and be economically viable.

There are many MSW management plans in Greece that were delayed or even abandoned, mainly due to local community opposition and the "Not In My Back Yard" (NIMBY) syndrome. Having this in mind, the main purpose of this study is to assess health impacts attributed to air pollution from a hypothetical operation of a MSW WtE plant that is planned to be developed in the outskirts of Thessaloniki, Greece (the second largest urban conurbation, population of more than 1 million). Considering that thermal treatment of MSW is under debate in Greece, the work herein presents the corresponding Health Impact Assessment (HIA) and external costs of air pollution attributed to mass burn incineration in the Greater Thessaloniki Area (GTA).

2. Materials and methods

2.1. Health Impact Assessment

The HIA to follow includes only selected health endpoints where quantification can be based on strong and direct evidence and where a broad consensus regarding evidence of reliable associations are available. This is an important aspect of the approach presented for asserting with confidence that air pollution causes damage at least as great as quantified. The most crucial step is the selection of the health endpoints under consideration, and in particular which Concentration – Response Functions (CRFs) are considered most reliable. Quantification of health impacts is followed by the monetary estimation of external costs. Health effects attributed to the aforementioned emissions are estimated on the basis of specific CRFs for the area under study: Years of Life Lost (YOLL) due to Chronic Mortality, Chronic Bronchitis (CB), Respiratory Hospital Admissions (RHA), Cardiovascular Hospital Admissions (CHA), Restricted Activity Days (RADs) and cases of cancers.

The unfavorable implications over the health endpoints after a scenario's adoption are estimated through the following equation:

$$HI_{i,s} = CRF_{i,s} \bullet LEVs \bullet Pop \quad (1)$$

where: (i) $CRF_{i,s}$: Correlation coefficient between the stressor's s levels (concentration variation in terms of chemical stressors) and the probability of experiencing or avoiding a specific health implication i (CRF's slope), (ii) LEVs: Stressor's s levels (μg/m^3) after the adoption of a WtE plant emissions scenario, (iii) Pop: Population exposed to stressor s (number of receptors).

2.2. Air quality modeling

For the quantification of the effects of WtE plants on the surrounding areas, average exposure fields were estimated under a number of emissions scenarios, using a numerical modeling approach. The analysis focuses mainly on particulate matter (PM_{10}), nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), heavy metals (Cd+Ti) and dioxins-furans. Annual averages were calculated using the Eulerian, three-dimensional chemical dispersion model MARS-aero (Moussiopoulos *et al*., 2012), which was driven by the non-hydrostatic mesoscale meteorological model MEMO (Moussiopoulos *et al*., 1993) in a doubly nested configuration. In order to efficiently obtain annual concentration averages, a weighting scheme was applied on the daily concentration fields based on a classification scheme for local meteorological patterns in relation to the prevailing synoptic situation (Sfetsos *et al*, 2005).

MEMO and MARS-aero models were applied for the year 2010 on a computational domain of 50×50 km^2. In the course of the dispersion calculations, the full chemistry of gaseous components as well as of primary and secondary PM_{10} was considered using the MARS-aero modules, while Cd and dioxins-furans were treated as chemically inert. The required high-resolution topographical input data were derived from the satellite elevation datasets of NASA's

Shuttle Radar Topography Mission (SRTM, van Zyl, 2001). For the study, thematic layers of land use data were obtained from the CORINE CLC dataset (EEA, 1995).

3. Case study

The scenarios under study are presented in Table 1 and the assumptions that are taken into consideration for the quantification of the emission rates are described in Table 2.

Table 1: Scenarios under study

Location	**Sindos**	Scenario 1 (S_1)	Scenario 2 (S_2)	Scenario 3 (S_3)
	Agios Antonios	Scenario 4 (S_4)	Scenario 5 (S_5)	Scenario 6 (S_6)
	Mavrorachi	Scenario 7 (S_7)	Scenario 8 (S_8)	Scenario 9 (S_9)

Emissions are highly dependent on parameters including -among others- the annual tonnage of the MSW to be processed, the composition of the MSW and the pollution abatement technologies that are installed in the WtE facility. Thus, for the calculation of the emissions resulting from a WtE facility in the present study, three relevant emission scenarios are considered for three alternative locations (Table 1). The first one (E_1) considers the emission factors from the operation of a modern WtE facility, namely the ASM Brescia S.p.A. in Brescia, Italy (E_1: S_1, S_4, S_7). Apart from data availability, this was also triggered by the incinerator's efficient performance in air pollution abatement, since it combines clean technologies such as electrostatic precipitators, fabric filters and wet scrubbers. The second (E_2: S_2, S_5, S_8) and the third (E_3: S_3, S_6, S_9) emission-factors related scenarios consider emission factors from the literature. More specifically, the emission rates considered refer to emissions of 142 active WtE plants that were operating in Europe in the early 2000's (FEAD, 2002). E_2 refers to average emission factors from this study, while E_3 refers to the worst-case WtE facility –i.e. the one with the highest emission factors– of the study. In this context, E_1 is the most favorable emission-factors' related scenario (and practically the most realistic one for a newly built, state-of-the-art WtE facility), while E_2 and E_3 are also considered as average and worse case scenarios, mainly for reasons of sensitivity analysis and also in order to be on the safe side and provide strong evidence on the facility's potential hazardousness to human health. More information on the assumptions adopted for the scenarios under consideration, the concentration and receptor fields, the values for the monetization of external costs can be analytically found elsewhere (Chatzibousios, 2013).

Table 2: Assumptions adopted for the 9 emission scenarios under consideration.

Parameter	Value	Comments
Total amount of MSW to be incinerated	180,000 t/a	Based on the local needs, as those are expressed by the Regional Agency for the Design of Waste Management
WtE facility's operational time	360 working days/year	The facility will be closed down only for scheduled maintenance works.
Emission factor	4,500 $m^3_{exhaust\ gas}$ per t of MSW	This figure is assumed as a mean value according to the proposed range between 3,500-5,500 $m^3_{exhaust\ gas}$ per t of MSW (Chatzibousios, 2013)
Waste gas stack height	50 m	
Reference year for the population data	2010	National Statistics Agency
Alternative locations for the WtE facility	Sindos	40^0 40' 36.47" North Latitude, 22^0 46' 56.48" East Longitude
	Agios Antonios	40^0 20' 25.17" North Latitude, 23^0 05' 03.65" East Longitude
	Mavrorachi	40^0 52' 59.18" North Latitude, 23^0 05' 53.21" East Longitude

4. Results and discussion

Negligible external cost is estimated for the three cases examined (scenarios S_1, S_4 and S_7), where emission factors considered refer to modern WtE infrastructures that are characterized by state-of-the-art air pollution control measures. Since WtE facilities that are planned to be built and operate in the future are expected to be developed with such abatement technologies due to the continually stricter legislative framework, the impact to the human health and the corresponding external cost is expected to be negligible. Regarding the results of the S_2, S_5 and S_8, it is clear that health impacts and hence the external costs generated per scenario are lower than the previously discussed scenarios of maximum permissible emissions S_3, S_6 and S_9. This is obviously due to the reduced emission rates, and hence lower concentrations in each case compared to the aforementioned scenarios.

Table 3: HIA and the corresponding externalities for the 9 scenarios under consideration.

Health effects	Stressor	Unit	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
YOLL	PM_{10}	YOLL	2.8	1.9	0.12	2.17	1.44	0.1	$4.23x10^{-3}$	$2.88x10^{-3}$	$1.82x10^{-4}$
		€	145,600	98,800	6,240	112,840	74,880	5,200	220	150	N
		€	214,620	146,020	9,242	162,680	110,740	7,007	326	223	
CB	PM_{10}	Cases	0.185	0.126	$8x10^{-3}$	0.14	0.096	$6x10^{-3}$	$2.8x10^{-4}$	$1.91x10^{-4}$	N
		€	35,150	23,940	1,520	26,600	18,240	1,140	53	36.3	
RHA	PM_{10}	Admissions	0.0913	0.062	$4x10^{-3}$	0.07	0.047	$3x10^{-3}$	$1.38x10^{-4}$	N	N
		€	183	124	8	140	94	N	N		
CHA	PM_{10}	Admissions	0.08	0.054	0.034	0.06	0.041	$2.6x10^{-3}$	$1.21x10^{-4}$	N	N
		€	307	208	131	231	158	N	N		
RADs	PM_{10}	Days	655.53	446.93	282.07	497.38	339.12	21.4	1	N	N
		€	54,410	39,095	23,412	41,283	28,147	1,776	83		
ACC	Cd+Ti	ACC	0.002	0.0018	$3.85x10^{-5}$	0.0014	0.00139	N	N	N	N
		€	4,000	3,600	77	2,800	2,780	59			
ACC	Dioxins	ACC	$13.6x10^{-5}$	$10.1x10^{-5}$	$9.026x10^{-7}$	$1.03x10^{-4}$	$7.65x10^{-5}$	N	N	N	N
		€	272	202	1.8	206	153				
Total External Cost (kEuro)			240	166	31.4	184.1	124.5	8.2	N	N	N

YOLL: Years of Life Lost, DBF: Deaths Brought Forward, CB: Chronic Bronchitis, RHA: Respiratory Hospital Admissions, CHA: Cardiovascular Hospital Admissions, RADs: Restricted Activity Days, ACC: additional cases of cancers, N: Negligible

5. Conclusions

Public acceptance is often considered as a prerequisite for the success of a WtE MSW management scheme. At the same time, the external costs for nine (9) alternative scenarios are assessed. Although the environmental impact in the case that WtE facility is located in Sindos (S_1 – S_3) seem to be greater this location is considered as the optimal one. This is mainly due to the fact that the specific area is more densely populated compared to the other available locations, while also it is located close to the GTA's industrial zone. In this manner, the logistics costs for the transportation of the MSW will be minimized, while also the thermal heat that will be produced from the operations of the WtE facility will be exploited, both making the investment economically viable. Of course, Sindos as the optimal location is also grounded on the fact that the health impacts and the corresponding external cost attributed to the emission of air pollutants from the facility, although larger than the other available locations, are negligible compared to the overall environmental status in the GTA. It should be also stressed out once again that the aforementioned figures correspond to the worst case scenario as regards the emission factors of the planned WtE facility. In this context, even when taking into account maximum emission rates, the impact of such a facility to the public health is almost negligible, especially when compared to the impacts attributed to other sources of pollution, such as industrial activities, urban transportation and space heating. For the case under study, the external cost attributed to the operation of a WtE facility in the GTA for any given scenario that is examined (3 YOLL in the worst case scenario) corresponds to a minimal fraction of the total external cost of deteriorated air quality in the region (approximately 11,000 YOLL), as discussed earlier and analytically presented in the work of Vlachokostas *et al*. (2012).

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