THE GRANULOMETRIC CLASSIFICATION OF AEROSOLS USING A NEW TYPE OF CASCADE IMPACTOR (FOUR STAGE AEROSOL DIFFERENTIAL SAMPLER)

L. MAMMARELLA

Laboratorio sull'Inquinamento Atmosferico, C.N.R., Rome, Italy

ABSTRACT

The importance of classification of aerosols according to diametric size is well known. In fact it is possible to find a series of differential devices working on this principle ('Cascade Impactors' of May, Orr, Lippman, 'Eolic Classificator' of Zurlo, 'Centripeter Impactor' of Hounam and Sherwood, etc.). The big interest in this field has led us to devise a four-stage aerosol differential sampler with the following principal characteristics:

(i) high efficiency and selectivity,
(ii) simplicity of use and function,
(iii) possibility of sampling high air volumes without conglomeration of particles in sampling surfaces,
(iv) employment of usual collecting surfaces (microscope slides).

The sampler gives satisfactory responses from all the above points of view.

INTRODUCTION

Many devices for collecting aerosols are based on the principles of impaction. We shall consider a gas stream to pass through a pipe at a certain speed. If we place an obstacle across the flow, the gas stream will be diverted but the particles suspended in the stream will tend to maintain their initial direction, insofar as they will settle over the surface of the obstacle.

This basic behaviour is conditioned by the following two factors: (1) the stream speed, and (2) the size of the particles. The greater the particle size, the greater the collection rate at a fixed flow speed. Conversely, the efficiency for collecting small particles can be enhanced by increasing the flow speed.

The principle of impaction sampling can be applied both to liquid and solid surface collecting devices. With regard to the latter type of device, the simplest is represented by a surface collector (e.g. a microscope slide) exposed across the jet stream or gaseous flow. Related to such a primordial system, which obviously has a low efficiency, there is a series of much more complicated, more efficient devices.

Using such instrumentation one can impact air which is convected at a known speed through a fixed hole, over a surface crossing the flow direction; the collecting surface retains the particles abandoned by the fluid stream. The collection of particles of different sizes is a primary function of the flow speed at the surface level. The system can be adapted into a series of collectors by imposing, in a single device, more impaction stages and reducing proportionally, the size of the hole for the flow passage, at each successive level. In this manner one may obtain, without varying the initial stream speed, a successive deposition of smaller and smaller particles; the number of size classes will be the same as the number of stages. A four-stage cascade impactor was built in 1945 by May; this instrument greatly enlarged the performance possibilities in the air sampling field.

After May's device some others were projected and developed (the impactors of Lippman[3] and of Orr[6], the centripeter impactor of Hounam–Sherwood[2], the powder classifier of Zurlo[7], the biological impactor of Andersen[1], etc.). The efficiency of all of these impactors is good, and they are practically of the same order of accuracy. They may possibly differ in some technical and mechanical peculiarities or in their ability to sample different volumes of air. In order to increase the availability of such devices a new type of cascade impactor ('Aerosol Differential Sampler')[4,5], has been designed and developed with the following principal characteristics:

(1) simplicity and low apparatus cost,

(2) possibility of dividing a polydisperse aerosol into various size classes with a higher selectivity also for coarse aerosols,

(3) possibility of employing normal microscope slides as collecting surfaces and of assaying medium and high air volumes, without coagulation or agglomeration of particles on the collecting surfaces,

(4) settling of aerosol uniformly for making rapid and accurate evaluations.

The cascade impactor which we now describe does indeed satisfy the above mentioned requirements.

DESCRIPTION OF THE DEVICE

The four stage aerosol differential sampler (see *Figure 1*), is constructed from two substantially similar mating shells which, when fitted together, form an elongated housing. Each of these shells is subdivided into a series of chambers situated longitudinally. Closing the shells forms a series of slits which are more and more narrow from the top to the bottom. The actual slit dimensions decrease from the first to the fourth stage as follows: 1 mm–0·5 mm–0·25 mm–0·10 mm. The body is connected to a suction system. The dimensions of this device are, approximately, $16 \times 5 \times 8$ cm.

EXPERIMENTAL ASSAYS

In order to ascertain the sampling efficiency of the above mentioned cascade impactor various series of collecting controls were originally performed either employing special aerosols (fluorescent under U.V. microscope) or assaying open air. The initial employment of fluorescent particles has been considered very useful because it is possible to have a whole series of well sized powders. From a large series of such sampling assays it has been concluded also that, by comparison with other cascade impactors (essentially of the types named above), the collection efficiency is very satisfactory. This high efficiency is developed even at the first stage level (for the coarse particles). Above all it was possible to ascertain the feasibility of long period samplings (up to 1000-1500 litres of air) without producing a high degree of particle conglomeration on the collecting surfaces. Obviously the volume of air treated is a function of the pollution level. This is primarily because of the amplitude of the collecting strip (about 6 centimeters); in this way the sampling becomes statistically valid.

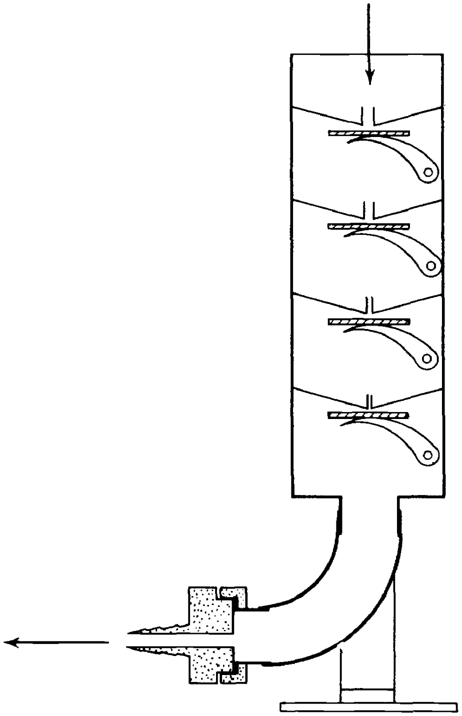

Figure 1. Four stage aerosol differential sampler.

Figure 2 shows a comparison of collection between an industrial area (left), an urban area (middle) and a suburban area (right), at the same time on a winter's day. The collection volume was 300 litres of air at a speed of 30 litres/minute.

SOME ADVICE FOR AN APPROPRIATE SAMPLING

First of all, it is necessary to clean carefully the interior of the collector before starting. This operation is particularly easy because the device may be completely opened. The separation between the slit and the corresponding microscope slide is assured by two guides engraved in the body of the collector. The differences between the slits and the collecting surfaces are strictly proportional to the breadth of each slit. Before use, the slide must be clean but great care is not necessary; an inexperienced operator need be only briefly trained to observe the aerosol background in the slide under a microscope. Very rapidly he will be able to differentiate this background from the depositing strip. In fact the latter is very characteristic and very regular.

SUMMARY

As a result of the various experiments made, the selective efficiency of the various stages of an aerosol differential sampler was determined. In this context it is worth noting that the selectivity of the impactor may vary, the

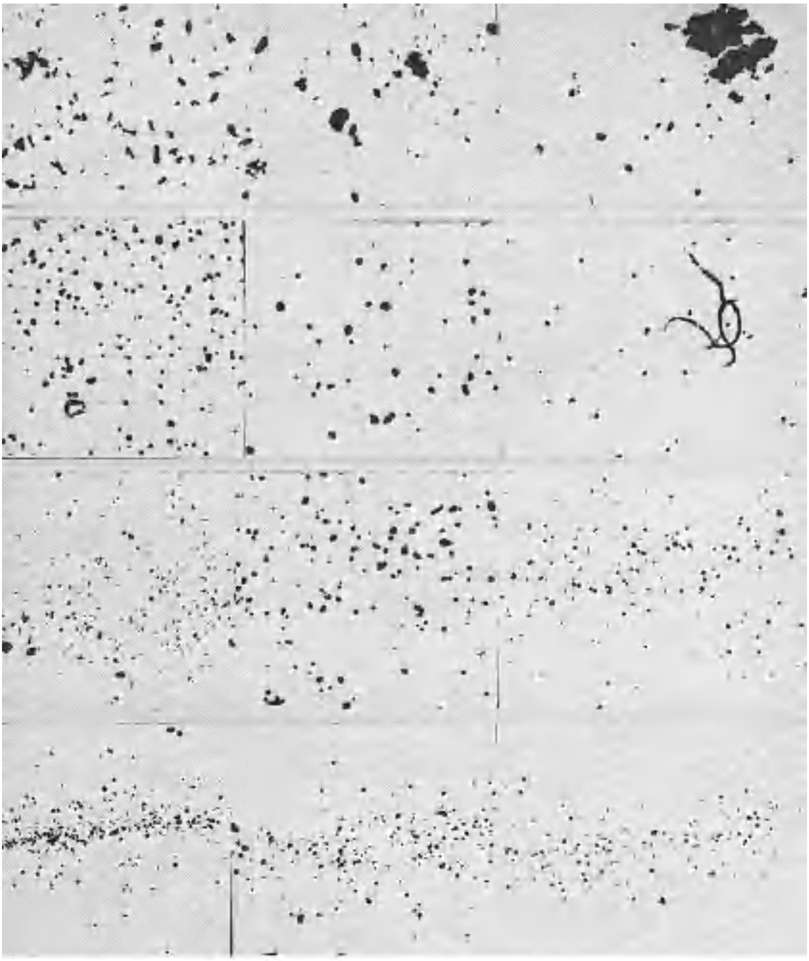

Figure 2. Comparison of aerosols collected from three different areas (*left:* industrial, *centre:* urban, *right:* suburban).

dimensional values both diminishing the breadth of slits (operationally not easy), and varying the suction speed. One may claim that the apparatus has a good selectivity at a reduced suction speed (20-30 litres/minute) especially when aerosols are grouped in size classes of multiples of 5 microns.

The employment of the linear cascade impactor that we have described is as simple as the methods of counting particles. This is principally due to the following:

(1) The very regular deposition of aerosols over the collecting strip; consequently it is only necessary to count over a few microscope fields

randomly chosen along the strip and then multiply the number of particles per field by the number of fields in the whole strip.

(2) The situation of the collecting strip along the middle of the microscope slide.

(3) The noticeably large total area of collecting surfaces, which allows the evaluation of medium and high air volumes and, therefore, gives statistically valid readings.

References

[1] A. A. Andersen. *J. Bacteriol.* **76**, 471–484, (27 Nov. 1958).
[2] Hounam–Sherwood. cf. ref.[5]
[3] M. Lippman. *Amer. Ind. Hygiene Assoc. J.* **22**, 3 (1961).
[4] L. Mammarella and L. di Giambernardino. Prove di prelievo comparativo fra il 'cascade impactor' (MAY) e il 'campionatore differeniale a 4 Stadi (Mammarell 1° modello).
[5] L. Mammarella. Inquinamenti dell'aria e loro rilevamento—"Il Pensiero Scientifico Editore"–Roma–nov. 1968.
[6] C. Orr, Jr. Cascade Impactor for Sampling Smokes, Dust, Fumes—U.S. Patent Office—2–967–164—August 2 1960.
[7] N. Zurlo. Nouveau pneumo-classificateur pour poussiéres fines–Comm–au "Quatriénne colloque sur les poussiéres" Institut Nationel sur le securite. 28–30 III, 1957, Paris.