CHAPTER 15

A Possible Method for the Sampling of Saharan Dust

B. STEEN

ABSTRACT

Most sampling methods for suspended particles in ambient air used today are designed for the urban environment and its possible related health effects. They are designed for measuring concentrations between 10 and 200 $\mu g/m^3$ particle sizes below 20 μg, moderate wind speed and a time scale of 0.5 to 24 hours. The data obtained with most of these methods are useful if the conditions do not differ too much from those described. In the case of the problematic erosion of Saharan dust, most of the critera mentioned above would probably not be fulfilled: The concentrations are likely to be much higher where the erosion occurs, the particle sizes up to several hundreds of microns, the wind speed high and the time scale longer (at least for practical reasons). If one wants to determine the real mass of particles suspended in air in this case or collect a representative sample, no other solution immediately presents itself than isokinetic sampling – at least for the larger particles.

This paper will describe such a method which has been developed at IVL.*

Basically the sampler consists of a small cylinder which is open at both ends. During sampling its axis is oriented parallel to the flow lines. The fluid is allowed to pass isokinetically through a nozzle at the front end of the cylinder by means of its own inertia. The particles are charged and deposited on the cylinder wall. The cylinder acts as a collecting electrode in an electrostatic precipitator and its weight is determined before and after the sampling. The collection efficiency was found to be above 90% for most particles. The sampler is battery-operated and its total weight is 2.3 kg.

15.1 INTRODUCTION

Aerosols emitted to or present in ambient air are mostly characterized by their concentrations. Consequently, most techniques for sampling and measurements of particles are designed to determine concentrations. In many cases, however, concentrations are not of prime interest. When determining emissions from stacks,

*Swedish Water and Air Pollution Research Laboratory.

ventilators or 'diffuse' sources such as stockyards, roads, etc., the prime interest is the flux of particles, i.e. the amount of particles transported through a certain area during a certain period of time. In such cases the mere measurement of the flux may be advantageous compared to conventional techniques that use instruments for the determination of both concentration and flow velocity.

15.2 GENERAL DESCRIPTION

The sampler consists basically of a nozzle, a cylindrical collecting electrode, an emission electrode, a flow regulator, a shaft, and a high voltage generator. (Figures 15.1 and 15.2).

During sampling, the axis of the cylinder is oriented parallel to the flow lines by a vane and the fluid is allowed to pass isokinetically through the nozzle by means of its own inertia. The particles are charged and collected on the inner cylinder wall due to electrostatic forces. The cylinder is weighed before and after the sampling to determine the particle mass. The particles may also be analysed by chemical or physical means.

15.2.1 Nozzle

Several different inlets may be used.

First, the cylinder was used without any nozzle. This makes it possible to measure a very low particle flux, but the collection efficiency may decrease significantly with increasing flow velocity.

Second, three similar nozzles with different inlet diameters were made of teflon (Figure 15.2). The diameters chosen were 5.0, 8.2, and 11.2 mm, giving approximately 25, 10, and 5 times reduction in flow velocity respectively from nozzle inlet to collection area.

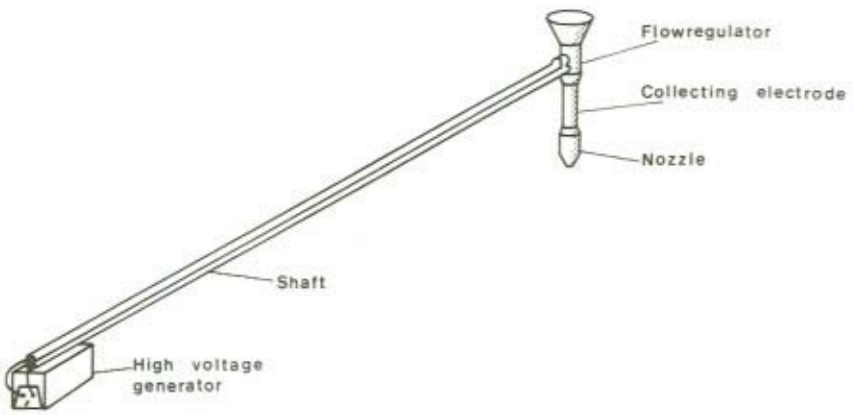

Figure 15.1 Sketch of particle sampler

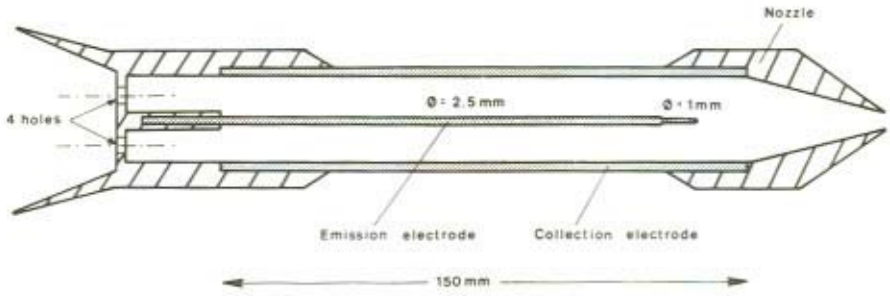

Figure 15.2 Cross-section of sampler

Third, a special 5 mm 'expansion-contraction' nozzle was constructed to be used in those cases when the collection efficiency obtained with the ordinary 5 mm nozzle is significantly reduced due to turbulence. The nozzle gives initially a reduction in flow velocity of 50 times just as the other nozzles but it also consists of a contraction section with an area ratio of 2 : 1 where the turbulence is smoothed out before the sample enters the cylindrical part.

Most of the tests and measurements described in this paper were carried out with the normal 5 mm nozzle.

15.2.2 Collecting electrode

The collecting electrode consists of a 150 mm acid-proof steel cylinder with an inner diameter of 25 mm and a weight of 145 g. Inside it may be covered with an aluminium foil. The foils used weigh around 3 g and may easily be folded and stored with the particles collected on it.

15.2.3 Emission electrode

The tip of the emission electrode is located 20 mm from the front end of the cylinder as shown in Figure 15.2.

15.2.4 Flow regulator

A cross section of the flow regulator is shown in Figure 15.2. It is made of teflon to give a good insulation and resistance to temperature. Its rear end is expanded in order to increase the flow velocity on the outside and provide an extra vacuum on the inside. This is necessary in order to achieve isokinetic sampling through the nozzle inlet. Without this expansion and a nozzle the friction losses on the inside would lower the flow rate through the cylinder resulting in sub-isokinetic sampling. When nozzles are used the sample flow is above that of isokinetic sampling if no extra flow restriction is made. Therefore an exchangeable plate with four holes is

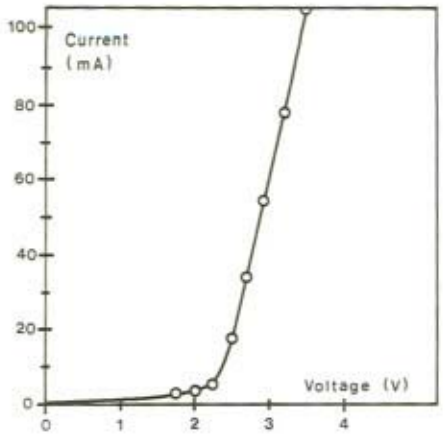

Figure 15.3 Battery current–voltage characteristics for high voltage supply working on sampler

placed just before the expansion at the rear end. The diameters of the holes are matched with the respective nozzles in order to obtain isokinetic sampling.

15.2.5 High voltage generator

The high voltage generator is battery-operated and consists of an oscillator, a transformer and a voltage multiplier. The output of the generator is around 12 kV at 4.5 V input voltage. The battery current as a function of battery voltage is shown in Figure 15.3 and indicates the formation of a stable corona discharge in the sampler.

15.3 PERFORMANCE

15.3.1 Flow characteristics

The flow velocity in the nozzle tip and outside the sampler was determined by means of a hot-wire anemometer. The sampler was placed in a wind tunnel and velocity measurements were made at a wind speed varying from 0.7 to 11.2 m/s.

The results given in Table 15.1 show that the deviations from isokinetic sampling conditions generally are small but ought to be considered when sampling is carried out at low flow rates or without a nozzle.

15.3.2 Collection efficiency

The collection efficiency was determined experimentally as a function of various

TABLE 15.1 Ratio of Flow Velocity Between Sample at Nozzle Inlet and Main Flow

Main flow velocity (m/s)	Relative Sample Flow Velocity			
	5 mm nozzle	8.2 mm nozzle	11.2 mm nozzle	Without nozzle
0.7	1.02	0.96	0.95	0.79
1.1	1.01	1.00	1.01	0.85
2.0	1.03	0.99	1.01	0.90
3.1	1.00	0.99	1.02	0.90
4.3	1.03	1.01	1.02	0.95
11.2	1.00	0.99	1.03	1.04

parameters. The experimental set-up consisted either of:

(a) the sampler, a filter, a dry gas meter and a pump, or
(b) the sampler, a Royco 220 light scattering particle counter and a pump.

15.3.2.1 Particle size

Table 15.2 shows the results obtained by using a Royco particle counter when determining the concentration of different particle size classes present in a room atmosphere before and after the sampler. The sampler was used without a nozzle and with a flow velocity of 1 m/s. The particle number concentrations were low, around 1000/l in the 0.3–0.4 μm range and 10–20/l in the 3.4–6.6 μm range.

TABLE 15.2 Collection Efficiency of Sampler for Different Particle Size Classes at Different Battery Currents

Latex equivalent particle diameter (μm)	Sampling efficiency (%)				
	Battery current (mA)				
	6	8	10	50	196
0.3–0.4	73.7	83.2	93.7	97.6	99.0
0.4–0.6	72.9	83.8	94.5	97.5	98.7
0.6–1.0	75.6	86.1	96.0	98.0	99.2
1.0–1.8	77.6	92.2	96.3	99.3	100
1.8–3.4	78.7	92.4	99.7	100	100
3.4–6.6	78.2	92.9	98.7	100	100
6.6–13	88.3	(80.0)	100	100	100

15.3.2.2 Concentration

Approximately 35 mg of a talc powder, with a mass median particle diameter of 2.5 μm ('ITX talc powder'), was dispersed in an air stream and fed into the 5 mm nozzle inlet at concentrations varying from 23 mg/m^3 to 15 g/m^3. The flow velocity was 25 m/s and the battery current was 50 mA.

The collection efficiency was determined by the filter method. No correlation between concentration and collection efficiency was found. The results showed a collection efficiency between 93.8 and 97.9%.

15.3.2.3 Flow velocity

Using a battery current of 50 mA and 5 mm nozzle, the collection efficiency was determined with ITX talc powder dispersed in a wind tunnel. The collection efficiency was 88.7, 91.8, 99.3% at 22.9, 16.6, and 10.4 m/s, respectively.

15.3.2.4 Amount of collected material

Varying the sampling time, and keeping the concentration constant the collection efficiency was determined as a function of the amount of ITX talc powder on the collecting electrode. The results, given in Table 15.3 indicate a decreasing collection efficiency with an increasing amount of talc. As talc is one of the most easily dispersed powders redispersion of talc particles may be the major cause of the decreasing collection efficiency. There are two things that indicate this. First the collection efficiency increases when an 'expansion–contraction' nozzle is used to suppress turbulence (Table 15.3). Second, when sampling more sticky dust, such as the fumes from an electric arc steel converter, a much higher collection efficiency will be obtained (Table 15.4).

TABLE 15.3 Influence of Electrode Deposits on Collection Efficiency

Amount of collected talc (mg)	Battery current (mA)	Nozzle type	Fluid velocity (m/s)	Collection efficiency (%)
5.2	50	normal, 5 mm	25	96.3
18.9	50	normal, 5 mm	25	95.5
40.6	50	normal, 5 mm	25	88.6
79.6	50	normal, 5 mm	25	72.9
27.7	250	normal, 5 mm	25	97.9
69.0	250	normal, 5 mm	25	78.4
84.0	400	normal, 5 mm	25	80.8
33.7	50	expansion–contraction, 5 mm	25	98.2
103.7	50	expansion–contraction, 5 mm	25	94.0
255.7	50	expansion–contraction, 5 mm	11.7	96.7

TABLE 15.4 Collection Efficiency Obtained from Measurements of Different Types of Particles

Gas velocity at nozzle (m/s)	Nozzle diameter (mm)	Battery current (mA)	Type of particles	Amount of collected dust (mg)	Collection efficiency (%)
0.8	25	50	Redispersed soot from oil combustion	27.8	99
	25	50	Redispersed Na_2SO_4 from craft pulp mill recovery furnace	8.7	98
0.8	25 5	50	ITX-talc Emissions from electric arc steel furnace	23.6	98
0.8	25	50	Fe_2O_3	8.4	100
0.8	25	50	Particles in ambient air	5.3	91
0.8	25	50	Sulphate in particles in ambient air	0.201	87

The sampler was later tested for redispersion by the filter method. The flow velocity was 17.0 m/s at the inlet of the 5 mm nozzle. The amount of initially collected ITX-talc was 38.8 mg. During 2 hours of extra sampling of dustfree air the redispersion was 0.9 mg corresponding to a decrease in the collection efficiency of 2.4%. This proves that a redispersion takes place, but the amount of redispersed talc is less than that indicated by Table 15.3. A possible cause is the presence and absence respectively of simultaneous collection of particles.

15.3.2.5 Types of aerosols

The collection efficiency obtained by the filter method for different types of aerosol is shown in Table 15.4.

15.3.2.6 Battery current

The battery current is the most simple electrical parameter to determine. According to the manufacturer of the high voltage generator, a 6 volt DC input should give a 15 kV DC output. The battery current as a function of the battery voltage is shown in Figure 15.3, which indicates that an input voltage of more than 2.25 V is needed to form a corona in the sampler. An example of the influence of the battery current on the collection efficiency is shown in Table 15.2.

15.3.3 Battery life

Battery life depends mainly upon the current output and the battery temperature. At temperatures above 23°C the 1.5 V Berec alcaline MN1300 batteries which were used in this study could run during approximately 75 hours before the battery voltage dropped from 4.5 V to 3 V.

15.3.4 Practical use

In order to get a general picture of the performance of the sampler in practical field operations, it was used to determine the total particulate emission from a ventilator system above two electric arc steel furnaces. 10 samplers were built and used simultaneously on different ventilator drums. 5 mm nozzles and an aluminium foil were used. The battery current was constantly above 140 mA and the flow velocity constantly below 15 m/s.

More than 35 samples were taken. Positive experience was gained from the measurements. The aluminium foils made the work handy as they could be folded and easily stored after sampling. Scattered rain storms did not seem to influence the operation although the high-voltage source and the shaft was getting wet. The sampling efficiency was 97.5% as determined with the filter method, the amount of collected particles being as high as 389 mg. Visually, it could be checked that the sampling efficiency was normal by the sight of the particle deposits on each sample. In such a case the rear end of the foil ought to be relatively free from particles and the front end, especially the first centimetres, well covered. Although there was rather intense vibrations from the fans, the deposits on the foils seemed to be intact.