Introduction

The term ‘best available techniques’ (BAT) can be defined as follows: “Best” refers to high level of environmental protection, the word “available” means in this context techniques developed on a scale which allows implementation in the relevant class of activity under economically and technically viable conditions, “Techniques” include both the technology used and the way in which the installation is designed, built, managed, maintained and operated.

While usually BAT is used as a reference for new installations, this study shows how actual performance of an existing since 1980 operating municipal waste incineration (MWI) plant of the “Intercommunale voor Slib- en Vuilverwijdering van Antwerpse Gemeenten” (ISVAG) in Wilrijk/Antwerp is assessed relative to BAT. Commissioned on behalf of the ISVAG board, the study aimed at identifying optimization potentials for the existing installation or showing better technical alternatives to improve the overall performance of the residual waste treatment for the municipality.

1. Best Available Techniques for municipal waste management

Legal basis for “Best Available Techniques Reference Documents” (BREF) is the Integrated Pollution Prevention and Control (IPPC) Directive (Directive 2008/1/EC)1. According to section 16 (2), “the Commission shall organize an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring, and developments in them. Every three years the Commission shall publish the results of the exchanges of information”. [Directive 2008/1/EC; 2008]

In order to implement this regulation, in 2006, the European IPPC Bureau completed the first series of 33 BREFs for selected industrial sectors. Their main target is to establish integrative knowledge on the implemented techniques in Europe and therewith the relevant impacts on the environment. This exchange of information should prevent imbalances in the technology sector and compensate competitive disadvantage. The BREF document is also a benefit for the member states for the implementation of the “Integrated Pollution Prevention and Control (IPPC) Directive”.

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Figure 1 gives an overview of the implementation process. For each BREF, the European IPPC Bureau sets up a Technical Working Group (TWG) to carry out the exchange of information on BAT. A TWG usually consists of between 40 to 100 experts. A lead expert from the European IPPC Bureau organizes the work of the TWG, fosters the exchange of information, makes a scientific and technical analysis of the vast amount of information exchanged, proposes compromise solutions on issues when views of TWG members differ, and writes the BREF. The European IPPC Bureau acts as a neutral, technically competent and permanent body to all TWGs. The procedure used to elaborate or review a BREF includes a few plenary meetings of the TWG, sub-group meetings, visits to installations, and submission of draft BREFs for comments. The BREF Outline and Guide provides\(^2\) an agreed basis for the work of the European IPPC Bureau and the TWGs. Once it has been finalised, each BREF is presented by the European IPPC Bureau to DG Environment at the Consultative Committee (Information Exchange Forum, IEF) established by the IPPC Directive. The BREFs are then formally adopted by the college of commissioners and a notice of their adoption is published in the Official Journal of the European Communities.

Figure 1: Preparation scheme for the BREF documents

All member states and therewith all interest groups have the opportunity to provide position papers. During a meeting of the TWG and the IPPC Bureau (Sevilla-Bureau), the main issues are discussed.

The benefit of the implementation of BREF document is the exchange of information. Information means in this context the description of modern and used techniques for waste treatment. The operation costs of those techniques are included.

A further advantage of BREF documents is that they

- define assessment criteria for the relevant for the determination of BAT and
- show applied processes and techniques and current emission and consumption levels
- and describe Best Available Techniques (BAT) and associated emission and consumption levels.

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For waste treatment two BREFs are relevant: „Best Available Technique Reference Document” (BREF) for Waste Incineration (WI-BREF) and “BREF document ‘waste treatments industries’ (WT-BREF). The WT-BREF covers the activities described in Section 5 of Annex I of the IPPC-Directive, namely Waste Management, excluding waste incineration and some thermal waste treatments (covered by the BREF ‘Waste Incineration’) and waste landfills. Thus, the scope of this document focuses on the following:

- installations for the disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day
- installations for the disposal of waste oils with a capacity exceeding 10 tonnes per day
- installations for the disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day.

The waste treatment activities covered by the BREF document include common treatments, biological treatments, physico-chemical treatments, treatments to recover mainly the waste material and treatments to produce mainly a fuel. Mechanical biological treatment plants (MBT) are not specifically mentioned, but there are two section dealing with elements of MBT plants: “biological treatments” and “waste treatments aimed to produce a material to be used as fuel”.

Case study for the city of Antwerp

The “Intercommunale voor Slib- en Vuilverwijdering van Antwerpse Gemeenten” (ISVAG) is operating a municipal waste incineration plant (MWI) in Wilrijk/Antwerp with a capacity of 147,000 tonnes per year (9 tonnes per hour). The permit for operation ends in 2011, and the operating municipalities have to decide upon how to assure the mid- and long-term safe disposal of non-recyclable mixed household waste for the city of Antwerp and surrounding communities. Against this background ISVAG commissioned a study on a technical and environmental assessment of the existing waste incineration plant ISVAG Antwerp and alternative waste treatment technologies.

A study was commissioned by ISVAG in January 2009 aiming at providing a comprehensive and easily understandable report describing the existing MWI and alternative technologies and their performance relative to “Best Available Techniques”

This study is divided into two steps with the specific objectives:

1. to compare the existing waste incineration plant of ISVAG in Antwerp with “Best Available Technique” (BAT) for waste incineration and showing potentials for optimization

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3 European Commission; The European IPPC Bureau; Reference Document on the Best Available Techniques for Waste Incineration; 2006; [http://eippcb.jrc.es/reference/wi.html](http://eippcb.jrc.es/reference/wi.html) (online: 01.05.2009)

4 European Commission; The European IPPC Bureau; Reference Document on the Best Available Techniques for Waste Treatment Industries; 2006; [http://eippcb.jrc.es/reference/kt.html](http://eippcb.jrc.es/reference/kt.html) (online: 01.05.2009)
2. to compare and assess alternative waste treatment technologies with, if applicable, BAT and other selected criteria in order to perform a SWOT analysis of alternative technologies.

For this study, the actual performance of the ISVAG Municipal waste incinerator (MWI) was compared relative to other European Waste Incineration plants in terms of emission and consumption levels and the energy production. The data basis for this comparison is the consensus definitions of BAT according to the „Best Available Techniques Reference Document“ (BREF) for Waste Incineration (WI-BREF)\(^5\) (FEAD 2002)

In order to assure that the BAT definition still refers to advanced technologies also other more recent data about emissions from MWI in Flanders (OVAM, 2006) and Germany from 2004 and 2006 were included (IFEU, 2007), (MVR, 2009)

For the assessment of alternative waste treatment technologies the following stepwise approach was followed

a) Definition and selection of applicable technologies (Pretz et al. 2003)
b) Mass flow modeling of four MBT alternatives in order to assess expected secondary waste flows for the further disposal, treatment and recovery.
c) Life-cycle inventory comparison of mercury and CO\(_2\) emissions for various scenarios over the entire process chain
d) Qualitative assessment of technological, environmental and market risks for the alternatives on the basis of an overview of the German situation

This resulted in a qualitative discussion of the applicability of alternative waste treatment technologies for ISVAG under Flemish conditions.

Results

**BAT assessment of the existing MWI**

In general it can be stated that the ISVAG MWI is a state of the art installation which applies BAT technologies. Following remarks can be made.

- The ISVAG MWI has a specific, gradually expanded, concept of combined half wet and wet flue gas cleaning. That enables very low emissions for HCl, SO\(_2\) and mercury. This combination also allows a wastewater free operation as suggested for BAT.
- The flue gas system does not include Selective Catalytic Reduction (SCR) of NO\(_X\). Due to the wet flue gas cleaning a sizable amount of additional energy to heat up the exhaust gas after the wet scrubber is required in order to enable the use of SCR technology.
- The ISVAG MWI operates at rather conventional steam parameters of 40 bar and 400°C in order to prevent corrosion and slagging in the boiler with the consequence of

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\(^5\) European Commission; The European IPPC Bureau; Reference Document on the Best Available Techniques for Waste Incineration; 2006; [http://eippcb.jrc.es/reference/wi.html](http://eippcb.jrc.es/reference/wi.html) (online: 01.05.2009)
a limited electrical efficiency. The location does not allow increasing the electrical efficiency through a water-cooled condenser.

- At the moment there is no use of heat and steam in order to increase the overall energy efficiency of the plant. Also here limitations of the actual location have to be considered.
- All solid residues from the incineration process are externally further processed for recycling (bottom ash) or disposal (fly ash and filter ash).

The applied technology of the ISVAG MWI leads to emission levels that are clearly below the limit values of the EU Waste Incineration Directive (WID) (2000/76/EC) and in the lower range of BAT associated emissions levels (Figure 1). For most parameters the actual emissions of ISVAG are only 10% of the allowed emissions according to the EU WID. The picture for NO\textsubscript{X} deviates a bit, since ISVAG does not apply Selective Catalytic Reduction (SCR). Therefore, ISVAG uses with its actual NO\textsubscript{X} emissions 70% of the allowed emissions values. An exemplary comparison with a MWI in Hamburg shows that it is possible to further reduce the ISVAG emission levels with modern state of the art MWI.

![Figure 1: Emission levels of ISVAG (24h-values) relative to the emission limit value according to the EU-WID (2000/76/EC) (100%), compared to the lower BAT range and to the emission level of the MWI Rugenberger Damm in Hamburg](image)

**BAT assessment of alternative technologies**

Potential alternative technologies for the treatment of household waste are pyrolysis, gasification and mechanical biological treatment (MBT). For the first two potential alternatives, pyrolysis and gasification as well for combination technologies, a number of failed projects in Germany could be shown. Technical and economical barriers led to the fact that presently there is no plant operating in Germany as a reference. That is why those technologies are not included in the further investigation.

Mechanical Biological Treatment (MBT) is a generic term for an integration of several biological and mechanical processes applied in waste treatment. It aims at the recovery of materials for one or more purposes (solid waste fuels, recyclables) and the increase of the
biological stability of the remaining organic fraction to be landfilled. They can be distinguished according to two main concepts:

- **Type 1** – “Separation” which seeks to split the waste into ‘biodegradable’ (that may be composted and afterwards landfilled) and ‘high calorific’ fractions

- **Type 2** – “Dry stabilization” which is less concerned with the splitting into fractions and more (focuses) with the use of heat from a ‘composting’ process to dry the waste (bio-drying) and to increase its calorific value thereby making the waste suitable for use as a fuel as well as facilitating the separation of fractions. As alternative to the bio-drying, drying with natural gas, landfill gas or biogas can be used (physical drying).

Figure 2 shows results for the mass distribution of MSW for four modeled technical alternatives of MBT treatment. Due to the high plastic content in the Flemish waste a relatively high RDF yield of 60% can be anticipated. For the MBT scenarios the residue to be landfilled accounts for 17-22% of the input waste, while in the scenario for the type 2 plants following the dry stabilization principle (bio-drying (MBS) and physical drying (MPS)), the residue to be landfilled is limited to an inert fraction of 10-16% of the input waste. In all scenarios some 2.5% of metals can be segregated for material recycling.

![Figure 2: Mass balances of MBT processes based on the input of 147.000 t of waste and the average household waste composition in Flanders in 2006.](image)

The fraction to be landfilled has a Total Organic Carbon (TOC) content of >20% (dry matter) and exceeds the Flemish limit value for waste to be landfilled of >10%. Thus, both type 2 MBT alternatives “MBT simple” and “MBT 2 RDF Qualities” do not comply with Flemish legislation.

The results also show that MBT treatment is not a final treatment. Both, the landfill fraction and the separated fuel (Refuse Derived Fuel - RDF) require further treatment and landfill capacities. For the RDF from household waste, co-combustion in cement kilns and co-combustion in coal fired boilers (lignite or hard coal) are options with a low acceptance on the market. On the other hand, mono-combustion in RDF-fired boilers (grate-firing or fluidized bed technology) for district heating or industrial supply of steam and electricity is in Germany an emerging market.
Emissions from MBT alternatives depend significantly on the subsequent disposal, treatment and recovery processes. Exemplary, figure 3 shows the net emissions to air for greenhouse gases and mercury. Besides the direct process emissions, this includes emissions and credits from down-stream processes (provision of electricity, urea, lime etc.) and up-stream processes (transport, landfilling, electricity generation, recycling of metals and bottom ashes, combustion of RDF) for the ISVAG MWI and four MBT scenarios with each different options of RDF utilization.

**Figure 3: Overall process emissions for greenhouse gases and mercury of MBT alternatives compared with the emission of the ISVAG MWI**

The greenhouse gas emissions including CO$_2$ fossil, CH$_4$, N$_2$O show specifically for the co-combustion scenarios, here shown as an average of 8 modeled alternatives, negative net emissions because CO$_2$ intensive hard coal and brown coal is substituted. Electricity producing MWI or mono-combustion RDF power plants, also get the produced electricity
credited according to the Belgium electricity mix (0.2 kg CO₂/kWh). These credits do not lead to negative net emissions⁶.

For mercury, co-combustion scenarios show increased net emissions because of the burning of RDF. The flue gas cleaning of power plants and cements plants is not adapted to high mercury concentrations in the raw gas resulting in coefficients transfer to air between 25 and 50%. This makes the inventory very sensitive to the mercury content in the RDF quality.

Thus, two scenarios were included, one optimized low metal containing RDF scenario and one scenario assuming a higher metal concentration as typically found in household waste derived RDF. The latter indicates the range of uncertainty of the achievable RDF quality. In figure 3, the ISVAG MWI and RDF mono-combustion show clear advantages in terms of mercury emissions. The limited data base for dioxin emissions in down-stream processes in general and co-combustion in particular did not allow an assessment of the net dioxin emissions.

Conclusions for the case study
A set of conclusion on the actual operation of the ISVAG MWI in Wilrijk relative to BAT standard could be made

**BAT assessment of the ISVAG MWI**

- The specific waste production rate of residual household waste in Antwerp and surrounding communities is with 170 kg per capita per year low due to extended source separation. The ISVAG MWI in Wilrijk is with its capacity of 147 000 tonnes per year well adapted to the domestic waste production.

- The ISVAG MWI stays significantly below the limit values of the EU-WID (2000/76/EC) (NOₓ 70%, all other parameters 25% to 1% of the allowed concentration)

- In general, the ISVAG MWI shows, due to the wet flue gas leaning systems, lower emission rates then are to be expected with other flue gas cleaning system (dry or half wet) for the parameters SO₂, HCl, TOC, total dust, fine dust, and PCDD/PCDF. Wet Flue gas cleaning systems are considered as BAT for low emission levels

- All emissions are at the lower range or below of the BAT associated emission levels, except for NOₓ although the emission is with 147 mg/m³ within the range 120 - 188 mg/m³ for selective non catalytic reduction (SNCR).

- Considering the reference year of the BREF BAT reference values, it can be stated that the average emission levels of MWI plants in Germany in the period 2005 to 2007

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⁶ The CO₂ substitution rule for electricity production in an life-cycle assessment depend on local condition. Due to the high percentage of “CO₂ neutral” nuclear power in Belgium, the specific credits are lower in Belgium as e.g. in Germany where a higher percentage of coal electricity will be substituted.
are below the BAT associated emission range. The ISVAG MWI performs within this typical range of German MWI plants. It has to be stated that lower emission levels can be achieved and are shown e.g. by the MWI Rugenberger Damm in Hamburg.\(^7\)

- A further reduction of the emissions can be considered as irrelevant relative to the total emission in Flanders. The actual ISVAG emission accounts for less than 0.01% for SO\(_2\), NO\(_x\), CO and dioxins.

- The ISVAG MWI produces electricity for roughly 20,000 households. It has a good energy recovery performance within the limitations of the existing location and the existing turbine which is not operated by ISVAG.

- ISVAG does not treat solid residues but subcontracts this. Thus no judgment of the quality of solid residues can be made.

### Assessment of alternative waste treatment technologies

- Considering available alternative waste treatment technologies it can be noticed that only for MBT technology there is full scale operational experience in Europe.

- Advantages of BAT technologies offer the advantage of modular flexible systems for decentralized application. They also can be applied with low technical standards in order to reduce significantly the emission of landfill gas and the pollution of landfill leachate relative to untreated waste. For countries with stricter landfill regulation MBT technologies focus on the recovery of refuse derive fuel (RDF).

- Described BAT for MBT does not exist on a European level. Practical experience exist specifically in Germany and Austria, where environmental emission standards were adopted that the emission are equivalent to the requirements for MWI.

- Based on the waste composition in Flanders, it can be estimated that by MBT technology about 75,000 to 90,000 t/a of RDF will be produced and about 20,000 - 30,000 t/a of landfill material remains. Both fractions need a further treatment and disposal. This implies a significant price uncertainty.

- The legal situation in Flanders does not allow the landfilling of mixed composted waste with an organic content > 10%. Thus, only stabilization MBTs qualify for waste treatment in Flanders.

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\(^7\) Due to different regulation of the emission reporting in Europe emission values cannot be compared uncommented. The reported data from Hamburg are “validated emission values” where a standard error of the measurements is distracted from the measurement result. The ISVAG values are the “normalized emission values” without the error correction. With an error correction also the ISVAG data might be lower. The maximum allowed error is 30% but differs depending on the measured parameter.
The RDF quality achieved in a stabilization MBT plant (Trockenstabilat© or MPS©) does not fit the requirements for the use in cement kilns due to the net calorific value (NCV) of 15,000 kJ/g. Co-combustion in coal fired power plants or mono-combustion in RDF fired power plants (fluidized bed and grate firing systems) are typically used. Due to the higher plastic content in Flemish waste a higher NCV could be anticipated.

Compared to MWI, the emissions of MBT depend strongly on downstream processes such as RDF utilization and landfilling of the residual fraction.

- For greenhouse gas emission, MBT scenarios with co-combustion show advantages relative to MWI or MBT with RDF mono-combustion because of the high CO₂ emission factor of the substituted fuel in co-combustion.

- For mercury, the co-combustion scenarios show higher overall mercury emissions due to the, for mercury reduction insufficient, flue gas cleaning of cement kilns and power plants. The limitation of controlling the mercury content in the RDF by mechanical processing has been shown number of studies.

- The assessment for dioxins is due to the uncertainties in the downstream processes (RDF combustion, landfilling) not possible.

The actual price level for MBT treatment cost in German is between 100-180 €/t with an average of 126 €/t. The price level for MWI is in a similar price range with an average of 130 €/t. Under Flemish conditions an additional landfill tax of 14 €/t waste input would apply for the MBT scenarios and exception permit for the landfill band would be required.

The main financial risk of applying MBT technologies is a not developed market for high calorific fractions from MBT plants in Flanders.

Recommendations

On the basis of this assessment two recommendations were made for the ISVAG MWI in Wilrijk:

- The potential of a further reduction and optimization of the SNCR technology of NOₓ should be considered for the location of the ISVAG MWI in Wilrijk.

- It can be stated that the environmental benefits are not evident for MBT technologies under Flemish conditions. Specifically long term impacts due to landfilling have to be considered. But there are market risks due to lack of capacity for the utilization of RDF in Flanders and, thus, uncertainties about the final disposal price have to be considered in the overall assessment.
In concreto, as a short term result of this study the decision was taken to adapt the existing SNCR in order to achieve the long-term target to stay below 100 mg/m³ NOₓ. Changes in the energy performance showed clearly limitation due to the location of the plant, while alternative waste treatment technologies were not considered as environmental beneficial and feasible under Flemish conditions.

Conclusions

The case study described in this article shows how BAT assessment can be used as an instrument for a continuous monitoring and improvement of waste treatment facilities. It allows regarding cross-media effects of technologies and environmental trade-offs of unidirectional improvements and gives sufficient flexibly to adapt remedies too local conditions.

Nevertheless, the actual set-up of the “Best Available Techniques Reference Document” (BREF) for Waste Incineration” (WI-BREF) is not suitable to assure the best environmental performance because published emission data are up to 12 years old and do not reflect new technical developments. In addition there are no uniform measuring, calibration and reporting rules for emission and consumptions data on a European level. Here plants will need in the future BAT conform monitoring. This might include the monitoring of down stream processes like treatment and disposal of solid residues.

Not possible to assess with BREF documents is the performance of MWI relative to alternative waste treatment technologies such as gasification, pyrolysis or mechanical-biological treatment. This requires additional evaluation tools.

References


