JOINT REPORT

Findings from IAQ Tests (IAQ 02, IAQ 09)

And HVAC Inspections in Portugal

MacWhirter Ltd
UK

National and Kapodistrian University of Athens
Greece

National and Kapodistrian University of Athens

By

Assimakopoulos Margarita-Niki, Konstantina Giannopoulou, Argyriou Maria

MacWhirter Ltd UK

By

Dave Wright, Mark Sheldon

Intelligent Energy – Europe (IEE) SAVE Project

May 7th 2011 to May 6th 2014

Project websites:

Main website: http://www.iservcmb.info

Database website: http://www.iservcmb.eu

INTRODUCTION

In the framework of iSERV Intelligent Energy for Europe project a compact Indoor Air Quality system was developed and placed in buildings with HVAC systems larger than 12kW in different European metropolitan cities in order to investigate the relationship of IAQ and energy consumption. The sensor was capable of measuring temperature, relative humidity, CO2 and level of VOC'Ss while energy monitoring systems were also engaged to provide information on the building and HVAC system energy consumptions. The data was recorded locally and downloaded on a regular basis by NKUA.

SUMMARY

The measurements taken for the air quality in the buildings can be considered satisfactory. The air quality in all offices can be considered as good, as all of them had a majority of values below 600 ppm, but 4 offices only recorded a significant percentage of CO_2 values over 1000 ppm. CO_2 concentrations in buildings below do not exceed the limit of 1000 ppm, indicating that ventilation is adequate and occurs in higher concentrations during the operation of the office. Moreover, with refer to VOCs, in offices the air quality could not lead to any irritation or discomfort. VOCs concentrations in buildings below could cause no irritation or discomfort for two months or possible irritation or discomfort depending on the interaction with the other factors for the first building, while for the second building the concentrations could cause no irritation or discomfort. Furthermore, Tair maintained at higher levels during the non - operation hours of the offices (Night), while RH was at the same levels during the whole day. By comparing days with great and small release, the conclusion is that volatile organic compounds do not appear to have any association with the traffic in the office. In contrast, the temperature and humidity seem to be at a constant level, maintaining the set points in the office. Finally, the frequency distributions showed that the ventilation is marginally adequate and the air quality leads to no irritation or discomfort. Finally Indoor Air Quality depends on the age and the maintenance of the HVAC, while it was found that a bad maintenance or an old system could lead to high consumption

1 DESCRIPTION OF THE BUILDINGS

The system IAQ 02 is located in offices in Portugal from October 2013 to March 2014, while the system IAQ 09 is located in offices in Portugal from July 2013 to October 2013 and in February 2014 to March 2014. The first building has been constructed on 1905 and the second one on 2000. Both buildings have an air conditioned area approximately of 2500 m^2.

2 RESULTS

2.1 Carbon dioxide measurements (CO_2)

CO_2 is produced by human expiration and is often observed in increased quantities in places with many people without adequate ventilation. It is not toxic, but it can cause suffocation in high concentrations. Based on the CIBSE guide the categorisation of the IAQ of buildings relative to carbon dioxide resulted as follows:

Indoor Air Quality	*CO_2 Concentration [ppm]*
Good	*< 600*
Acceptable	*600 – 1.000*
Bad	*>1.000*

To reduce carbon dioxide indoors it would be necessary not only to eliminate the emission but also to ventilate often the room.

The second office indicated values between 600 and 1000 ppm thus it can be classified in the category of acceptable air quality, suggesting that the ventilation of the building is marginally adequate. The chart of the CO2 frequency distribution and an indicative diagram of one office are given below:

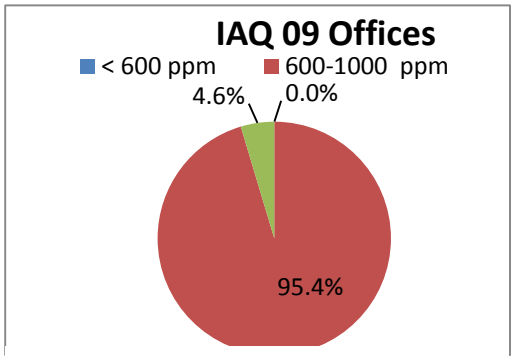
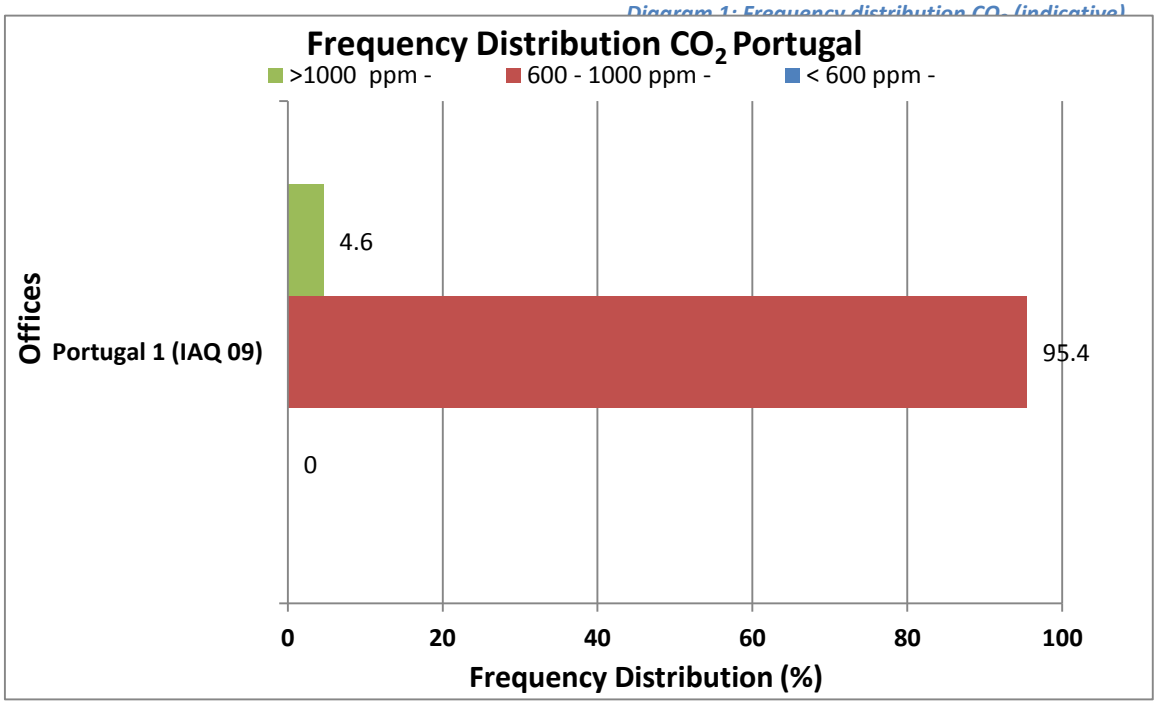


Diagram 1: Frequency distribution CO_2 (indicative)

Diagram 2: CO_2 Frequency distribution



2.2 Volatile Organic Compounds measurements (TVOC's)

According to the European Directive 2004/42/CE as Volatile Organic Compounds, TVOC'S, defined as all organic compounds having an initial boiling point less than or equal to 250°C, measured at atmospheric pressure 101.3 kPa. According to EPA, the class of volatile organic compounds composed of all carbon compounds, which are involved in atmospheric photochemical reactions, except for carbon monoxide, carbon dioxide and carbonic acid.

The concentration of volatile organic compounds in the interior of buildings is derived from two species of sources (Wiglusz et al., 2002):

- The background emissions, such as chemical compounds derived mainly from construction materials and building equipment (furniture, etc). The background emission is continuous and has nearly constant transmission rate.

- Periodic emissions resulting from human activities such as smoking, cooking, cleaning etc.

The final concentration of volatile organic compounds in the interior of buildings depends on the transmission rate, the concentration in the external environment and the level of ventilation in the building.

Emissions of volatile organic compounds from the materials inside the building are an extremely complex phenomenon. These emissions are classified into two major categories (Wolkoff 1999, Zabiegala et al, 1999).

According to studies[1], the concentrations of TVOC'S can be classified into four categories, depending on the effects that can cause in a person's health. Furthermore, based on the accredited Laboratory of the University of Athens the kits were calibrated, from which emerged the following correlation between the VOC'S values / output of the instrument and the scales by Molhave, as shown in the following table:

Table 1: Scale of exposure to concentrations of volatile organic compounds (TVOC's)

Total concentration	Sensor output (o/u)	Discomfort and Irritation Show	Exhibition scale
Less than 0.2 mg/m³ (Less than 0.05 ppm)	**Up to 10**	**No irritation or discomfort**	**Comfort Scale**
From 0.2 mg/m³ to 3.0 mg/m³ (from 0.05 to 0.80 ppm)	**From 10 to 20**	**Possible irritation or discomfort depending on the interaction with the other factors**	**Scale Exposure to multiple factors**
From 3.0 mg/m³ to 25 mg/m³ (From 0.80 to 6.64 ppm)	**From 20 to 30**	**Symptoms - Possible headaches depending on other factors**	**Discomfort Scale**
Over 25 mg/m³ (Over 6.64 ppm)	**Over 30**	**Additional neurotoxic effects may occur, apart from the headache**	**Toxic Exposure Scale**

[1]A. Molhave L., Human reactions to controlled exposures to VOC'S's and the "total VOC'S" concept. In: H, Knoppel and P. Wolkoff (eds.), Chemical, Microbiological, Health and Comfort Aspects of Indoor Air Quality - State of the art in SBS, Netherlands 1992, pp 247-261,

B. Molhave L., Volatile Organic Compounds, Indoor Air Quality and Health. In: Walkinshaw (ed.), Proceedings of Indoor Air 90, Toronto 1990, Vol.5, pp 15-33

C. Molhave L., Evaluations of VOC'S emissions from materials and products: solid flooring materials. In: Maroni M. (ed.), Proceedings of Healthy Buildings, '95, Milano 1995, Vol. 1, pp 145-162

Similarly to carbon dioxide, a frequency distribution for the VOC's was performed and indicated that the air quality of the building was classified to the comfort scale 'no irritation or discomfort', as the majority of the hourly values ranged from 0 – 10 o/u at both buildings. The chart of the VOCs frequency distribution and an indicative diagram of one office are shown below:

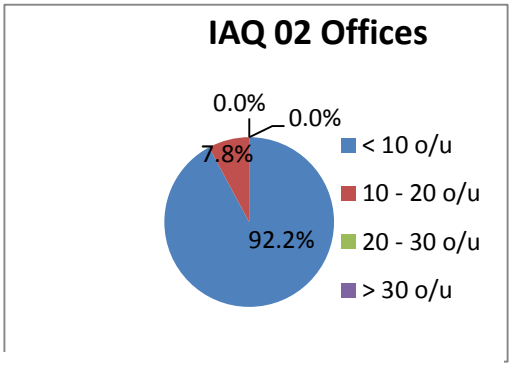


Diagram 3: Frequency distribution VOC'S

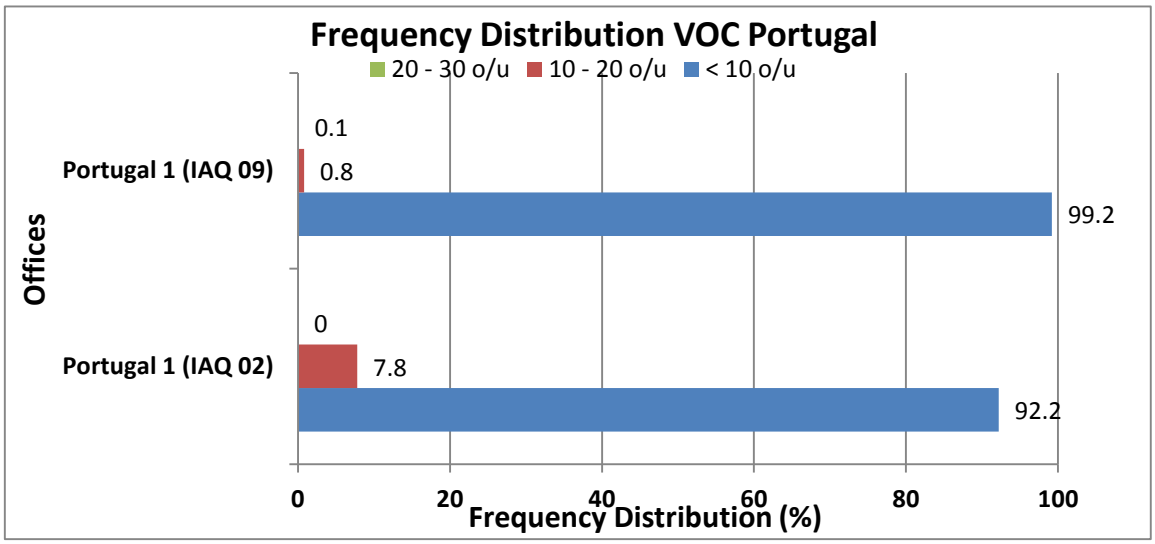


Diagram 4: VOCs Frequency distribution

3 MONTHLY VARIATIONS

In the following diagrams, the monthly morning and daily values are illustrated. That means that the daily variation only in operation hours of each building for each month is depicted. The operation hours of the office buildings are 8:00 – 18:00.

3.1 CO_2

There is a floating trend in the monthly CO_2 measurements for the system IAQ_09 where the maximum value does not exceed the 1000 ppm limit.

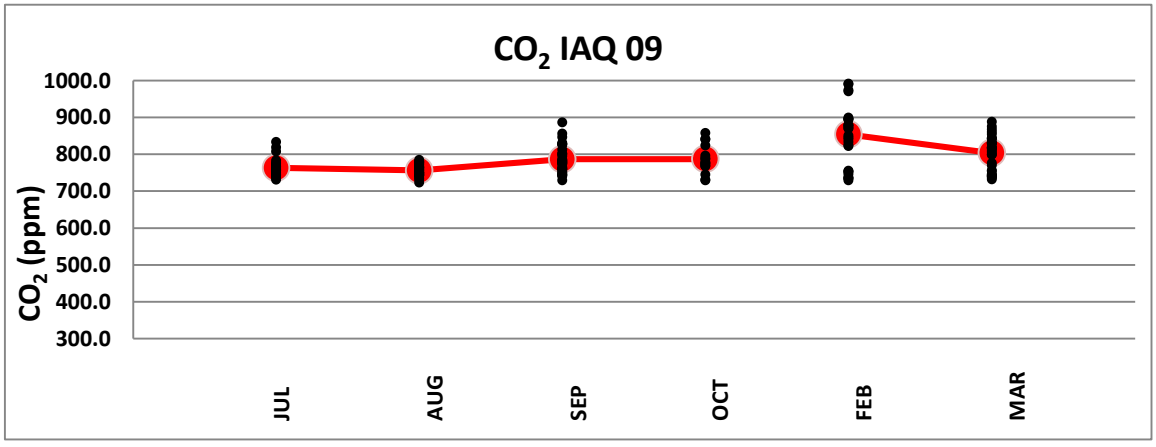


Diagram 5: Monthly CO2 measurements

3.2 VOC's

There is a floating trend at the monthly VOC'S rates for systems IAQ_02 and IAQ_09. The indoor air quality of the building is categorized in the 'no irritation or discomfort' class, even though in some days the limit of 10 o/u was exceeded.

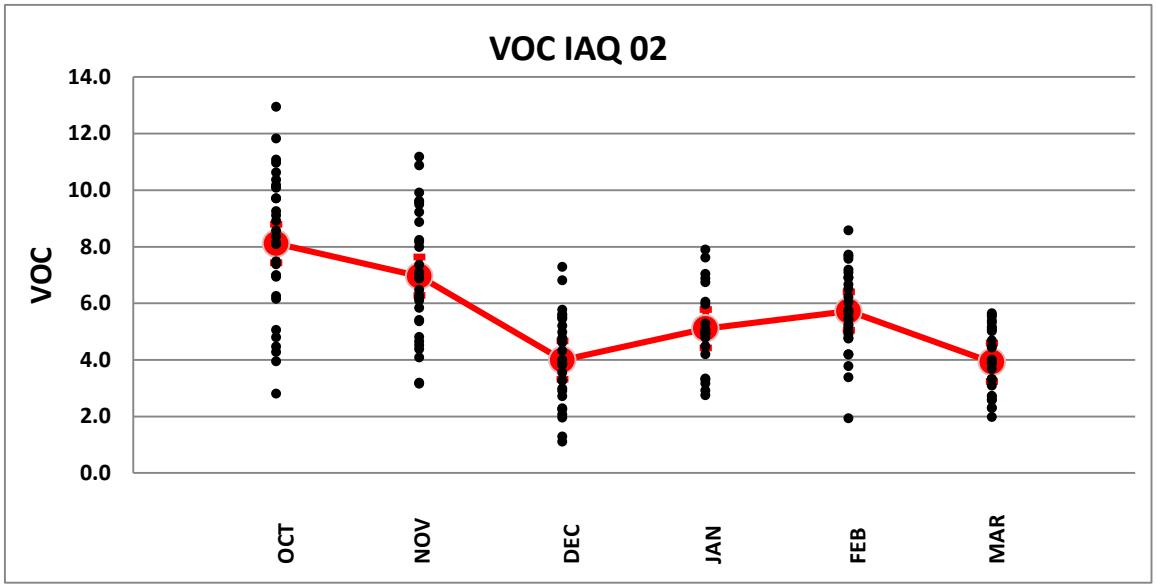


Diagram 6: Monthly VOC measurements

4 CONCLUSIONS

In conclusion, the building's air quality is considered to be acceptable, since the recorded CO_2 values were between 600 and 1000 ppm. Moreover, in both buildings the majority of the hourly VOC's measurements were between 0 – 10 o/u (0 - 0,05 of the Molhave scale), so they are categorized in the 'no irritation or discomfort' class. The table below shows the overall IAQ evaluation of the buildings:

CO_2 (%)					
IAQ No	Building Type	< 600 ppm	600 - 1000 ppm	>1000 ppm	Category
02	Office	-	-	-	-
09	Office	*0*	*95.4*	*4.6*	Acceptable
VOC's (%)					
IAQ No	Building Type	*< 10 o/u*	*10 - 20 o/u*	*20 - 30 o/u*	Category
02	Office	*92.2*	*7.8*	*0*	No irritation or discomfort
09	Office	*99.2*	*0.8*	*0.1*	No irritation or discomfort

Table 3: Percentages of values for CO_2 and VOC's from Frequency distributions for each building

5 CONCLUSIONS FROM THE HVAC INSPECTIONS

IAQ 02

Installed capacity

This building is conditioned using floor mounted hydronic fan coil units which only condition recirculated internal air. Fresh air is supplied 100% fresh air hydronic fan coil units. It was calculated using the information gathered as part of the inspection that 0.788 m^3/S of fresh air is supplied per 517.6 m^2 floor.

The installed capacity within the building of 50 to 60w/m^2 compares favorably with our calculated building heat loads

Maintenance

Receiving four visits per annum the fan coil units were in a good clean condition, there was nothing to indicate that there would be any adverse effect on air movement, which would affect air quality.

Operation and Control

The building has full fresh air hydronic FCUs on each floor to maintain a temperature of 25°C, controlled centrally, with smaller local, floor mounted free air discharge terminal hydronic units to trim the temperature by +/- 2°C, as required, using inbuilt controllers, whilst operating on a daily time schedule.

Efficiency

The system efficiency EER of 2.91 is more than adequate to maintain comfort conditions during the peak heat gain and was able to deliver off coil temperatures and humidity levels commiserate with good indoor air quality.

IAQ 09

Installed capacity

The building is served using three plenum roof top AHUs which maintain a general zone temperature of 25°C using both recirculated and fresh air as required, with smaller local floor mounted free air discharge chilled water terminal units which only use recirculated air to trim the temperature by +/- 2°C

It was calculated using data gathered during the inspection 1.62 m^3/S of fresh air was being supplied to an area of 2579.1 m^2

The installed capacity of 83 to 93W/m^2 compares favorably with our calculated building heat load of 64 to71.55 W/m^2.

Maintenance

The equipment outwardly appeared generally to be in a good and clean condition, which was testament to the maintenance visits every three months although there were visual signs of refrigerant leakage.

Of the three roof top AHUs only one was in operation during the inspection, the other two being off due to various faults which may have an adverse effect on air movement and indoor air quality

Operation & Control

The building has full fresh air hydronic FCUs on each floor to maintain a temperature of 25°C, controlled centrally, with smaller local, floor mounted free air discharge terminal hydronic units to trim the temperature by +/- 2°C, as required, using inbuilt controllers, whilst operating on a daily time schedule.

Efficiency

The system efficiency is more than adequate to maintain comfort conditions during the peak heat gain and was able to deliver off coil temperatures and humidity levels commiserate with good indoor air quality.

6 CORELLATION IAQ – HVAC SYSTEM

Finally Indoor Air Quality depends on the age and the maintenance of the HVAC, while it was found that a bad maintenance or an old system could lead to high consumption. HVAC systems also maintain the appropriate Tair – RH Set Points of the stores.

	CO_2	VOCS	HVAC		
OFFICES			AGE OF EQUIPMENT	ENERGY CONSUMPTION (Kwh/m²)	MAINTENANCE
IAQ 02	-	NO IRRITATION OR DISCOMFORT	-	-	GOOD
IAQ 09	ACCEPTABLE	NO IRRITATION OR DISCOMFORT	-	-	GOOD

Table 4: IAQ – HVAC Correlation