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Ultra fine particles emissions from municipal solid waste incineration

by

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Ultra fine particles emissions from municipal solid waste incineration

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1 Background and goal of the project

In the last century the emissions of acid gases, heavy metals and particulate matter (PM) from industrial processes have been drastically reduced. However the emission of ultra fine particles seems to be still very high. Ultra fine particles are important because of their very small diameter and their associated health impact. Ultra fine particles with a diameter of less than 10 µm are defined as PM10. The PM10 immission along main traffic connections and in cities is mostly above the local limit. Important PM10 sources are road traffic, the off road sector, house heating, incineration and industrial processes. Generally it is expected that road traffic contributes 40 to 60% to the PM10 immission. Little is known about other PM10 sources.

In the past, waste incineration plants have estimated to be an relevant source for air pollution. Due to the incineration temperature and the waste composition (heavy metals salt and mineral componts) relevant PM10 concentrations can be expected. However, little is known about the efficiency of the flue gas treatment systems and the emissions of ultra fine particles in the range between 0.01 and 10 µm from waste incineration.

The goal of this project therefore is to measure the efficiency of different flue gas treatment technologies for ultra fine particles and to get a situation analysis of the emissions from waste incineration plants.

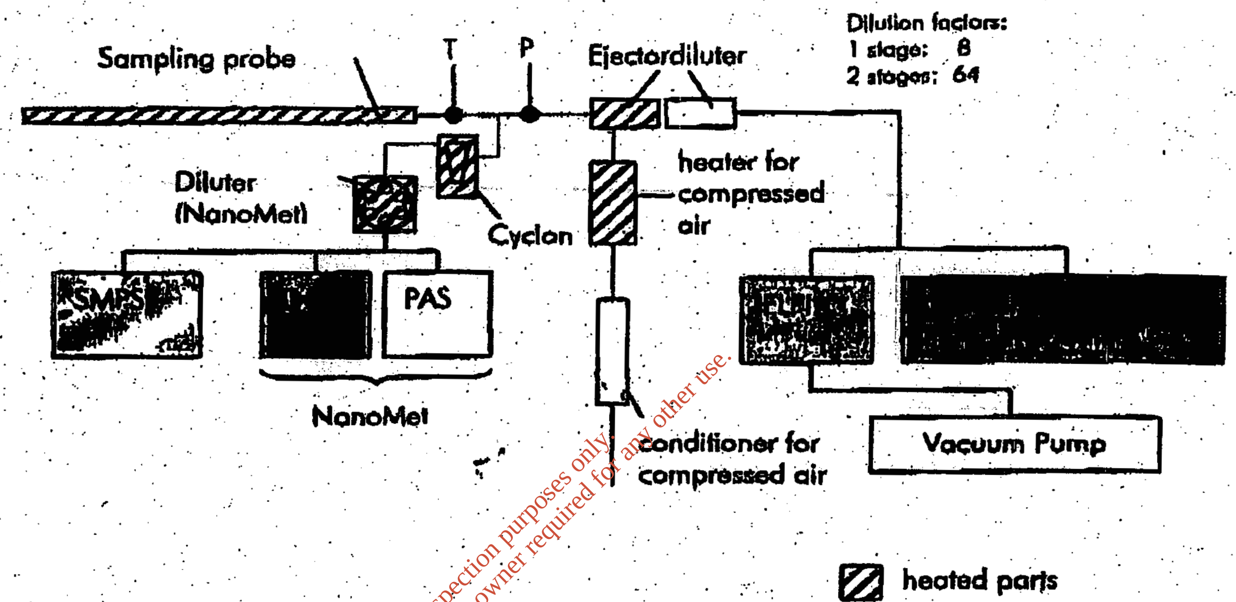
2 Particle detection systems

For the measurement of particulate matter usually gravimetric systems are used. These systems show the total mass of the particles, but nothing is known about the size and the size distribution of these particles. In this project the following measuring devices were used: NanoMet, SMPS, ELPI and OPC.

- NanoMet measures the total particle surface and delivers a qualitative signal of the total particle number.
- SMPS (Scanning Mobility Particle Sizer) is a measuring device for the particle concentration in function of the particle diameter up to 1 µm.
- ELPI (Electrical Low Pressure Impactor) measures the particle concentration in function of the particle size up to a diameter of 10 µm.
- OPC (Optical Particle Counter) is a laser optical particle counter and measureseres particles from 0.35 µm up to 17.5 µm in 13 size classes.

The following sketch shows the sampling system and the gas conditioning for the measuring devices.

<u>Sketch measuring setup</u>



The flue gas was heated up to 130°C and then diluted to prevent condensation. The dilution grade was depending on the particle concentration and was in a range between 1 : 75, 1: 300 for the SMPS and the NanoMet and 1 : 8, 1 : 64 for the ELPI

Removal efficency of traditional flue gas cleaning systems

During the project measurements in four different municipal solid waste incinerations (MSWI) have been carried out.

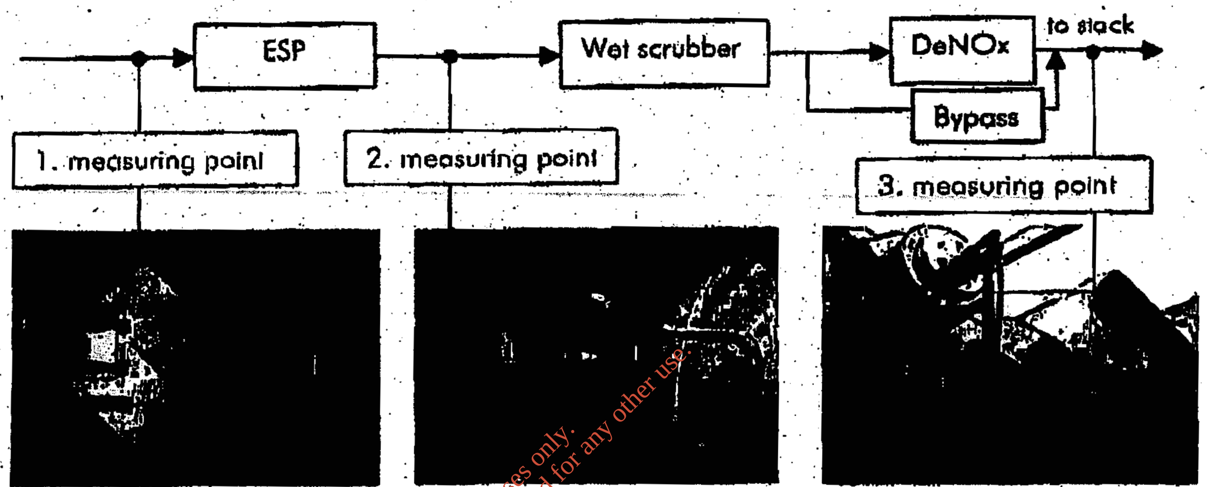
All plants were equipped with different flue gas treatment systems which included:

- Electro Static Precipitor or baghouse filter
- Wet scrubber
- SNCR or SCR – DeNox System
- Wet ESP

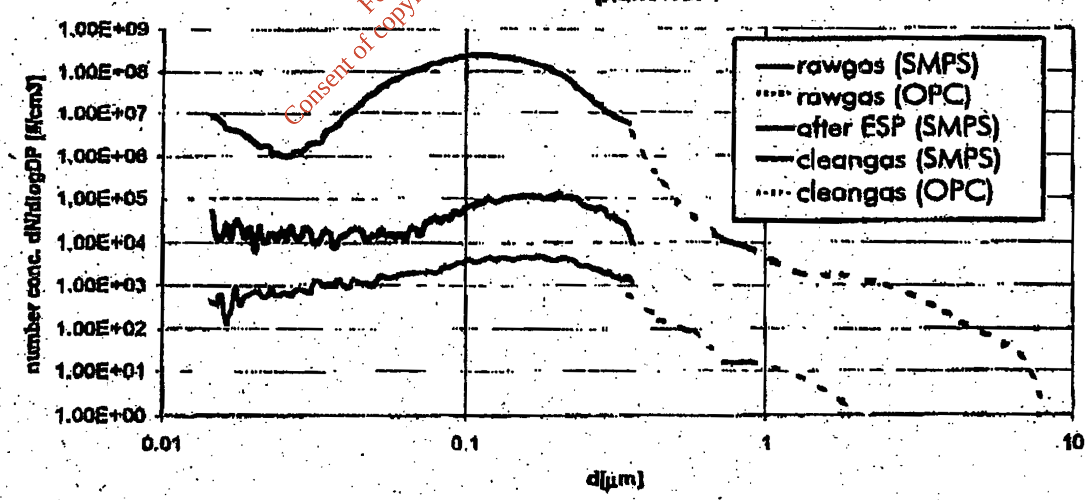
Plant No. 1

This plant is equipped with an ESP, wet scrubber and SCR-DeNOx. The mesurements were carried out:

- before ESP
- before scrubber
- in the stack



Measured values in rawgas, after ESP and in cleangas
plant No. 1

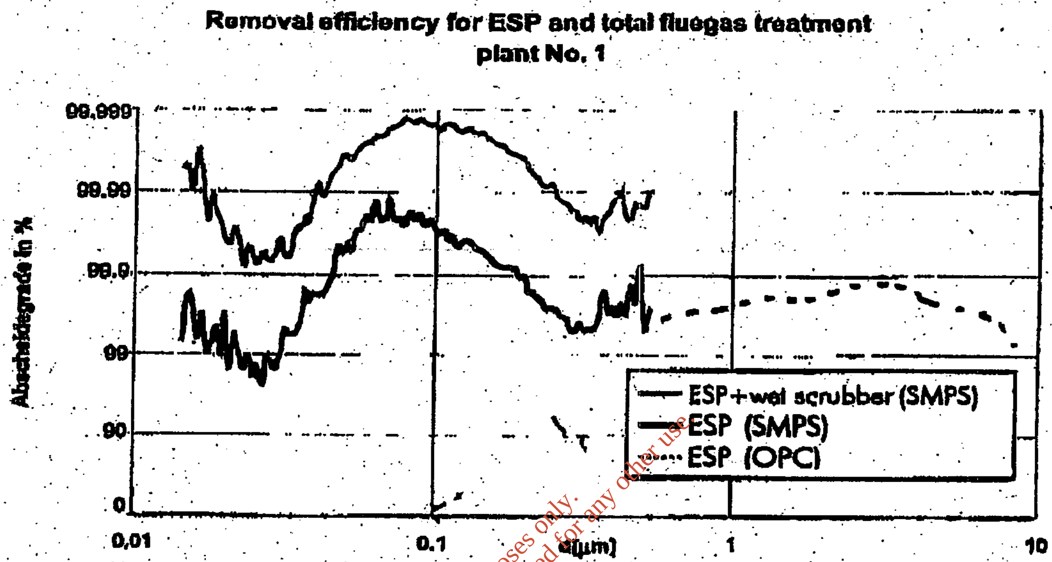


The flue gas before ESP has a maximum particle concentration of 10^8 particle/cm^3. This concentration is reduced down to 10^5 by the ESP and down to 10^4 by the wet scrubber. There are certain differences between the mesurements of the SMPS and OPC which results from different measuring principles. The tendencies of both results are the same.

It's interesting to see the slight shift of the maximum of the particle spectrum by the ESP. As a result of the charging characteristic the ESP has a minimum of efficiency at around 0.5 µm. Therefore the particle concentration after ESP has a maximum at 0.2 µm.

Removal efficiency

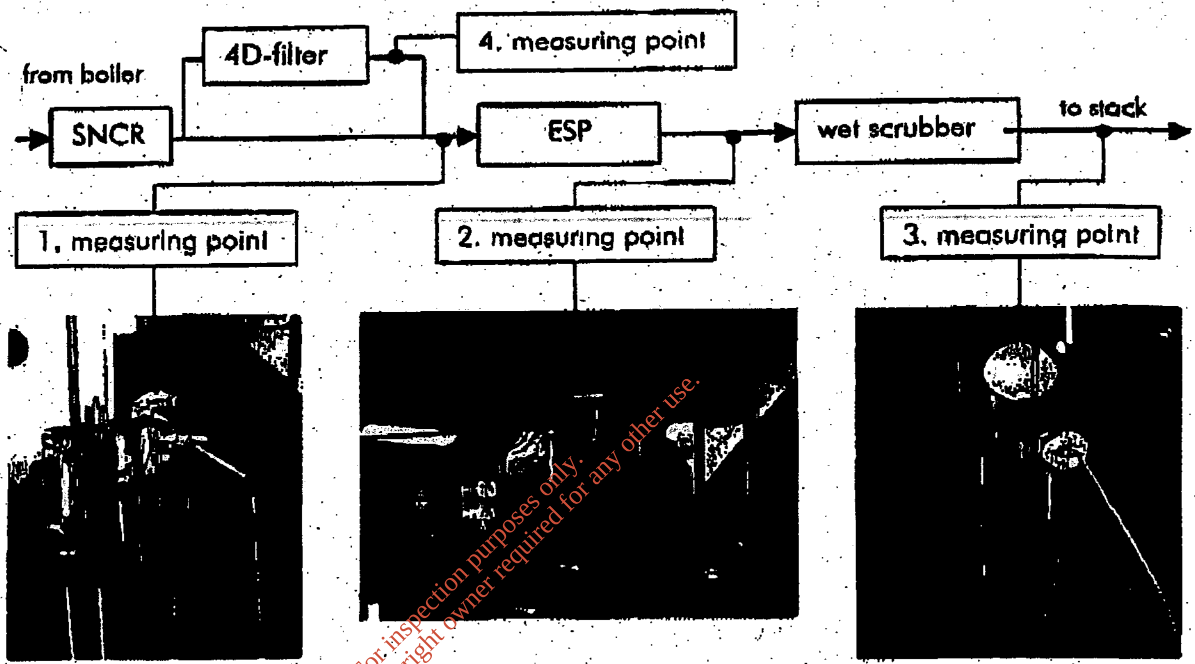
The following diagram shows the removal efficiency of the flue gas treatment for the plant No. 1. The ESP has a removal efficiency of 99 to 99.99 %. The total flue gas cleaning system has a removal efficiency of 99.95 to 99.995 %. It seems that the removal efficiency for particles smaller than 0.05 µm is smaller. This might be a result of condensation of sulfuric acid.



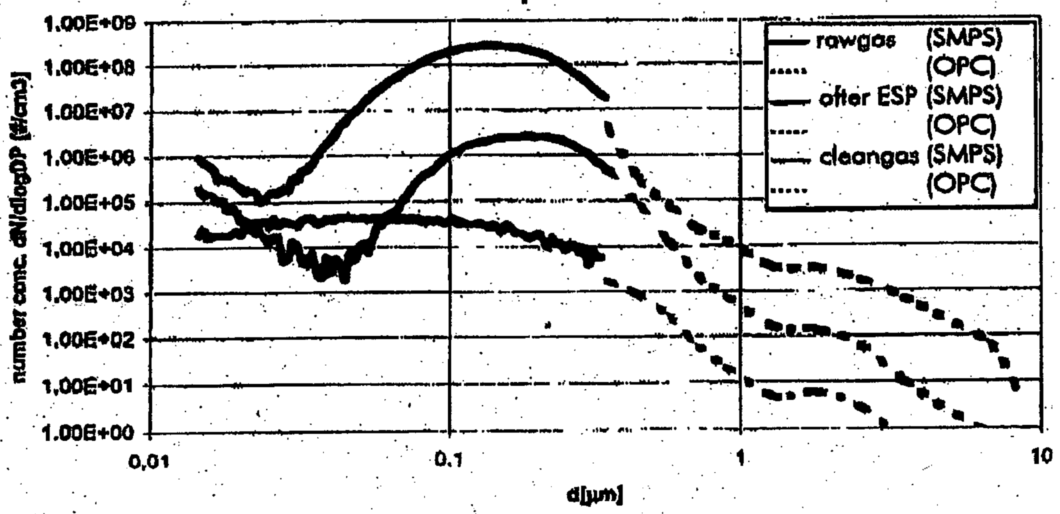
Plant No. 2

Plant No. 2 is equipped with an ESP, wet scrubber and SNCR-DeNOx. The measurements were carried out:

- before ESP
- before scrubber
- in the stack
- after 4D-Filter

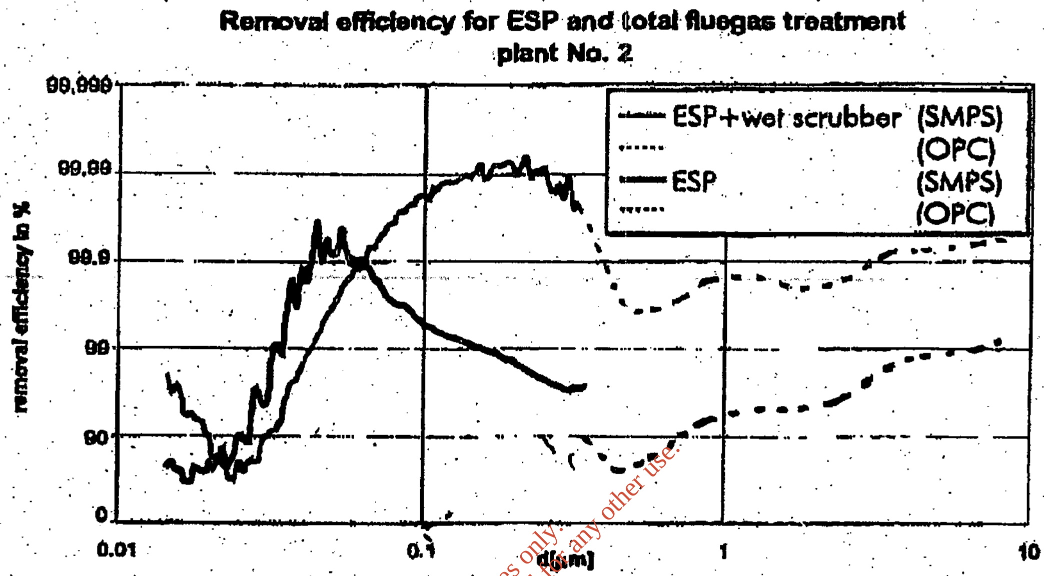


Measured values in rawgas, after ESP and in cleangas plant No. 2

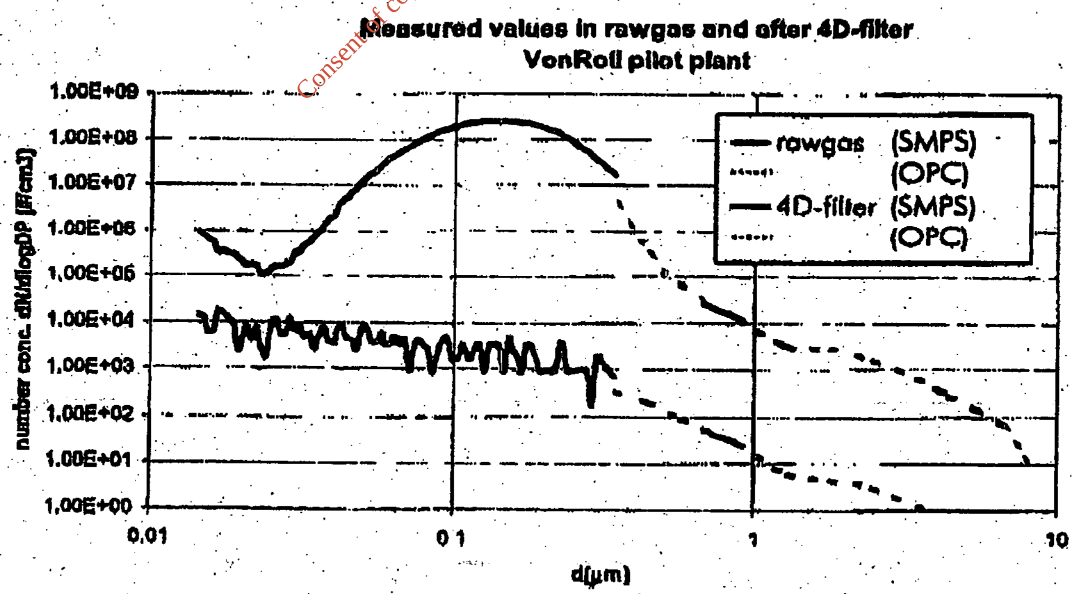


The conditions in the raw gas of plant No. 2 are similar to those in plant No. 1. Remarkably is, in comparison with plant No. 1, the much smaller concentration around 0.03 µm. The ESP reduces the maximum particle concentration by two orders of magnitude.

The wet scrubber again reduces the particles >1 µm by 99%. The reason for this significant reduction might be the "ring-jet"-Venturi stage of the wet scrubber. The observed slight increase of the particle concentration around 0.04 µm could be caused by the agglomeration of ultrafine dust by Amonium from the SNCR-System.



The removal efficiency of the total flue gas treatment (ESP/wet scrubber) in the concentration maximum amounts to 99.99% .

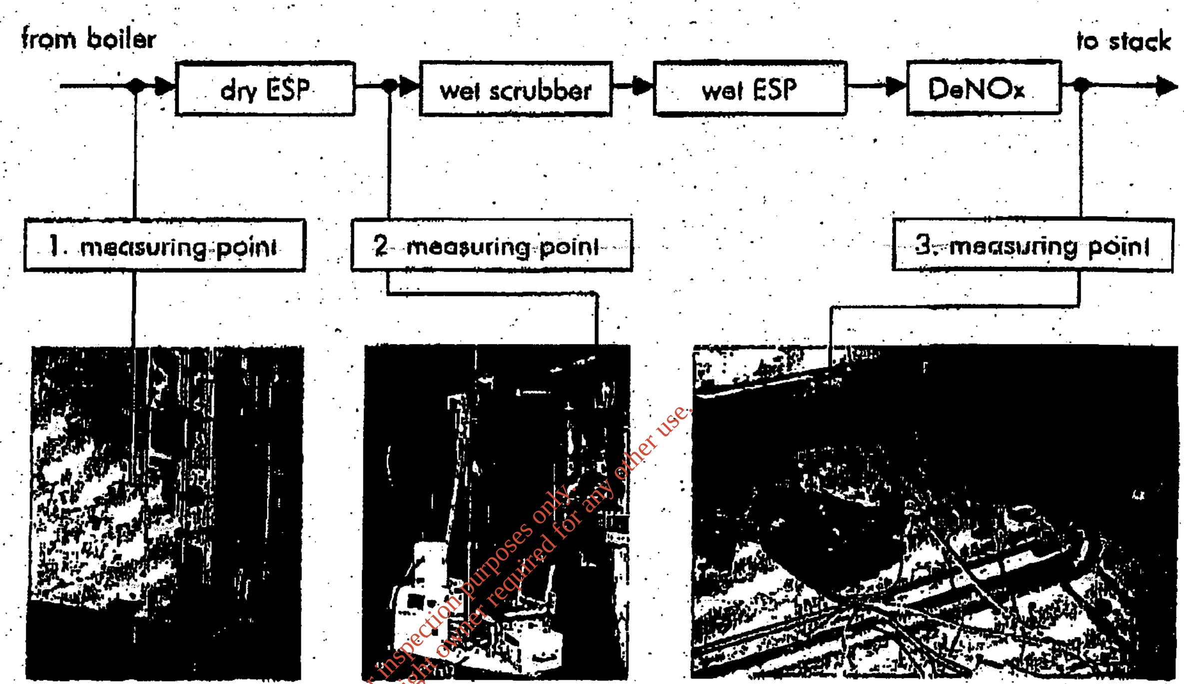


The "4D-Filter" (DeDust, DeNOx, DeDioxin, Desulferisation), a pilot plant of VonRoll in the plant No. 2 was also measured for its PM10 removal efficiency. Concerning the fine particles, the pilot plant works highly efficient. Values below 10^4 particle/cm³ are achieved by the ceramic filter candles. The fine particle removal efficiency is higher than the configuration 2-field ESP and Venturi wet scrubber.

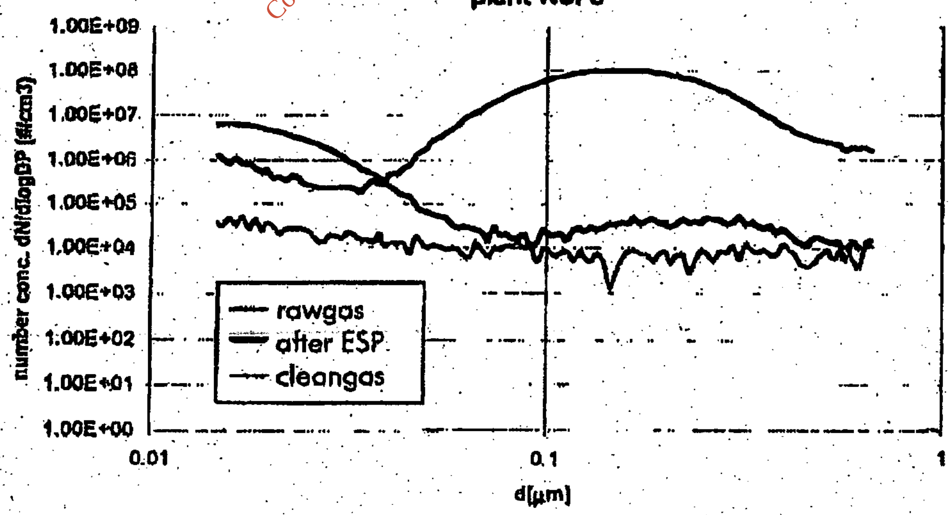
Plant No. 3

Plant No. 3 is equipped with an ESP, wet scrubber, wet ESP and SCR DeNOx. The measurements were carried out:

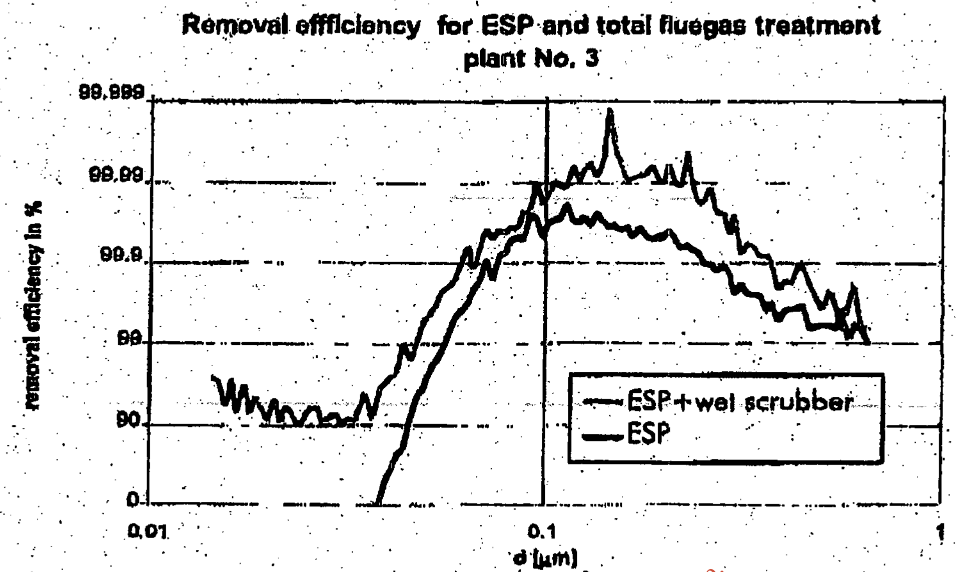
- before ESP
- before scrubber
- in the stack



Measured values in rawgas, after ESP and in cleangas plant No. 3



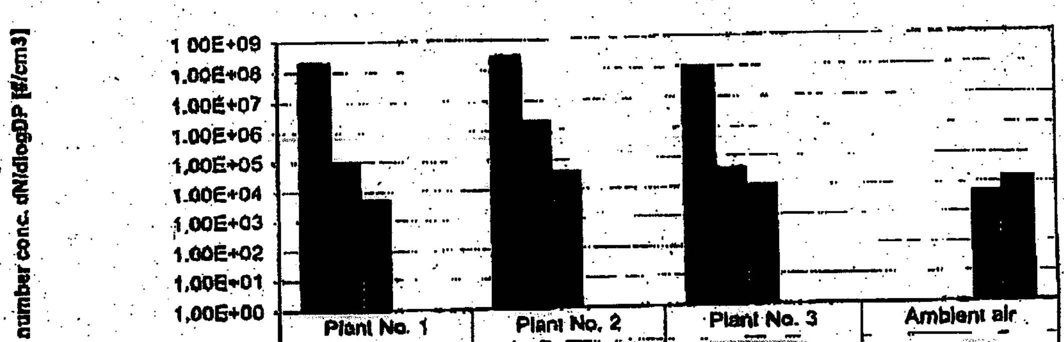
The particle concentration in the raw gas has a maximum of 10^8 particle/cm³ at a diameter of 0.15 µm. The ESP lowers the concentration to 10^6 particle/cm³ and after the further flue gas treatment to values between $5*10^4$ and 10^1 particle/cm³. Below 0.04 µm a recombination of particles after the ESP is observed. This might be a result of condensation of sulfric acid, as already described under plant No. 1.



The removal efficiency of the ESP in the concentration maximum is in the range between 99.9 and 99.99%. The total flue gas cleaning system achieves over the entire measured diameter range a removal efficiency between 90 and 99.99% .

Summary

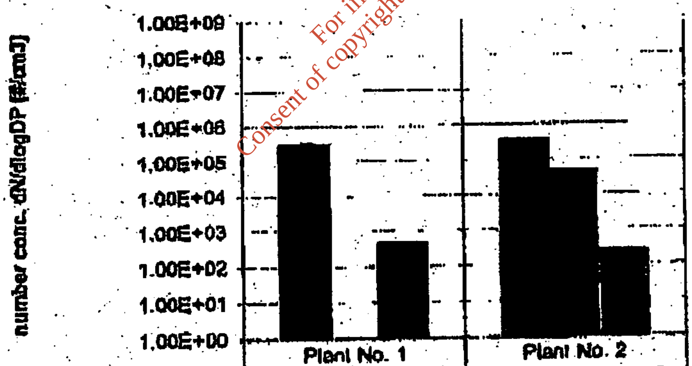
Ultra fine particle concentration at 0.1 - 0.2 µm



	Plant No. 1	Plant No. 2	Plant No. 3	Ambient air
before ESP (raw gas)	2.00E+08	3.00E+08	1.00E+08	
after ESP	1.00E+05	2.00E+06	4.00E+04	
stack (clean gas)	5.00E+03	4.00E+04	1.00E+04	
ambient air rural				5.00E+03
ambient air urban				1.50E+04

In comparison to ambient air it can be stated, that particles around 0.1 µm are in a similar concentration, as in ambient air. For smaller particles the stackgas is even below ambient air.

Fine particle concentration at 0.35 - 8.25 µm



	Plant No. 1	Plant No. 2
before ESP (rawgas)	314338	381601
after ESP		40887
stack (clean gas)	474	242

The number concentration of fine particles in clean gas with diameters between 0.35 and 8.25 µm is very low (300 – 400 particles/cm^3). As a consequence, particles above 0.35 µm can be neglected.

Conclusions

The removal efficiency for PM10 of the flue gas treatment systems in all plants is very good. The number concentration of most plants is in the same order of magnitude as ambient air. According to our measurements we can state that waste incineration plants with up-to-date flue gas cleaning systems are not a relevant source for the emission of ultra fine particles into the environment. Particles above 1 µm are almost completely eliminated.

Reference work

Final report "Messmethodik und Abscheidemöglichkeiten von Feinstaubpartikel (PM10) in Abfallverbrennungsanlagen"

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Prof. Dr. H. Burtscher — Institute for signals ans sensors (ISS), University of Aargau

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FINE PARTICLE EMISSION FROM WASTE INCINERATION

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Keywords: Incineration, fine particle emisisons, flue gas cleaning, Electrostatic Precipitator.

INTRODUCTION

So far only few studies were performed to investigate the fine particle emissions from waste incineration. Usually the total particle mass concentration and concentration of certain species (dioxin, mercury,...) are measured. Sophisticated flue gas cleaning systems, consisting of electrostatic precipitators, wet scrubbers, catalysts and so on are applied, but again, the efficiency of these devices therefore also is not known well. Within the project presented here measurements of raw gas concentrations and concentrations after the different stages of the cleaning systems were done. Plants with different cleaning technologies have been investigated.

METHODS

Particle size distributions were measured using a scanning mobility particle sizer (SMPS), an electrical low pressure impactor (ELPI), and an optical particle counter (OPC). The combination of these instruments allows to cover a size range from about 10 nm to 10 µm. In addition, integral information was obtained by a NanoMet System, consisting of a diffusion charging sensor, yielding informaion on the total particle attachment cross section and a photoelectric senor for products from incomplete combustion (Kasper et al., 2000). Figure 1 shows the setup. The exhaust gas is sampled by a heated probe, the flow is then split into

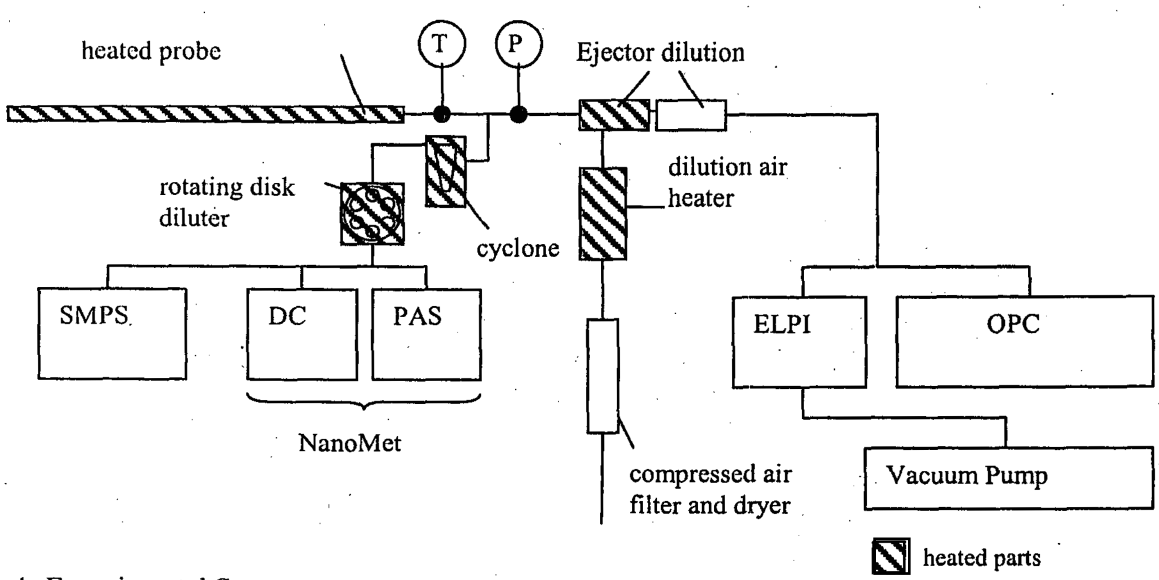

Fig. 1: Experimental Setup

two parts. One passes a cyclone, where larger particles are removed, is diluted by a rotating disk diluter (Hüglin et al. 1997), and feeds SMPS and NanoMet-Sensors. The second part is diluted by a two stage ejector dilution system and is used for ELPI and OPC.

RESULTS

Figure 2 shows an example of size distributions, measured at a plant equipped with an electrostatic precipitator (ESP), a wet scrubber, and,a DeNOx catalyst. Measurements were done before the ESP (raw gas), after the ESP and after the catalyst, where the flue gas enters into the chimney. The results show the very high efficiency of the gas cleaning system. The emitted particle concentrations are close to ambient air concentrations.

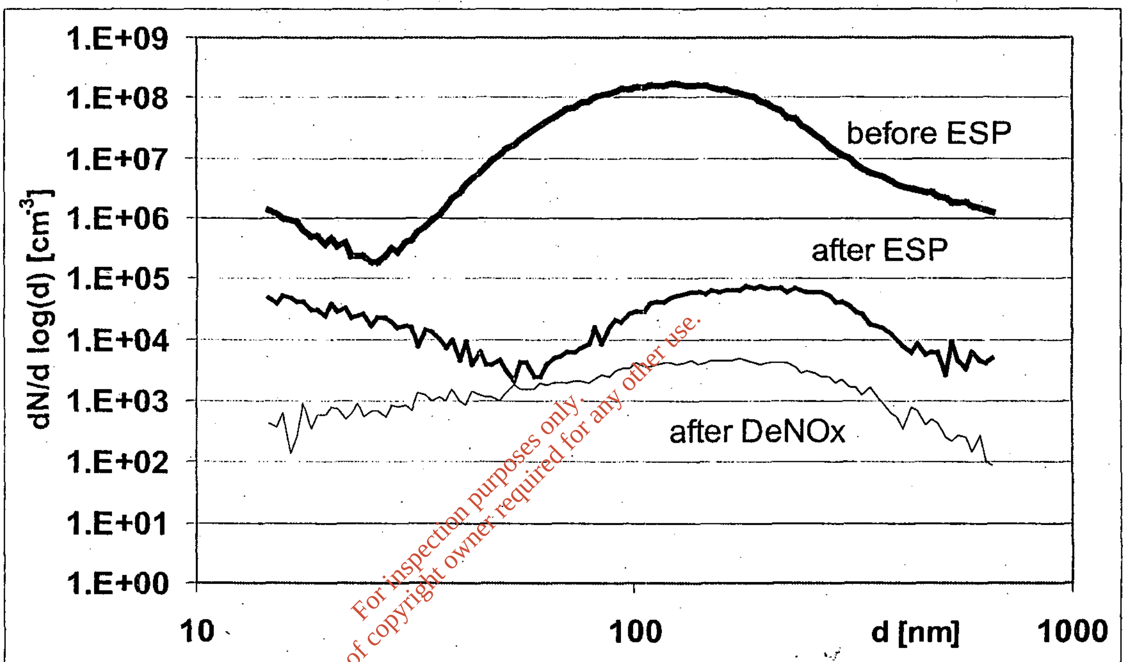

Figure 2. This is the sort of Figure which illustrates good agreement between theory and experiment.

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| Homepage Dr. H. Burtscher | Curriculum vitae | **Publikationen** | Vorträge |

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