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Aerosol tracers deposition in a controlled field experiment: role of surface building materials

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***Abstract* – Submicronic fluorescein aerosols were used as the tracer during four test releases in a field experiment performed at the University of Salento, Lecce (Italy) during October 2014. The role of surface building materials is investigated through the analysis of near surface thermal flow characteristics. Turbulence and thermal conditions in the flow and wall boundary layer were measured simultaneously using an array of meteorological instruments, while concentration of fluorescein deposited on the five different surface building materials were measured by spectrofluorometric techniques. Wall and boundary layer temperatures were determined.**

Here fluorescein concentration and deposition velocity during the first release test are shown.

I. INTRODUCTION

The interactions between building materials and enviro nmental factors, such as meteorological and climatic fact ors, effects of air pollutants, as well as the effects of water and those of biological organisms, represent the cause of the deterioration mechanisms of buildings materials. Heritage degradation represents both an aesthetical problem and a risk for the structural integrity of buildings [1]. Starting from the knowledge that dry deposition is an important pathway for the transfer of pollutants from the atmosphere to surfaces [2] and that vertical surfaces are the prevalent surfaces in urban environments, in our study we intend to improve knowledge about the mechanism of dry deposition onto vertical surfaces and investigate the role of different surfaces building materials in order to improve the urban air modeling. For this purpose micrometeorological and local turbulent flow parameters, such as surface and air temperatures were determined during four release tests in the frame of a field experiment performed in October 2014 at the University of Salento (Lecce, Italy). The experiment consisted in the emission of an aerosol following the 'fluorescein release technique' presented in [3-5]. The experiment was followed by the measurement of concentration data of aerosol deposited on different building materials samples (for more details see Conry et al., 2016 and Di Nicola et al., 2016 [6,7]). We used thermography to highlight the thermal behaviour of materials commonly employed in building construction and its effect on aerosol deposition, the latter evaluated via Computational Fluid Dynamics (CFD) simulations.

II. EXPERIMENTAL SET-UP AND MEASURMENTS

The experiment followed the method by Maro et al. [3] and was based on the simultaneous emission of an aerosol consisting of fluorescein and Sulphur hexafluoride (SF6) as tracer gas, used to track the plume in the environment close to the wall. The scheme of instrumentation shown in Figure 1a was employed to acquire data on aerosol concentration, temperature, and wind speed and direction at high frequency (20 Hz).

A wooden panel (OSB3, sizes: 2.50m x 1.25m) was hung up on the façade of a wall facing west and located between two buildings, which formed a wide "street canyon" in the Ecotekne Campus of the University of Salento (Lecce, Italy) (Figure 1b,c,d). The whole experiment was carried out during three days (25 to 27 October 2014). In total, four 1h Tests (Test 1, Test 2, Test 3 and Test 4 hereinafter) were performed. Samples of five different materials were attached to the panel (Figure 1e): standard glass (SG), auto-cleaning glass (AG), marble (M), ceramic (C) and Lecce stone (L) (from left to right in the figure). Each sample was 10cm x 10cm square, with a thickness ranging from 4mm to 1cm. Insulating material (polystyrene) was used to cover the underlying surface of the panel to make uniform the surface and avoid interspaces that could disturb the flow. Further, the insulating material was painted black to reduce the albedo. The aerosol generator (source) was positioned 6m away from the samples, see Figure 1 of Conry et al. 2016 [6].

The deposition rate was evaluated as [3]:

$$v_d = -J / C_\infty \qquad (1)$$

where J is the mass flux (kg m^{-2} s^{-1}) of fluorescein aerosol on the wall and C_∞ is the fluorescein concentration in the air. Chemical spectrofluorometric techniques were used to evaluate concentration of fluorescein deposited on the various samples. Wind speed and direction were also obtained from two sonic anemometers and a wind master placed close to the wall (sonic A, B, and E, respectively, in Figure 1 of Conry et al. 2016 [6]). Data from a micrometeorological station placed upstream to the site were used to characterize incoming flow conditions for CFD modelling.

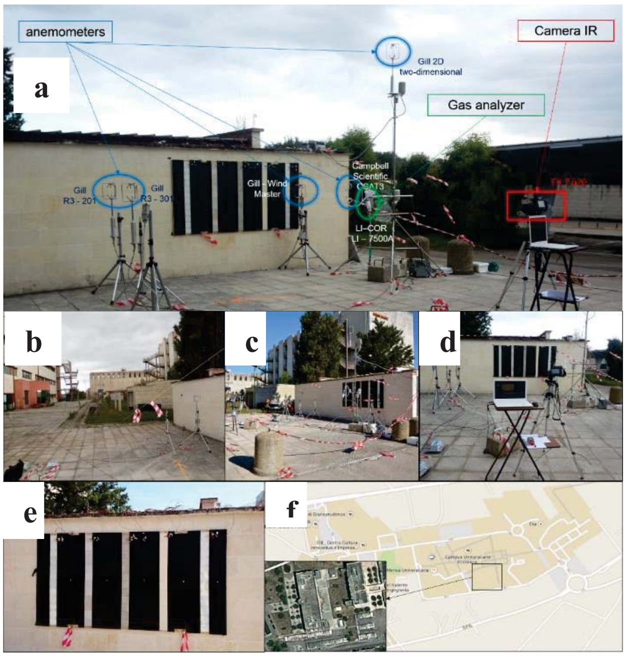

Fig. 1. a) Experimental set-up; South (b), South-West (c) and West (d) view; e) panel with material; f) aerial view.

III. FLORESCEIN CONCENTRATION DURING THE FIRST RELEASE TEST

In figures 3 – 7 fluorescence spectra obtained during the first release test are shown for the different building materials used in the experiment: autocleaning glass (figure 3), standard glass (figure 4), ceramic (figure 5), marble (figure 6) and Leccese stone (figure7). In each figure the overlapping of building material samples spectra can be observed. In the legend the first number indicates the test's number, the captions indicate the building material and the second number the position of the 10cm x 10cm samples of building material from the top to bottom of panel, as you can see in figure 2.

Fig. 2. Panel with material (zoom of figure 1e). SG: Standard Glass; M: Marble; C: Ceramic; L: Leccese stone; AG: Autocleaning Glass.

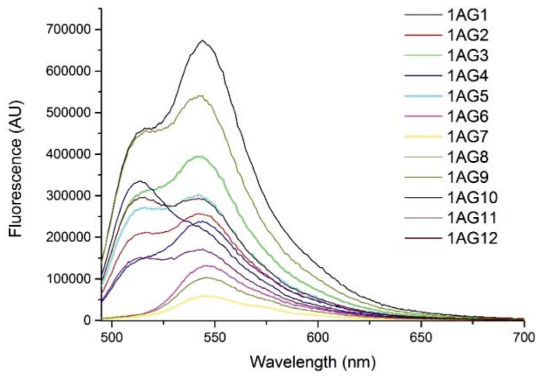

Fig. 3. Fluorescence spectra in the range 500-650 nm in autocleaning glass samples during the first release test. Overlapping of the 12 spectra related to the 12 autoclenaing glass samples.

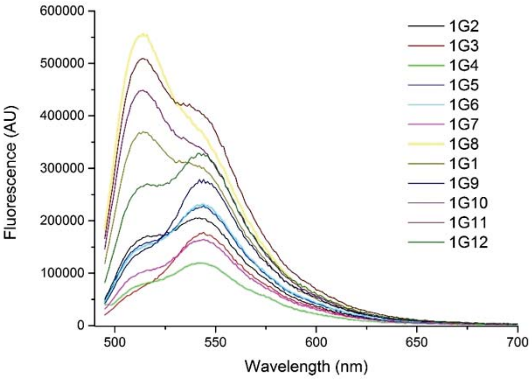

Fig. 4. Fluorescence spectra in the range 500-650 nm in standard glass samples during the first release test. Overlapping of the 12 spectra related to the 12 standard glass samples.

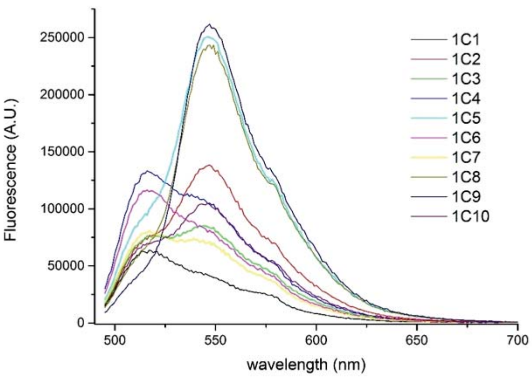

Fig. 5. Fluorescence spectra in the range 500-650 nm in ceramic samples during the first release test. Overlapping of the 12 spectra related to the 12 ceramic samples.

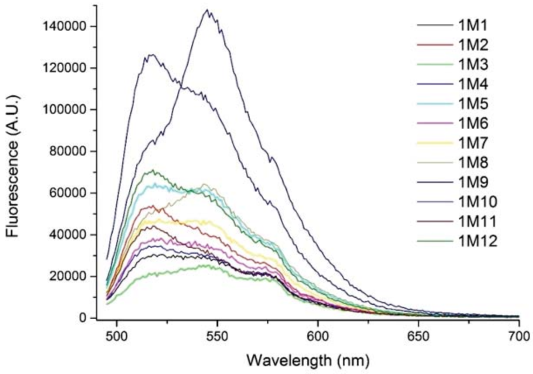

Fig. 6. Fluorescence spectra in the range 500-650 nm in marble samples during the first release test. Overlapping of the 12 spectra related to the 12 marble samples.

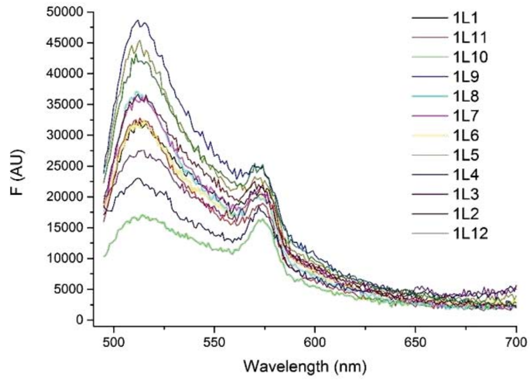

Fig. 7. Fluorescence spectra in the range 500-650 nm in Leccese stone samples during the first release test. Overlapping of the 12 spectra related to the 12 Leccese stone samples.

During the first release test, the analytical peak of fluorescein (512 nm) is visible for each material, as you an see observing figures from 3 to 7. Moreover, in each spectrum a peak at 550 nm is overlapped to analytical peak for all materials investigated except for Leccese stone one.

The interference at 550 nm has been observed also on the field blank filters exposed during the experiment and on the building material standards used except for Leccese stone standard.

It was not possible to identify the interference neither investigate additionally its physical-chemical characteristics.

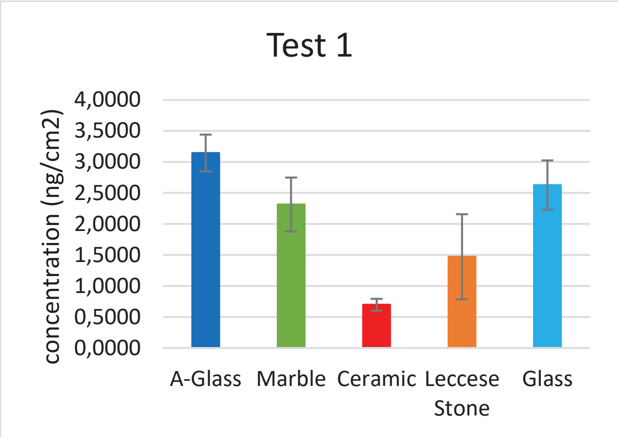

Fig. 8. Fluoresceine mean concentration values for different building materials used during the first release test.

Under the first release test conditions mean concentration values of fluoresceine showed high variability among building materials. In particular ceramic showed lower value, while standard glass material the bigger.

IV. DEPOSITION VELOCITY DURING THE FIRST RELEASE TEST

By chemical analysis via spectrofluorometric technique the total mass of fluorescein deposited on each sample has been determined, as well as mass of fluorescein collected on the LVSs' filters (fluorescein in air was collected by Low Volume Samplers). The mass on each sample's surface was integrated over sample's area and the emission duration to calculate the mass flux onto the sample, which is the term in the numerator of Eq. 1. The mean concentration at LVS 1 was obtained by dividing the deposited mass on the filter by the total volume sampled based on pump's flow rate.

Eq. 1 was then used to calculate the deposition velocity for each material and emission interval. The average deposition velocities are presented in figure 9.

Results of the first releasee test indicate that deposition velocity have a variability ranging between 10^{-2} and 10^{-3} m/s in magnitude, with bigger value for autocleaning glass material and lower value for ceramic one (in absolute terms). In the same experimental and meteorological conditions different building materials showed different deposition velocities.

Comparing the deposition velocities of the investigated material surfaces among the all tests performed (not shown here), it has been observed that the presence of a temperature gradient may have played a dominant role in the different deposition of fluorescein found in tests. As shown in details in Di Nicola et al. [7], the different thermophoretic force was in fact responsible for moving particles with V_{th} depending on the temperature gradient and directed opposite to the gradient itself. In particular, V_{th} in Test 1 was constantly negative being the material samples colder (about 2°) than the air close to the sample and with the surrounding air. More details can be find in Di Nicola et al. [7].

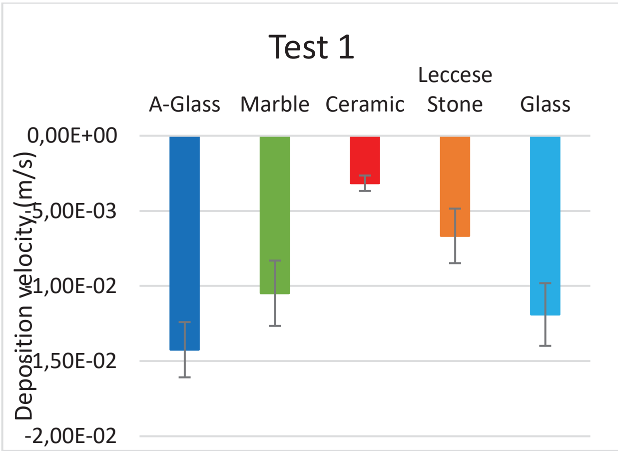

Fig. 9. Deposition Velocity for all surface building materials during the first release test.

V. CONCLUTIONS

In order to investigate the dry deposition of submicronic aerosols onto building materials, a field experiment was conducted in an urban-like environment.

Results showed that in the same experimental and meteorological conditions different building materials showed different deposition velocities.

The use thermographic techniques allow the evaluation of temperature differences between different materials at a frequency close to atmospheric turbulence. It is suitable to study the combined effect of near-surface atmospheric turbulence and buoyancy.

The analysis showed the presence of a temperature gradient during the tests and thermophoretic velocity suggests that thermophoresis acted in a decisive way increasing the deposition of fluorescein greatly [6-7].

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