Catalytic Destruction of PCDD/F in a Fabric Filter

Experience at a Municipal Waste Incinerator in Belgium

Jean Luc Bonte
C.V. IVRO
Oostnieuwkerksesteenweg 121
8800 Roeselare
Belgium

Keith J. Fritsky
Marc Plinke
W. L. Gore & Associates, Inc.
101 Lewisville Road
Elkton, MD 21921
U.S.A.
kfritsky@wlgore.com

Michael Wilken
Michael Wilken
UmweltConsulting
Florastrasse 8
D-12163 Berlin
Germany

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ABSTRACT

In order to comply with dioxin and furan (PCDD/F) emission regulations in Belgium, the IVRO municipal waste incinerator adopted catalytic filters for use in the plant's two existing fabric filters. This system replaced the injection of powdered activated carbon (PAC) because of concerns that PAC, used at temperatures above 200ºC, would ignite and lead to fires and plant downtime. The performance of the catalytic filter system, since its installation in 1997, is described. PCDD/F emissions are controlled to well below the regulatory limit of 0.1 ng I-TEQ/Nm^3. The amount of PCDD/F entering and exiting the fabric filter is quantified. The resulting mass balance shows that greater than 99.5% of the gaseous PCDD/F entering the fabric filter is destroyed by the catalyst within the filter media.

INTRODUCTION

Plant Description

The IVRO municipal waste incinerator is located in Roeselare, Belgium. The plant configuration is shown in Fig. 1. The plant was built in 1976 and consists of two incinerator lines, each having its own air pollution control train consisting of an electrostatic precipitator, dry lime scrubber, and fabric filter. Each incinerator and flue gas cleaning line feed into one common stack. Over the years the capacity of each incinerator line has increased from 3.2 tons of waste per hour to 4 tons of waste per hour. In 1996, new PCDD/F regulations were enacted, prompting IVRO to install a powdered activated carbon (PAC) injection system. The PAC system was used at temperatures of 200ºC - 230ºC. At these high temperatures corrosion can be kept to a minimum, however, there is an increased risk of a fire in the fabric filter. To avoid the risk of fires and plant shutdowns, IVRO began to look for alternatives to PAC. In 1997, catalytic filters were installed in three compartments in the existing Line 2 fabric filter. Tests were conducted to verify that the filters could destroy PCDD/F below the regulatory limit of 0.1 ng I-TEQ/Nm^3. Upon successful verification, in 1998 IVRO equipped the remaining 17 fabric filter compartments of both lines with catalytic filters.

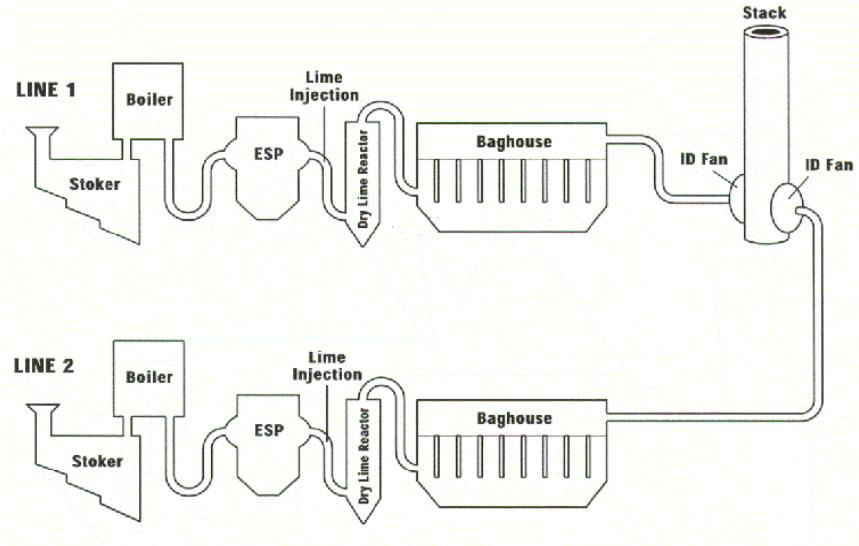

Figure 1. Plant configuration for the IVRO Municipal Waste Incinerator.

Regulatory Situation in Belgium

In the Flanders region of Belgium where IVRO is located, municipal waste incinerators are not allowed to operate unless the PCDD/F regulatory limit of 0.1 ng I-TEQ/Nm^3 is met. Continuous sampling and bi-weekly analysis for PCDD/F are performed to ensure compliance with the regulation during all stages of operation, including startup and shutdown. If an incinerator is found to be out of compliance, immediate measures to solve the problem must be enacted. An incinerator can be closed down if satisfactory progress toward compliance is not demonstrated. As a

result of regulatory and enforcement actions to reduce PCDD/F emissions, 6 incinerators were closed down in 1997 after a measurement campaign of 19 incinerators; the remaining 13 incinerators instituted measures to control emissions [1]. By 1998 the remaining incinerators were in compliance with the regulatory limit, and by 2000 the average annual emissions of PCDD/F from all municipal waste incinerators in Flanders, were reduced from more than 120 g/yr to less than 1 g/yr [1].

DESCRIPTION OF CATALYTIC FILTER SYSTEM

The catalytic filter system employed by IVRO is the REMEDIA™ D/F Catalytic Filter System. This system is an evolution of two proven technologies: catalysis and surface filtration. The system consists of an ePTFE membrane and a catalytic felt substrate. This substrate is a needlepunched felt made from ePTFE fibers containing a proven dioxin-destroying catalyst. The catalytic felt destroys gaseous PCDD/F at low temperatures (160°C - 260°C) by means of a catalytic reaction. PCDD/F molecules diffuse on the catalyst surface and react to form trace amounts of CO_2, H_2O, and HCl.

The filters also employ a microporous, ePTFE membrane for particulate control, which is laminated to the catalytic felt substrate. The membrane, which is a GORE-TEX® membrane, captures submicron particulate (including heavy metals) without allowing particles to penetrate or pass through the catalytic felt substrate. Gaseous PCDD/Fs, however, pass through the membrane and into the catalytic felt. The catalysis and surface filtration principles are illustrated in Fig. 2.

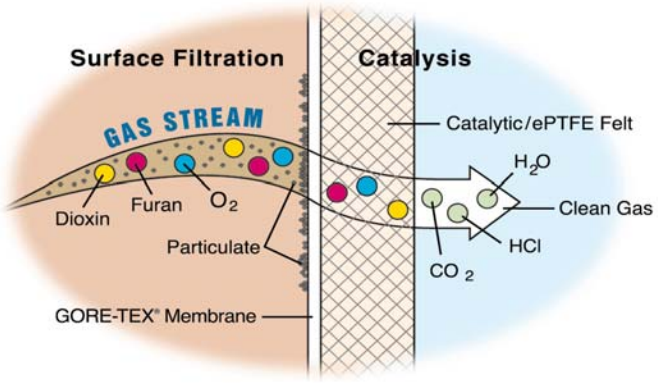

Figure 2. Cross-sectional view of the catalytic filter. The membrane removes particulate while the catalytic felt destroys gaseous PCDD/F.

PERFORMANCE OF CATALYTIC FILTER SYSTEM

PCDD/F Emissions

Figure 3 shows PCDD/F inlet ("raw gas") concentrations and outlet ("clean gas") emissions at IVRO since installation of the catalytic filters. Emissions have been well below the 0.1 ng I-TEQ/Nm^3 regulatory limit over a period of 42 months. Figure 4 shows the homologue distribution of PCDD/F in the raw and clean gas for one specific measurement performed on the fabric filter of Line 1. Figure 5 shows the distribution of all toxic isomers in the raw and clean gas for this same measurement on Line 1. The reduction of gas-phase PCDD/F is greater than 99.29% for all toxic isomers.

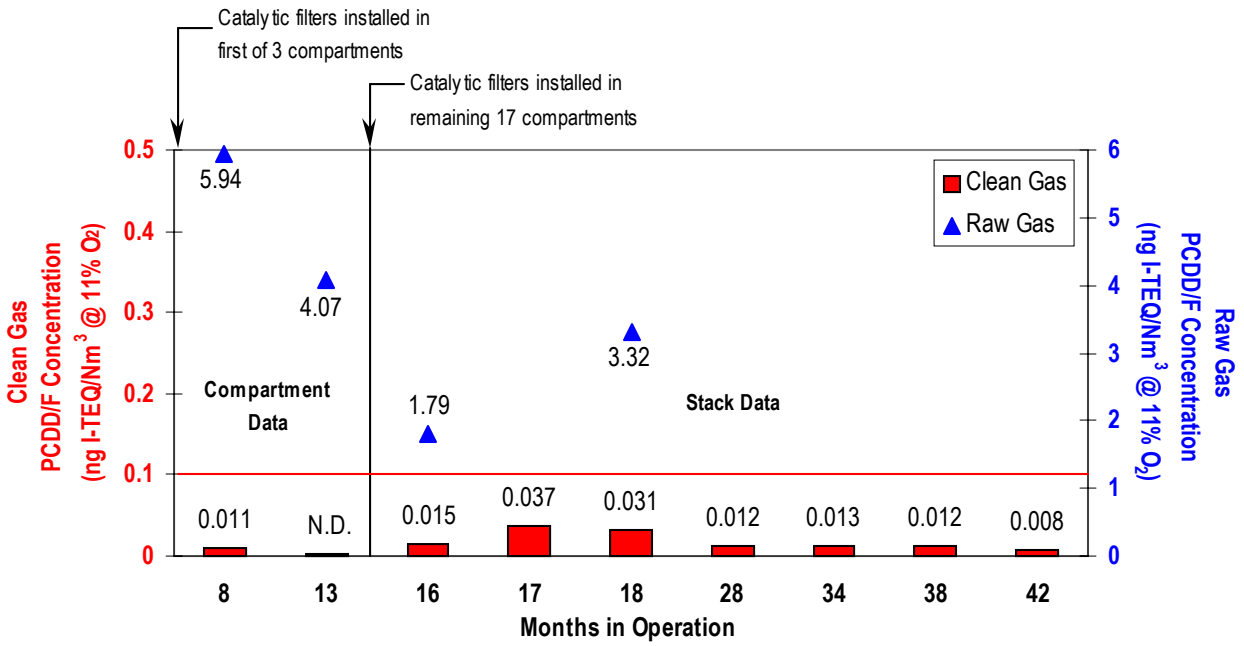

Figure 3. **PCDD/F concentrations (I-TEQ) in the raw and clean gas. Clean gas values represent total (solid + gas phase) PCDD/F. Raw gas values represent gas phase PCDD/F only; the total raw gas concentrations are 34% higher on average. Compartment data from Line 2. N.D. indicates values below the detection limit of 0.004 ng I-TEQ/Nm^3 for the total TEQ concentration. Measurements conducted in accordance with EN 1948, the European standard for sampling and analysis of PCDD/F.**

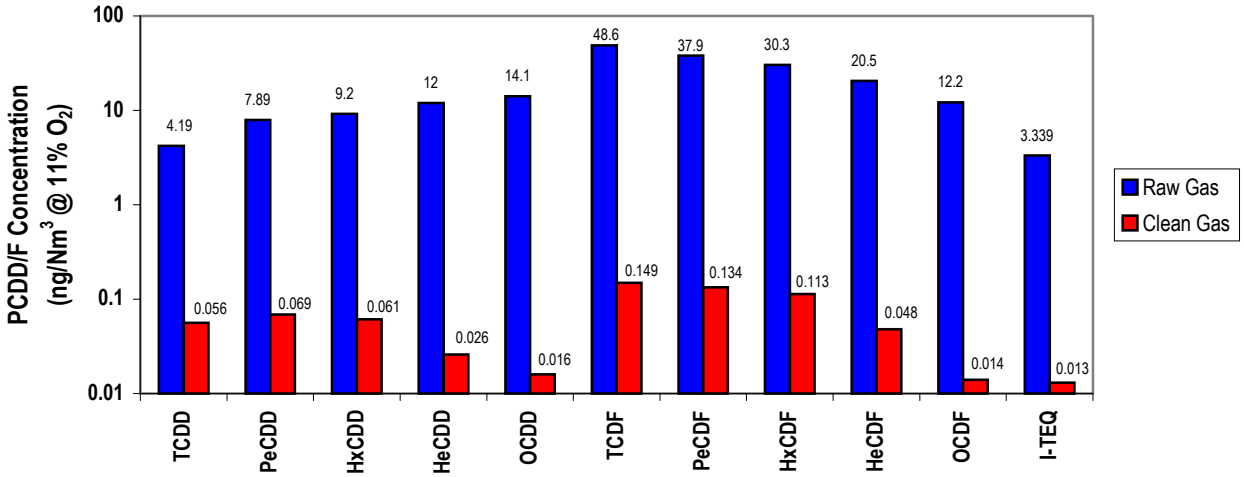

Figure 4. **PCDD/F concentrations in the raw and clean gas for all homologue groups – non-TEQ basis (Fabric Filter - Line 1). Raw and clean gas values represent gas phase PCDD/F only. The overall I-TEQ concentration is also represented. Measurements conducted in accordance with EN 1948, the European standard for sampling and analysis of PCDD/F.**

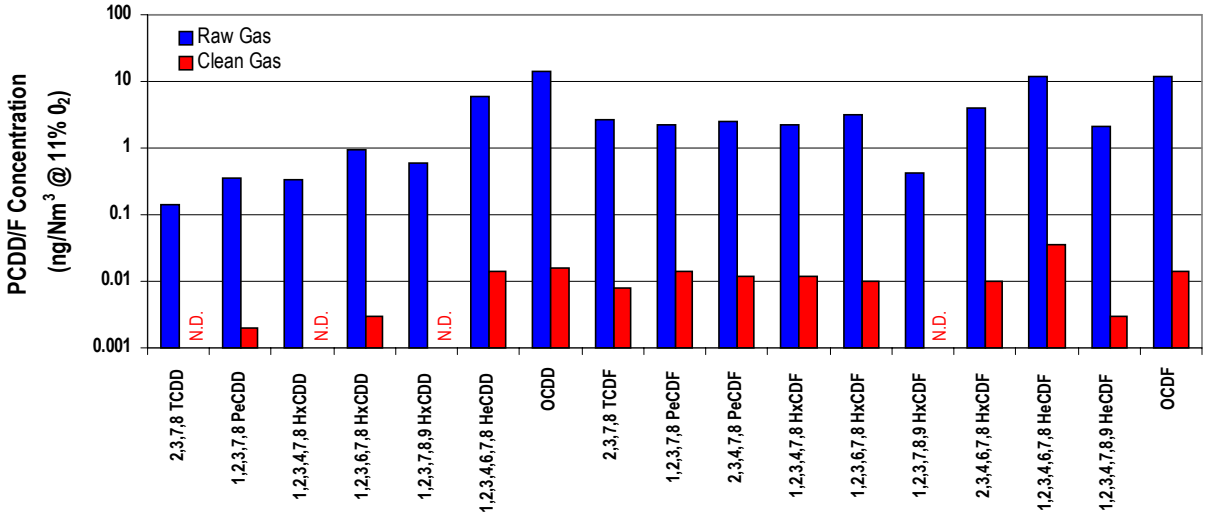

Figure 5. **PCDD/F concentrations in the raw and clean gas for all toxic isomers – non-TEQ basis (Fabric Filter - Line 1). Raw and clean gas values represent gas phase PCDD/F only. N.D. indicates values below detection limits of 0.001 ng/Nm^3 for the TCDD isomer and 0.002 ng/Nm^3 for the HxCDD/F isomers. Measurements conducted in accordance with EN 1948, the European standard for sampling and analysis of PCDD/F.**

Particulate Emissions

Over a period from August – September 1997, particulate concentration measurements were conducted at the outlet of a compartment in the Line 2 fabric filter. This compartment was the first in which catalytic filter media was installed. The particulate emissions ranged from below the detection limit (0.2 mg/Nm^3) to 0.4 mg/Nm^3 (at 11% O_2). In January 1999 the particulate concentration in the raw gas was measured as 2100 mg/Nm^3 at 11% O_2 [2]. Thus, the particulate removal efficiency at IVRO has been demonstrated to be >99.98%.

Destruction of PCDD/F

In the laboratory study of Weber et al., it has been shown that PCDD/F does not readily adsorb on the catalytic filter at 200ºC [3]. Approximately 0.05% is adsorbed on a TEQ basis, while the destruction efficiency is greater than 99.5% on a TEQ basis [3]. In another study by Xu et al., no organic compounds were found after the reaction of a model PCDD compound with the catalytic filter media, thus lending support to the theory that PCDD/F is converted to CO_2, H_2O, and HCl [4]. Both these studies were performed in the absence of particulate; therefore, the adsorptive effect of particulate (or lack thereof) on gas-phase PCDD/F could not be measured.

In order to quantify PCDD/F destruction in an actual plant where particulate is present, measurements of PCDD/F concentration on the filter media as well as fabric filter dust were performed for the IVRO case. The analysis of the dust reveals that there is no measurable adsorption of gas-phase PCDD/F on particulate within the IVRO fabric filter and normal operation temperatures of 200 – 230ºC. In Fig. 3 the average gas-phase concentration of PCDD/F in the raw gas is 3.78 ng I-TEQ/Nm^3. On a non-TEQ basis, the average is 215.75 ng/Nm^3. For 10 raw gas measurements where PCDD/F was partitioned between solid and gas phase, the solid-phase contribution to the total concentration averaged 25.3% on a non-TEQ basis. Using this percentage with the average gas-phase concentration yields an average solid-phase concentration in the raw gas of 73.07 ng/Nm^3. Given that the particulate concentration in the raw gas was measured to be 2.1 g/Nm^3, the amount of PCDD/F entering and discharging from the fabric filter in the form of particulate is 34.79 ng/g. The amount of PCDD/F bypassing the filter is negligible (<0.003 ng I-TEQ/Nm^3) due to extremely low particulate emissions. In a previous study of IVRO, the amount of PCDD/F in the fabric filter dust averaged 26.92 ng/g [2]. Therefore, the solid-phase PCDD/F entering the fabric filter accounts for all the PCDD/F found in the dust.

Since there is no adsorption of PCDD/F on particulate, the gas-phase PCDD/F must do one or all of the following: a) adsorb on the filter media, b) go through the filter media and be emitted, or c) be destroyed by the catalyst. Analysis of the filter media is required to determine the amount of gas-phase PCDD/F destroyed by the catalytic filters. For one line at IVRO, 707 m^2 of catalytic filter media are used. An analysis of a filter sample after 20 weeks of operation at approximately 200ºC showed that 4377.3 ng/m^2 of filter media was present on the sample. This translates into **3 mg** for the entire fabric filter (**PCDD/F_{FILTER}**). Given an average gas-phase PCDD/F concentration of 215.75 ng/Nm^3, and an average volumetric flow rate of 30,000 Nm^3/h for one line, the estimated amount of PCDD/F entering the fabric filter in 20 weeks is **21748 mg** (**PCDD/F_{IN}**). In Fig. 3 the average clean gas PCDD/F concentration is 0.92 ng/Nm^3 (0.016 ng I-TEQ/ Nm^3) which results in a total emission of **93 mg** in a period of 20 weeks (**PCDD/F_{OUT}**). The overall removal efficiency is defined as:

$$\mathbf{(PCDD/F_{IN} - PCDD/F_{OUT}) / (PCDD/F_{IN}) \times 100}$$

The percentage adsorbed on the filters is:

$$\mathbf{(PCDD/F_{FILTER}) / (PCDD/F_{IN}) \times 100}$$

The percentage destroyed is:

$$\mathbf{[PCDD/F_{IN} - (PCDD/F_{FILTER} + PCDD/F_{OUT})] / (PCDD/F_{IN}) \times 100}$$

On a non-TEQ basis, the overall removal efficiency is **99.57%**, the percentage adsorbed on the filters is **0.01%**, and the percentage destroyed is **99.56%**. On an I-TEQ basis, the overall removal efficiency is 99.52%, the percentage adsorbed on the filters is 0.01%, and the percentage destroyed is 99.51%. These results are consistent with the laboratory study of Weber et al. [3].

CONCLUSIONS

The performance of a catalytic filter system at the IVRO municipal waste incinerator has been monitored for over 42 months. Over this time, IVRO has maintained PCDD/F emissions well below the regulatory limit of 0.1 ng I-TEQ/Nm^3. The system reduces the raw gas concentration of each toxic isomer by more than 99%. Particulate removal was measured at more than 99.98%. By performing a mass balance for PCDD/F going in and out of the fabric filter, it was demonstrated that greater than 99.5% of the incoming PCDD/F is destroyed by the catalyst. As a result of adopting the catalytic filter technology, IVRO has been able to maintain temperatures in the fabric filter which inhibit corrosion, and has ceased using PAC, thus avoiding the risk of fire and plant shutdowns.

ACKNOWLEDGMENTS

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KEY TO ABBREVIATIONS

Nm^3	normal cubic meter
ePTFE	expanded polytetrafluoroethylene
I-TEQ	amount of 2,3,7,8 tetrachlorodibenzo-p-dioxin equal to the total PCDD/F calculated using International Toxicity Equivalency Factors
ng	nanogram
PAC	powdered activated carbon
PCDD/F	polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans

FOOTNOTES

*Jean Luc Bonte is currently the Director of IVRO.

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