17th European Symposium on Computer Aided Process Engineering – ESCAPE17
V. Plesu and P.S. Agachi (Editors)



# Emissions abatement in Waste-to-Energy Systems

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## Abstract

The paper is focused on analyzing methods which enable a substantial reduction of POP emissions to meet the environmental limits. Technologies based on adsorption of harmful compounds using activated carbon, technologies DeNOx/DeDiox as well as technology of catalytic filtration using a special material REMEDIA D/F are considered and compared. The latter technology consists in using a bag-house with bags manufactured from a special material (two layers – membrane from expanded PTFE and felt with bound in catalyst) called REMEDIA which has successfully been used for removal of PCDD/F during recent period. An optimum design is based on computational support concerning the bag-house. It is illustrated through an industrial application of municipal solid waste (MSW) incinerator with capacity of 15 t/h of waste treated.

**Keywords:** PCDD/F, dioxins, catalytic filtration, municipal solid waste,

## 1. Introduction

The emission limits for all pollutants, liquid and solid particulates of incineration and processing, have become stricter by the new European Union regulations [1].

The toxic character of a group of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/F), also known as “dioxins“ is now required to be at lowest possible level of their concentration. This has been set in the European Union in 1994 to 0.1 ng TEQ/$m_N^3$.

## 2. Methods of removing dioxins

For reduction of POP emissions and comply with the emission limits a number of widely used methods based on the adsorption principle of undesirable compounds using activated carbon are used, for example DeNOx/DeDiox technology or catalytic filtration REMEDIA D/F.

The efficiency running and operation costs of these approaches have to be analyzed. The analysis has been made for a waste incineration plant unit with a capacity of 15 t /h.

### *2.1. Municipal Solid Waste (MSW) incinerator*

The analyzed incinerator unit (Fig.1) is composed of four combustion chambers with cylinder grates with an equal output of up to 15 t/h. Three boilers are used for energy thermal processing, the fourth serves as a backup. The boilers output is 36 t/h of steam at a temperature of 235 °C and pressure 1.37 MPa. The steam is distributed into the heating power grid.

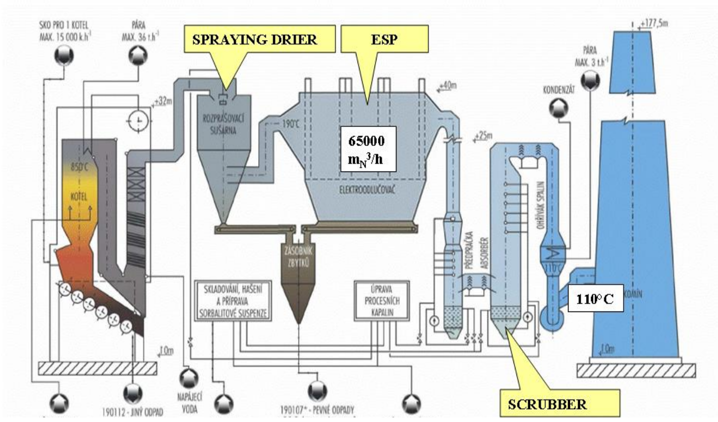



Fig.1 Configuration of an incinerator

### *2.2. Adsorption method*

Reduction of the concentration of dioxins is reached by adsorption cleaning of the flue gases in this incineration plant. Activated carbon is used as an adsorbent (SORBALIT). Undesirable high molecular particulates and heavy metals (mainly mercury) are caught on the surface of activated carbon, which is dosed together with a lime suspension in the technological part of the wet cleaning of the flue gases and is then sprayed in the spray chamber.

Notable reduction of the level of dioxins was reached using this method up to 0.098 - 0.054 ng TEQ/$m_N^3$. These values have reduced the concentration of dioxins under the emission limits, but not substantially. This method does not guarantee complete removal of dioxins, only their adsorption and as a result a large amount of contaminated waste is created. For this reason the process could be further equipped by the dioxin technology with the aim of reducing dioxin emissions far below the emission limit of 0.1 ng TEQ/$m_N^3$.

*2.3. Combined $NO_x$ selective catalytic reduction (SCR) and dioxins destruction*

Another efficient technology for removal of dioxins is their catalytic decomposition, occurring together with selective catalytic reduction of nitrogen oxides (SCR) by means of ammonia [2] according to the following stoichiometric equations:

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O \qquad (1)$$

$$C_{12}H_nCl_{8-n}O_2 + (9 + 0{,}5\text{n})\ O_2 \xrightarrow{TiO_2} (n-4)\ H_2O + 12\ CO_2 + (8-n)\ HCl \qquad (2)$$

The reactions leading to the concurrent destruction of both nitrogen oxides and dioxins ($DeNO_x$/DeDiox) proceed in a catalytic reactor in a temperature interval from about 200 to 300°C. The efficiency of destruction of nitrogen oxides and dioxides is high in the catalytic reactor, but the reactor also has a certain disadvantage in its sensitivity to catalytic poisons and in a necessity to include it in the technology line only at a point where the flue gases is free from particulates, which practically means behind mechanical and chemical cleaning operations (Fig.2).

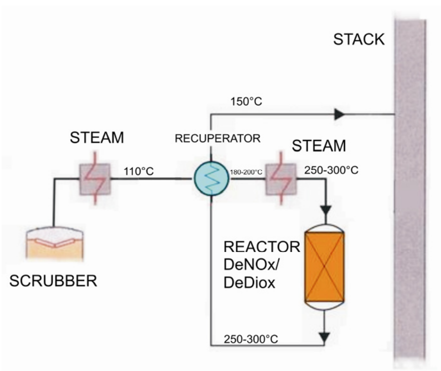



Fig.2 Scheme of DeNOx/DeDiox technology

This configuration requires reheating of flue gases up to a temperature necessary for reactions taking place in the DeNOx/DeDiox reactor.

*2.4. Catalytic Filtration*

On the basis of applied applications it has been found that the method of dioxin removal by catalytic filtration REMEDIA™ D/F [3] is still highly effective even after nine years, which considerably reduced the total annual cost. The method of catalytic filtration is based on a special GORE-TEX® texture which is used for the filtration bags of the fabric filter, where solid matters of fly ash are successfully separated and at the same time dioxins present in the filtered gas are broken down. The outer filter layer which is made out of a membrane from ePTFE, can separate about 96.6% of fly ash particles also containing compounds of heavy metals in the filtered gas. The cleaned gas enters the inner layer of the filtration layer which has in its structure built in components acting as catalysts which break down dioxins with 98.8% efficiency (see Fig.3) (at a level 0.01 to 0.03 ng TEQ/$m_N^3$). The inner filtration area is cleaned by a pulse-jet cleaning method.

The results obtained by the application of this technology at an incineration plant with a capacity of 96,000 t/y are shown in Fig.4. Catalytic filtration is situated directly behind the mechanical cleaning of the flue gases (electrostatic precipitator, thus there are no costs for heating of flue gases).

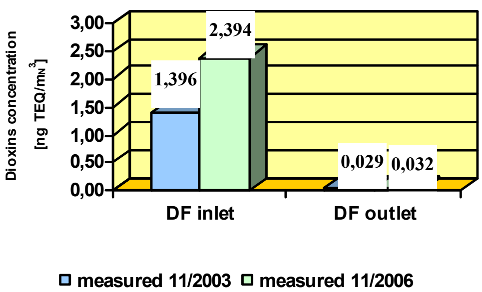



Fig.3 Efficiency of dioxin destruction in DF

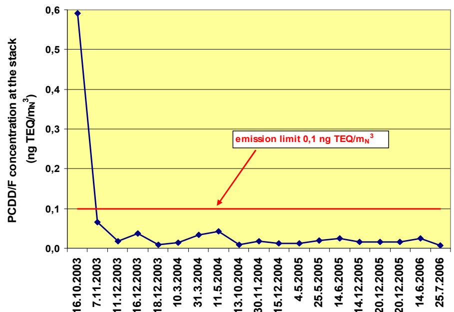



Fig.4 Result of PCDD/F measurements

## 3. Economical balance

To analyze the economical balance a computer based system for simulation calculations was used, making solution more approachable [4]. The resulting values are energy flows. Balance models can analyse various operation stages. Economic analysis has been carried out with the following values:

- Flow rate of flue gases — 65000 $m_N^3$/h
- Temperature of flue gases — (DeNOx/DeDiox) 110 °C; (REMEDIA D/F) 220 °C
- Annual period of running of the incinerator plant — 8,000 h/y

### *3.1. Economic balance of technology DeNOx/DeDiox*

Annual economic balance of the operation of DeNOx/DeDiox technology is composed of:

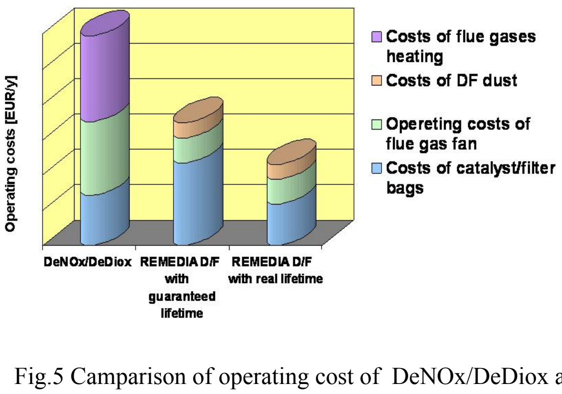
- Catalyst costs (*from the balance calculations space speed 2,300 $m_N^3/m^3.h$ was set, from which the minimum volume of the catalyst was given. The operation life of the catalyst for the economic analysis was considered as 4 years.)*
- Energy costs of the fan drive (*the pressure drop of all parts of the DeNOx/DeDiox technology based on the balance calculation was 6 kPa which set the energy consumption of 218 kW required to increase the output of the fan.)*
- Cost for heating of flue gases *(the amount of the supplied heat required for preheating of flue gases at a certain temperature was calculated from the balance calculations as 3.92 GJ/h).*

### *3.2. Economic balance of technology REMEDIA D/F*

Annual economic balance of the operation of the REMEDIA D/F technology is composed of:

- Cost of the filtration bags (*from the balance calculations the filtration space 2,233 $m^2$ of the dioxin filter was set. For the economic analysis the guaranteed lifespan of the filtration tube was 4 years and its real lifespan 8 years.)*
- Energy cost of the fan drive (*the pressure drop of the dioxin filter based on the balance calculation was 2 kPa which set the energy consumption of 94 kW required to increase the output of the fan.)*
- Cost required to spray the flue gases before entering the filter

### *3.3. Results of the economical balance*




All running cost linked with a one year operation of the unit is included. The operating cost of the catalytic filtration DeNOx/DeDiox rises due to the reheating of flue gases to the required temperature of the reaction of about 250 °C and the cost linked with the increased pressure drop (Fig.5).

Fig.5 Camparison of operating cost of DeNOx/DeDiox and REMEDIA D/F technology

Catalytic filtration REMEDIA D/F does not require heating of flue gases and the cost of the filtration bags fall due to their real lifespan.

## 4. Conclusions

Results gained from the operation of a process based on catalytic filtration REMEDIA D/F show high efficiency, i.e. its ability to reduce the concentration of dioxins under required emission limits. The operation cost is up to 61.4% lower than those of the DeNOx/DeDiox technology mainly due to real lifespan of filtration bags. This method of cleaning of flue gases from dioxins is used in about 50 incinerator plants at present with a various rated output on a worldwide basis.

## Acknowledgements

We gratefully acknowledge financial support of the Ministry of Education, youth and sports of the Czech Republic within the framework of research plan No. MSM 0021630502 „Waste and Biomass Utilization focused on Environmental Projection and Energy Generation" as well as support from the Czech Science Foundation within project No. OE 156.

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