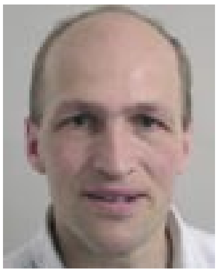
# Emissions



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**Waste incineration solves one important environmental problem: It reduces the waste disposal problem by volume and weight, saving precious land from being "destroyed" by landfills. Moreover, it sterilises and makes it possible to recover the incombustible part of the waste (the bottom ash). But it also generates environmental problems, especially an air pollution problem, which requires extensive flue gas treatment before discharge to the air. However, as the text below demonstrates, these pollution problems are manageable.**

**Incineration generates energy, thereby substituting fossil fuels. This results in less $CO_2$ per unit of energy produced. Incineration thus contributes to reducing the greenhouse effect. Especially when the alternative disposal route, i.e. landfilling and the consequential methane formation are taken into consideration, the overall environmental effect of incinerating the waste is extremely positive.**

## Emissions to air

In order to comply with the EU Directive 2000/76 on the incineration of waste, the flue gas from the incineration furnace/boiler system must be treated for the following air polluting substances:

- dust
- acid gases (HCl, HF, $SO_2$)
- heavy metals (Hg, Cd+Tl, Sb+As+Pb +Cr+Co+Cu+Mn+Ni+V)
- dioxins

which may be done either in up to 4 subsequent stages (wet treatment) or in one common treatment step (dry and semi-dry treatment), possibly supplemented by a polishing stage.

In addition, the content of nitrogen oxides ($NO_x$) must be reduced (see later).

In ***wet flue gas treatment,*** the first stage is normally the removal of dust, *i.e.* the fly ash from the combustion process. This is uaually done in an electrostatic precipitator (ESP). Properly designed, the ESP also removes the heavy metals (except Hg), to below the respective emission limit values. The fly ash is also the major outlet of dioxins from the incineration process. The fly ash is often mixed with ash collected in the boiler and disposed of as hazardous waste.

In the next treatment stage the gas is washed with water in an 'acid' scrubber. This process removes the HCl to below the emission limit value under formation of a diluted hydrochloric acid with a pH of around 0. The acidic environment ensures that most of the Hg is also removed, and the content of other heavy metals and of fly ash is further reduced. In addition, most of the HF is removed. The spent scrubber liquid is passed on to a wastewater treatment plant (see below).

Then the gas is led to an 'alkaline' scrubber (the third treatment stage), where it is washed with a solution of sodium hydroxide (NaOH) or a suspension of limestone ($CaCO_3$). This process removes the $SO_2$ (and the remaining HF) to below the respective emission limit values. The spent liquid is subsequently treated in a wastewater treatment plant, as explained below.

Finally, the flue gas is treated with activated carbon or lignite coke (the fourth treatment stage) to have the remaining quantities of dioxins and Hg adsorbed. This usually takes place in a bag house filter, but wet variants may also be found. The spent carbon is normally passed back to the furnace for combustion. In this way the dioxin content is thermally destroyed.

The *wastewater* from the 'acid' scrubber must be neutralised. This is typically done in two steps, one with $CaCO_3$ to a pH of around 3 and a second with a NaOH solution to around pH 9. By addition of other chemicals, like $FeCl_3$ and TMT 15, the heavy metals and other solids are precipitated as a 'hydroxide sludge', which is dewatered in a filter press. The treated water is discharged as described below.

The water from the 'alkaline' scrubber is either a solution of sodium sulphate ($Na_2SO_4$) or a suspension of gypsum ($CaSO_4,2H_2O$) depending on the absorbent applied. In some cases the sulphate solution may be discharged, while in other it is treated with a solution of calcium chloride ($CaCl_2$, *e.g.* the treated wastewater from the acid scrubbing system) to form gypsum before discharge. The gypsum is filtered away and represents a third, separate solid residue from the wet flue gas treatment process. If necessary, $FeCl_3$ and TMT 15 are also added as described for the acidic wastewater, to precipitate remaining heavy metals and other solids.

In ***dry and semi-dry flue gas treatment systems,*** the flue gas is brought to react in a reactor with calcium hydroxide ($Ca(OH)_2$) introduced as a dry powder or in an aqueous suspension, respectively. In either case the lime reacts with the acidic gases, converting them to solid compounds ($CaCl_2$, $CaF_2$ and $CaSO_3/CaSO_4$). These compounds are removed – together with the dust (fly ash) – in a subsequent dust collector, normally a bag house filter. By adding activated carbon or lignite coke between the reactor and the bag house filter, it is also possible to remove the dioxins and Hg in the bag house to below the emission limit values.

One advantage of these processes is that no wastewater is generated, whereas a disadvantage is that it is necessary to add $Ca(OH)_2$ in excessive quantities, which end up in the residue. Consequently, dry and semi-dry processes produce a larger quantity and a more harmful solid residue than the wet process.

A variant supplements the semi-dry system with a polishing wet stage, designed in such a way that all the spent water from the final stage can be reused in the preparation of the lime suspension for the semidry treatment. Consequently, this variant is also wastewater-free.

***$NO_x$ Reduction*** is performed by bringing the flue gas to react with ammonia ($NH_3$) or urea. In either case the two compounds react to form free nitrogen and water vapour, which are harmless and may be discharged with the flue gas. Without a catalyst (Selective Non-Catalytic Reduction, SNCR), the process requires a temperature of around 900 °C and is therefore made in the afterburning chamber of the furnace. With a catalyst (Selective Catalytic Reduction, SCR), the process may be effected at temperatures between 160 and 350 °C, normally at the end of the 'flue gas treatment train'.

Both processes have advantages and disadvantages. A major disadvantage, when applying the SCR process, is that it is necessary to reheat the flue gas to the catalyst temperature. This requires a consumption

*Dry flue gas treatment systems*

of steam from the boiler lowering the net electrical efficiency, or even a fossil fuel like natural gas or gas oil. For that reason no Danish plant has yet selected the SCR process.

**Emissions to water**

The text above shows that only the wet process generates wastewater to be discharged, and the treatment has also been described. In this way, not only the fairly lenient water emission limit values of the waste incineration directive, but also some more strict national emission limit values may be complied with. The actual treatment requirements are stipulated in a wastewater permit.

**Bottom ash**

15-20 per cent of the waste by weight leaves the waste-to-energy facility in the form of raw bottom ash. The bottom ash is sorted, and in this process iron and other metals are recovered.

The sorted bottom ash is reused for construction works in accordance with the national ‘Residue Order’ issued by the Ministry of the Environment. In 2004, 564,000 tonnes of bottom ash was produced, and of this amount 554,000 tonnes, corresponding to approx. 98 per cent, was reused. The remaining quantity was landfilled as the environmental requirements for reuse could not be complied with. The iron, aluminium and other metals recovered from the bottom ash make up approx. 50,000 tonnes per year, which are recycled.

**Flue gas treatment residues**

The residues from the flue gas treatment are hazardous wastes, which, due to their leaching properties, cannot be landfilled even at a landfill for hazardous waste. Consequently, they are sent to special treatment/recovery facilities in Norway or Germany.

Approximately half of the amount in the form of fly ash comes from the waste, while the rest represents reaction products from the lime and activated carbon added in order to clean the flue gas. If a wet flue gas treatment method is applied, the result is a significantly smaller amount of solid residue, because the chloride is discharged with the wastewater.

In 2004, 181,000 tonnes of incinerator flue gas treatment residues were exported from Denmark.

**Environmental benefits**

Although (as indicated above) incineration of waste generates air and water pollution and residues for disposal, the overall environmental effect is positive.

When energy is recovered from waste, fossil fuels are substituted. Energy production on the basis of waste also results in air emissions lower than in the case of fossil fuels. This particularly applies to carbon dioxide ($CO_2$).

Had the waste been landfilled, it would have resulted in air pollution in the form of methane ($CH_4$) and a risk of soil and ground water pollution, due to leaching.

Carbon dioxide, methane and nitrous oxide ($N_2O$) are ‘greenhouse gases’ which have a climate change impact. On a weight basis, methane has 21 times more greenhouse effect than $CO_2$.

Denmark has ratified the Kyoto protocol and committed itself to reducing the total emission of greenhouse gases. Waste incineration makes a significant contribution to this reduction.

Waste landfills are extremely space consuming; if the waste is incinerated, landfill areas are saved. When incinerated, the waste is reduced as follows: by weight by 80-85 per cent and by volume by 95-96 per cent. Finally, incineration makes it possible to reuse the mineral components of the waste (the bottom ash). Hereby, natural raw materials in the form of gravel and iron are saved.

For a quantification of benefits in relation to the greenhouse effect, see the next article.

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