PROTOCOL FOR DETAILED INVESTIGATION AND INTERVENTION STUDY

Version 1

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A. General planning of the InAirQ field campaigns

The procedure described in this document is prepared for:

- The "***Detailed investigation***" of 12 school buildings per country in 5 countries in which indoor and outdoor environmental parameters will be investigated in the heating season in 2017-2018.
- The "***Intervention study***" of 1 school building per country in 5 countries in which indoor and outdoor environmental parameters will be investigated twice: before and after an intervention aimed at improving indoor air quality (spring 2018).

The 12 school buildings per country will be selected from the 12 - 28 buildings per country investigated by the checklist and questionnaire for the school building.

The ***Detailed investigation*** will comprise of:

- sampling/monitoring of chemical/physical parameters in one classroom per school building and at one outdoor location;
- a checklist and questionnaire to collect more precise information at the classroom scale and to confirm information on building characteristics collected during the preliminary investigation;
- a time-activity diary filled in by the form master (or teachers);
- a questionnaire on respiratory and allergic health of schoolchildren and home environment filled in by the parents of the pupils.

The ***Intervention study*** will comprise of (to be updated):

- sampling/monitoring of chemical/physical parameters in one classroom per school building and at one outdoor location;
- a checklist to collect new information at the classroom and building scales;
- a time-activity diary.

B. Detailed investigation

B.1. Planning

The detailed investigation will take place in the heating season in 2017/2018 in 12 school buildings per country. The time schedule for the detailed investigation of one building is presented in Table 1.

Table 1. Time schedule for the detailed investigation

	Communication tasks + checklists and questionnaires + time-activity diary	Monitoring campaign
Week(s) before the detailed investigation	1) Send information e-mail/make phone call to the school management and the form master about the schedule	1) Prepare for the monitoring campaign (e.g., select the sampling location outdoors, label the samples, check the instruments, etc.)
Monday	1) Organize a short meeting with the form master and hand-out the time-activity diary (between 7:30 and 8:00)	1) Set up the samplers/equipment to investigate IAQ and start the sampling/monitoring (between 7:30 and 8:00)*
	2) Fill the checklist and questionnaire about the classroom in	2) Measure the air flow rate (if applicable; between 7:30 and 16:00)
	3) Distribute the questionnaire on respiratory and allergic health of schoolchildren and home environment (it can also be done the week before the investigation or later this week)	3) Finish sampling at 16:00 (continuous monitors can run also during evening, there is no need to stop them)
From Tuesday to Thursday	1) Collect the questionnaire on respiratory and allergic health of schoolchildren and home environment	1) Set up the samplers to investigate IAQ and start the sampling (between 7:30 and 8:00) every day
		2) Finish sampling at 16:00 every day
		3) Check the instruments regularly
Friday	1) Collect the time-activity diary (around 16:00)	1) Set up the samplers to investigate IAQ and start the sampling (between 7:30 and 8:00)
		2) Measure the air flow rate (if applicable; between 7:30 and 16:00)
		3) Finish sampling/monitoring (around 16:00)

		4) Return to the laboratory and store the samples according to the detailed procedure described later
Later		1) Send sampling tubes and filters to NPHI
		2) Fill the templates in and upload them to the Google Drive

* except for radon passive samplers

B.2. Investigated physical and chemical parameters

Sampling/monitoring will take place in one classroom per building and at one outdoor location simultaneously from Monday to Friday between 8:00 and 16:00 every day (when the students are present in the classroom). The physical and chemical parameters investigated in the InAirQ project are listed in Table 2. Please note that the sampling/monitoring of some chemical compounds is optional. It has been indicated in Table 2.

Table 2. Time schedule for the detailed investigation

Pollutants / parameters	Sampling/monitoring	Analysis
Volatile organic compounds (VOCs): benzene, toluene, xylenes, ethylbenzene, n-hexane, trichloro-ethylene, tetrachloroethylene, α-pinene, limonene, 2-butoxyethanol, 2-ethylhexanol, styrene	Passive sampling (Radiello) diffusive body code 1202 (reusable) + cartridge code 145 (reusable)	TD-GC-MS According to: ISO 16017-2 Central laboratory: NPHI
Aldehydes: formaldehyde, acetaldehyde, acroleine, propionaldehyde, benzaldehyde, hexanal, glutaraldehyde	Passive sampling (Radiello) diffusive body code 1201 (reusable) + cartridge code 165	LC-UV According to: ISO 16000-4 Central laboratory: NPHI
Temperature (T), relative humidity (RH), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2)*, ozone (O_3)	Continuous monitoring equipment with data logger (frequency: preferably 1 minute; not more than 3 minutes) /OPTIONAL: indoor and outdoor CO and O_3; outdoor CO_2/	
$PM_{2.5}$ mass concentration	1. Low-volume aerosol sampler (pump with low noise level + sampling head; preferred flow rate: 4-10 L/min or more) + quartz fiber filter	According to: BS EN 12341: 2014 Central laboratory: NPHI

	2. Continuous monitoring equipment with data logger (frequency: preferably 1 minute, not more than 5 minutes) /OPTIONAL: outdoor/	
Particle number concentration /ultrafine particles/	Continuous monitoring equipment with data logger (frequency: preferably 1 minute; not more than 5 minutes) /OPTIONAL: indoor and outdoor/	
Radon (only indoors)	Passive sampling	Central laboratory: NPHI
Air exchange rate (if applicable)	Thermo-anemometer to measure air flow rate	

* NPHI can provide passive samplers to all partners

B.3. Building codes, labelling of the samples

The school building codes are the same as those used in the preliminary investigation (e.g., **CZ10**; **IT08**, **PL12**). Each building will keep the same code all along the InAirQ field campaigns. The building code will be used in the checklists and questionnaires, time-activity diary, the questionnaire on the respiratory and allergic health of the schoolchildren and home environment, and to label the sampler and filters and the files on continuous monitoring.

For each sample, the following labelling procedure will be applied:

School building code - **location** (indoor or outdoor) - **parameter** - **extension**

- Indoor and outdoor samples will be marked as follows: **IN** and **OUT** respectively.
- The following air pollutants will be sampled:
  - volatile organic compounds – **VOC**
  - aldehydes – **ALD**
  - $PM_{2.5}$ mass concentration (gravimetric analysis) – **PM_{GA}**
  - Radon – **Rn**
  - (- Nitrogen dioxide – **NO_2**).
- The following extension can be applied:
  - field blank – **bl**.

For example:

SI01-IN-VOC: Passive sampler for VOC sampling in the classroom in the Slovenian building SI01

PL02-IN-PM_{GA}-bl: Field blank of the PM2.5 sampling in the classroom in the Polish building PL02

HU03-OUT-ALD: Passive sampler for aldehyde sampling outdoors in the Hungarian building HU03

The labels should be printed onto sticker papers and placed on the plastic tube of the cartridges, filter holders or packages. A template has been provided.

B.4. Procedures

B.4.1. Sampling of air pollutants

a) Volatile organic compounds and aldehydes

The Radiello® passive sampler is a very reliable tool to determine the concentration of different air pollutants such as VOCs and aldehydes. The parts of the Radiello® passive sampler required for the sampling of VOCs and aldehydes can be purchased via Sigma-Aldrich: http://www.sigmaaldrich.com/ (Table 3). NPHI will provide the triangular supporting plates, vertical adapters, diffusive bodies, cartridge adsorbent for the sampling of VOCs and some additional accessories (e.g., outdoor shelter). Each partner is responsible to buy the cartridge adsorbents for the sampling of aldehydes (RAD165).

Table 3. Parts of the Radiello® sampler for VOCs and aldehydes

Cartridge adsorbent		Diffusive body	Triangular supporting plate or vertical adapter	
Aldehydes: RAD165 VOCs: RAD145	Aldehydes RAD1201	VOCs RAD1202	RAD121	RAD122
 (they have to be stored in the refridgerator before sampling)				

Copyright: Radiello®

Please note that the VOC cartridge adsorbents can be re-used (the analyses is carried out through thermal desorption). They should be conditioned (cleaned) before each use (including the first use). This conditioning will be performed by NPHI.

For aldehydes, look at the expiry date to be sure to use valid cartridge adsorbents.

Each day of the monitoring campaign, the cartridge adsorbents have to be placed into the corresponding diffusive bodies in the morning (between 7:30 and 8:00) and they have to be removed from the diffusive bodies and placed into the glass tubes at around 16:00. During the week of investigation the diffusive bodies stored in the glass tubes should be kept at the sampling site (indoor samplers in the classroom, outdoor samplers outdoors) when sampling is not carried out (between 16:00 and the following day 7:30-8:00; from Monday to Friday). After sampling (on Friday afternoon), all these cartridge adsorbents should be stored in the refrigerator (4°C) in the glass tubes and plastic bags. Please note that nitrile gloves must always be used when handling passive devices. Moreover in order to avoid any contamination gloves should not come from boxes kept in a chemical laboratory.

During the field work, follow the steps described here:

1. Open the plastic bag and label the glass tube before the week of investigation.
2. On Monday morning (between 7:30 and 8:00), open the glass tube and insert the cartridge adsorbent into the corresponding diffusive body (RAD165 to the blue one; RAD145 to the yellow one) (Figure 1).

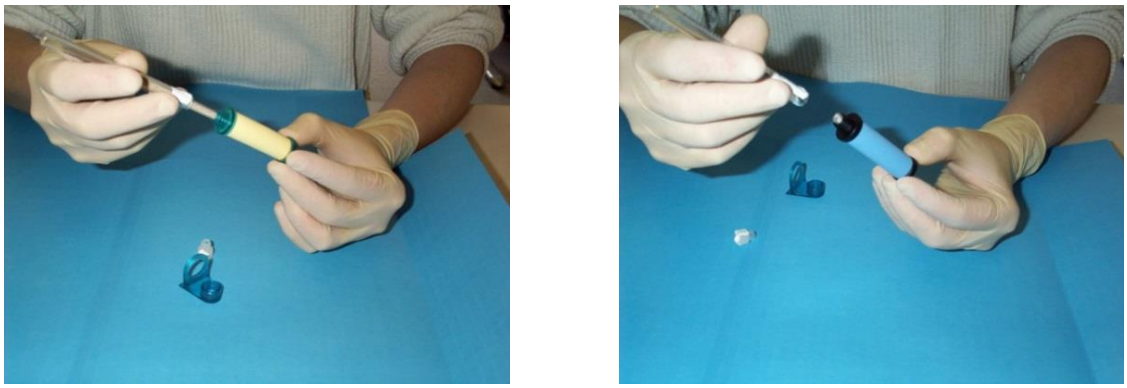

Figure 1. Procedure to set up the Radiello® samplers

3. Keeping the diffusive body in a vertical position, screw it onto the triangular supporting plate (you can also use the vertical adapter instead of the supporting plate).
4. The Radiello® sampler is ready to use.
5. At around 16:00, remove the cartridge adsorbent away from the diffusive body and put it back into the glass tube (Figure 2). Close it.

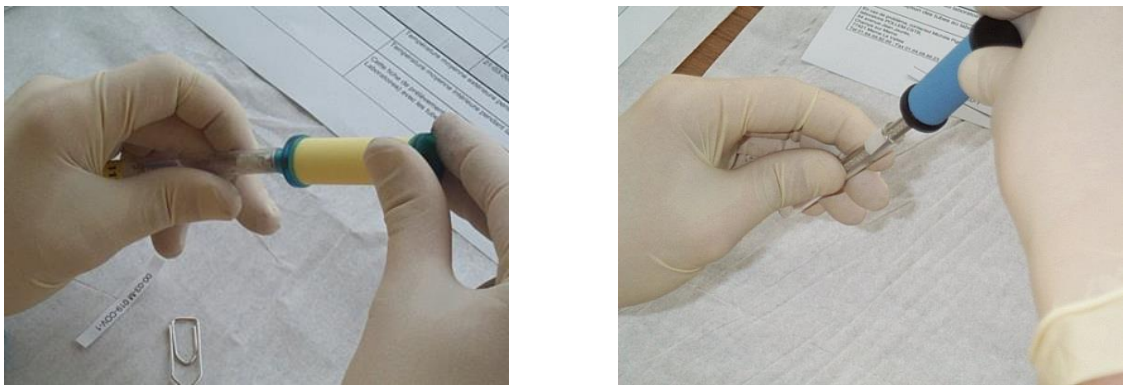

Figure 2. Handling of the Radiello® samplers after sampling

6. Store the cartridge adsorbents in the glass tubes at the sampling site (indoor samplers in the classroom, outdoor samplers outdoors) when sampling in not carried out (between 16:00 and the following day 7:30-8:00; from Monday to Friday). Thus one sampler per sampling site will be used during the week of investigation with a sampling time of about 40 h.
7. It is recommended to bring a cooling box while collecting the samplers on site. Samplers should be as soon as possible stored in the refrigerator (4°C).

Start time and stop time should be reported for each sampling site and each day. Any comment regarding problems that could have occurred during the sampling period should be mentioned. This information (Excel file) will be provided through e-mail to the central laboratory, parallel to the sample shipment.

Several field blanks have to be collected during the monitoring campaign for both aldehydes and VOCs. It is recommended to collect at least four field blanks (in the classroom, one at every third school buildings) per parameter. After having removed the cartridge adsorbent from the glass tube and put it in the diffusive body, the cartridge adsorbent must be placed again in its tube. The latter should be closed and it remains the 5 days in the classroom.

Exposed cartridge adsorbents should be sent in refrigerated packages within 3 weeks after exposure to the central laboratory (NPHI):

National Public Health Institute

2-6, Albert Flórián út.

1097 Budapest

BUDAPEST (Hungary)

b) $PM_{2.5}$ (gravimetric analysis)

$PM_{2.5}$ samples will be collected by low-volume aerosol samplers (pump with low noise level + sampling head; preferred flow rate: 4-10 L/min or even more) onto quartz fiber filters (with a diameter of 37 or 47 mm). Sampling will be carried out in the classroom and at the outdoor location simultaneously from Monday to Friday (8 h sampling each day; sampling onto the same filter on the five consecutive days).

Filters (pre-heated at 550°C for 8 h in an oven; conditioned /20 ± 1°C and 50 ± 5% RH/ and weighed on a microbalance with a readability of 1 µg) will be provided by NPHI. In total, each partner will receive 30 filters (24 filters for sampling + 4 field blank filters + 1 spare filter + 1 filter for flow calibration) in filter keepers placed in plastic bags (Figure 3). You will find a laboratory identifier at the back of the filter keeper (e.g., PL01 – it means that this is the first filter in the pack of filters sent to Poland). Please, do not remove this identifier from the filter keeper. Moreover, do not forget to label the filter keeper with the proper code (described in Section 2.3.).

Please, handle the filters with special care and with plastic tweezers.

Figure 3. Quartz fiber filters in filter keepers and plastic bags

Before sampling, the air flow has to be calibrated as follows:

1. Place the calibration filter to the impactor/cyclone.

2.a. (Option 1) Using flexible tubing, connect the outlet of the impactor/cyclone to the inlet of the pump. Connect the inlet of the impactor/cyclone (a calibration adapter might be needed) to the outlet of a standard flow meter suitable for calibrating the pump (e.g., rotameter).

2.b. (Option 2) Connect the outlet of the impactor/cyclone to the inlet of a the flow meter. Connect the outlet of the flow meter to the inlet of the pump.

3. Turn on the pump and wait for the warm-up of the pump (2 minutes).

4. Check the flow rate and adjust it until it is close to the reference value and wait for the stabilization of the flow rate (1 minute).

5. Record the flow rate on the sampling sheet provided. Calibration is completed.

6. Remove the calibration filter and insert a new, pre-weighed quartz fiber filter to be used for $PM_{2.5}$ sampling in the sampling head using plastic tweezers.

Place the pump inside a noise-reducing case and set the sampling head at a height of about 0.8 m (representative of the breathing zone of sitting children). Turn on the pump and record the start time of the sampling (between 7:30 and 8:00 every day). In the afternoon (around 16:00), manually turn off the pump and record the stop time. Keep the filter in the sampling head.

The following day, start the procedure with the calibration of the flow rate. Please do not use the calibration filter between Tuesday and Friday, keep the exposed filter in the sampling head during the whole week (the filter is very fragile and losses can occur in case of the filter is often handled). After a quick calibration (hopefully you do not have to adjust the flow rate), start sampling and record the start time. Please, repeat the procedure every day.

On Friday afternoon, carefully place the filters into the filter keepers paying attention to not turn filters upside down. Place the filter keeper in the plastic bag.

Exposed filters have to be stored in the refrigerator.

Four field blanks have to be collected (in the classroom, one at every third school buildings). Open the filter keeper, insert the filter into the sampling head, close it, wait 2 minutes, then take it out and put back the filter into the filter keeper.

Two spare filters will be provided by NPHI. They should not be opened only in the case of emergency.

Loaded and field blank filters (together with the Radiello® cartridges) should be sent in refrigerated packages to the central laboratory (NPHI).

c) Radon

Radon will be measured by passive sampling method followed by instrumental analysis. Passive samplers will be provided by NPHI. One passive sampler will be placed at the classroom in each school building on the first week of December 2017 and the samplers will be collected on the last week of February. Please, place the samplers to a secured place in the classroom.

Please, follow the instructions:

Open the grey bag, the trace detector in the small black capsule is used to determine the radon activity concentration (Figure 4). After the grey bag has been removed, the trace detector measures the radon activity concentration in the room. Until the end of the exposure period no other action is needed with regard to the black capsule.

Figure 4. The passive radon detector

Please, consider the following when placing the trace detector:

Please, place the detector so that they are not right next to a wall and they are not exposed to intensive air movements (draught) or dust. The vicinity of vents, windows, fans, and heaters is therefore to be avoided. Please, place the detector at least 40 cm from the floor, but not above head level. The suggested places are the top of smaller furniture, shelves. Please, – if possible – do not move the detector during the exposure period!

Don't forget to write the detector's number on the sampling sheet, which can be found on the top of the detector.

Collecting/sending the detector back:

After the given time period, pack the detector in aluminium foil and place it in the attached plastic bag and close it hermetically! Careful packaging is necessary for precise measurement. Please, fill-out the part of the data sheet about collection and indicate the exact date of collection!

Place the bags (with the detectors) in an envelope and close it. Send the envelope to the NPHI.

d) Nitrogen dioxide (passive method)

Palmes-type diffusion tubes will be used to determine the mean concentration of nitrogen dioxide during the sampling period. This cost effective device also does not require specialist skills or time commitment. The device consists of an acrylic tube, a stainless steel grid, a black cover and two caps. Samplers will be provided by NPHI. Please store the samplers in a refrigerator before use. Please note, that plastic gloves have be used during the handling of the samplers. To start sampling, remove the bottom end cap and place the sampler into the holder (Figure 5). Diffusion tubes must be held vertically with the open end downwards during sampling. Please record the start time of the sampling. Take back the bottom end cup to stop sampling. Similar to Radiello® passive samplers, sampling has to be carried out from about 8:00 to 16:00 from Monday to Friday.

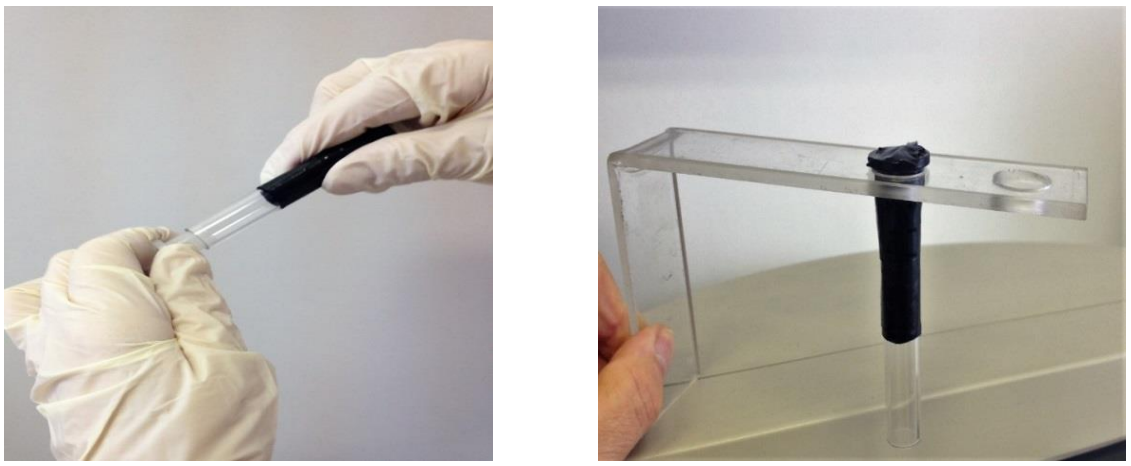

Figure 5. Procedure to set up the passive nitrogen dioxide samplers

Store the samplers at the sampling site (indoor samplers in the classroom, outdoor samplers outdoors) when sampling in not carried out (between 16:00 and the following day 7:30-8:00; from Monday to Friday). Thus one sampler per sampling site will be used during the week of investigation with a sampling time of about 40 h.

Several field blanks must be collected (one per school building) in the same way as in the case of Radiello® passive samplers.

Please store the samples refrigerated and send them to the central laboratory (NPHI) within 4-5 weeks of exposure.

B.4.2. Monitoring of physical parameters

a) Temperature

Temperature has to be monitored both indoors and outdoors during the sampling time. It is recommended to continuously record the temperature from Monday morning to Friday afternoon. Sampling/reporting sheet is not provided. Please upload the data in a convenient format (e.g. excel sheet indicating the day, time and temperature values).

Name of the sampling/reporting table: **School building code** - **location** (indoor or outdoor) - **T** (e.g. HU01-IN-T; HU01-OUT-T)

b) Relative humidity

Relative humidity has to be monitored both indoors and outdoors during the sampling time. It is recommended to continuously record the relative humidity from Monday morning to Friday afternoon. Sampling/reporting sheet is not provided. Please upload the data in a convenient format (e.g. excel sheet indicating the day, time and relative humidity values).

Name of the sampling/reporting table: **School building code** - **location** (indoor or outdoor) - **RH** (e.g. PL01-IN-RH; PL01-OUT-RH)

c) Air flow rate

In case mechanical ventilation is present in the school building, air flow rate has to be measured two times (Monday and Friday) during the week of investigation. There are different techniques to measure the air flow rate. The easiest way to determine air flow rate is to use a thermo anemometer (e.g. testo 405i /cost is about 100 EUR/) to measure the air flow velocity and convert it to air flow rate.

Place the sensor of the anemometer to the grill of the fresh air intake. Make sure that you measure the air velocity at different points of the grill (e.g. Figure 6).

Figure 6. Selection of different points to measure air velocity

Please, keep the sensor at each point for a couple of seconds and write down the mean value. If you measured the air velocity at different point of the grill, then calculate the mean value (unit: m s^{-1}) and multiply it with the dimensions (surface) of the grill (unit: m^2). This value will be the air flow rate. Measure the air flow rate at all grills present in the classroom and add the values together. Please, report the air flow rate values in the sampling/reporting sheet provided.

Name of the sampling/reporting table: **Country code** - **AF** (e.g. CZ-AF)

B.4.3. Continuous monitoring of the concentration of air pollutants

a) Gaseous air pollutants (CO_2, NO_2, CO, O_3)

There are several (calibrated) devices which can be used to monitor the concentration of CO_2, NO_2, CO and O_3 continuously. Please check Table 2 in which some details have already been listed. Sampling/reporting sheet is not provided. Please upload the data in a convenient format (e.g. excel sheet indicating the day, time and concentration values). The time resolution is preferably 1 minute.

Name of the sampling/reporting table: **School building code** - **Location** (indoor or outdoor) – **CO_2** or **NO_2** or **CO** or **O_3**

b) $PM_{2.5}$ (continuous monitoring)

Mass concentration of different size fractions (PM_{10}, $PM_{2.5}$, $PM_{1.0}$) can be monitored by aerosol spectrometers (e.g. Grimm aerosol spectrometers). Please measure the $PM_{2.5}$ mass concentration (also other particle sizes can be measured) during the field campaign and

upload the data. Sampling/reporting sheet is not provided. The time resolution is preferably 1 minute.

Name of the sampling/reporting table: **School building code** - **Location** (indoor or outdoor) - **PM**

Also, particle number concentration of different size fractions should be measured if possible.

B.5. Recommendations

Devices should ideally be put not closer than 1 m to the wall, at the level of respiratory tract, avoiding ventilation channels and heating source.

It is recommended to prepare a cage in which the devices are stored in order to avoid that pupils interrupt the sampling. Devices must be placed at a secured place outdoors. In case of mechanical ventilation, place the devices at the fresh air intake of the HVAC system. In case of natural ventilation, street side or at the schoolyard (at the same floor of the selected classroom) will be preferred to characterize the most polluted air likely to enter in the building. Practically the location will be chosen depending on the possibility to put the samplers in a secured place.