EVALUATION OF AEROSOL POLLUTION USING A THREE DEVICE SYSTEM

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ABSTRACT

The characterization of air pollution)in a particular area is connected with the acquisition of a series of statistically significant data. The actual case referred to is a sampling campaign developed in a station in an urban area (Rome), throughout a period of 12 months. For controlling the behaviour of aerosol pollution according to a most complete characterization the three following apparatuses have been employed:

(a) continuous impact sampler (Hirst Spore Trap)
(b) continuous filtration sampler (Aisi Sampler)
(c) differential 4-stage sampler (Mammarella).

Through comparison of data resulting from the three series of sampling it has been possible to analyze:

(i) the behaviour of pollution in its complexity
(ii) the rate of pollution due to coarse aerosol particles
(iii) the median diameters of different fractions of aerosols.

INTRODUCTION

There are several methods for sampling and classifying air pollutants; in addition the types of samplers, when used to determine both aerosol or gaseous (vapour) pollution, may differ. With regard to aerosol sampling procedures, in particular, the best known and most frequently applied principles are the following: settling, impaction (both on liquids and solids), filtration and the application of thermal or electrical forces.

Settling procedures are principally employed for characterizing coarse aerosols; in fact the more diameters of particles decrease, for a given mass value, the more the settling speed decreases. The collection efficiency for small particles is therefore more and more influenced by meteorological parameters (namely, temperature and wind). Consequently such a type of procedure may be considered useful only for aerosol particle sizes of over 30–40 microns. Higher efficiencies may be obtained however by exposing deposit gauges for long periods of time, utilizing in this case the washing action of rain.

Impaction procedures, both on liquids and solids, exhibit a wide range of efficiencies, which depend principally on the suction speed and the diameter of suction openings. However, in contrast to the settling technique, an impaction sampling implies a volumetric measure of the inspired flow and, as a consequence, one may correlate the pollution levels with the flow volume assayed.

Filtration procedures also give different efficiencies, depending on the flow rate or the porosity or thickness of the filter. Frequently in this order of apparatus, large volume samplers are employed. However these devices, while allowing the collection of a relevant quantity of aerosols, are mainly directed to characterize coarse aerosols. Dependence on the fact that small particles are increasingly discharged behind the filter system, necessitates a longer aspiration time for release, scattering phenomena, etc. Finally, thermal or electrostatic precipitators are highly efficient; however, and particularly in the case of the thermal devices, the flow rate is so low that it is very difficult to find a statistically meaningful interpretation.

Above all it is very difficult to foresee continuous sampling over an extended period. The evaluation of aerosol pollution must be extended to all diametric values with the possibility of making long period samplings. Only after fulfilling such conditions will it be possible to obtain useful results. For this reason efficient, but at the same time simple, devices capable of being employed for prolonged periods of time are needed to analyse representative air volumes. In this way sample periods can be extended to days, weeks and months; it must be possible to evaluate both the deposition and the risk of inhalation.

The simplicity of the apparatus described here involves, from a practical point of view, the possibility of employing unspecialized people and hence a low cost of all the operations and devices. These considerations are of prominent interest when we remember that often, for coordinated research work, a high density sampling becomes necessary.

DEVICES EMPLOYED

From the above considerations we recognize the necessity of having more than a single type of collector in a sampling system, because the whole system must be able to identify and classify various aerosol sizes. Apart from providing a characterization of the settling rate and risk of inhalation, it will also be possible in this way to envisage the behaviour of gases and vapours in the atmosphere, the diffusion model of these pollutants being strictly related to that of fine aerosols. In order to have a good sampling response, a three device system as now described has been chosen: an impaction continuous sampler (Hirst Spore Trap), a filtration continuous sampler (Aisi) and a four stage aerosol differential sampler (Mammarella).

The Hirst apparatus (see *Figure 1*) is essentially a suction pump (flow rate 20 litres/minute) and a slit sampler; the aerosol impacts over a microscope slide which moves slowly from the bottom to the top (speed: 2 mm/hour). Along the slide a depositing trace corresponding to the pollution levels through the different periods of a day will become evident. The sampler, which can be employed regularly over periods of months, was developed by Hirst with the primary purpose of sampling airborne spores or pollens (hence the name 'Spore Trap') because it attains a better selectivity for low mass particles of diameters above 5–7 microns.

The Aisi apparatus (see *Figure 2*) may develop a suction speed very near to that of the Hirst sampler. An air stream passes through a paper strip filter automatically moving with a preassigned period. In this way a series of spots is obtained along the paper strip, the optical density of which depends on the quality and quantity of depositing aerosols. In our case we have timed each spot every four hours, thus obtaining six readings each day. Furthermore the Aisi device is able to operate continuously for a very long time.

The four stage differential sampler (Mammarella, see *Figure 3* and described on pages 715–719) is a new type of cascade impactor. Because of the

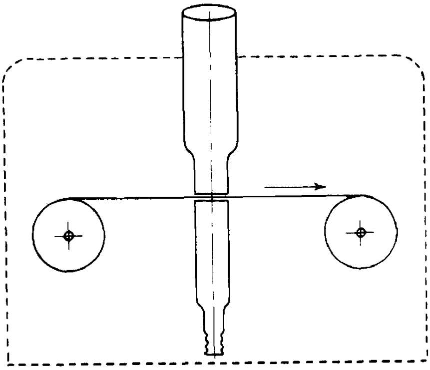

Figure 1. Diagram of the Hirst Spore Trap.

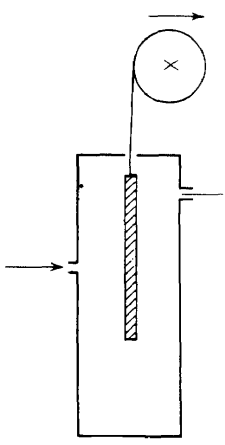

Figure 2. Diagram of the Continuous Aisi Sampler.

length of the sampling strip (practically the length of a microscope slide), the sampler is able to assay medium and high air volumes, subdividing an aerosol into four size classes. This cascade impactor has been employed for discontinuous operations, however, always assaying the same air volume (300 litres at a rate of 30 litres/minute), to control the size variations through the various seasons and through different hours of the same day.

Evaluation of aerosol pollution has been made as follows:

(1) for Hirst and Aisi samplings a densitometer device is used (the same instrument for both apparatuses to obtain the same magnitude of reading).

(2) for the differential aerosol sampler the different slides are observed under a microscope and the deposited particles are classified.

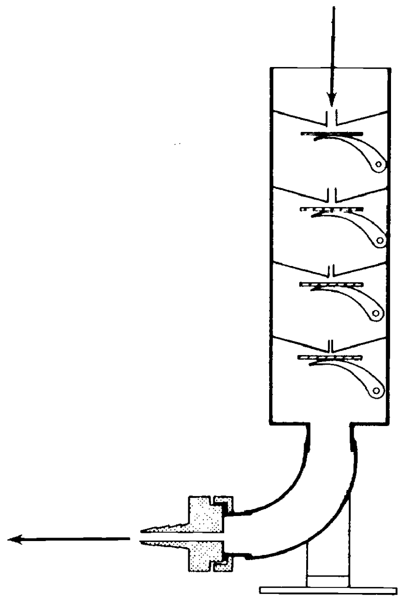

Figure 3. Section through the Four Stage Differential Sampler.

RESULTS

Tabulation of the data has allowed construction of daily curves for the Hirst samplings and six histograms per day for the Aisi samples, which were plotted in a Cartesian axis system. The curves derived via the Hirst apparatus indicate the behaviour of coarse particles, while the Aisi device histograms characterize the entire aerosol pollution.

We carried out experiments for some three years with this method and we have had very interesting results. For example, a winter day sampling in Rome (see *Figure 4* top) shows a noticeable concentration of coarse aerosols (particularly in the early morning hours and in the early afternoon) accompanied by a corresponding quantity of complete (total) pollution. Both coarse and whole aerosols exhibit a certain decrease (not always exactly proportional to each other) on passing from winter, through spring, to the summer months. *Figure 4*, lower portion, shows a sampling result during the spring (March 13) and *Figure 5* shows the minimal levels in summer. By comparing the double series of results (obtained from the two apparatuses) one may derive useful indications regarding the prominent sizes of captured aerosols throughout the various seasons.

A more clean and complete orientation may however be obtained through the simultaneous examination of data derived from the employment of the cascade impactor; for the same time periods of observation, *Figure 6* shows

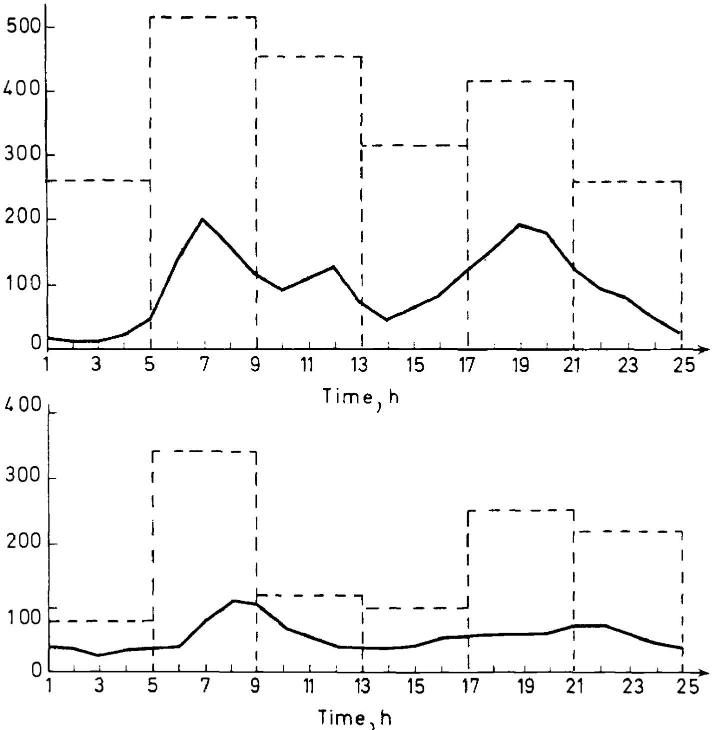

Figure 4. The behaviour of aerosol pollution (histograms: total; coarse aerosols: curves) Top: a winter day, bottom: a spring day.

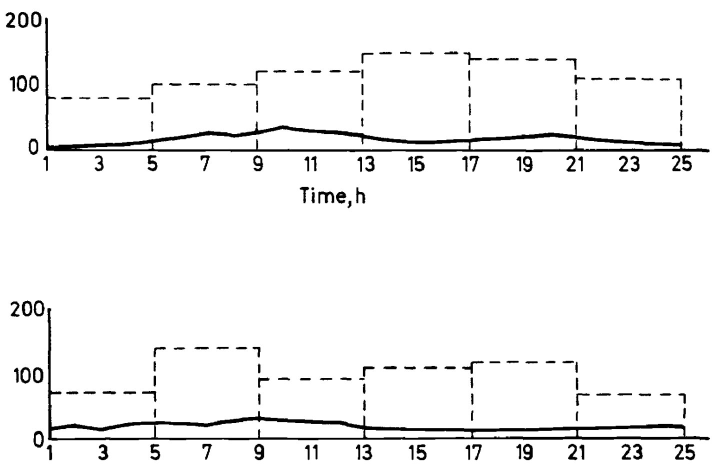

Figure 5. Minimal aerosol pollution levels on summer days (top: June, bottom: July).

the incidence of size classes in a more detailed manner. The continuous decrease of coarse aerosols starting from winter to summer (from about 15–5 per cent for aerosols larger than 20 microns, and from 20–10 per cent for aerosols of about 10 microns) is particularly evident. While the median size particles tend to maintain a constant rate during the different seasons, the smaller particles increase from 20–30 per cent (winter) up to 50–55 per cent (summer).

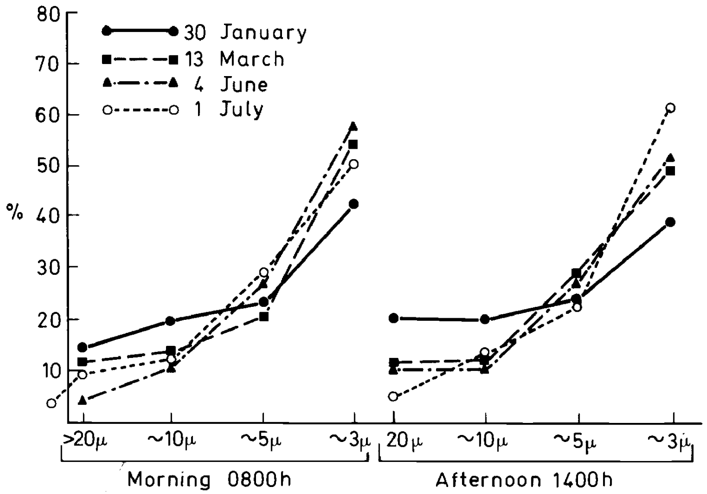

Figure 6. Variation of granulometry of aerosols in different periods of the year (measurements taken with the aerosol differential sampler).

DISCUSSION AND CONCLUSIONS

An examination of the results obtained demonstrates the interesting possibility of using an integrated system of aerosol sampling devices. In fact, a settling sampling system would characterize mainly the coarse aerosol components without the possibility of extrapolating volume concentration data; on the contrary an impaction sampling procedure will give correlated data of the same order but more reliable and complete. If we compare the data obtained from the impaction and filtration systems, it is easy to make correlation between the coarse aerosol pollution and the total pollution. Furthermore the periodic employment of a cascade impactor allows the comparison of diametric values through the different seasons and hours. From an analysis of the slides of the cascade impactor it is also possible to obtain more detailed data for the size, morphology and nature of aerosols.

Finally, another advantage may be the possibility of relating a greater or smaller diffusion of gases or vapours, according to the ratio of fine aerosols. Other pollutants (e.g. biological) may also be studied with the above mentioned system. In fact, by examining the findings of both the Hirst and Mammarella devices under a microscope one may identify numbers and species of spores, pollens, or other biological pollutants. Such a system appears, therefore, to be capable of representing the backbone of a sampling system.

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