Dioxin removal: *Adiox* for wet scrubbers and dry absorbers

Adiox is an innovative technology for removing toxic dioxins from gases. Tower packings, droplet separators and fixed bed fillings can be made of this dioxin absorbing material. Sven Andersson, Siegfried Kreisz and Hans Hunsinger discuss the use of this novel technology under wet and dry conditions.

Introduction

There are a number of technologies available for removing or destroying dioxins from gases, such as baghouse filters and catalysts. The investment and/or running costs of these technologies are usually very high.

Adiox (patent pending) is a new dioxin removal technology that has established itself as an efficient and economic way to reduce dioxin emissions, and is marketed and sold by **Götaverken Miljö AB** as material deliveries, package units or turn key flue gas treatment systems.

Adiox: carbon filled plastics

The background for inventing *Adiox* resulted from an observation that plastics can absorb large amounts of dioxins from gases*; these can later be desorbed.

This absorption/desorption equilibrium is known as the *Memory Effect* (*see figure 1a*).

A situation where the *Memory Effect* plays an important role is during the start-up of an incineration unit, when large amounts of dioxins are formed due to unstable combustion conditions characterised by an incomplete flue gas burnout. The dioxins are absorbed in the construction materials of the flue gas cleaning system during the start-up phase, but are desorbed during the following period of normal operation. This desorption can lead to increased emissions over a very long time range.

Adiox was developed to avoid the dioxin desorption described above*. The *Adiox* material consists of a polymer, such as polypropylene (PP) – containing carbon particles. The dioxins are first absorbed in the polymer. Then they diffuse to the surface

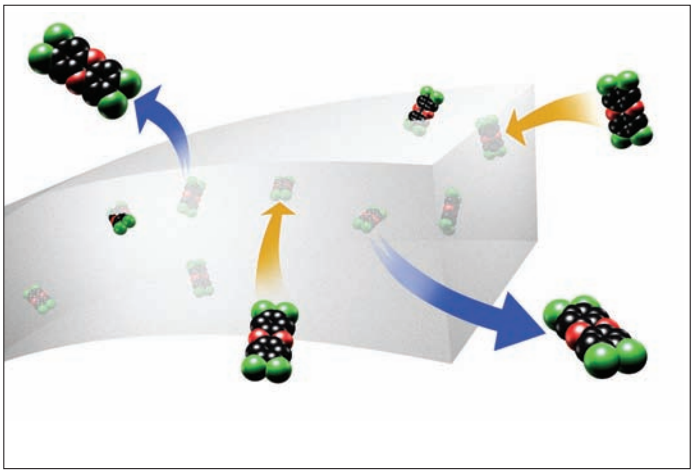

Figure 1(a): Schematic view of absorption/desorption in plastic

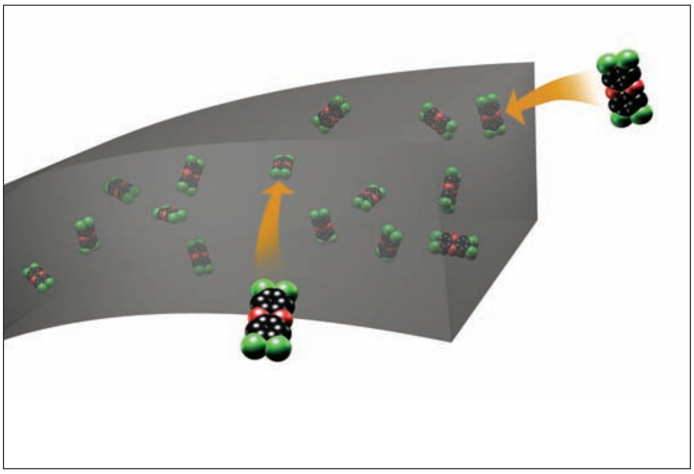

Figure 1(b): Schematic view of absorption/adsorption in *Adiox* (plastic containing carbon particles)

Figure 2: Adiox has been in operation as a primary dioxin removal system at Måbjergværket (Denmark) since the fall of 2004. All measurements are far below the 0.1 ng TEQ/Nm^3.

of the carbon particles, where they are irreversibly adsorbed (*see figure 1b*). The polymer acts as a selective barrier, which protects the carbon from adsorption by other contaminants such as Mercury (Hg.)

Several types of components, such as tower packings, demisters (droplet separators) and fixed bed fillings can be produced from *Adiox* material. By applying *Adiox* tower packings in existing wet scrubbers (gas-liquid contactor) the dioxin emissions are efficiently reduced and the *Memory Effect* is almost completely avoided.

The dioxin removal capacity of *Adiox* tower packings and demisters is favoured by the large specific surface area, selectivity for dioxins and high absorption capacity.

The expected life time of the *Adiox* material is 2-4 years, depending on the application. After usage, the dioxins are destroyed by incinerating the loaded material.

35 installations in 4 years

Adiox has been installed at more than 35 full scale incineration lines within three years, since its market introduction in 2002. The gas flows of these plants range from 5,000 to 180,000 m^3/h (normal, wet gas).

The first full-scale test installation was performed at the **municipal solid waste incineration plant of Thisted (Denmark)** in 2001, where the existing tower packings were replaced with the *Adiox* material.

A constant removal efficiency of 70% was maintained for one year, after the limited amount of *Adiox* tower packing had been installed in the existing scrubbers*.

A material optimisation program was carried out in parallel at the plant, by exposing different modifications of *Adiox* to the high dioxin concentration of 8 ng TEQ/m^3 (n., dry gas). The high absorption capacity of *Adiox* was thereby demonstrated.

Further research was done at a **second installation in Kolding (Denmark)**, where a pilot *Adiox* scrubber was operated to develop and demonstrate the concept of using *Adiox* as the main dioxin filter.

The impressive results of this pilot plant have lead to the **first full scale installation at Måbjergværket (Denmark)**, using only *Adiox* for dioxin reduction (*see below*.)

Adiox is particularly well suited for removing dioxins from gases including municipal solid waste incineration, hazardous waste incineration, chemical and biomass industries; *Adiox* has been successfully installed in all of these application fields.

Another application area is the metal industry, where several potential installations have been identified and are currently being discussed.

Adiox in wet scrubbers

Adiox allows the design of multifunctional wet scrubbers, where HCl, HF, SO_2 and oxidised Hg as well as dioxins can be removed simultaneously. Elemental Hg can be oxidised and captured in the scrubber using the MercOx process*, which can also be combined with *Adiox*.

Extended energy recovery using condensation of the flue gas can be integrated into the scrubber as well.

Adiox is easy to install in existing wet scrubbers. The circulation of the scrubber liquid keeps the material clean from dust deposits.

The use of *Adiox* tower packing as a "police" filter in a scrubber – downstream of a primary dioxin removal system such as a baghouse filter – results in additional security to guarantee low emission values. In this case, *Adiox* increases the margins in the case of, for example, carbon dosage failure, filter leakage or increased dioxin concentrations during start-up.

Adiox has been installed in scrubbers with additional carbon injection (**at AVR Avira, Netherlands**) as well as in a MercOx-scrubber, downstream of a baghouse filter with carbon injection (**at a hazardous waste incineration facility at Sakab, Sweden**).

At **Måbjergværket** (*see figure 2 on page 23*), wet *Adiox* scrubbers in combination with one electrostatic precipitator (ESP) per line have acted as the main dioxin filter since the fall of 2004. The eleven dioxin measurements performed so far show that the concentrations in the stack are permanently far below the emission limit of 0.1 ng TEQ/m^3 (n., d.g.).

Flue gas condensation for energy recovery is also integrated in the system. The required amount of *Adiox* material is typically larger than for a traditional scrubber, and is determined on the basis of the dioxin concentration after the electrostatic precipitator.

What are Dioxins?

Dioxins, or polychlorinated dibenzo-p-dioxins and -dibenzo furans (PCDD/Fs), are a group of persistent and extremely toxic chlorinated organic compounds. Major emission sources are known to be processes like waste incineration, metal production, bio-fuel incineration and uncontrolled combustion. Under stationary effective combustion conditions, dioxins are almost completely destroyed during incineration, but are re-formed during the cooling of the flue gas* and during dust separation at temperatures above 200 °C by de-novo synthesis*. A review of the formation mechanisms involved is given by Tuppurainen et al*.

Dioxin concentrations are commonly reported as toxic equivalents (TEQ), which is the sum of the congener concentrations multiplied by their specific TEQ-factors. The extreme toxicity of 2,3,7,8-Tetra-CDD (also known as Seveso-dioxin) is the reference and has a TEQ-factor of one. Dioxins and furans with larger numbers of chlorine atoms (including the 2-, 3-, 7- and 8-positions) have lower TEQ-factors.

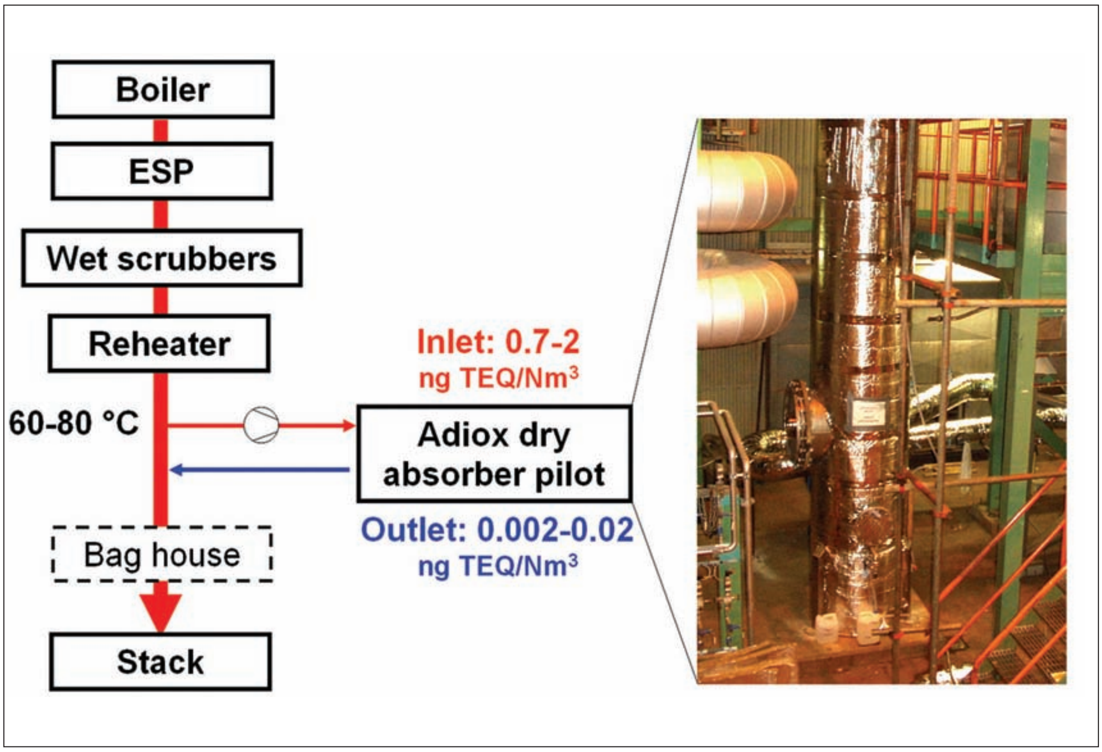

Figure 3: A compact state-of-the-art air pollution control system consisting of ESP, wet scrubber and dry Adiox absorber.

Adiox in dry absorbers

Using *Adiox* in a dry absorber instead would have the effect of making the installation more compact. The initial laboratory tests with *Adiox* were performed with dry gas. The full-scale installations made so far, however, have been carried out in wet scrubbers.

If *Adiox* is employed in a dry absorber instead of a wet scrubber, the removal efficiency per installed amount is higher, since the water film in a wet scrubbing process poses a mass transfer limitation for the dioxins. Less material is thereby required for the same removal efficiency. Fixed bed carbon filters are sometimes used as a final dioxin removal stage.

There is a risk of fire in these filters, and contaminated dust particles may escape during operation or on handling of carbon pellets.

Using *Adiox* material instead of carbon pellets would not have these disadvantages. The design of the absorber can be kept simple, since no material dosing systems are required. Granular beds have porosities around 30%. If the gas contains particles, parts of the bed may be clogged, leading to channelling and increased pressure drop. Tower packings, originally designed for the use in wet scrubbers, can be used instead. The porosity is typically 95%, which reduces the risk for clogging. Intermittent rinsing may be used to clean the surface during operation.

A simple, cost-effective pollution control system can be obtained by combining an ESP, a multi-functional wet *Adiox* scrubber and a dry *Adiox* absorber (*see figure 3 above*).

A dry pilot absorber, using *Adiox* tower packings, was installed **at line 1 of the Renova municipal waste incinerator in Göteborg (Sweden)**. The flue gas treatment consists of an ESP, two wet scrubbers, reheater and a baghouse filter as seen in *Figure 4*.

The second scrubber is used for enhanced energy recovery with flue gas condensation by cooling the gas from 60 to 40°C using heat pumps during the cold season. The gas is reheated to typically 60-80°C. The pilot absorber operates with a fraction of the total gas flow (approximately 3000 m^3/h) extracted after the reheater. Today, SO_2 and dioxins are removed in the baghouse filter.

The pilot experiments demonstrate the possibility of removing the dioxins in a dry *Adiox* absorber instead of a baghouse filter. In such a case, SO_2 could be removed in the wet scrubbers.

The inlet concentrations ranged from 0.7 to 2.0 ng I-TEQ/m^3 (n, d.g., 11% O_2), and the clean gas concentrations ranged from 0.002 to 0.02 ng I-TEQ/m^3 (n, d.g., 11% O_2). No trend of decreasing removal

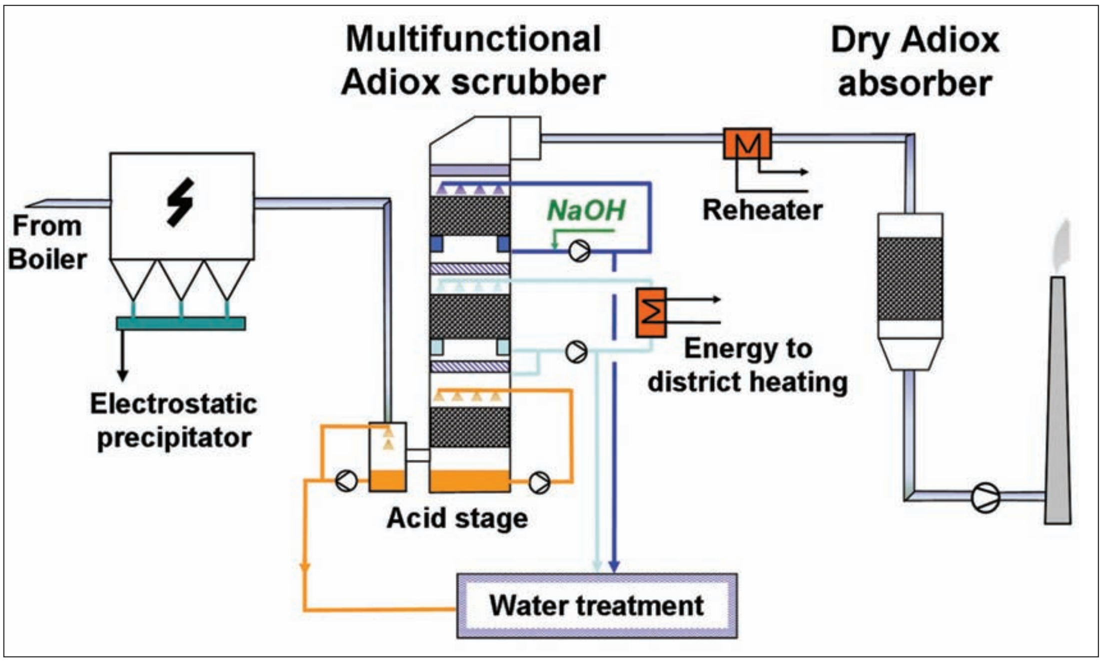

Figure 4: Pilot Adiox absorber at the Renova municipal waste incineration plant in Göteborg, Sweden. The dry Adiox absorber is located downstream of an ESP, wet scrubbers and re-heater. The removal efficiency was higher than 97.5% in all measurements with this configuration.

efficiency with time could be seen. All measured particle associated dioxins were <<0.1 ng TEQ/Nm^3 in this plant.

The highest temperature during the tests was 90 °C Initial tests have been made with glass fibre filled *Adiox* in order to guarantee dimensional stability of the packings at even higher temperatures.

One important consideration for the pilot test was to assess the amount of fly ash collected on the *Adiox* surface during operation. No rinsing of the tower packings was therefore made during the test.

After 9 months, the *Adiox* tower packings were covered by a thin, porous layer of particles, which could easily be removed by rinsing with water. No change in pressure drop or decrease in removal efficiency with time could be seen during the whole period.

The aim of this pilot installation was to demonstrate how the complete dioxin removal can be achieved in a static, compact and robust piece of equipment downstream of a conventional flue gas cleaning system.

Conclusion

Adiox is very well suited for selective absorption of dioxins and has a high loading capacity.

It can be integrated in new or existing wet scrubbers without the need for additional equipment.

Using the material in a dry absorber can decrease equipment sizes due to the higher efficiency per volume.

It is effective even during start-up and in stationary operating conditions, where other technologies may not work optimally. Other advantages are:

- Ease of installation;
- A reduction (or even avoidance) of the *Memory Effect*
- Multifunctional HCl, HF, SO2 removal, and condensation;
- A high porosity – low clogging risk;
- Clean handling and no "hot-spots";
- No final residue (PCDD/Fs are destroyed by incineration);
- A simple, static system with high availability. ●

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