Some practical experience on fine dust emission monitoring.

A comparison of results, using different types of equipment.

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Summary

Different particle sizing sampling equipment is compared. Measurements were carried out with a Johnas, an Andersen cascade impactor and a PM10 separator monted on a Tecora. The results were compared with each other and with the results of dust concentrations measured with a Tecora in accordance with ISO 9096. Measurements were performed at different sources; with different kinds of dust and different concentrations.
Although the amount of data is rather small, at low dust concentrations, an interesting resemblance was found in the particle size distribution between the Johnas and the Andersen. A PM10 separator at the Tecora was malfunctioning at rather high concentrations of sticky dust. Using the results of the dust concentration measurements in accordance with ISO9096, it was found that the dust concentration, measured with the Johnas, decreases with an increasing dust concentration in the stack.
In general, the application of the Johnas for measuring particle size distribution seems to be promising. In contradistinction to other equipment to measure the particle size distribution, the Johnas is easy to operate and can be applied in a wide range of dust sources.

Introduction

Exposure to fine dust is more and more considered a human health problem. Industrial sources are giving an important contribution to the ambient fine dust concentrations. To practice appropriate abatement measures more attention is given to the inventory of industrial emissions. In general in The Netherlands it is not common use to deal with fine dust emissions in environmental permits. Only the concentration or emissions of total dust are limited. So, by absence of enforcement, there is still no need to diagnose the particle diameters of dust emissions.

In practice, the fine dust emissions are often derived from the permitted total dust emissions or from the measured total dust emissions. In this way, large and undefined errors are made. Monitoring of fine dust emissions by specific measuring equipment is often considered to be uncertain, difficult and expensive.

To abolish this prejudice, DCMR Environmental Protection Agency started comparison measurements with specific fine dust emission measuring equipment. The work was done in close collaboration with measuring teams of Corus, Pro Monitoring and KW2. Measurements were carried out with different fine dust separating probes. To monitor the effect on the results due to the properties of dust, the concentration and different source parameters, the measurements were performed at different stacks.

Investigation plan

To compare the results of different fine dust measuring probes, it was necessary to find different sources of fine dust with a more or less stable dust concentration. The measurements were carried out at four different sources: an iron-ore grinding installation, a boiler fired with heavy oil and at the inlet and at the outlet of an electric filter of an aluminum silicate processing installation. The dust concentrations differed from about 5 up to 200 mg/m^3. Also the type of dust differs. The emitted dust of the boiler, for example, was more sticky than the other dust types.

At these four different sources the measurements were performed with different series of instruments. A Tecora provided with a PM10 separating probe. A Johnas multi-stage cascade impactor, measuring PM2.5 particles, particles between 2.5 and 10 µm and particles larger than 10 µm. Also an Andersen 8-stage cascade impactor was used. To compare the obtained results with a more traditional measuring device a Tecora TSP probe was used. A general view of the used equipment is given in table 1.

Table 1. Used measuring equipment

	Johnas PM 2.5-10 probe	Andersen 8-stage impactor	Tecora PM10 separator	Tecora TSP
Iron-ore				
Soot				
AlSi inlet				
AlSi outlet				

All measurements were carried out at vertical ducts in turbulent gas streams.
The measurements were performed in accordance with ISO 9096 concerning iso-kinetic sampling. However no traverse measurements were carried out. Due to the type of measurement it is only possible to sample with a once chosen sampling velocity. Changing the sampling rate will cause a malfunctioning of the separation function of the equipment. On the other hand this way of measuring gave the possibility to fit different instruments in the sampling area in the vicinity of each other at the same time. This was particularly done during the measurements of iron-ore and soot. Figure 1 shows the equipment during the measurements at the iron ore grinding installation. The nozzles of the four samplers were situated in each other vicinity, without disturbing the flow pattern of each other. So the effects of possible difference in the dust concentration or composition in the sampling area may be neglected.
At the AlSi source the Johnas and the Tecora TSP samples were not taken at the same time.

Fig. 1. Sampling equipment at the iron-ore grinding installation.

The equipment.

The dust sampling probes which were used are commercially available. The Tecora TSP sampling device and the Andersen are applied for many years. Johnas is a rather new instrument. The PM10 separating device, mounted on the Tecora probe is specially modified to get an easy entrance to sampling ports. A picture of these probes is given in fig. 2.

Fig. 2. Sampling probes.
Starting above: Andersen, Johnas, PM10 separator, Tecora TSP.

Al the used equipment is suitable for in-stack sampling. To equilibrate the temperature inside the probe with the temperature in the stack it is necessary to take enough time in account. For the same reason it is not recommended to operate the sampling equipment outside the stack in a hotbox.

The Tecora TSP is widely used as a half-automatic gravimetric dust sampling instrument.

The Andersen cascade impactor separates the dust in 8 fractions in the range of about 0.5 up to 20 µm. The exact diameters are depending on a number of off-gas parameters and the type of dust. Operating the Andersen is a very delicate and time-consuming matter. To receive optimal results it is often necessary to perform several samplings. Therefore it is less popular and not commonly used. In fig 3. a picture of the Andersen cascade impactor is given after the sampling of iron-ore dust.

Fig. 3. The Andersen cascade impactor, opened after the sampling of iron-ore dust.

The PM10 separator, mounted on the Tecora-probe is rather new. Because the original probe is very large and not applicable for most of the sampling ports, this device is given less attention in this paper.

The Johnas is an easy to handle instrument, which gives the possibility to separate the fine dust into different parts. With this instrument it is possible to sample three fractions: larger than 10 µm, the fraction between 2.5 and 10 µm and smaller than 2.5 µm. These dust fractions are interesting for ambient air dust concentration monitoring. So the use of this probe is expected to grow in popularity. Therefore the investigation is concentrated on this instrument. Fig. 4 shows the Johnas, opened after sampling.

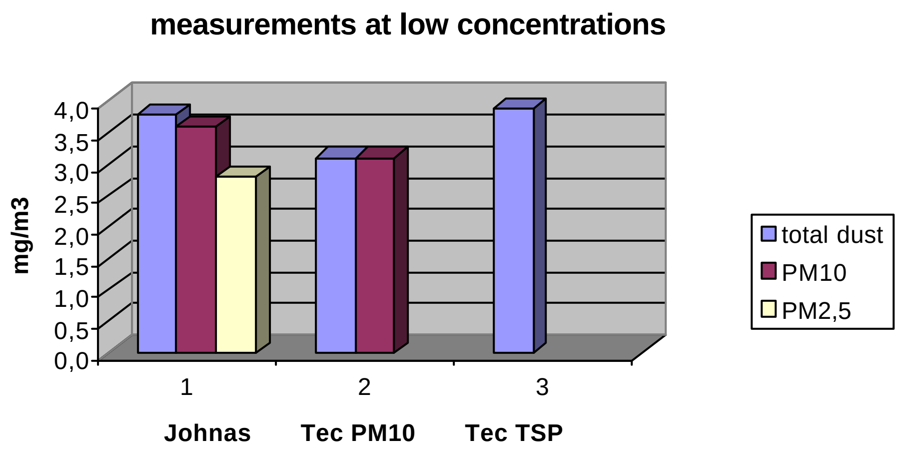
Fig. 4. The Johnas probe, opened after sampling of iron-ore dust.

In general all particle-separating devices used, are giving aerodynamic diameters, based on ball-shaped particles with a density of 1 g/cm^3.

Experiences with separating sampling probes show two specific problems.
In the probe itself an amount of dust is precipitated on the walls. This dust will not be taken into account in the gravimetric analysis. In general it is difficult to remove this dust in accordance with an analytical procedure. Also it is difficult is to answer the question to what fraction it has to be accounted.
The second problem is that the gravimetric results of the dust separating probes are not comparable with the results of the TSP measurements, using the traditional gravimetric method in accordance with ISO 9096.
Special attention was given to these phenomena.

The results

The first measurements were carried out at the outlet of an electric filter of the iron-ore grinding installation. These results are given in fig. 5a. In fig. 5b some results are given of



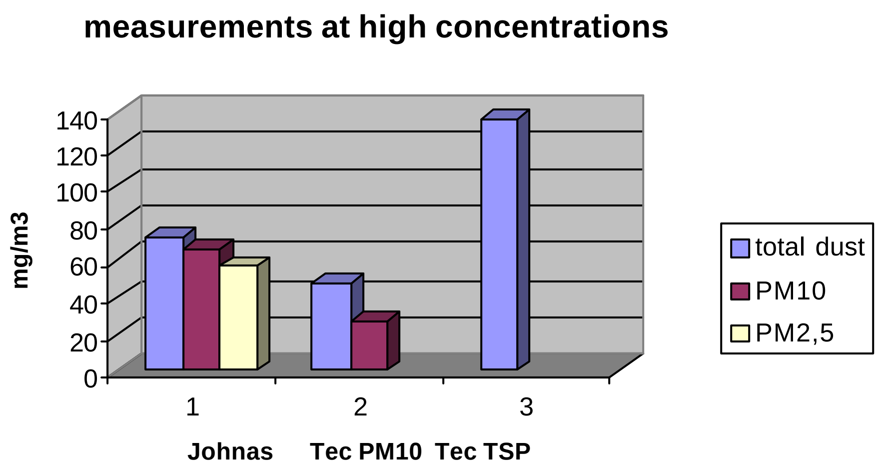
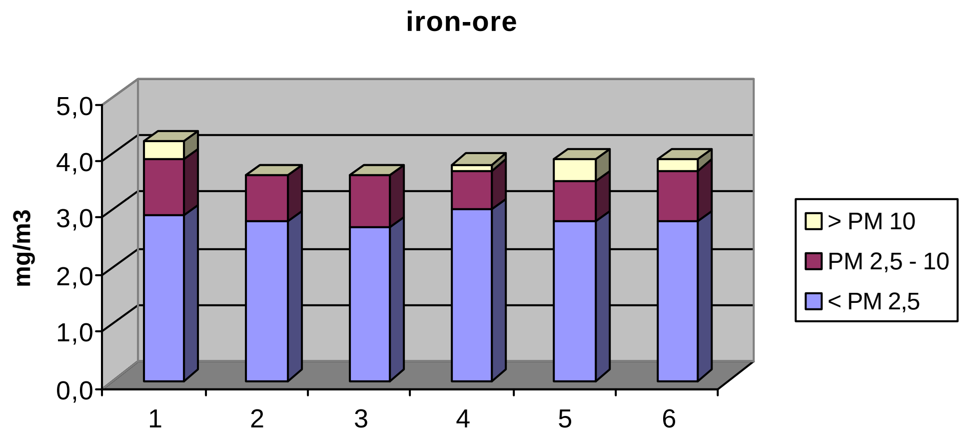


Fig. 5a and 5b. Measurements with different types of probes at different dust concentrations.

measurements of soot emissions of higher concentrations. The concentrations were at the outlet of the iron-ore grinding installation were very low, but the results of the comparison samplings seemed to give a reliable result.

The results of the measurements with the Johnas probe at the iron-ore source and the outlet of the boiler are given in fig. 6a and 6b. In spite of the very low dust concentrations the results seem to be very consistent. The calculated standard deviation of the results of the iron-ore samples is 0.2 mg/m^3 based on the total dust concentration. The dust concentration at the outlet of the boiler in fig. 6b seems to be varying a little, probably caused by very small process variations. In this case the standard deviation amounts to 13 mg/m^3.



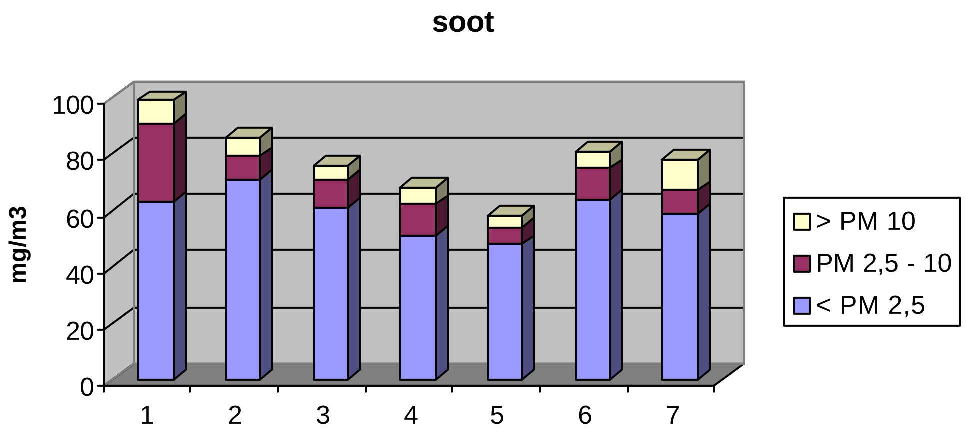
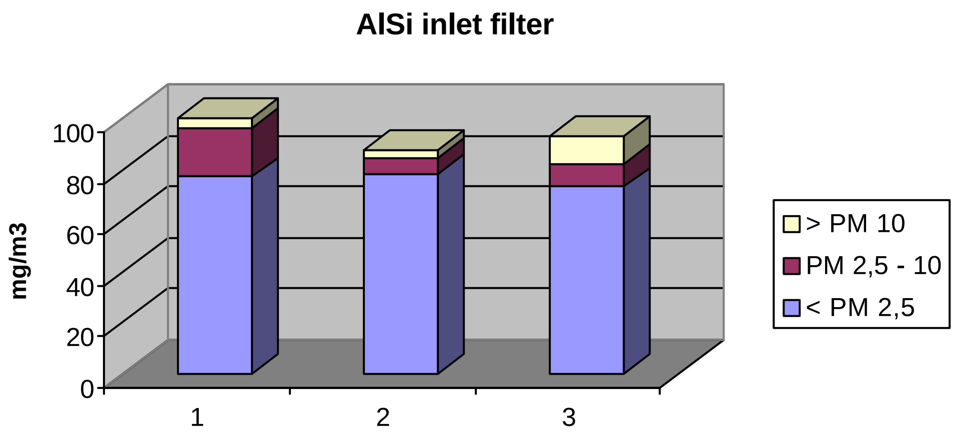


Fig. 6a and 6b Measurements with the Johnas probe at the outlet of an electric filter and at the outlet of a boiler.

The same results are given in fig. 7a and 7b of measurement at the inlet and at the outlet of an electric filter at a AlSi processing installation. The measurements were carried out in an alternating way. Inlet – outlet – inlet, and so on. Although the electric filter has a poor efficiency, especially for the lager particles, the results are rather consistent.



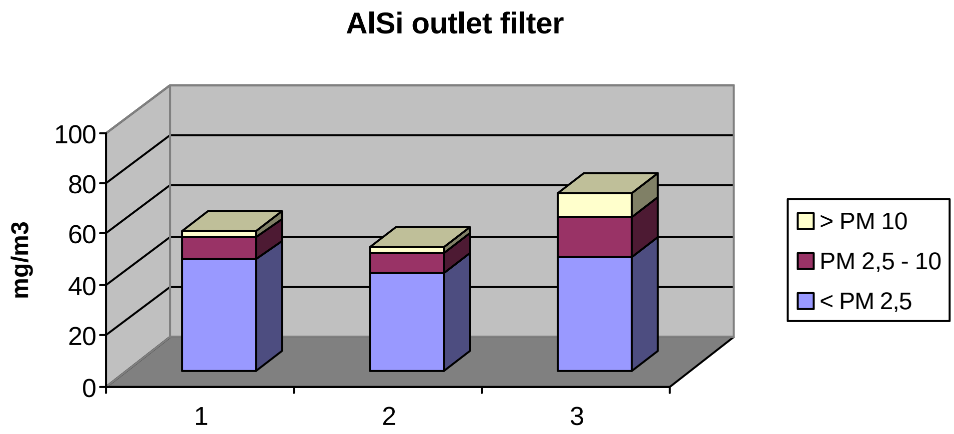


Fig. 7a and 7b Measurements with the Johnas probe at the inlet and at the outlet of an electric filter.

During the measurements at the outlet of the electric filter of the iron-ore grinding installation also measurements with the Andersen cascade impactor were carried out. The results were transformed in the range total particulates, PM10 and PM2.5. These results were compared with the results, obtained with the Johnas probe. The results are given in fig. 8. These measurements were only performed at the iron-ore source.

After each series of measurements with the Johnas the probe was internally cleaned and the dust was carefully collected and weighed. The weight was proportionally added to the weight of the other filters from the separating Johnas probe. The amount of dust weight, found during the iron-ore measurements was 11.2 %, related to the total dust weight. In case of the soot measurements is was 13.0 %. It is not possible to account this to one or more of the separating parts of the probe.

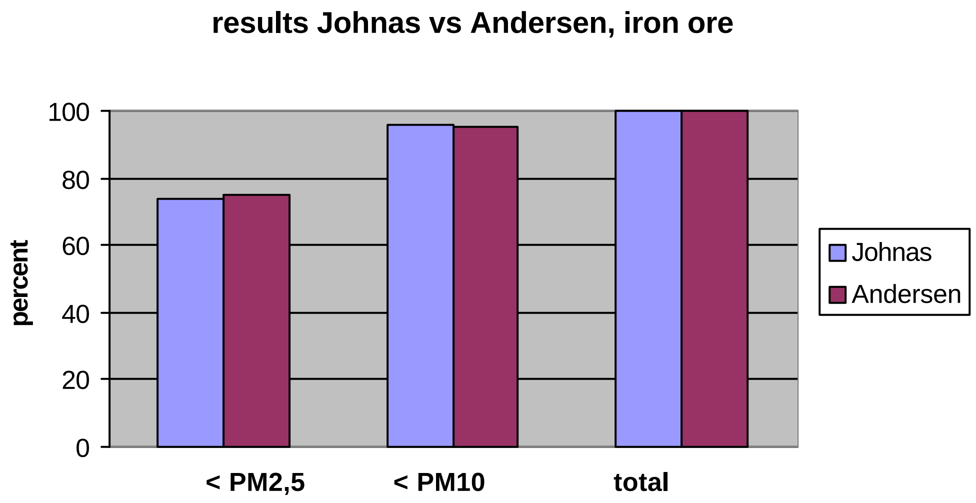


Fig. 8 Results of the comparison of the measurements with the Johnas probe and the Andersen impactor at the outlet of the grinding installation.

Using the results of the total amount of dust from the separating probes it is, in principle, possible to calculate the total dust concentration. However, there is always a certain difference between these results and the result of a total dust measuring probe, used in accordance with ISO 9096. In fig. 8 such a comparison is made. In this figure the “efficiency” of the Johnas probe is related to the measuring device which is used in accordance with ISO 9096.

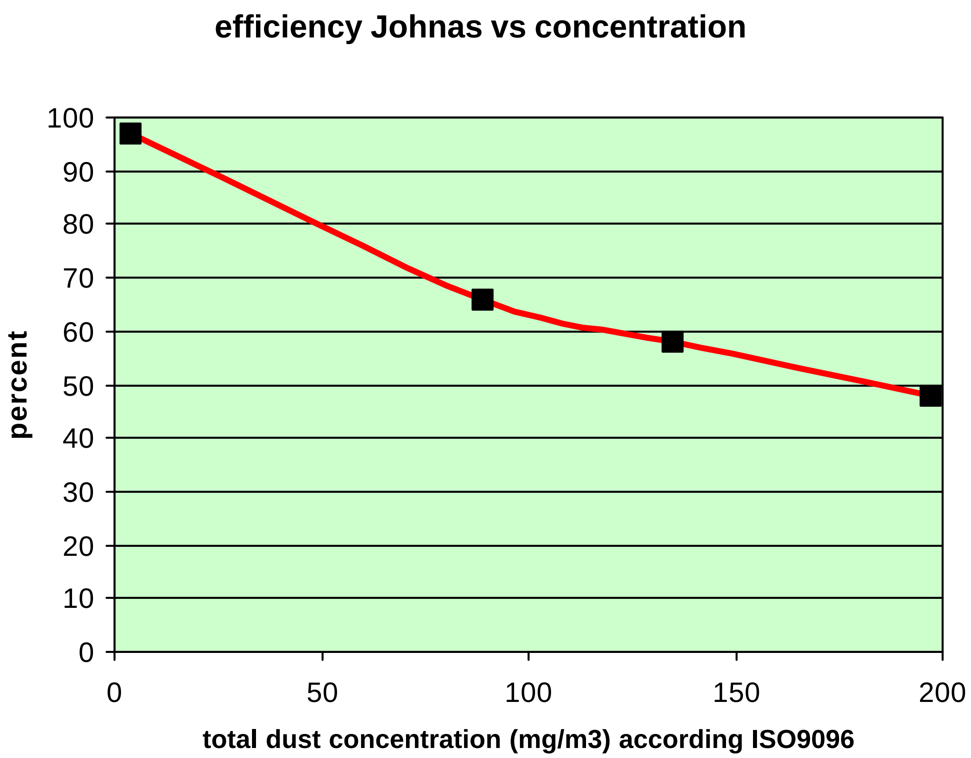


Fig. 9. Efficiency of the Johnas probe to measure the total dust concentration, compared with a Tecora used in accordance with ISO 9096.

Conclusions

- The Johnas probe is applicable for particle size distributions measurements.
- Measurements at low concentrations, the Johnas was giving a nice resemblance with the Andersen 8-stage cascade impactor.
- It is advised to use the Johnas probe always in combination with a total dust sampling measurement in accordance with ISO9096.
- The dust recovery in the Johnas probe is decreasing with an increasing dust concentration in the stack. It is not found what causes the change of recovery. Also is unknown to what particle size it has to be accounted.
- 11 – 13 % of the sampled dust is found on the internal walls of the Johnas probe. Although it is not known what particle size is impacted to the different parts in sampling equipment it is decided to distribute the dust proportional to the particle size distribution.
- A PM10 separating device, mounted on a Tecora, was malfunctioning at higher concentrations of sticky dust.
- The Johnas particle size distribution probe is an easy to handle and promising instument for in-situ measuring the particle size distribution. However more tests are necessary to collect enough data sets for a reliable validation of the instrument under all circumstances.

Literature

[1] ISO 9096

[2] A.C. John et al. Entwicklung eines PM10/PM2,5-Kaskadenimpaktors zur Messung der Emissionen von Feinstäuben. Gefahrstoffe – Reinhaltung der Luft, 59 (1999) Nr. 11/12 November/Dezember p 449 – 454.

[3] L.G. Wesselink et al. Fijn stof: emissies, immissies en omissies. Lucht nr 1, 1999