ENEP profile of MARIO GROSSO

I am an environmental engineer graduated at Politecnico di Milano. I hold a PhD on the topic of dioxin formation and destruction in waste incineration plants. I am currently Associate Professor at the Department of Environmental Engineering of Politecnico, where I teach "Solid waste management and treatment" and my major research topics are waste management and treatment technologies, atmospheric emissions from industrial plants and life cycle assessment (LCA). I have co-authored more than 150 scientific publications, of which 36 on ISI-rated journals. I am founding member and member of the Board of AIAT, the Italian Environmental Engineers Association, as well as Vice-President of ENEP, the European Network of Environmental Professionals. I am member of the International Waste Working Group (IWWG).

My current research and teaching activity includes the followings:
** experimental studies on the fate of organic and inorganic micropollutants in waste incineration plants;*
** technologies for energy recovery from waste;*
** recovery of solid residues from waste incineration plants;*
** Best Available Technologies (BAT) for the control of atmospheric emissions from industrial plants;*
** analysis of waste management strategies following an LCA approach;*
** technologies for waste recycling;*
** technologies for biological treatments of waste;*
** environmental impact assessment;*
** risk assessment.*

Identification and contact details

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Working experiences

Present activity:
Associate Professor at Politecnico di Milano (Italy)

Education

2001: Dottorato di Ricerca in Ingegneria Sanitaria
1997: Laurea in Ingegneria per l'Ambiente e il Territorio

Languages

	Written	Read	Spoken
English	Advanced	Advanced	Advanced
French (France)	Advanced	Advanced	Advanced
Italian (Italy)	Mother tongue	Mother tongue	Mother tongue

Projects

E. Regalini, M. Grosso (2005) - ***ENEP Platform*** (developed for: EFAEP)

EFAEP European Network of Environmental Professionals

Publications

M. Grosso, L. Biganzoli, L. Rigamonti, S. Cernuschi, M. Giugliano, V. Poluzzi, V. Biancolini (2012) - ***Experimental evaluation of PCDD/Fs and PCBs release and mass balance of a WTE plant*** (published by: Chemosphere 86, 293-299)

The behaviour of waste incineration plants with respect to organic toxic trace contaminants such as PCDDs, PCDFs and, to a minor extent, PCBs, is still a matter of concern for the public opinion and the decision makers. It is therefore very important, first, to evaluate the release of these organic toxic trace contaminants in the environment during waste incineration, not only through the stack gas emission but also with the solid and liquid residues, and then to compare the total release with the input through the treated waste in order to assess the plant behaviour as a "sink" rather than a "source" of organic toxic trace contaminants. The experimental investigation carried out on an Italian full scale incineration plant has shown a total 17 PCDD/Fs and 12 dioxin-like PCBs release of 5.5-27 µgWHO-TEQ per tonne of treated waste and an input flux of 1.6-44 µg WHO-TEQ per tonne waste, with the difference between the input
and the output fluxes rather small and the plant behaviour toward organic trace toxic contaminants in average neutral. Results are compared with similar evaluations conducted in the last decade on a number of waste-to-energy (WTE) plants operating in Italy.

F. Antognazza, S. Caserini, M. Grosso (2011) - ***GHGs emissions from waste disposal in Lombardia (Italy): inventory 1975-2008 and projections 2009-2020*** (published by: Waste Management & Research 29(8), 834-842)

A survey has been conducted across all MSW landfills with gas extraction system in the Lombardia Region (Italy) in order to collect data for an emission inventory assessment of greenhouse gas (GHG) emissions in the timeframe 1975-2008. The survey results identified a large number of landfills opened over the last 35 years and characterized by different kinds and amounts of waste disposed. Using the IPCC methodology, GHG emissions in the year 2008 were quantified to be 1.81Mt CO2-eq, which corresponds to 1.9% of overall GHG emissions in Lombardia. A dependency between collection efficiency and age of the collecting network has been established and used for the projection of GHG emission in the period 2009-2020, and for two scenarios: a business as usual (BAU) and an alternative one that implies policies to reduce biodegradable carbon content in the residual waste. The latter allows for a 45% reduction of the GHG emissions in 2020 compared to the year 2008, whereas in the BAU scenario the expected reduction is 32%. The sensitivity analysis shows that a variation of parameters that represent the carbon content of the waste category and degradation rate constant, within the range reported in the literature, could affect GHG emission level by about +- 18%, whereas the uncertainty due to landfill gas (LFG) composition is less relevant.

M. Giugliano, S. Cernuschi, M. Grosso, L. Rigamonti (2011) - ***Material and energy recovery in integrated waste management system. An evaluation based on life cycle assessment*** (published by: Waste Management 31, 2092-2101)

This paper reports the environmental results, integrated with those arising from mass and energy balances, of a research project on the comparative analysis of strategies for material and energy recovery from waste, funded by the Italian Ministry of Education, University and Research. The project, involving the cooperation of five University research groups, was devoted to the optimisation of material and energy recovery activities within integrated municipal solid waste (MSW) management systems.
Four scenarios of separate collection (overall value of 35%, 50% without the collection of food waste, 50% including the collection of food waste, 65%) were defined for the implementation of energetic, environmental and economic balances. Two sizes of integrated MSW management system (IWMS) were considered: a metropolitan area, with a gross MSW production of 750,000 t/year a average province, with a gross MSW production of 150,000 t/year.
The environmental analysis was conducted using Life Cycle Assessment methodology (LCA), for both material and energy recovery

activities. In order to avoid allocation we have used the technique of the expansion of the system boundaries. This means taking into consideration the impact on the environment related to the waste management activities in comparison with the avoided impacts related to the saving of raw materials and primary energy.
Under the hypotheses of the study, both for the large than for the small IWMS, the energetic and environmental benefits are higher than the energetic and environmental impacts for all the scenarios analysed in terms of all the indicators considered: the scenario with 50% separate collection in a drop-off scheme excluding food waste shows the most promising perspectives, mainly arising from the highest collection (and recycling) of all the packaging materials, which is the activity giving the biggest energetic and environmental benefits. Main conclusions of the study in the general field of the assessment of the environmental performance of any integrated waste management scheme address the importance of properly defining, beyond the design value assu for the separate collection as a whole, also the yields of each material recovered; particular significance is finally related to the amount of residues deriving from material recovery activities, resulting on average in the order of 20% of the collected materials.

M. Grosso, L. Biganzoli, L. Rigamonti (2011) - ***A quantitative estimate of potential aluminium recovery from incineration bottom ashes*** (published by: Resources, Conservation and Recycling 55, 1178- 1184)

The recovery of ferrous and non ferrous metals from the bottom ashes is a common practice in the most part of Europe, both for the environmental advantages of their recycle and to avoid problems of swelling and expansion that metals can cause when bottom ashes are reused in concrete production or in road construction. This paper focuses on metal recovery from bottom ashes produced in Municipal Solid Waste (MSW) incinerators, with a particular focus on aluminium. A forecasting model was developed in order to evaluate the quantity of aluminium scraps recoverable from the bottom ashes. The model was applied to the Italian situation but its validity can be extended to other countries. Focusing on Italy, by applying conventional technologies for the separation of non-ferrous metals, the amount of aluminium potentially recoverable from bottom ashes is estimated in the range from 16,500 to 21,000 tonnes at the year 2015, and from 19,000 to 28,500 tonnes at 2020.

R. Turconi, S. Butera, A. Boldrin, M. Grosso, L. Rigamonti T. Astrup (2011) - ***Life cycle assessment of waste incineration in Denmark and Italy using two LCA models*** (published by: Waste Management & Research 29, 78-90)

In Europe, about 20% of municipal solid waste is incinerated. Large differences can be found between Northern and Southern Europe regarding energy recovery efficiencies, flue gas cleaning technologies and residue management. Life cycle assessment (LCA) of waste incineration often provides contradictory results if these local conditions are not properly accounted for. The importance of regional differences and site-specific data, and choice of LCA model itself, was evaluated by assessment of two waste incinerators representing Northern and Southern Europe (Denmark and Italy) based on two different LCA models (SimaPro and EASEWASTE). The results showed that assumptions and modelling approaches regarding energy recovery/substitution and direct air emissions were most critical. Differences in model design and model databases mainly had consequences for the toxicity related impact categories. The overall environmental performance of the Danish system was better than the Italian, mainly because of higher heat recovery at the Danish plant. Flue gas cleaning at the Italian plant was however preferable to the Danish, indicating that efficient flue gas cleaning may provide significant benefits. Differences in waste composition between the two countries mainly affected Global Warming and Human Toxicity via Water. Overall, SimaPro and EASEWASTE provided consistent ranking of the individual scenarios. However, important differences in results from the two models were related to differences in the databases and modelling approaches, in particular the possibility for modelling of waste-specific emissions affected the toxicity related impact categories. The results clearly showed that the use of site-specific data was essential for the results.

F. Viganò, S. Consonni, M. Grosso, L. Rigamonti (2010) - ***Material and energy recovery from Automotive Shredded Residues (ASR) via sequential gasification and combustion*** (published by: Waste Management, 30, 145-153)

Shredding is the common end-of-life treatment in Europe for dismantled car wrecks. It produces the so called Automotive Shredded Residue (ASR), usually disposed of in landfill. This paper summarizes the outcome of a study carried out by Politecnico di Milano and LEAP with the support of Actelios SpA on the prospects of a technology based on sequential gasification and combustion of this specific waste stream. Its application to the treatment of ASR allows the recovery of large fractions of metals as non-oxidized, easily marketable secondary raw materials, the vitrification of most of the ash content and the production of power via a steam cycle. Results show that despite the unfavourable characteristics of ASR, the proposed technology can reach appealing energy performances. Three of four environmental impact indicators and the cumulative energy demand index are favourable, the main positive contributes being electricity production and metal recovery (mainly aluminium and copper). The only unfavourable indicator is the global warming index because, since most of the carbon in ASR comes from fossil sources, the carbon dioxide emissions at the stack of the thermal treatment plant are mainly non-renewable and, at the same time, the avoided biogas production from the alternative disposal route of landfilling is minor.

S. Caserini, S. Livio, M. Giugliano, M. Grosso and L. Rigamonti (2010) - ***LCA of domestic and centralized biomass combustion: The case of Lombardy (Italy)*** (published by: Biomass and Bioenergy, 34, 474-482)

This paper analyzes and compares the environmental impacts of biomass combustion in small appliances such as domestic open fireplaces and stoves, and in two types of centralised combined heat and power plants, feeding district heating networks. The analysis is carried out following a Life Cycle Assessment (LCA) approach. The expected savings of GHG (greenhouse gases) emissio due to the substitution of fossil fuels with biomass are quantified, as well as emissions of toxic pollutants and substances responsible for acidification and ozone formation.
The LCA results show net savings of GHG emissions when using biomass instead of conventional fuels, varying from 0.08 to 1.08 t of

CO2 eq. per t of dry biomass in the different scenarios. Avoided GHG emissions thanks to biomass combustion in Lombardy are 1.32 Mt year-1(1.5% of total regional GHG emissions). For the other impact categories, the use of biomass in district heating systems can again cause a consistent reduction of impacts, whereas biomass combustion in residential devices shows higher impacts than fossil fuels with a particular concern for PAH, VOC and particulate matter emissions. For example, in Lombardy, PM10 emissions from domestic devices are about 8100 t year-1, corresponding to almost one third of the total particulate emissions in 2005.

M. Grosso, A. Motta, L. Rigamonti (2010) - ***Efficiency of energy recovery from waste incineration, in the light of the new Waste Framework Directive*** (published by: Waste Management, 30, 1238-1243)

This paper deals with a key issue related to municipal waste incineration, which is the efficiency of energy recovery. A strong driver for improving the energy performances of waste-to-energy plants is the recent Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives), which allows high efficiency installations to benefit from a status of "recovery" rather than "disposal". The change in designation means a step up in the waste hierarchy, where the lowest level of priority is now restricted to landfilling and low efficiency waste incineration. The so-called "R1 formula" reported in the Directive, which counts for both production of power and heat, is critically analysed and correlated to the more scientific-based approach of exergy efficiency. The results obtained for waste-to-energy plants currently operating in Europe reveal some significant differences in their performance, mainly related to the average size and to the availability of a heat market (district heating).

L. Rigamonti, M. Grosso, M. Giugliano (2010) - ***Life cycle assessment of sub-units composing a MSW management system*** (published by: Journal of Cleaner Production 18, 1652-1662)

This paper summarises the results of a number of life cycle evaluations that we have carried out in recent years about some of the sub-units (in particular, the recycling of the packaging materials, the treatment of the bio-waste, and the energy recovery from the residual waste) that compose a municipal solid waste management system (MSWMS) and about the MSWMS as a whole. The range of values estimated for cumulative energy demand (CED), global warming (GWP100), human toxicity, acidification, and photochemical ozone creation indicators according to the different analyses are presented in the paper for each sub-unit. The assumptions influencing the results have been identified, too. The proper aggregation of sub-units has allowed the estimation of the impacts associated with two integrated MSWMSs implemented in Italy and of the order of magnitude of those associated with a generic MSWMS, similar to those of the two case studies.
The results show that the assumptions that most influence the environmental indicators are those about selection efficiencies and quality deterioration in the recycling of the packaging materials, about process emissions and avoided products in the composting, about the biogas yield and its way of utilisation in the anaerobic digestion, and about the efficiency of the plant and the kind of avoided energy in the energy recovery. All the indicators, except GWP100 under certain assumptions, are negative in sign, thus indicating a benefit for the environment thanks to the avoided impact associated with the production of material and energy during the waste management. The estimated order of magnitude of the CED and GWP100 indicators turns out to be respectively thousands MJeq. and tens of kgCO2eq. per tonne of managed waste.

L. Rigamonti, M. Grosso and M. Giugliano (2009) - ***Life cycle assessment for optimising the level of separated collection in integrated MSW management systems*** (published by: Waste Management, 29, 934-944)

This life cycle assessment study analyses material and energy recovery within integrated municipal solid waste (MSW) management systems, and, in particular, the recovery of the source-separated materials (packaging and organic waste) and the energy recovery from the residual waste. The recovery of materials and energy are analysed together, with the final aim to evaluate possible optimum levels of source-separated collection that lead to the most favourable energetic and environmental results; this method allows identification of an optimum configuration of the MSW management system.
The results show that the optimum level of source-separated collection is about 60%, when all the materials are recovered with high efficiency; it decreases to about 50%, when the 60% level is reached as a result of a very high recovery efficiency for organic fractions at the expense of the packaging materials, or when this implies an appreciable reduction of the quality of collected materials. The optimum MSW management system is thus characterized by source-separated collection levels as included in the above indicated range, with subsequent recycling of the separated materials and energy recovery of the residual waste in a large-scale incinerator operating in combined heat and power mode.

L. Rigamonti, M. Grosso, M.C. Sunseri (2009) - ***Influence of assumptions about selection and recycling efficiencies on the LCA of integrated waste management systems*** (published by: International Journal of Life Cycle Assessment, 14, 411-419)

Background, aim, and scope
Life cycle assessment (LCA) applied to alternative waste management strategies is becoming a commonly utilised tool for decision makers. This LCA study analyses together material and energy recovery within integrated municipal solid waste (MSW) management systems, i.e. the recovery of materials separated with the source-separated collection of MSW and the energy recovery from the residual waste. The final aim is to assess the energetic and environmental performance of the entire MSW management system and, i particular, to evaluate the influence of different assumptions about recycling on the LCA results.
Materials and methods
The analysis uses the method of LCA and, thus, takes into account that any recycling activity influences the environment not only by consuming resources and releasing emissions and waste streams but also by replacing conventional products from primary production. Different assumptions about the selection efficiencies of the collected materials and about the quantity of virgin

material substituted by the reprocessed material were made. Moreover, the analysis considers that the energy recovered from the residual waste displaces the same quantity of energy produced in conventional power plants and boilers fuelled with fossil fuels.
Results
The analysis shows, in the expanded model of the material and energy recovering chain, that the environmental gains are higher than the environmental impacts. However, when we reduce the selection efficiencies by 15%, the impact indicators worsen by a percentage included between 10% and 26%. This phenomenon is even more evident when we consider a substitution ratio of 1:

M. Giugliano, M. Grosso, L. Rigamonti (2008) - ***Energy Recovery from Municipal Waste: A Case Study for a Middle-Sized Italian District*** (published by: Waste Management, 28, 39-50)

This paper reports the main outcome of research to compare and assess the merits of alternative strategies for energy recovery from municipal solid waste downstream of material recovery for an Italian province. Strategies analysed are based on well-established combustion technologies available at the commercial scale in the Italian market in comparison with an innovative but not yet proven option of refuse derived fuel gasification and subsequent co-combustion of syngas in a combined cycle power plant. The comparison is made using mass and energy balances, environmental assessment and economic analysis.
From an energetic point of view, the best strategy is the one based on the refuse derived fuel gasification, which, on the contrary, does not show interesting environmental results. In this perspective, the best results are from strategies based on a dedicated plant, particularly when unsorted residual waste collected downstream of material recovery is used. Finally, from an economic point of view, the strategy with gasification allows the highest revenues from the sale of energy.

M. Grosso, S. Cernuschi, M. Giugliano, G. Lonati, L. Rigamonti (2007) - ***Environmental release and mass flux partitioning of PCDD/Fs during normal and transient operation of full scale waste to energy plants*** (published by: Chemosphere, 67, S118-S124)

The paper reports on global release and mass partitioning in the flux of residues of PCDD/Fs, evaluated with dedicated field campaigns at a municipal solid waste incineration plant during normal and transient operation. Results are compared with those obtained in other installations equipped with furnaces, energy recovery options and flue gas treatment technologies representative of most of the European incineration plants currently in operation. Levels of the pollutants of interest were determined in all the solid, liquid and gaseous residues produced by every single facility, and the results analysed in terms of the effects arising from the fed waste and the configuration of the plant. PCDD/Fs total release between 1.5 and 45 µgI-TEQ per ton of burned waste was evaluated, with lower values resulting from the adoption of catalytic conversion process for flue gas treatment. Most of the mass flux emitted is associated with solid residues deriving from activated carbon PCCD/F dry removal options, with significant contributions also from fly ash produced by particulate removal devices located immediately downstream the boiler and from scrubber blowdowns treatment sludge. During transient operating conditions the dioxin total release may increase by 50% with comparison to steady-state functioning.

G. Lonati, S. Cernuschi, M. Giugliano, M. Grosso (2007) - ***Health risk analysis of PCDD/F emissions from MSW incineration: comparison of probabilistic and deterministic approaches*** (published by: Chemosphere, 67, S334-S343)

Incremental lifetime health risks due to polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) emitted from municipal waste incineration (MSWI) facilities were evaluated for resident population in the area of the plant. Risk assessment was performed through a multipathway combined probabilistic/deterministic approach for analyzing the effects of uncertainty and intrinsic variabilità of the main PCDD/F emission related parameters on final predicted values. Exposure through direct inhalation of contaminated air, soil ingestion, soil dermal contact and diet were considered, with the propagation of the variability of input parameters throughout the evaluation performed with Monte Carlo simulation techniques. The application to a case study representative of two different technological scenarios (modern facilities equipped with BAT Best Available Technology and older incinerators) in a location site typical of Northern Italy situation results in median values of the maximum individual excess risk on the order of 10^-9 and 10^-7 for most recent and older plant configurations, respectively. Corresponding ratios for the 90th and 10th percentile values are around 7 and 9. Individual risk estimates derived for the same scenarios from conventional deterministic approaches, where large conservative assumptions are normally adopted for compensating the lack of knowledge about uncertainty, are essentially comparable with maximum values resulting from the probabilistic approach, thus leading to situations with extreme and very low probabilities of occurrence. PCDD/F health risks from MSWI emissions might thus result largely overestimated if real emission characteristics are not properly considered in the assessment procedure. Sensitivity analysis for identifying the contribution of different input parameters on final predicted risk variance indicates, for the area considered in the simulation, a prevailing influence of PCDD/F stack concentration, with exposures arising from soil depositino phenomena substantially negligible: this latter result further points out the requirements for a very careful identification of base input data values for PCDD/F stack concentrations, at least for those situations where plants are located nearby urban areas.

M. Giugliano, G. Lonati, P. Butelli, L. Romele, R. Tardivo, M. Grosso (2005) - ***Fine particulate (PM2.5-PM1) at urban sites with different traffic exposure*** (published by: Atmospheric Environment 39, 2421-2431)

Fine particulate concentration data resulting from several monitoring campaigns performed in Milan at urban sites with different exposure to the emission sources are presented. Low volume PM2.5 and PM1 samplers are utilised together with a low volume optica analyser, enabling the intercomparison between the measurements obtained by the gravimetrical and the optical method. The concentration levels observed at the different sites are compared in order to point out intra-site seasonal differences and the inter-site differences for corresponding seasons of the year. These different concentration levels are analysed and explained

considering the exposure to the primary emissions and accounting for the role of meteorology. PM10, PM2.5 and PM1 are described in terms of the distribution of 1-hour concentration data and their relative mass fractions are determined. A PM2.5 high volume sampler is utilised for the collection of dust-loaded filters to be analysed for chemical characterisation in order to assess the significance of the secondary PM2.5 sources.

S. Consonni, M. Giugliano, M. Grosso (2005) - ***Alternative strategies for energy recovery from municipal solid waste. Part A: mass and energy balances*** (published by: Waste Management, 25, 123-135)

This two-part paper assesses four strategies for energy recovery from Municipal Solid Waste (MSW) by dedicated Waste-To-Energy (WTE) plants generating electricity through a steam cycle. The feedstock is the residue after Materials Recovery (MR), assumed to be 35% by weight of the collected MSW. In strategy 1, the MR residue is fed directly to a grate combustor. In strategy 2, the MR residue is first subjected to light mechanical treatment. In strategies 3 and 4, the MR residue is converted into RDF, which is combusted in a fluidized bed.
To examine the relevance of scale, we considered a small Waste Management System (WMS) serving 200,000 people and a large W serving 1,200,000 people. A variation of strategy 1 shows the potential of cogeneration with district heating.
The assessment is carried out by a Life Cycle Analysis where the electricity generated by the WTE plant displaces electricity generated by fossil fuel-fired steam plants. Part A focuses on mass and energy balances, while Part B focuses on emissions and costs.
Results show that treating the MR residue ahead of the WTE plant reduces energy recov-ery. The largest energy savings are achieved by combusting the MR residue as is in large scale plants; with cogeneration, primary energy savings can reach 2.5% of total societal energy use.

S. Consonni, M. Giugliano, M. Grosso (2005) - ***Alternative strategies for energy recovery from municipal solid waste. Part B: emission and cost estimates*** (published by: Waste Management, 25, 137-148)

This two-part paper assesses four strategies for energy recovery from Municipal Solid Waste (MSW) by dedicated Waste-To-Energy (WTE) plants. In strategy 1, the residue of Material Recovery (MR) is fed directly to a grate combustor, while in strategy 2 the grate combustor comes downstream of light mechanical treatment. In strategies 3 and 4 the MR residue is con-verted into Refuse Derived Fuel (RDF), which is combusted in a fluidized bed.
The results of Part A, devoted to mass and energy balances, clearly show that pre-treating the MR residue in order to increase the heating value of the feedstock fed to the WTE plant has marginal effects on the energy efficiency of the WTE plant. When considering the efficiency of the whole strategy of waste management, the energy balances show that the more thorough the pre-treatment, the smaller the energy recovered per unit of MR residue.
Starting from the heat/mass balances illustrated in Part A, this Part B examines the envi-ronmental impacts and economics of the various strategies by means of a Life Cycle Assess-ment (LCA). Results show that treating the MR residues ahead of the WTE plant does not pro-vide environmental or economic benefits. RDF production worsens almost all impact indicators because it reduces net electricity production and thus the displacement of power plant emis-sions; it also increases costs, because the benefits of improving the quality of the material fed to the WTE plant do not compensate the cost of such improvement.

S. Caserini, S. Cernuschi, M. Giugliano, M. Grosso, G. Lonati, P. Mattaini (2004) - ***Air and soil dioxin levels at three sites in Italy in proximity to MSW incineration plants*** (published by: Chemosphere, 54, 1279-1287)

Levels of Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in both air and soil samples were measured at three different sites in Italy, in proximity to three MSWI (Municipal Solid Waste Incinerator) to determine baseline contamination and the contributory role of incinerator emissions.
At the first site, located in an agricultural, cattle-breeding, typically flattish area of the Po Valley, the dioxin concentrations had already been measured before the start-up of the new MSWI. These dioxin concentrations were then again measu after two years of continual operation of the incinerator. Despite the presence of the plant, the PCDD/Fs levels appear not to have been affected and were found to be in a range of 22-125 fg I-TEQ m-3 in the air samples and 0.7 1.5 pg I-TEQ g-1 in the soil samples.
The second site is located in an industrial district of the Veneto Region, in the surroundings of an old MSWI that is not equipped with Best Available Technology (BAT) dioxin removal system. The PCDD/Fs concentrations in the air samples were between 144 and fg I-TEQ m-3. This is a typical range of values for industrial areas, while the soil samples showed contamination levels between 1.1-1.4 pg I-TEQ g-1.
The third site lies in the Adige Valley, near a MSWI that has been equipped with BAT for flue gas cleaning. The observed values ranged from 10 to 67 fg I-TEQ m-3 for the air samples and 0.08-1.2 pg I-TEQ g-1 for the soil samples.
The contributory factors of the varying characteristics of the different areas together with the types of technology adopted at each MSWI plant are discussed. The PCDD/Fs levels are subsequently compared with established values from previous studies.

M. Giugliano, S. Cernuschi, M. Grosso, E. Aloigi, R. Miglio (2002) - ***PCDD/F mass balance in the flue gas cleaning units of a MSW incineration plant*** (published by: Chemosphere, 46, 1321-1328)

With the main purpose of evaluating PCDD/F presence and the corresponding mass balance over the emissions control system, an extensive study was performed on a MSW full scale incinerator equipped with a best available technology flue gas treatment line. Present paper reports the main results obtained, with particular reference to the PCDD/F concentration profiles and mass balances derived for every process unit of the flue gas control system. Total release evaluated for the plant is also outlined in comparison with data on PCDD/F content of raw wastes and with reference values included in most recent guidelines.

M. Giugliano, S. Cernuschi, M. Grosso, E. Aloigi, R. Miglio (2001) - ***The flux and mass balance of PCDD/Fs in a MSW incineration full scale plant*** (published by: Chemosphere, 43, 743-750)

PCDD/F are one of the most significant environmental concerns of municipal solid waste disposal through incineration processes. With the main purpose of evaluating their presence along the flue gas line and establishing a mass balance over the whole system, an extensive research study was performed on a full scale plant. Present paper reports the main results obtained, with particular reference to the PCDD/F concentration profiles and mass balance in the post-furnace region, where significant formation of these compounds might take place. PCDD/F mass fluxes evaluated in all the residues arising from the process are also reported.

M. Giugliano, S. Cernuschi, U. Ghezzi, M. Grosso (1999) - ***Experimental evaluation of waste tyres utilisation in cement kilns*** (published by: Journal of the Air & Waste Management Association, 49, 1405)

Present work outlines the main results of a full scale study conducted on the utilisation of waste tyres as auxiliary fuel in cement production. Experimental tests were conducted for determining the influence of shredded tyres on combustion conditions, emissions produced and the characteristics of clinker obtained, for feeding ratios over 35% in terms of total heat input. The addition of tyre chips did not lead to any appreciable modification either in the operation of the whole process or in the quality of clinker produced; gaseous emissions were mostly unaffected, with significant improvements related to the reductions obtained in nitrogen and sulphur oxides concentrations. Experimental findings from tests conducted with tyre chips exposed to combustion flue gases of the kiln compare favourably with typical burn-out times derived from theoretical approaches. These experimental data and calculations to estimate particle trajectories beyond injection point, through proper theoretical analysis of the kinetic behaviour, result in important indications for the shredding operation and for the optimum injection modes.