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Efficiency of flue gas cleaning in waste incineration for submicron particles

EFFICIENCY OF FLUE GAS CLEANING IN WAST INCINERATION FOR SUBMICRON PARTICLES

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1. Introduction

Waste incineration used to be a relevant source for emission of dust, heavy metals, acids, and many other species. Meanwhile the plants have been equipped with efficient flue gas cleaning devices, which led to a significant reduction of the above mentioned pollutants. However, not much is known about the efficiency of theses systems for fine particle removal. Recent investigations indicate that especially the ultrafine particles may be of relevance for health effects.

The objective of this program was to learn more about particle emissions from waste incineration in the submicron range and to investigate the efficiency of the different steps of the flue gas cleaning system for particles in this size range.

2. Setup of a waste incineration plant

Fig 1 shows a typical setup of a waste incineration plant. Just by looking at the size of the different parts it is obvious that the flue gas cleaning system is a large part if the whole plant.

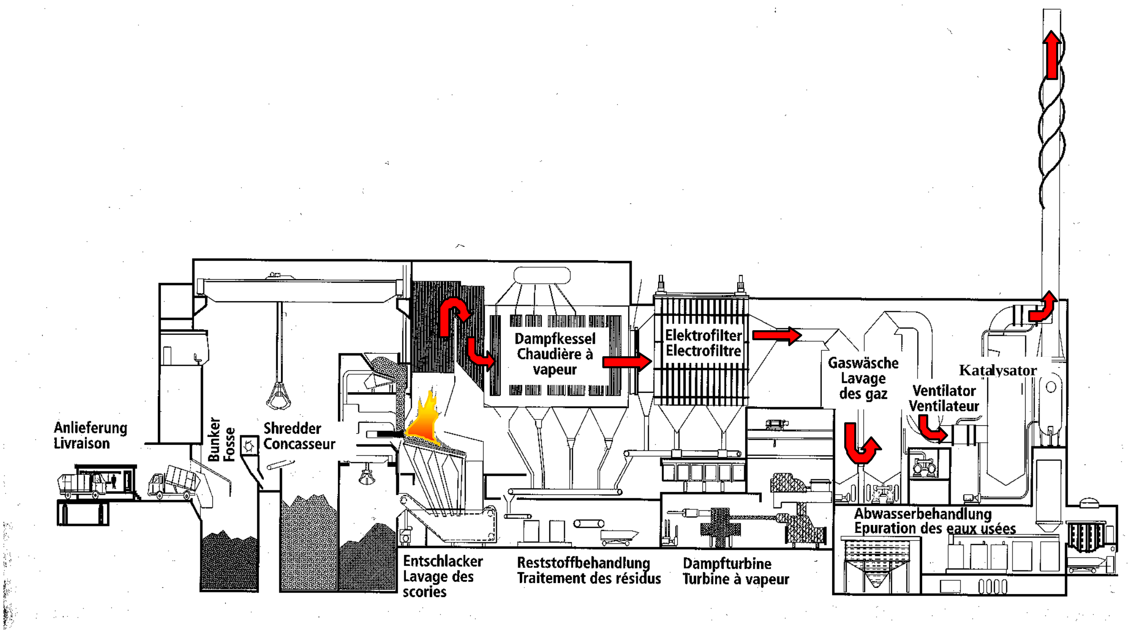


Fig. 1: Typical setup of a waste incineration plant

The same is also true for the costs. Flue gas cleaning is done by the following devices:

Electrostatic Precipitators (usually dry, sometimes operated wet) or bag filters
- Dust
- Fine particles

Wet scrubber
- SO_2
- HCl
- HF
- Heavy metals
- Aerosol particles

DeNox system
- Selective non catalytic reduction (SNCR) of NOx: NH_3 injection, NOx reduced at about 900°C
- Selective Catalytic Reduction (SCR) of NOx: Catalyst as last stage of cleaning system, reduction by NH_3

Typical capacity of one line is 80'000 Nm^3/h. The plants we looked at had 2 – 3 lines.

3. Experimental setup

The setup used is shown in Fig. 2. Particles are sampled by a heated sampling tube. The sampled flow is splitted into two parts. One is first guided through a cyclone to remove particles >2µm, the diluted by a rotating disk diluter (Hüglin et al. 1997) and the feeds a scanning mobility particle sizer (SMPS, Wang and Flagan, 1990) and a NanoMet (Kasper et al. 2000). The SMPS is used to determine the size distribution n the submicron range. The NanoMet allows to obtain the active particle surface (Keller et al, 2001) and a chemical fingerprint online. The NanoMet results will not be treated here.

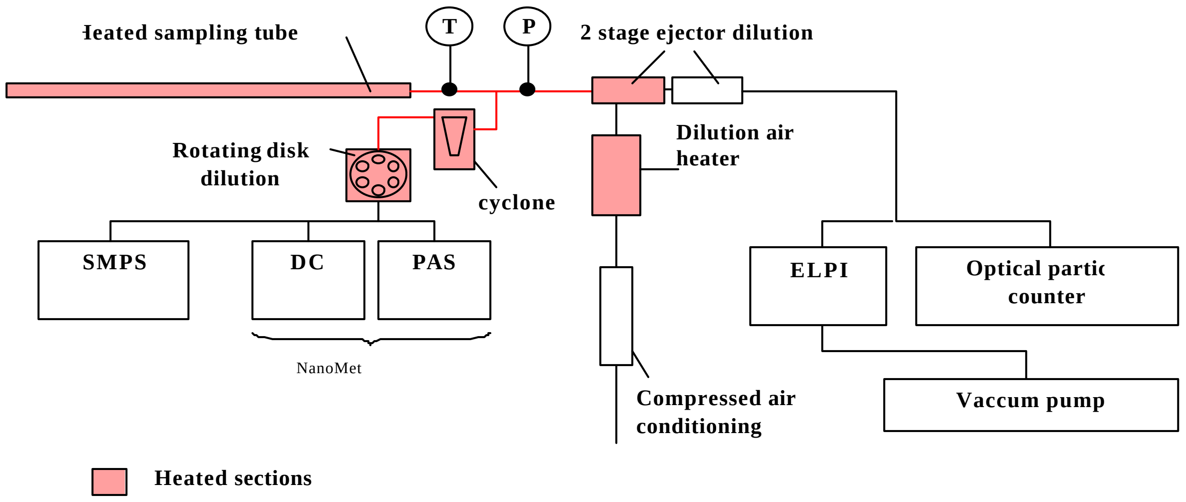


Fig 2 Experimental setup.

The second branch is diluted by one or two stages of ejector diluters (manufactured by Dekati). The first stage is heated. Particles are then analyzed by an optical particle counter (Grimm 1.008) and an Electrical Low pressure Impactor (ELPI, Keskinen et al., 1992). As sampling is not really isokinetic, the results for larger particles therefore are estimates, which may have significant errors. As already mentioned, the program focuses on the submicron fraction, OPC and ELPI are used to get an idea about emissions between 1 and 10 µm, not precise measurements.
Ambient conditions at some locations allowed only short measurements. In the vicinity of furnace or boiler temperatures up to more than 40°C occurred, the stack measurements sometimes had to be done on the roof, where the temperature could be very low. Mainly the condensation particle counter caused problems under these conditions.

4. Results

Measurements were taken in the raw gas, after the Electrostatic precipitator (ESP) and at the entrance to the stack (clean gas). Fig. 3 shows the configuration for the first plant measured.

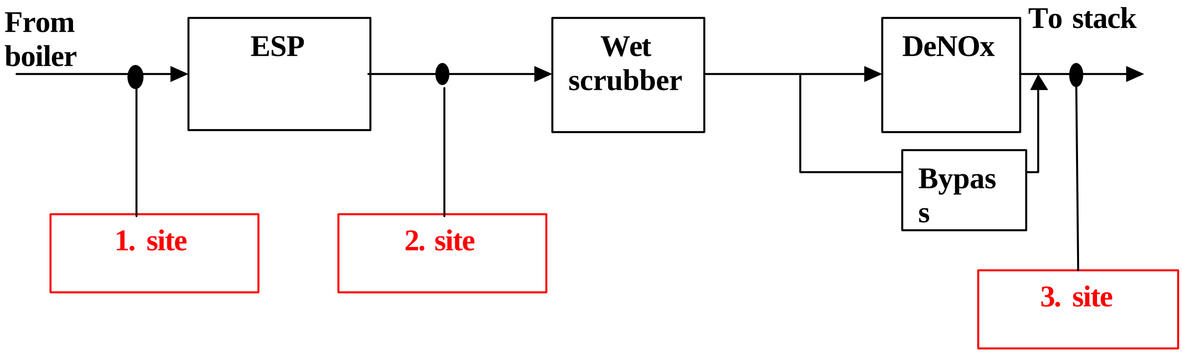


Fig. 3 Measurement sites at plant 1

The corresponding results are shown in Fig. 4 (SMPS and OPC data, no ELPI was used here). The raw emissions are high, but already the ESP remove about 99.9 % of the particles. The increase at the small particle side most probably has to be ascribed to nucleation of volatile material. The wet scrubber reduces the particle concentration by another order of magnitude. The resulting stack concentration is in the order of ambient concentrations. Fig. 5 shows the corresponding removal efficiency or penetration, respectively.

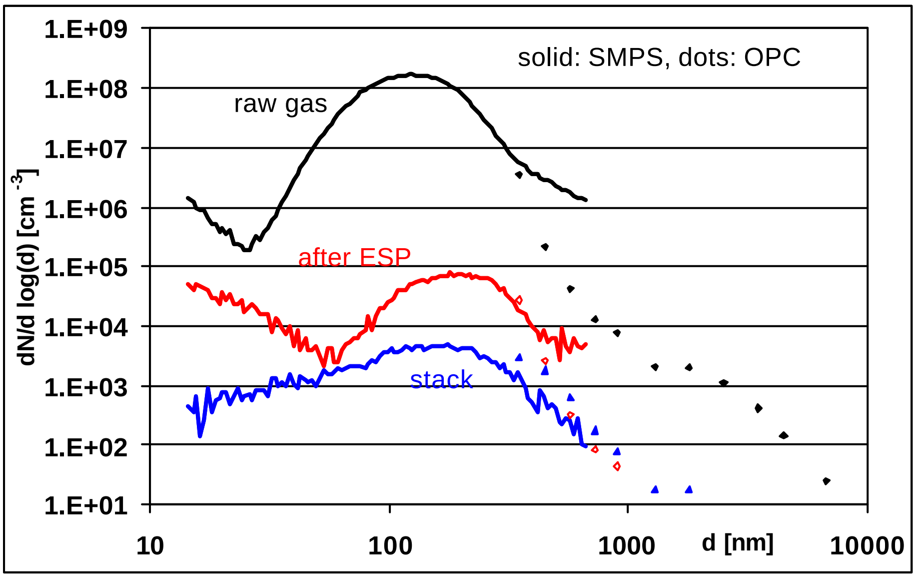


Fig. 4 Size distribution at the three measurement sites

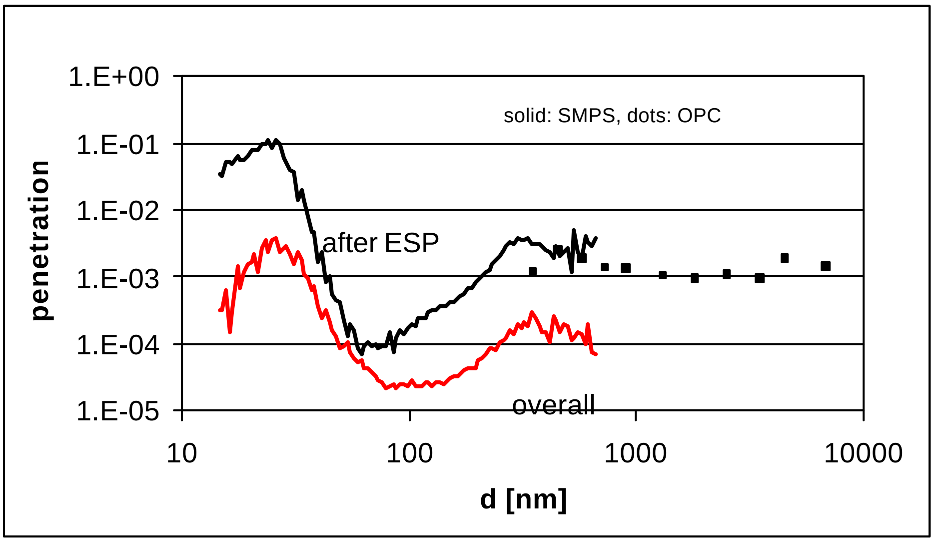


Fig. 5 Penetration through the cleaning system of plant 1. The apparent increase in penetration for the very small particles most probably is an artifact due to nucleation of particles, which occurs less pronounced in the raw gas than after cleaning.

The setup for plant 2 is shown in Fig. 6. This plant used a SNCR-DeNox system. In addition to the main cleaning system it is equipped with a pilot 4D-filter, which is a newly developed device by Von Roll Inova, and which is intended to do the whole cleaning in one device (4D: deDust, deNox deSulfur, deDioxine). Results are shown in Figure 7. Again a very high efficiency is observed. The operation of the experimental 4D filter is very good.

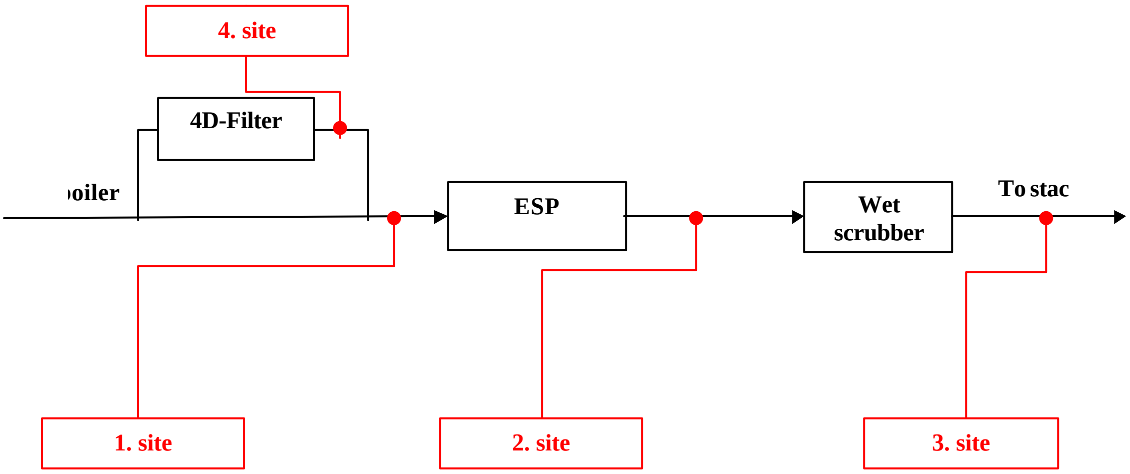


Fig. 6 Measurement sites at plant 2

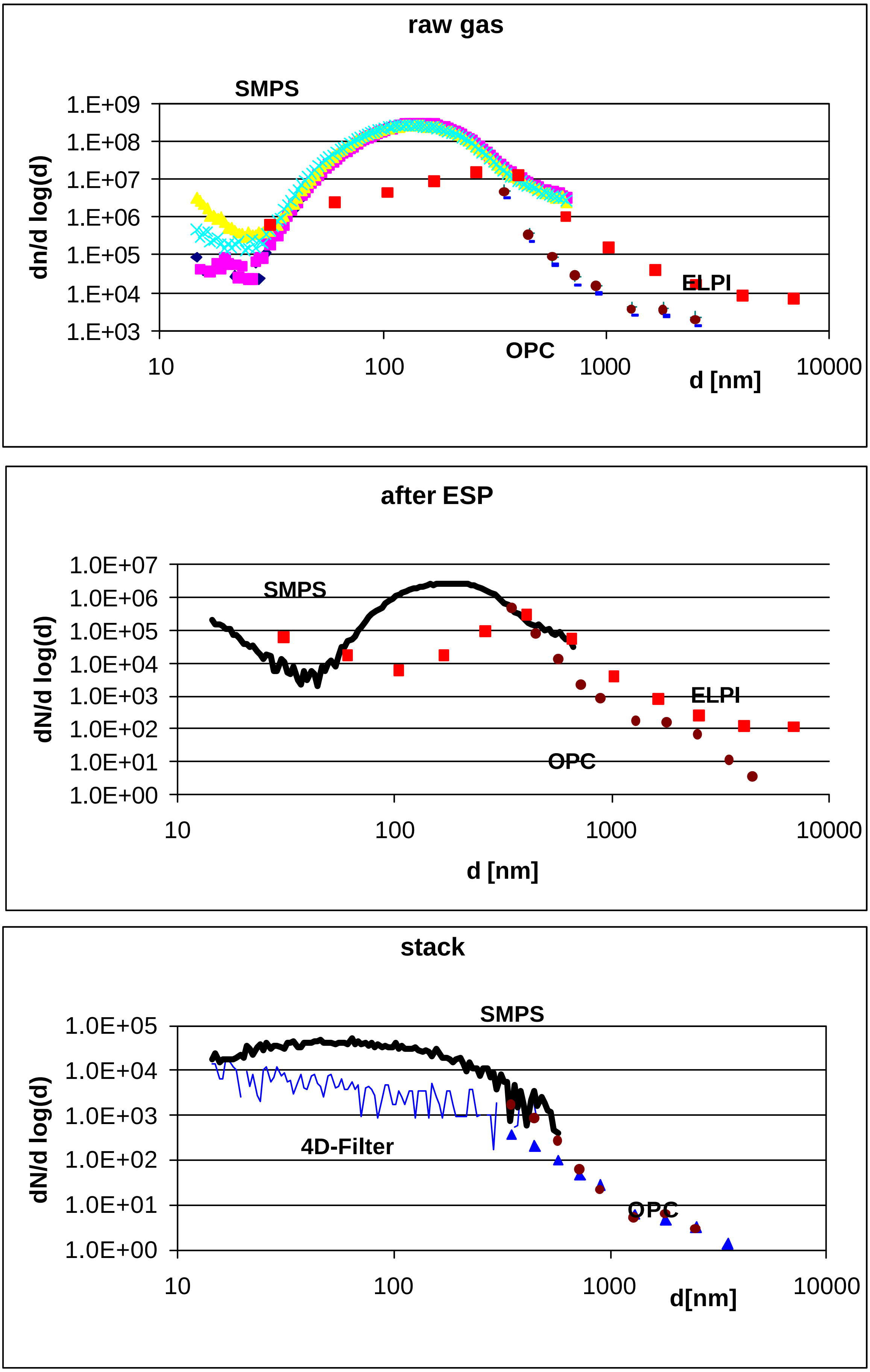
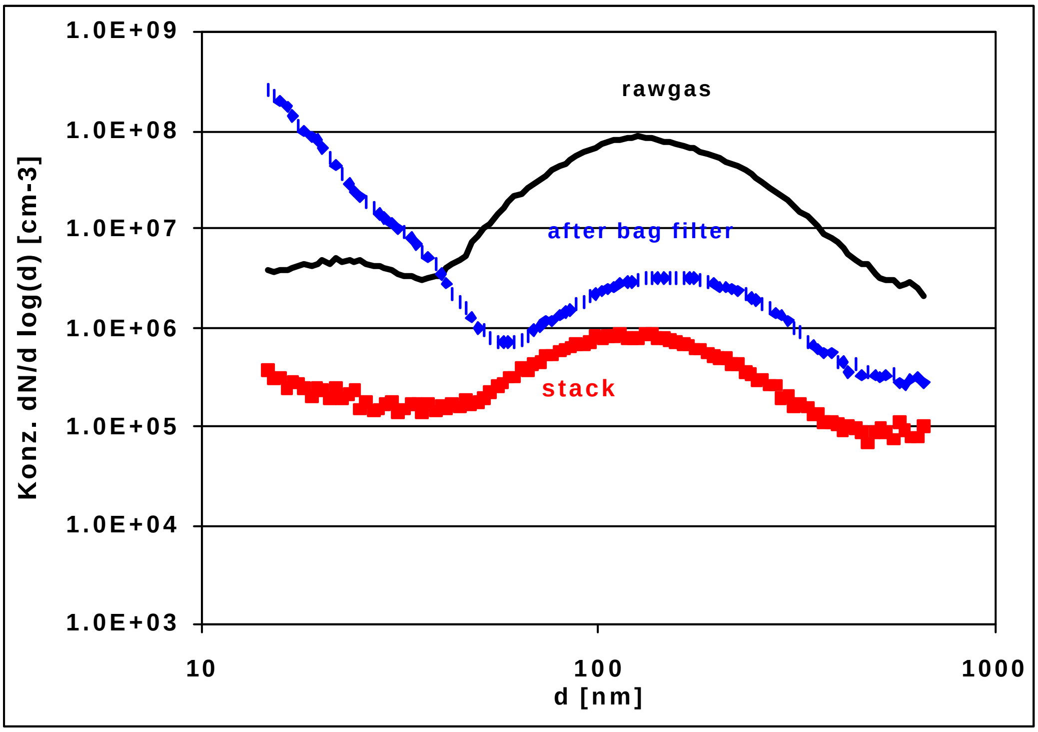


Fig. 7 Size distributions measured at plant 2. The upper graph shows some measurements to give an idea about the reproducibility.

Finally, Fig. 8 shows results from a third plant, which is equipped with a bag filter, wet scrubber and SNCR-deNox. In this case the performance of the filter is rather poor. As bag filters are expected to have a higher efficiency in this size range than ESP's this probably has to be ascribed to a malfunction of the filter.



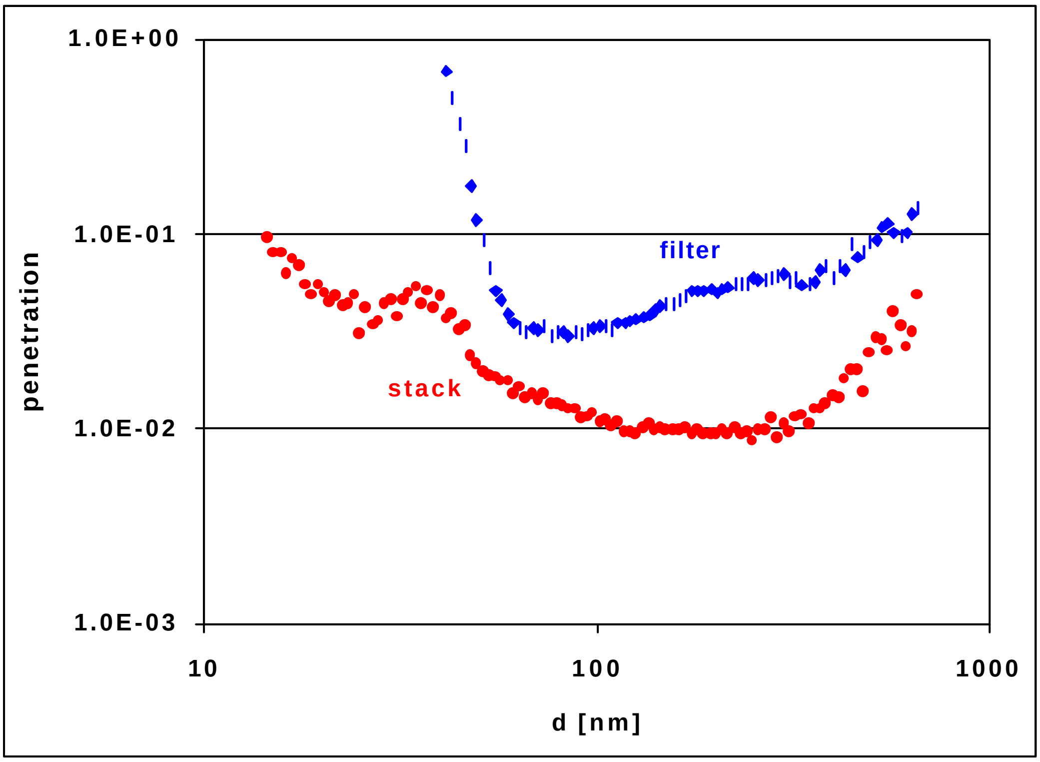


Fig. 8 Size distribution and penetration for plant 3. Again a strong nucleation mode is observed.

5. Conclusions

The results shown here arise from a short program which did not allow repeated measurements at the same location. The results are 'snapshots', no information on variation is obtained. A more detailed investigation of the nanometer particles by use of a thermodesorber or by variation of the dilution temperature would also have been desirable. As already mentioned sampling was not isokinetic. For larger particles this means an additional uncertainty. Nevertheless, the results shown allow some qualitative conclusions:

- The flue gas cleaning system of modern waste incineration plants is very efficient concerning fine particle removal.
- Typical concentrations on the stack are in the same order as ambient concentrations.
- The much worse performance of the plant equipped with a bag filter probably is due to inadequate maintenance, not to principle problems of bag filters.
- Properly maintained waste incineration plants are no relevant PM10 source.

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