The analysis of the fine and ultrafine dusts present in the atmosphere

C. Giglioni¹ & F. Patania²
¹ Con.Tec Engineering Srl
² Energy and Environment Division of D.I.I.M.- Engineering Faculty of University of Catania, Italy

Abstract

One of the main sources of air pollution is the emission of fine and ultrafine dusts (PM₃) originated by processes of combustions both from private and public transportation and from industrial activities. The knowledge of both types of dusts and the concentration of such PM₃ in the air which people breathe is very important in order to provide Health Authorities with the necessary information to face the problem and to forecast suitable interventions to reduce health negative effects of this kind of air pollution. In this way, it is necessary to have “technics of measurement” and relative equipment able to measure in real time the concentration both of “less than 10 μm” and less than 1,0 μm” particulate matters. The aim of this paper is to show some methods of measurement and particularly, the “light - scattering” technics.

1 The measurement methods for fine dusts

Among the different methods to measure PM₃ in the air some of them are well known as:
A) “Weighting Method” (WM), where a flow of polluted air pass through a membrane which retains the dusts. Knowing the volume of air passed through the membrane and weighing the amount of dusts retained by itself, it is possible to measure the concentration in weight of whole dusts referred to the air volume. The inconvenience of technics are:
  • people are not able to have information about the quantity of each kind of particulate matter, that is how much concentration there is for each PM₁₀ ,PM₂,₅, PM₁,₀ , and so on;
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- It is necessary to have the equipment to collect dusts and to weigh dusts and, in this way it is not possible to have in real time the measure of each kind of particulates;
- There is some difficulties to carry in situ of measurements the whole equipments.

B) “β-rays method” (BRM), where a well – known and controlled flow of polluted air is drawn through a well defined space of paper tape during a fixed period of time. A β-rays emitting sources is allocated at the back of the tape and, by measuring β-rays emissions before and after the passing of polluted air flow through the equipment people is able to measure the attenuation of β-rays. The attenuation is proportional to the thickness of layer of dusts deposited on paper tape and so it is possible, by knowing the mass of dusts deposited on tape, and the volume of air passed through the cell, to correlate the concentration of PM in the air to the attenuation of β-rays. The method presents some inconveniences as like:
  - Difficulties to correlates the thickness of layer with attenuation phenomena (i.e. calibration)
  - The matter of particulates can influence the measure (i.e. radioactive emission from particulates)
  - Impossibility to have in real time informations about the sizes of particulates.

C) “Electronic Balance Method”(EBM), where a well –known and controlled flow of polluted air strikes a quartz device. Because of the frequencies of oscillation of quartz have to change in function of the mass of dust trucking the device, by measuring the difference of oscillation of quartz before and after the flow of air passing through, people are able to correlate the difference with the concentration of PM in the air sample. The method present quite the same inconvenience of previous ones.

D) “Light – Scattering Method” (LSM). This new method uses a laser ray sources and utilizes the “scattering of light” to obtain the measure of dust concentration for each kind of thickness. With reference to fig.1 a probe with radial symmetry aspirates a flow of polluted air kept constant by apposite little pump, than the air flow is guided into the chamber where is struck by a laser light radiation coming from laser source. The rays of laser light which strike particulates contained in the air are reflected back, whilst the rest of them pass on.

The amount of reflected light has pointed out by a high-speed photodiode. More, as well known by Max Planck laws on radiation, the particles strucked by laser radiation, in their turn, send out a luminescent radiation proportional to the surface of particles themselves. The luminescent radiation has pointed out by photodiode too that converts both the reflected light and the luminescent radiation into electrical signals recorded and then elaborated in real time by microprocessor equipped with data logger.

Because people know exactly the quantity of air passed through the measurement cell during certain period of measuring time, it is possible by LSM
Figure 1: Light-scattering measurement method

Figure 2: Equipment based on LSM.
to know not only the number of dust particles present in the flow (light - scattering) but also their division in granulometric classes (luminescent radiation).

More, it is possible to couple to this method also the previous “Weighing Method”, in fact it is in-off to pass through a traditional filter with about 47 mm of diameter after that flow of air comes out from the chamber of measure.

There are some industrial application of method [1] which permits following interesting results:

- The kind of physical process on which is based on the method permits to use it a part from the matter constituting the particles;
- It is possible to obtain the measure in real time (about 6 sec) of concentrations of each size of dusts (PM$_{10}$, PM$_{2.5}$, PM$_{1.0}$)
- The equipment which includes the measure instrument and relative facilities (data logger – microprocessor), can be easily transportable (fig. 2)

2 The measurement method for ultrafine dusts

The method utilizes the same “light - scattering” phenomenon utilised for fine dust with the addition of particular processing equipments that permit to screen the ultrafine sizes of dusts (fig.3), that is:

- impactor: the device utilizing “lamination – phenomena” (Joule Thompson theories) lets that pass through itself particles of size less than 1,0 μm;

![Figure 3: Ultrafine dusts measurement Loop.](image-url)
• chamber: where is contained butyl – alcoholic saturated atmosphere: and where the particles act as nuclei of condensation increasing their diameters in such a way that a light – scattering system (see previously) it is able to make measurement.
• Electrostatic classifier: where for each set out of electrical tension only a correspondent size of granulometry is able to pass through

Of course utilities, as like microprocessor and date logger, conclude the loop of measurement. This method is able not only to give the global concentration of less than 1.0 μm dusts, but also to select particles ranging from 7 to 900 nm of diameter.

3 Conclusion

The “light – scattering” method associated with laser source seems to be one of the best method to measure in real time not only the concentration of dust but also their precise granulometry (PM\(_{10}\), PM\(_{2.5}\), PM\(_{1.0}\)). Infact, some experimental works [2],[3] has been done utilizing portable equipment, shown in fig. 2, based on such method.

There is the possibility to control too results coming from LS method by WM method, utilizing the same sample of polluted air in successive phase of laboratory.

References

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