



# iSERVcmb IAQ Methodology

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By

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This part of iSERVcmb is designed to check the Indoor Air Quality (IAQ) in spaces being conditioned by the iSERVcmb systems. IAQ is a major issue to be considered when trying to achieve energy efficiency in HVAC systems. An HVAC system exists to provide comfortable and healthy working conditions, and this requirement should not be compromised in the search for more efficient systems. While the project assumes that complaints in the spaces conditioned will normally lead to improvements in the IAQ, it is prudent to check this is actually the case, and whether the data monitored in this project can also be used to automatically indicate potential problems with IAQ e.g. a fan electrical energy consumption below a certain value per m<sup>2</sup> could indicate lower flow rates than needed.

## Overview

The present document describes the Indoor Air Quality (IAQ) methodology procedures to be followed in order to investigate the environmental quality of large buildings. The six basic steps which describe the IAQ methodology are summarized and further described below.

1. Selection of Buildings
2. Buildings Survey
3. Selection of Measuring Equipment
4. Selection of Monitoring Locations
5. Measurement Campaign
6. Evaluation of Results - Reporting

1. Buildings to be selected for monitoring will represent either public and commercial office buildings in all or most of the participating to the iSERVcmb project countries. Buildings that perform poorly or well in HVAC consumption and Indoor Air Quality (IAQ) will be included in the study.

2. All selected buildings will be physically characterised in terms of location, physical structure, ventilation, occupant activities, and potential indoor pollutant sources. Finally occupants will be surveyed on perceived IAQ and health symptoms using a questionnaire which will be distributed during the physical inspection of the building.

3. The measuring equipment to be used for the monitoring of the selected building has already been designed and assembled. A general description of the system will be given in this section.

4. Monitoring locations in the selected buildings will be decided taken into account the information collected about the building and the questionnaires distributed to the users. Specific guidelines will be given in order to avoid wrong placement of the monitoring equipment and inaccurate data recorded.

5. The measurement campaign will include measurements concerning the IAQ levels of the specific building/system as well as temperature and relative humidity. The IAQ measuring equipment will be placed in the selected locations for a period of 6 to 9 months depending on the data collected and the building characteristics. Standard measurement and strict quality assurance and quality control (QA/QC) procedures will be used to ensure the collection of high quality and comparable data.

6. Evaluation of the results and reporting will be performed by the NKUA team in order to provide the deliverables defined by the iSERVcmb contract.

This document provides a detailed methodology for conducting the building investigations and occupant surveys as described directly above. All steps described in the methodology will be initiated following the selection of the buildings to be investigated and only after consent has been given by the building owner/manager.

## IAQ Methodology

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## 1. Selection of Buildings

The building selection is the most critical step of the methodology. The building except its technical specifications should be selected considering both the environmental characteristics and the operating conditions. In this respect the proximity of the building to major polluting sources, the population density on the immediate environment as well as the type of building and the operating conditions should all be taken into account for the building suitability. Thus building selection involves the following criteria:

1. Building availability for 6-9 months so that the measurements will not be interrupted.
2. Building equipped with HVAC system of at least 12kW for commercial use and operating for at least during working hours and different energy performance/classification.
3. Buildings for which the indoor environment is reportedly poor.
4. Buildings preferably in different geographical areas in the same city (different environmental location and population density).

## 2. Building Survey

Selected buildings from the previous step should be visited by experienced personnel (engineer or else) having the responsibility to identify the basic operating conditions of the dwelling, building occupancy, local pollution sources and collect information to be used for the selection of monitoring locations. At the same time of the visit a questionnaire will be issued to the building users (appendix ....) the results of which will also be considered for the instrumentation sitting.

The steps to be followed for the completion of the building survey should be as follows:

1. Meet with the building owner/manager to describe the purpose of the IAQ study, the monitoring activities and instrumentation details, time schedules.
2. Check the availability of general background information on the building (Building Description Checklist (Appendix A-1).
3. Perform a walkthrough to collect information to be used for the identification of potential monitoring areas. Information such as overview of the HVAC system(s), documentation of the updated floor plans and HVAC plans, identification of HVAC systems and air handlers serving each floor and/or major area, relative amounts of open and closed space and hallways on each floor etc are not requested since they are considered to be available as part of WP2 of the project.

However, the additional information required for the present work is as follows:

- Basic information necessary for the IAQ evaluation
- Estimate the number of occupants per floor.
- Note low and high occupant density areas.
- Major polluting sources if any (note special use areas e.g., cafeterias, print shops, labs, etc.) or major heating sources.
- Users activities.
- Distribution of IAQ questionnaires to the building users in order to draw useful conclusions on perceived IAQ and health symptoms. (Appendix A-2).

Information on occupants' perception of IAQ and health symptoms will be obtained using the Indoor Environmental Quality Questionnaire given in Appendix A-2. The questionnaire will be distributed to building users, preferably full time employees (18 or more hour per week) in order to identify possible problematic areas which a single visit could not point out. It is also very important to divide all

personnel into groups with similar characteristics to obtain the best statistical results from the data analysis.

All survey administration and data handling activities will be performed using procedures that maintain confidentiality of the results.

All questionnaires will be accounted for. Each questionnaire will be reviewed to ensure consistency of responses. All data from the questionnaires will be logged in and checked for completeness. Once all the data has been checked, a statistical analysis will be performed in order to derive conclusions helpful for the identification of monitoring locations as well.

All data collected as part of the occupant questionnaire will be treated as confidential data.

It is important to note that if either the basic required information is incomplete and/or specific problems obstructing the execution of indoor air quality measurements, another building should be selected for the available local list following step number 1.

### **3. Selection of Measuring Equipment**

For the purpose of the project needs it was decided to design a complex sensor which combines measurements of temperature, relative humidity, CO<sub>2</sub> and VOCs and which will maintain the capability of wireless transmission of data on request. In this respect, the instrument packaged kit was designed by the NKUA team and assembled by the Scientific Enterprises Company. A total of 50 Indoor Air quality measuring kits (IAQ kits) are now available. The kits will be delivered to the users calibrated at the NKUA certified indoor air quality laboratory (ISO 17025).

A brief technical description of the Indoor Air Quality measuring kit (IAQ kit) is given below:

The IAQ kit comprises of:

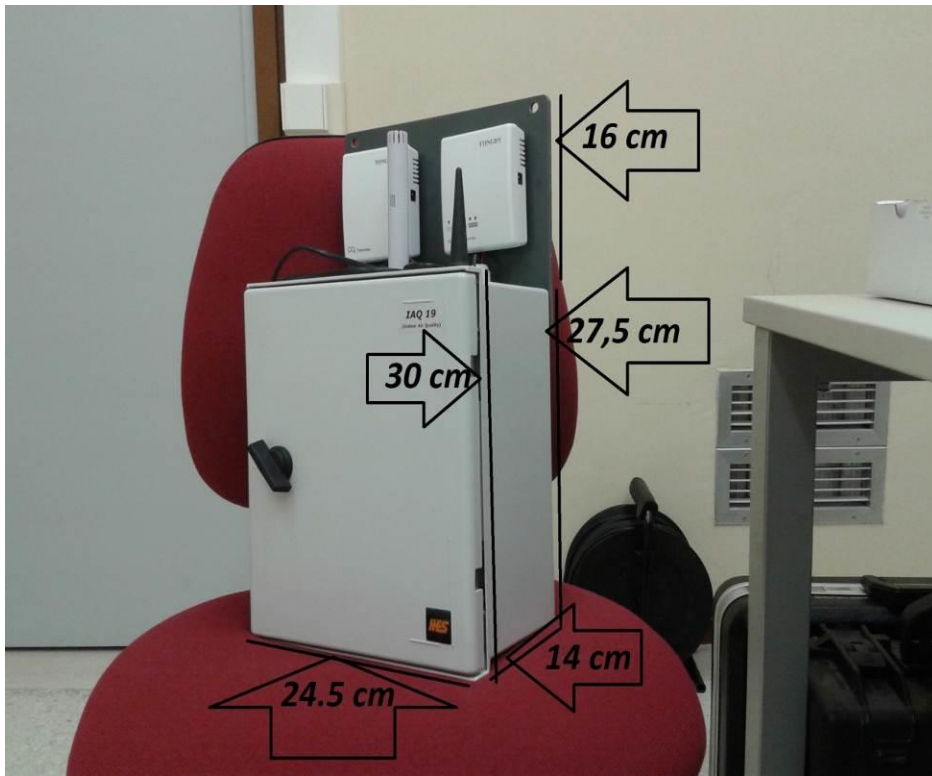
1. Envelope for all equipment
2. Sensors for the measurement of temperature- relative humidity-CO<sub>2</sub>-VOCs.
3. A data logger
4. A modem in order to transmit data remotely
5. A power supply (220V)
6. Wiring connecting the sensors and the modem to the datalogger.

#### **Operation**

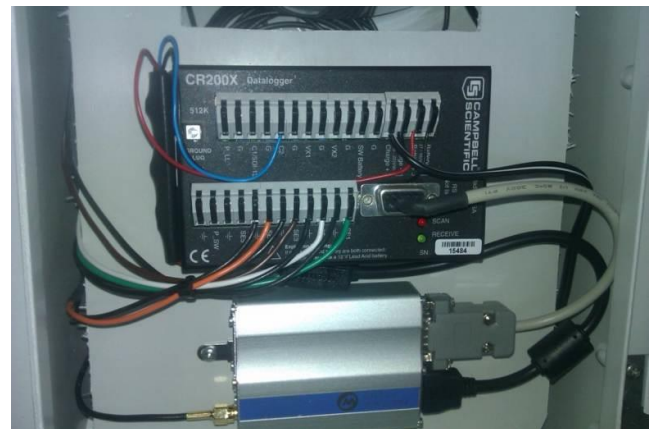
The selected sensors will monitor the desired parameters (Temperature- Relative Humidity-CO<sub>2</sub>-VOC) and will record them in the data logger by converting the measurement into an analog signal. The data logger is programmed to receive, interpret and store the signal every 60 seconds.

The built-in GSM modem is installed inside the box which will use a GSM simm card which offers the possibility of remotely collecting the data recorded. The appropriate software (LoggerNet) for the collection of the data will be installed in a computer which will be equipped with a modem. Connecting to any of the IAQ kits will be possible at any time in order to check the proper operation of the system, collect data and/or change settings of the systems.

The IAQ kit is portable (4 kg) and can be moved according to the needs of the project (if sampling in different locations is required). Because of its relatively small size and weight, it can be wall mounted or placed on the desired surface without causing any inconvenience to the building users. Figures 1 and 2 show the IAQ kit layout and dimensions.



**Figure 1. Dimensions of the IAQ measuring kit**



**Figure 2. General view of the IAQ kit sensors and data logger.**

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### **Real-Time Measurements**

Instruments that use real-time measuring methods are used to monitor parameters continuously. Instantaneous measurements may be recorded or they may be averaged over a period of time (time interval). All parameters will be continuously recorded over an approximate period of 6 to 9 months in the selected buildings in order to include both summer and winter periods. Each parameter will be monitored at an interval of 60 seconds. Every 15 min the datalogger records the instantaneous values and 60sec measurements averaged in a hour (60 min interval). Data will be downloaded once a week using a portable computer and GSM modem. Routine hourly meteorological and environmental data will be collected from the National Observatory of Athens and will be included in the IAQ database.

#### **4. Selection of Monitoring Locations**

Following steps 1 and 2 the site(s) selection of the instrumentation will take place by the NKUA group in collaboration with the partner. In particular the NKUA group will indicate the general area that the IAQ measuring kit will be placed while the partner will specifically decide the exact location following the general guidelines given below:

##### **General Guidelines for Siting Indoor Monitoring Locations**

- Monitoring/sampling should be conducted at a location that represents work activities.
- Locations should be at least one-half (0.5) meter from corners or windows.
- Locations should not be directly under or in front of air supply diffusers, induction units, floor fans, or heaters (personal), etc.
- Locations should not be where direct sunlight will impact instrumentation.
- Locations in hallways or passageways are not preferred.
- Locations should not be within one (1) meter of localized and major sources of pollution such as photocopiers, printers, or cigarette smokers.
- Locations should be 0.8 to 1.8 metres from floor depending on building use.

The instrumentation availability per partner and the need to complete the measurement campaign within the project time schedule leads as to the use of 1 kit per building. However, the sufficient number of buildings which will be monitored and the length of the measurements answer the question of the validity of measurements. Furthermore, a small number of buildings will be selected to be monitored by more than one measuring kit.

It is also of great importance to note that outdoor corresponding measurements are desirable for the evaluation of the results. In this respect, data from nearest local air pollution station (if available) could be used for the evaluation procedure. In particular, hourly data of temperature, relative humidity, CO<sub>2</sub> and VOCs will be valuable.

#### **5. Measurement Campaign**

The measurement campaign will last 6 to 9 months so that a wide variety of meteorological and environmental conditions will be included. The measurements must not be discontinued unless a major problem occur. Short power failure interval or else is automatically detected and appropriate actions will be taken. The instrument is programmed for automatic restart safeguarding the recorded measurements. The measurements will be collected and the instrument will be checked in regular intervals by the NKUA group remotely. It is very important to report any major changes take place during the course of the measurements such as: indoor building alterations that might change the local pollutant source distribution (new furniture, change of users' habits such as smoking or else, new paintings etc.)

In case a problem with the measuring kit arises the NKUA group will be in contact with the responsible partner in order to offer guidance for the repair.

All data collected from the IAQ kits will be statistically treated (e.g. extreme values, lack of data etc) so that a High Quality DataSet (HQDS) will be developed. The final form of the HQDS will be compatible to the iSERV database. Access to the HQDS will be limited to the participants of the project while use by other groups should be approved by the iSERV coordinator.

**6. Evaluation of Results - Reporting**

The collected IAQ data will be analysed by the NKUA team, considering the level of pollution, the type and site of the building and the building use. In particular, the buildings will be categorized with respect to their general pollution level, temperature and humidity. Extreme high level pollution cases will be separately investigated to identify the causes. Having obtained that, it will be possible to link buildings HVAC performance and IAQ. It is visualised that in a small number of buildings which present scientific interest further IAQ measurements will be performed incorporating more sensors and in depth study of the dynamics of the phenomenon. This will be decided when the basic evaluation procedure is completed.

Following the statistical analysis of the collected data, a report will be prepared for the buildings/systems under investigation which will include

- a. Limit values for the measured parameters
- b. Results (data analysis, comparison to limit values etc.)
- c. Possible Solutions and guidelines for the users

**APPENDIX A-1. BUILDING DESCRIPTION CHECKLIST**

Please indicate which of the following information are available for your building

1. Occupied floor area	
2. Gross floor area (total floor area at the building)	
3. Building age	
4. Latest renovations or additions	
5. Number of floors	
6. Space usage (enter the activity of each floor)	
7. Building Occupancy	
<i>a. Occupants number</i>	
<i>b. Building occupation (days per week)</i>	
<i>e. Building occupation (hours per day)</i>	
8. Site characterization (urban, suburban, rural)	
9. Building Equipment	
<i>a. Heating Systems</i>	
<i>b. Cooling Systems</i>	
<i>c. Ventilation</i>	
10. HVAC control system	
<i>a. Control system type</i>	
<i>b. Control system response strategy</i>	
10. Conditioning and ventilation operation schedule	
11. Building envelope	
<i>a. Construction materials (exterior walls, roof)</i>	
<i>b. Operable windows</i>	
<i>c. Shading elements</i>	



**APPENDIX A-2. IAQ QUESTIONNAIRE**



**INSPECTION OF HVAC SYSTEMS THROUGH CONTINUOUS MONITORING AND BENCHMARKING**

IAQ QUESTIONNAIRE

This questionnaire is conducted to help us determine the Indoor Air Quality of your building. It contains three parts of questions, which try to find out the effect of your workplace environment at your productivity and health. Your willingness to answer these questions accurately and completely is essential for our research and for the improvement of the Indoor Air Quality of your building.

<b>JOB CHARACTERISATION</b>	
<b>1. Your job categorization (mark the right category)</b>	<i>a. Managerial</i> ___
	<i>b. Professional</i> ___
	<i>c. Technical</i> ___
	<i>d. Secretarial</i> ___
	<i>e. Other</i> ___
<b>2. What is your educational level? (mark the right answer)</b>	<i>a. Primary school graduate</i> ___
	<i>b. High school graduate</i> ___
	<i>c. College graduate</i> ___
	<i>d. Other</i> ___
<b>3. Are you satisfied with your workplace? (mark the right answer)</b>	<i>a. Very satisfied</i> ___
	<i>b. Satisfied</i> ___
	<i>c. Quite satisfied</i> ___
	<i>d. Not satisfied</i> ___
<b>WORKPLACE INFORMATION</b>	
<b>1. How long have you worked in this building (years)?</b>	
<b>2. How many days a week do you work in this building?</b>	
<b>3. How many hours a day do you work in this building?</b>	

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4. How can you describe the space of your workplace? (mark the correct answer)	a. Single person office ___
	b. Shared office ___
	c. Open space with partitions ___
	d. Open space without partitions ___
	e. Other ___
5. Indicate the number of the people working in the same workplace with you	
6. How clean do you think your workplace is? (mark the correct answer)	a. Very clean ___
	b. Satisfied ___
	c. Dirty ___
7. How many windows do you have in your workplace?	
8. Indicate which of the following changes have taken place in your workplace in the recent five months (mark the correct answers)	a. Change carpeting ___
	b. Wall painting ___
	c. Wall covering ___
	d. New furniture ___
	e. Re-roofing ___
9. Could you indicate any of the following environmental conditions in your workplace? (mark the correct answers)	a. High temperature ___
	b. Low temperature ___
	c. Humid air ___
	d. Dry air ___
	e. Unpleasant odors ___
	f. Much air movement ___
	g. Little air movement ___
	h. other (specify)

<b>HEALTH INFORMATION</b>	
1. Are you male or female?	
2. How old are you? (mark the correct answer)	a. Under 20 ___
	b. 20-29 ___
	c. 30-39 ___
	d. 40-49 ___
	e. 50-59 ___

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	<i>f. Over 59</i> ___
<b>3. Could you say that you have any of the following? (mark the correct answers)</b>	<i>a. Headache or Migraine</i> ___
	<i>b. Asthma</i> ___
	<i>c. Fever</i> ___
	<i>d. Eczema</i> ___
	<i>e. Allergy to dust</i> ___
	<i>f. Cough</i> ___
	<i>g. Sneezing</i> ___
	<i>h. Tired or strained eyes</i> ___
	<i>i. Dry or itchy skin</i> ___
	<i>j. Sore or dry throat</i> ___
	<i>k. Feeling depressed</i> ___
	<i>l. Shortness of breath</i> ___
<b>4. Indicate any other symptoms that you have, related to your workplace</b>	
<b>5. Are you a smoker? (yes/no)</b>	
<b>6. If you are please describe your smoking status (mark the correct answer)</b>	<i>a. Former smoker</i> ___
	<i>b. Current smoker</i> ___
<b>7. Is smoking permitted in the building? (yes/no)</b>	
<b>8. Is Smoking Restricted to Designated Areas? (yes/no)</b>	
<b>9. How could you describe the level of presence of tobacco smoke in the air of your workspace? (mark the correct answer)</b>	<i>a. Low</i> ___
	<i>b. Medium</i> ___
	<i>c. High</i> ___
	<i>d. Smoking is forbidden</i> ___

<b>ADDITIONAL INFORMATION</b>	
<b>1. Indicate if there is any of the following outdoor contaminant sources near your workplace (mark the correct answers)</b>	<i>a. Heavy motor vehicle traffic</i> ___
	<i>b. Construction activities</i> ___
	<i>c. Industrial stacks</i> ___
	<i>d. Garbage dumpsters</i> ___

<b>2. Is there any occurrences (past or latest) of water leakage at your workplace? (yes/no)</b>	
<b>3. Is there any occurrences (past or latest) of fire damage at your workplace? (yes/no)</b>	
<b>4. Describe your workplace cleaning schedule (frequency/occupied hours/weekend schedule)</b>	
<b>5. Where the location of indoor trash storage is?</b>	
<b>6. Are any of the following cleaning methods used in your workplace? (mark the correct answer)</b>	<i>a. Dry mopping</i> ___
	<i>b. Wet mopping</i> ___
	<i>c. Vaccuming</i> ___
	<i>d. other</i>
<b>7. Which of the following cleaning material are used in your workplace? (mark the correct answers)</b>	<i>a. Liquid soap</i> ___
	<i>b. Ferniture cleaner</i> ___
	<i>c. Floor cleaner</i> ___
	<i>d. Bathroom cleaner</i> ___
	<i>e. Window cleaner</i> ___
	<i>f. Other</i> ___
<b>8. Is there any use of pesticides at your workplace (interior or exterior application)?</b>	
<b>9. If there is, what is the frequency of the pesticide application?</b>	
<b>10. Does your building have any of the following spaces? (mark the right answers)</b>	<i>a. Laboratory Areas</i> ___
	<i>b. Smoking Areas</i> ___
	<i>c. Kitchenettes</i> ___
	<i>d. Printing rooms</i> ___
	<i>e. Commercial Kitchens</i> ___
	<i>f. Restrooms</i> ___
	<i>g. Parking Garages</i> ___
	<i>h. Conference rooms</i> ___
	<i>i. Computer rooms</i> ___
	<i>j. Loading Docks</i> ___
	<i>k. Graphic Art Areas</i> ___