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Analysis of vertical profile of particulates dispersion in function of the aerodynamic diameter at a congested road in Catania

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Abstract

During last decades the aerosol concentrations have increased causing a further restriction of current regulations. The World Health Organization (WHO) has estimated that the impact of aerosol air pollution to health, especially for PM10 and PM2.5, constitutes one of the main preoccupations in terms of the interaction health-environment. Since last report about air quality in Europe, published by European Environment Agency (EEA), it is evident that the 90% of citizens of European citiesis exposed to very dangerous pollution levels and, furthermore, it has been estimated that between 2009 and 2011 the 96% of population of main European cities was subjected to aerosol levels greater than the limits imposed by WHO.One of the main tasks of UE, within 2020, is aiming at reducing the pollution with a consequent improvement of its effects to health. In this work it was analyzed experimentally the distribution of aerosol particles in function of the sampling height and the aerodynamic diameters of particles. There were used portable samplers. The experimental campaign was conduced during rush hours in a high congested road of Catania at three different heights. Thanks to analysis of variance (ANOVA) it was possible to verify the interaction between the aerodynamic diameter of particles and the considered sampling heights.

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Keywords: Aerocet, Vertical profile, Particulate matter, Aerodinamic diameter.

1. Introduction

The atmospheric pollution is mainly caused by the presence in the air of one or more noxious substances, that could be very dangerous for human health in relation of their quantities or time present in the air [1]. A very interesting field of study concerns the particulate matters that represent the pollutants more diffused in the territory [2]. These aerosol particles could stay in the atmosphere for a considerable time, representing a danger for humans, animals and plants.

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The atmospheric pollution is mainly caused by the presence in the air of one or more noxious substances, that could be very dangerous for human health in relation of their quantities or time present in the air [1]. A very interesting field of study concerns the particulate matters that represent the pollutants more diffused in the territory [2]. These aerosol particles could stay in the atmosphere for a considerable time, representing a danger for humans, animals and plants.

The World Health Organization (WHO) has estimated that the impact of air pollution caused by aerosol particles (especially for PM_{10} and $PM_{2.5}$) constitutes one of the main worries for the interaction environment- health. The risk varies in relation with the particles sizes, as they are smaller as it is easier for them to cross the defences of respiratory system. The effects may be worse if these particles absorbed acid substances such as sulphur dioxide or nitrogen oxides. Many studies in European countries and Unite States have highlighted an association between the atmospheric pollutants levels and the daily number of deceases caused by cardiovascular or respiratory problems [3].

The equivalent aerodynamic diameter is one of many ways to measure the dimensions of particles. This physical quantity was introduced to compare particles of different shape, size and density.

In this work it was conduced a measurements campaign to study the aerosol particles in function of their aerodynamic diameter and height, the predominant aerodynamic diameter interval was also investigated [4]. The measures were taken at a very congested road during rush hours at three different heights. The simultaneous use of three instruments placed at different heights in the same point allowed to establish through Analysis of Variance (ANOVA) the possible interaction between the aerodynamic diameter of aerosol particles and the sampling heights [5].

Nomenclature

d	Aerodynamic diameter [μm]
h_i	Height [m]

2. Field of study

The orography and meteorology are fundamental elements to understand the dynamics of phenomena of emission, accumulation and dispersion of atmospheric polluting substances.

Catania presents an advantageous natural context. The climate is variable with sea breezes and ventilation speeds that facilitate the dispersion of pollutants mostly all the days of the year. The winter is characterized by mild temperatures, this allows to limit the use of domestic heating whose emissions would

be added to those caused by urban traffic. Vice versa, the torrid summers limit the deposition of suspended particles to the ground, facilitating the formation of photochemical pollution [6].

The favourable natural context partly compensates the negative effects of the intense vehicular traffic due to a robust commuting especially during working days toward the functional centre of the city.

3. Methods and materials

3.1. Sampling tools

The levels of particulate matter concentration were monitored in real time with portable instruments, Aerocet 531 particle profilers model. The operating principle the tool is based on uses laser light scattering technology that allows tocount the total number of particles and calculates the equivalent mass concentration using a proprietary algorithm (Met One Instruments™).

The calculated mass concentration ranges are: PM_1, $PM_{2,5}$, PM_4, PM_7, PM_{10} and TSP with a sampling rate of minimum 60 s. The instrument uses a right angle scattering method at 0,780 μm. The source light travels at a right angle to the collection system and detector, and the instrument uses the information from the scattered particles to calculate a mass per unit volume. A mean particle diameter is calculated for each of the five different sizes. This mean particle diameter is used to calculate a volume (cubic meters), which is then multiplied by the number of particles and then a generic density (μg/m^3).

The resulting mass is divided by the volume of air sampled for a mass per unit volume measurement (μg/m^3). The evaluation of particles mass, using this technology, could be influenced by an increase of relative humidity [7].

3.2. Sampling method

In order to obtain a vertical profile of concentrations there were used three Aerocet located in the same position at three different heights 1,5 [m] (h_1), 3 [m] (h_2) e 4,5 [m] (h_3)in a high congested road of Catania (Fig.1) . It was assumed first to start by1,5 [m] from the ground because averagely this is the height of human respiratory system and then it was used a step of the same height. The aim of this collecting data process is to identify the concentration of particles in function of aerodynamic diameters and sampling height [8].

The measurements were made during a critic time slot for the studied area. The measures were sampled for 5 weeks from 9:00 am to 6:00 pm. The humidity values detected during the sampling period were maintained at below the critical threshold of the instrument. The sampling method allowed the realization of a Database of homogeneous data in order to apply statistical evaluation methods.

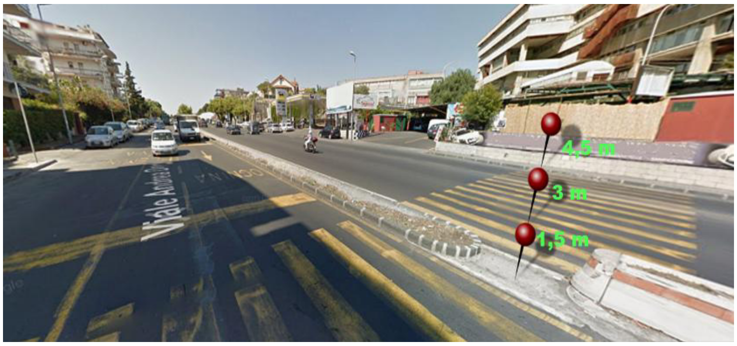

Fig. 1. High road of Catania and points of measure at three different heights [Google Maps,Online]

4. Data analysis

4.1. Anova

The analysis of variance was used in order to evaluate the possible correlation between the heights and the particles diameters. There were used two hypotheses: the null hypothesis foresaw that the concentration particles averages μ_{hi} calculated for the different diameters did not have a correlation with the heights (H_0:$\mu_{h1} = \mu_{h2} = \mu_{h3}$); the other hypothesis foresaw that the concentration particles diameters did have any correlation with heights (H1: $\mu_{h1} \neq \mu_{h2} \neq \mu_{h3}$).

Table 1 shows the results of this analysis for all cases: the variance between groups and inside groups, the ratio Snedecor-Fisher ($F_{(calc)}$) for a typical week.

The analysis of results was conduced considering a significant level α-value=0,05 and $F_{(critical)}$ = 3,23. H_0 is demonstrated when $F_{(calc)} < F_{(critical)}$.

According Table 1 H_0 is always rejected for PM_1 therefore height is not significant. In the case of $PM_{2,5}$ the hypothesis H_0 is accepted just for some days. It is possible to observe that the days where there is correlation between heights and concentration are those with low vehicular traffic. The other classes of particulate matters (PM_4, PM_7 and PM_{10}) present almost the same results: for all daysH_0 is demonstrated and height is not a significant parameter.

Table 1. Result Anova

		MON	TUE	WED	THU	FRI	SAT	SUN
PM_1	*Var. between*	2,65	2,79	3,40	5,39	14,36	4,97	1,85
	Var. within	0,42	0,66	0,93	1,58	0,67	1,53	0,29
	$F_{(calc.)}$	6,33	4,18	3,64	3,42	21,55	3,25	6,34
$PM_{2,5}$	*Var. between*	2,98	7,31	9,14	34,04	63,25	1,64	3,78
	Var. within	6,59	2,01	2,68	9,78	5,06	7,07	3,31
	$F_{(calc.)}$	0,45	3,63	3,42	3,48	12,49	0,23	1,14
PM_4	*Var. between*	18,29	8,04	14,20	595,58	170,00	0,38	2,07
	Var. within	10,42	35,97	15,81	959,40	70,23	18,92	36,62
	$F_{(calc.)}$	1,75	0,22	0,89	0,62	2,42	0,02	0,06
PM_7	*Var. between*	34,22	64,28	171,21	780,62	247,78	8,16	109,33
	Var. within	50,37	156,56	98,86	974,69	470,16	40,47	250,99
	$F_{(calc.)}$	0,68	0,41	1,73	0,80	0,52	0,20	0,43
PM_{10}	*Var. between*	84,49	189,41	412,24	470,88	467,60	29,69	395,98
	Var. within	109,08	328,75	305,29	950,07	486,82	56,38	562,09
	$F_{(calc,)}$	0,78	0,58	1,35	0,49	0,96	0,52	0,70

4.2. Analysis of aerosol particles concentrations for aerodynamic diameters intervals

According the results of ANOVA it is possible to deduce that the concentrations of PM_1 and $PM_{2,5}$ are effected somehow by the height of sampling point.

Therefore there were analyzed the predominant intervals of aerodynamic diameters for each height. There were considered five ranges: Range 1 ($7 \leqslant d < 10$ µm), Range 2 ($4 \leqslant d < 7$ µm), Range 3($2,5 \leqslant d < 4$µm) , Range 4 ($1 < d < 2,5$ µm) and Range 5 ($d \leqslant 1$ µm).

These ranges were compared in terms of their percentages for a typical working day and a non-working day. In Fig. 2 it is showed that Range 2 is the predominant for all heights, while for a non-working day (Fig. 3.) there is a different trend with a greater percentage of Range 3 for almost all heights.

Table 2 shows the percentuals concentration of particulate during working day and non-working day for each range.

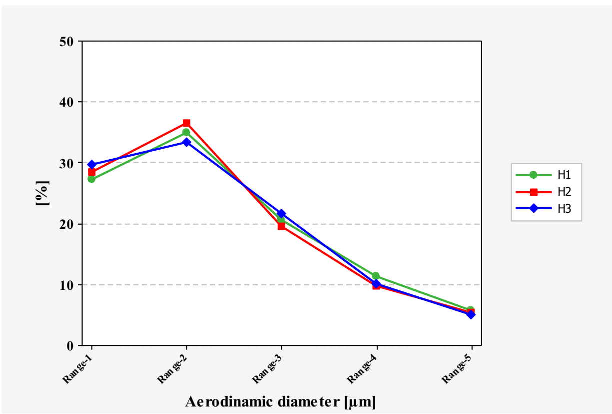

Fig. 2. Working day percentual concentration of particulate

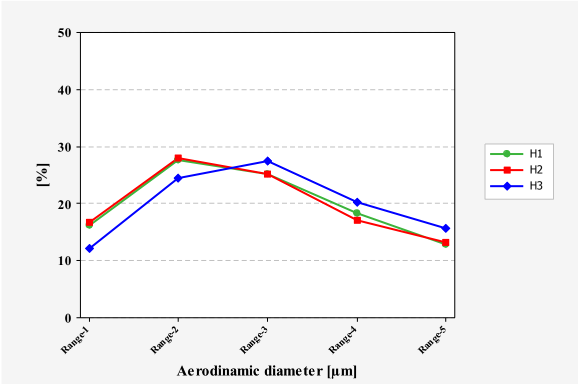

Fig. 3. Non-working day percentual concentration of particulate

Table 2. Percentual concentration of particulate

		Range 1 [%]	Range 2 [%]	Range 3 [%]	Range 4 [%]	Range 5 [%]
Working Day	*H1*	27,31	34,96	20,55	11,37	5,81
	H2	28,48	36,54	19,62	9,87	5,49
	H3	29,67	33,45	21,63	10,20	5,05
Non-Working Day	*H1*	16,15	27,65	25,13	18,26	12,81
	H2	16,73	27,96	25,09	17,10	13,12
	H3	12,15	24,51	27,51	20,20	15,64

5. Conclusions and future works

In this work it was analyzed the level of aerosol particles in an important arterial road with high traffic volume in Catania (Italy). The measures were conducted at different heights in the same place with three portable sampling instruments.

The analysis highlighted a great variability in terms of particles concentration; this variability tends to weaken with greater aerodynamic diameters. During the sampling period analysis of variance revealed that the vertical profile concentrations did not show a direct correlation with heights for all cases except the smallest particles (PM_1 and $PM_{2,5}$).

It was also analyzed the distribution of particles in terms of ranges of aerodynamic diameters showing a different trend between working days and non-working days. According all these results it was showed that the vehicular traffic effects somehow the distribution of these intervals causing a greater percentage of bigger particles.

Thanks to this approach it is possible, for future works, to apply it with greater heights and using at the same time anemometers. In this way it would be possible to investigate about the possible correlation with these data and those information such as velocity, direction and volumetric flow of wind.

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Biography

Andrea Caramagna received the M.Sc. degree in Computing Engineering at the University of Catania in 2008. He achieved in 2010 the master in management of energy and environment at University of Rome "La Sapienza". He is currently working at the Industrial Department of the University of Catania.