Action P3 ; Field Campaign Strategy

The general objective of the field campaigns included in the PhotoPAQ project is to assess on the field the effects of the photocatalytic materials on the air quality of the area where applied. This objective implies to set up a strategy which would allow to obtain measurable effects which can then be extrapolated at larger scale.

The basic principle of the field campaigns is to compare under very similar environment the effect of active surfaces with that of “normal” surfaces.

General strategy

The general strategy which has been adopted is based on deployment of two identical sets of scientific instruments upon two measurement stations: one under influence of air which have been in contact with the active surfaces, the other under influence of “normal” air.

Tunnels campaigns strategy

General

The first field site which has been chosen is a urban tunnel travelling underground below Brussels city centre: the Leopold 2 tunnel.
The Leopold II tunnel is a bi-directional tunnel located in the Brussels city centre along the Basilica – Midi axis, within a densely built urban environment (Figure 1).

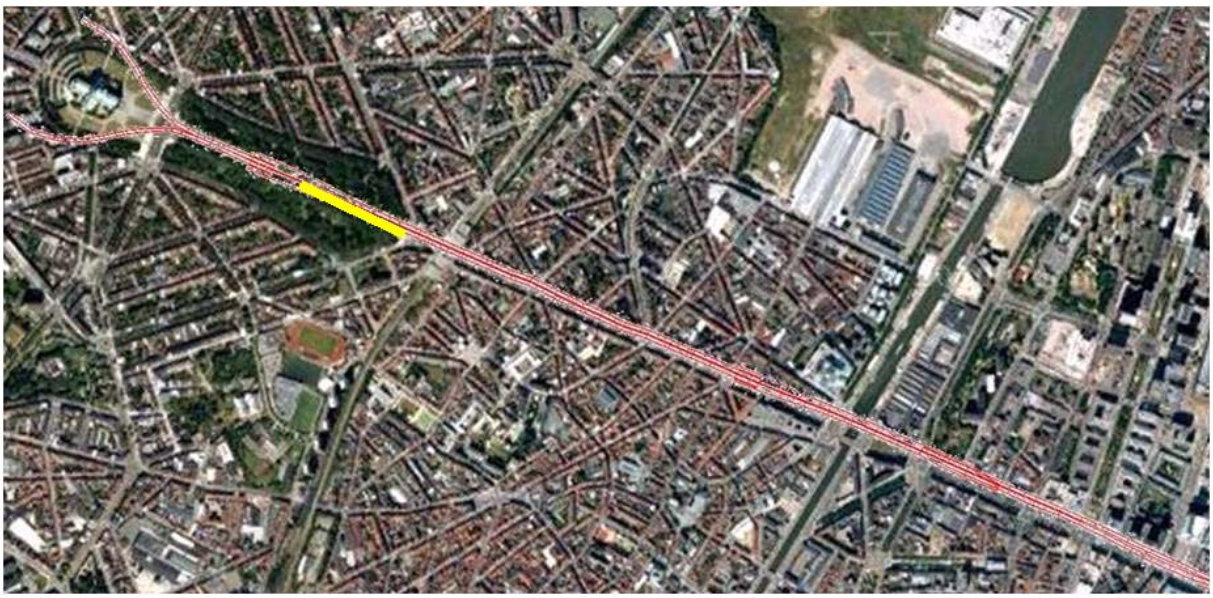


Figure 1 : Leopold II tunnel pathway – In yellow the segment chosen as field site

The geometry of the overall tunnel is highly complex as it is about 2.3 km long and consists of two segments separated by a wall, with varying cross sectional areas along each direction.
The above described criteria have been applied to the tunnel to identify a suitable section.
The tunnel is subject to a heavy traffic and a flow of several thousands of vehicles per hour is regularly reached. This assures a sufficient level of pollutants. In spite of the complexity of

the tunnel geometry, it was possible to identify a section of a length of 80 meters for the first campaign (180 me for the second) exhibiting a regular cross-section which enable a precise modelling of the air flow. It should be noted that as the two segments are separated by a wall, each one can be considered as a one-directional tunnel.

To apply our strategy, two heavily instrumented monitoring stations have been set up ☹see figure 2) The first one - referred from now as the front site – is the first to be encounter by an air mass when the flow of car induce sufficient movements of air. The measurements here are considered not to be affected by photocatalytic material effects in most of the case. The second one – referred as the main site – is generally fed with air which has encounter contact with photocatalytic material.

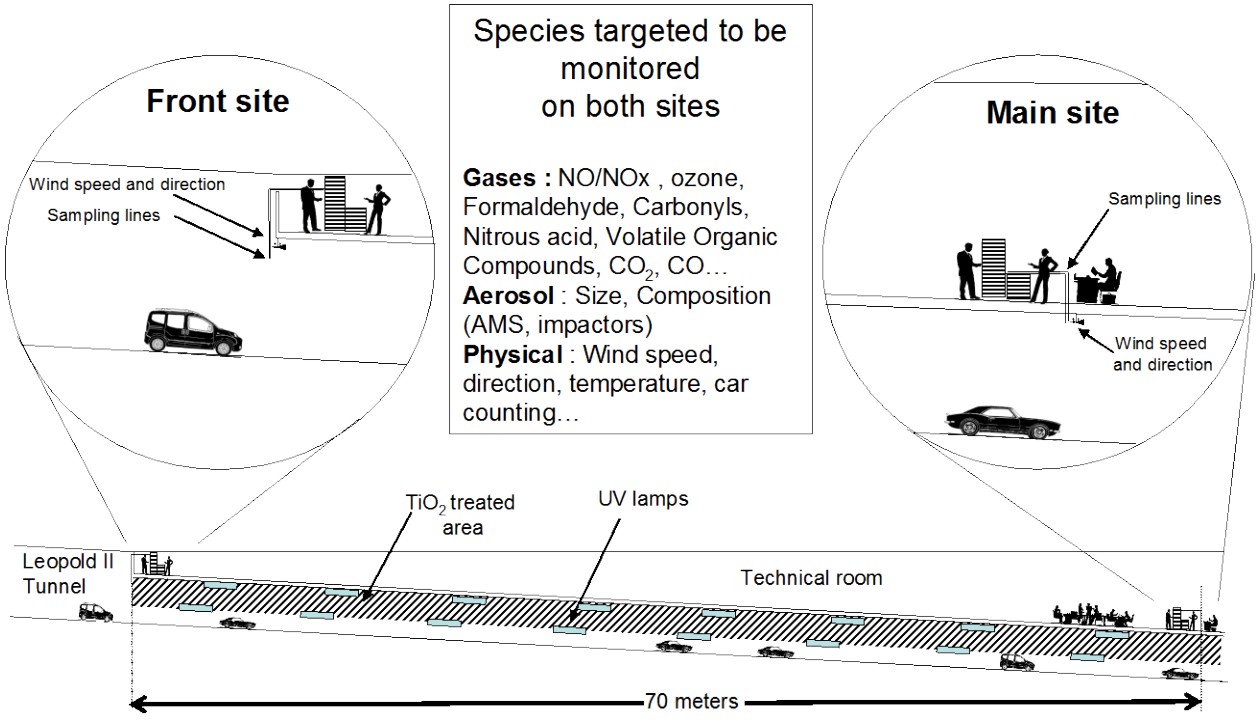


Figure 2 : Schematic of the monitoring station built in the Leopold II tunnel for the first Brussels campaign (September 2011) – the airflow is following in most of the case the car flow (i.e. here from the left to the right)

Compounds/Parameters to be monitored

Gas phase measurements

A series of gas phase measurement techniques have been targeted to be deployed on both site. They include:

NO/NOx: Nitrogen oxides are key species for air quality. They play a significant role in oxidizing capacity of the atmosphere as propagating species of the photocatalytic cycles which lead to the accumulation of ozone. In addition, NO_2 is regulated for which target levels have been decided by the EU (European Parliament and the Council or the European Union, 2008). Furthermore, experimental evidences from P1 and P2 actions from PhotoPAQ have shown that nitrogen oxides are highly sensitive to oxidation induced by photo-reactive

materials. It is certainly among the most critical species to follow for the assessment on the field of the air cleaning efficiency of Photocatalytic surface

Formaldehyde: Formaldehyde is toxic and is also involved in photo-oxidation cycles of transformation of air pollutants as initiating specie. Experimental evidences from P1 and P2 actions from PhotoPAQ have shown that HCHO is highly sensitive to oxidation induced by photo-reactive materials but can also be produced during the oxidation process of VOC. It was hence necessary to monitor it on the field.

CO_2. Carbon dioxide is certainly not affected by TiO_2 containing surface as being a very stable gas. Nevertheless its monitoring was mandatory as a tracer of vehicles emission to normalize observation (see below)

Nitrous acid: HONO is a very important initiator of photo-oxidation cycles of air pollutants. It is generally produced by heterogeneous reaction. P1 and P2 actions have shown a significant production of HONO by photo-catalytic surface when not alkaline. In spite of a well established alkaline nature of the applied material in the tunnel but considering that HONO formation could be one of the major drawbacks of the TiO_2 de-polluting techniques, it has been decided to carefully monitor it on both sites of the tunnel.

Ozone: As its reaction with NO is very fast, O_3 is unlikely to be found in significant concentration in a NO rich environment such as a freeway tunnel. Nevertheless, considering its major importance for air quality and the fact that a previous study has shown its production on TiO_2 surfaces (Monge et al, 2010) its monitoring on both sites of the tunnel have been decided.

Volatile organic compounds (VOCs): Volatile organic compounds are a class of species which is also critical for photo-oxidation cycles that lead to harmful air pollutants (ozone, aldehydes, peroxyacyl nitrates, particles). Some of them such as aromatic species are directly toxic. Furthermore, experimental evidences from P1 and P2 actions from PhotoPAQ have shown that some VOCs are sensitive to oxidation induced by photo-reactive materials.
This class of species covers both primary emitted species and secondary produced compounds. It consists in several thousands of species. It would be hence certainly an illusion to aim at monitoring all these species. It has, hence, be decided to cover a selection of light and heavier primary VOCs by deploying adequate techniques (GC-FID and GC-MS after sorbent cartridges sampling) and, on the other hand, for secondary (oxidized) species specific techniques were applied (HCHO monitor and DNPH-derivatization HPLC)

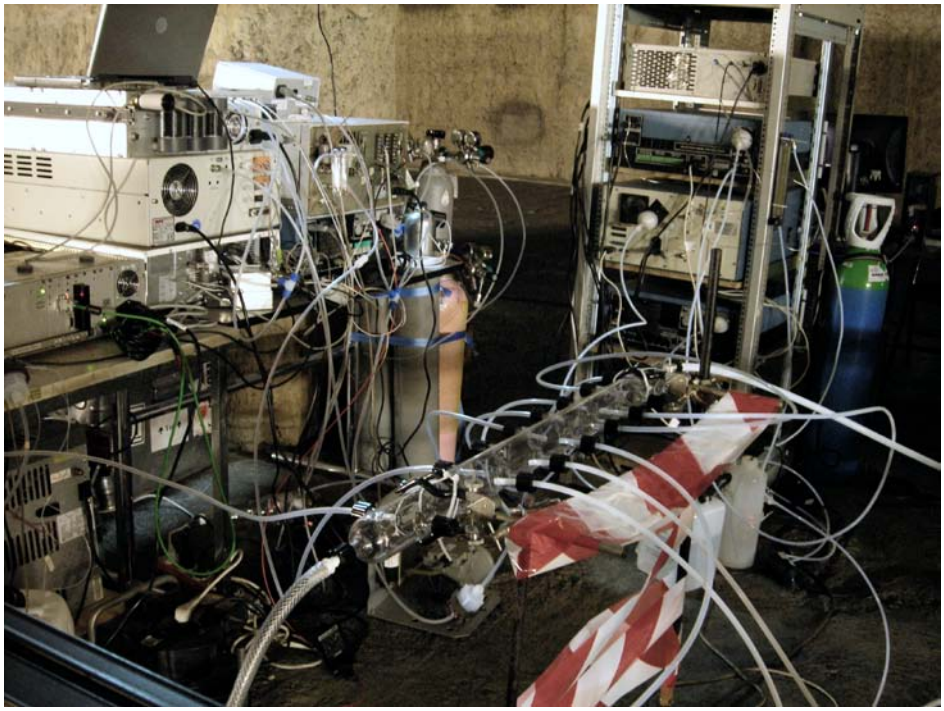
Physical parameter measurements

It has been identified that air flow modelling is certainly a key point in interpretation of the data arising from the Brussels tunnels campaign. In consequence two wind speed /direction sensor were installed near the exits of the sampling line. These sensors were also equipped with temperature and relative humidity sensors.
It has been also considered that characterizing the light flux as received by the treated surface was a priority. Spectroradiometry measurements were hence organized to determine spectral irradiance as received by the walls/ceilings.

Sampling strategy

The general strategy for sampling was based upon three criteria: i) choosing appropriate sampling lines ii) ensure the representativeness of the measurements iii) organize the co-localisation of sampling.

In both sites, gases phase sampling was achieved through a unique ½" outer diameter pipe made of PTFE to insure chemical inertia. All the instruments were connected to a glass manifold with ¼" PTFE tubes. At one extremity the manifold was connected to the sampling line in the tunnel and, at the other end, it was connected to a pump in order to have a sufficient flow to minimize the residence time. Indeed, it has been identified that minimizing the residence time was necessary to limit the chemical evolution of the air mass sampled.



View of the gas phase manifold at main site

This configuration allowed some flexibility, since instruments could be added to the ports which are not used or these ports can be closed. At the other end, the sampling line from the inlet to the manifold was of about 6 meters.

For aerosol sampling, PTFE was not permitted due to its electrostatic properties which lead to losses inside tubing so stainless steel ½" outer diameter pipe were installed. Large diameter was also chosen to minimize losses.

Outdoor campaigns strategy

General

The choice of the outdoor field campaign site has been the subject of many investigations. With the help of satellite imaging, the information available from the civil engineering companies in charge of the related urbanisms projects and information available to the consortium many potential site have been carefully studied. Eventually a field site in southern Europe (Petosino-Sorisole – Bergamo, Italy). Here a dual field site (based on existing industrial facility) with high surface-to-volume ratio has been constructed and equipped in a urban area.

The field site is an industrial site located in Petosino – Sorisole few kilometres north of Bergamo. The industrial site is does not exhibit any significant local industrial emission as most of the production activity has been stopped. On the contrary, it is located on the side of a major road (SS 470 div) on which it has been counted an average traffic of 8487 light vehicle per days and 1488 heavy duty vehicles per day. The ambiant air quality of the site is hence certainly highly impacted by car emission. Furthermore, the whole area of the Po valley is one of the more polluted areas in Europe. As can be seen on figure 1., in a radius of 5 km, the chosen field site is surrounding by 4 air quality monitoring station operated by Arpa Lombardia (www.**arpalombardia**.it/).

Satellite view of the region of the Petosino field site (the local air quality monitoring stations are indicated together with the relevant parameters monitored)

To give an estimation of the nitrogen oxides levels which can be encounter in Petosino, the concentration of this pollutant all along one full year have been plotted in figure 2. Keeping in mind the limit-values recommended by the EU of 40 µg/m^3 as an annual mean and 200 µg/m^3 as an hourly mean, it can be observed that the site can probably be considered as significantly polluted area. It is hence unlikely that artificial polluting device (motor bench…) need to be employed during the campaign.

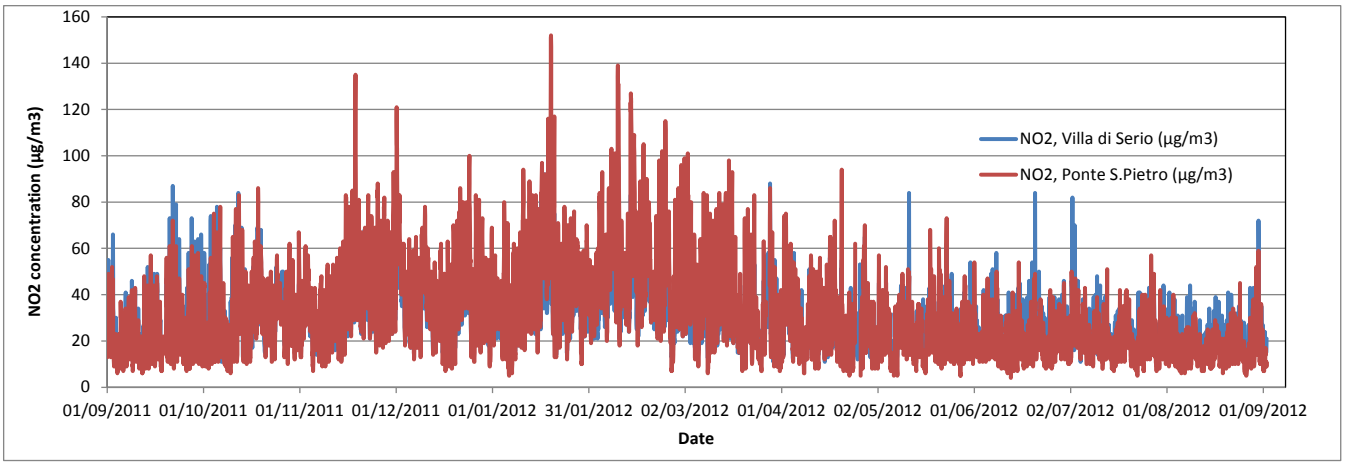


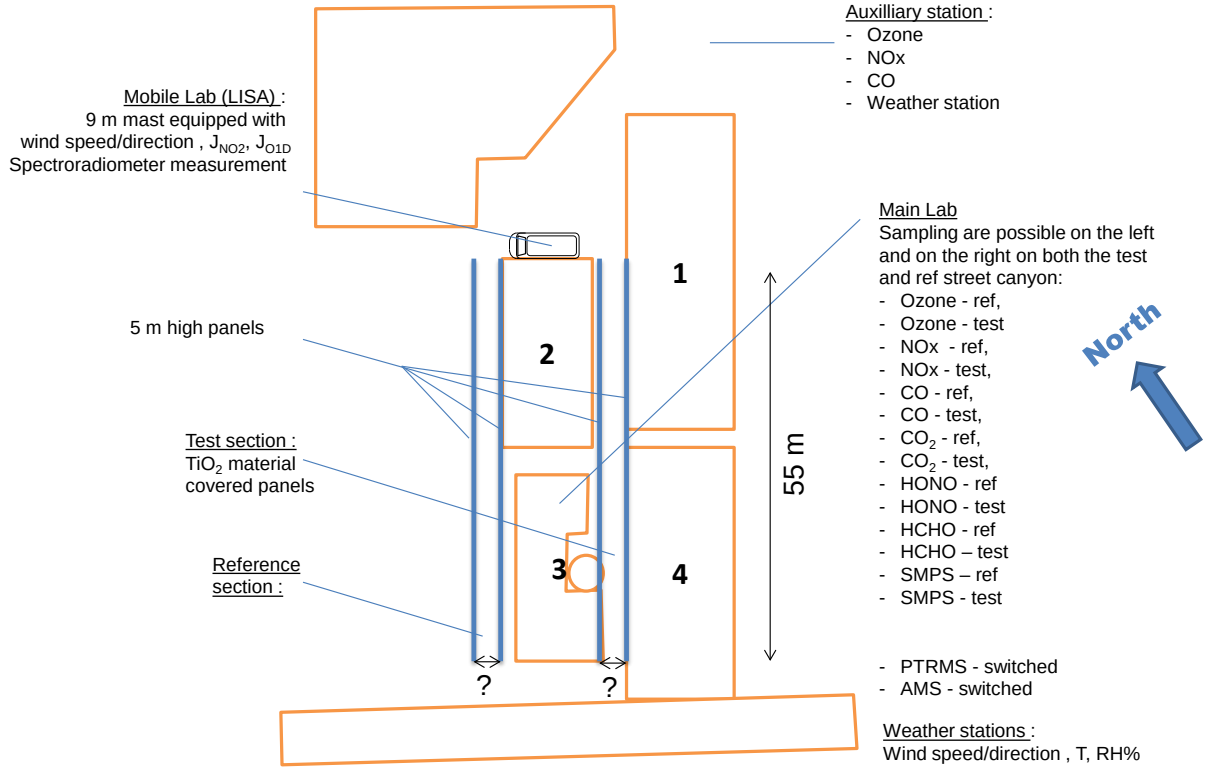
Figure 2: Year round NO_2 concentration as recorded by the closer monitoring stations of the *Arpa Lombardia* network

The site is a former production site of the ItalCimenti company. It comprises a serie of industrial building made of brick and mainly unused. The site is nowadays essentially used for Gray pipes storage. A general view of the site where the SS 470 road can be seen on top of the picture.

The basic idea of the outdoor PhotoPAQ field campaign to be conducted in Petosino was to create two parallel streets-canyons with mortar/glass fibers panel. Hence, two streets canyons of 5 m wide by 5 m height has been installed. The length of this structure was of 55 m.

Figure 3: General view of the field site (the red rectangle define the area used in fugure 4)

On the “equipped side”, the photocatalytic material has been applied both on the vertical surfaces and on the ground.

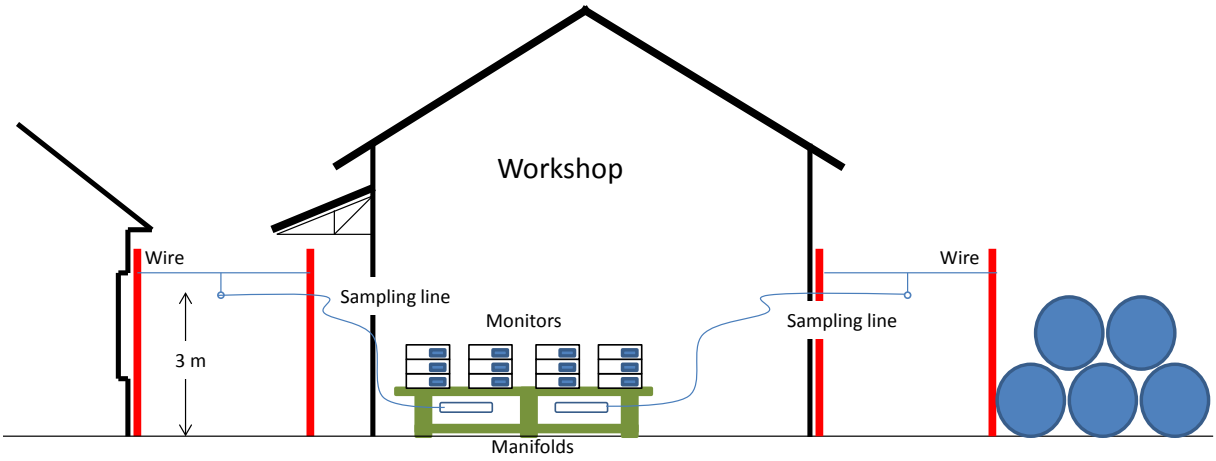


General scheme of the field site. Blue lines represent the panels installed to built the street canyon

Campaign strategy.

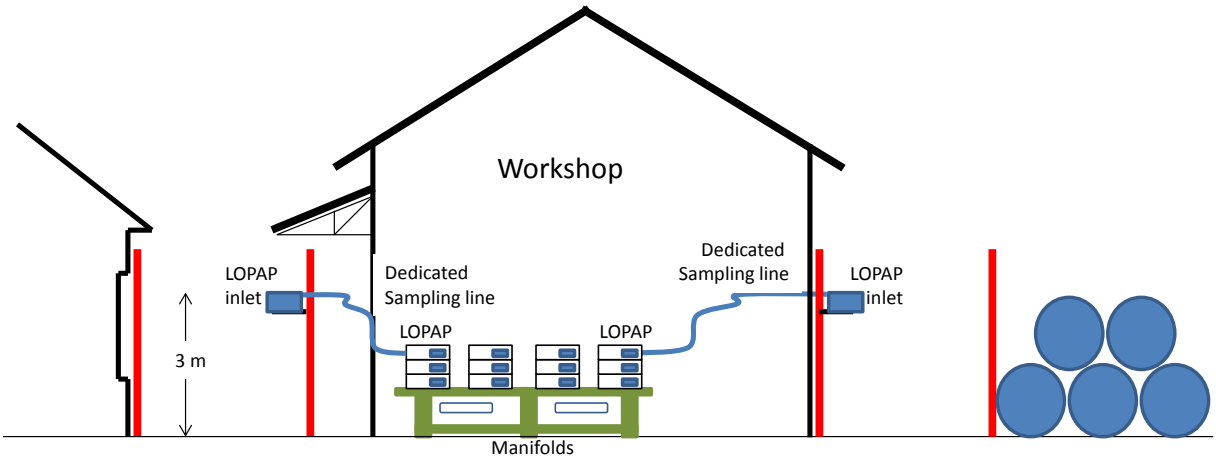
The general strategy is based on two building phases and two measurement phases
- To build the two street-canyons both covered with "normal concrete” this role was played by the panels which are made of mortar.
- To perform one week to ten days of monitoring with the full analytical combination in parallel the two streets in order to assess the comparability of the two streets
- To cover one of the street with photo-catalytic material
- To perform again one week to ten days of parallel monitoring.

The wind direction and speed measurements were critical to well define the position of the sampling inlet. The two types of sampling lines (Teflon for gases and stainless for aerosol) must have their inlet as close as possible.
Sampling lines must be hung at a height of 3 m in the middle of the street canyon (i.e. approximately 2.5 meters from the panels and 22 meters from the beginning of the streets. Technically, a steel wire or a rope can be used to set the inlets at the sampling points. Such an arrangement would have the advantage not to perturb the flow in the sampling area.



Sampling setup for monitors on the site of Petosino- Sorisole (in red are figured the vertical panels)

For the LOPAP operated with the external sampling units, a specific installation has been organised. A specific shelf (40x40 cm approx.) has been installed to receive the specific LOPAP sampler



Sampling setup for LOPAP on the site of Petosino- Sorisole (in red are figured the vertical panels)

View of the of Petosino- Sorisole site (photoactive canyon is on the left)

View of the of active canyon on Petosino- Sorisole site (inlet and physical sensor can be seen on the middle)