Report Belgium

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 offices below could cause no irritation or discomfort, while Tair maintained at higher levels during the non - operation hours. Last but not least RH was at the same levels during the whole day. Finally, the frequency distributions showed that in this office the ventilation is adequate and the air quality leads to no irritation or discomfort.

1 DESCRIPTION OF THE BUILDINGS

The system IAQ 23 is installed in offices in Diegem, Belgium in July 2013 and from October 2013 to February 2014, while the system IAQ 27 is located in offices at research building in Arlon, Belgium in July 2013 and from October 2013 to April 2014. The first building also has been constructed on 1/2/2009 and has an air conditioned area of 11240 m^2 The second building has been constructed on 1/6/1971 and has an air conditioned area of 2332,1 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. Initially there was an attempt to select limits of CO_2 and Volatile Organic Compounds (VOC'S). Guided by CO_2 limits by ASHRAE it was made an adaptation to the limits to the buildings and it was used as limits the values 800 ± 2 standard deviation and 1000 ± 2 standard deviation, 800 ± 1 standard deviation and 1000 ± 1 standard deviation which led to a large overlap between categories. For this reason a frequency distribution took place, based on classes by CIBSE guide and the classes 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 need for selecting the most appropriate limits of carbon dioxide led to frequency distribution and found that the second office recorded the majority of values 0 - 600 ppm thus it can be classified in the category of good air quality, suggesting that the ventilation of the building is adequate Below are given the total chart of CO2 frequency distribution and an indicative diagram of one office:

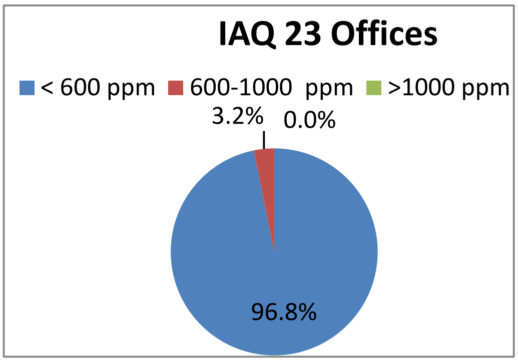
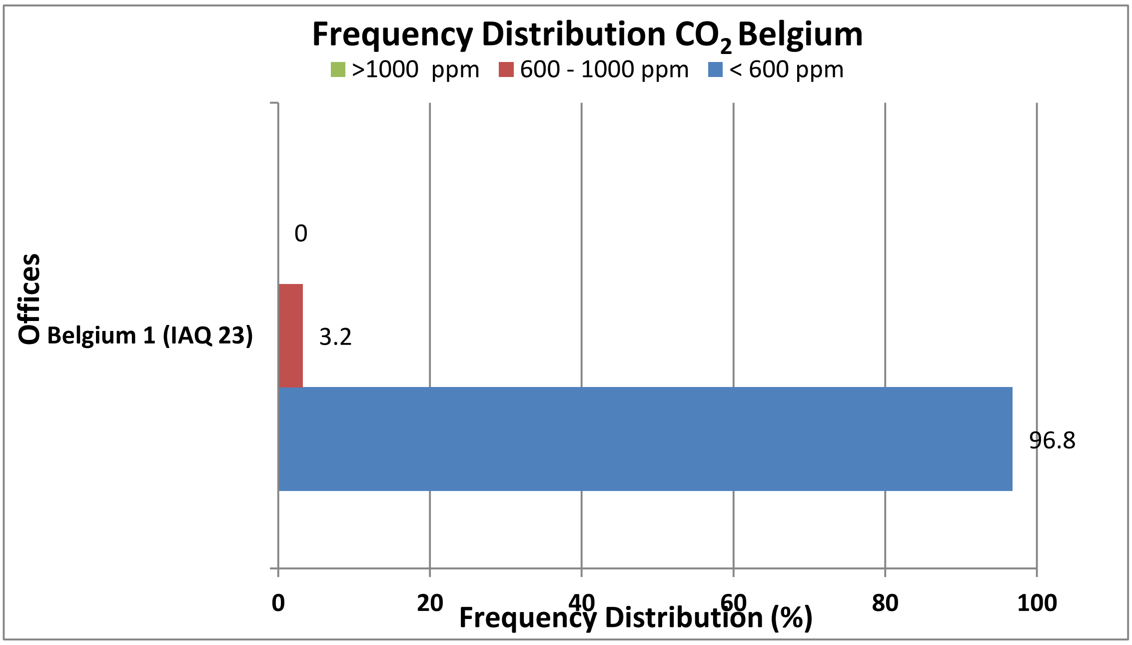


Diagram 1: Frequency distribution CO_2 (indicative)

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 health. Furthermore, based on accredited institutions of the University of Athens the kits were calibrated, from which emerged the following correlation between price VOC'S 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

Similar to carbon dioxide, it was made a frequency distribution for VOC's and found that the air quality could to lead to no irritation or discomfort, as the majority of hourly rates ranging from 0 – 10 o/u at both buildings Below are given the total chart of VOCs frequency distribution and an indicative diagram of one office:

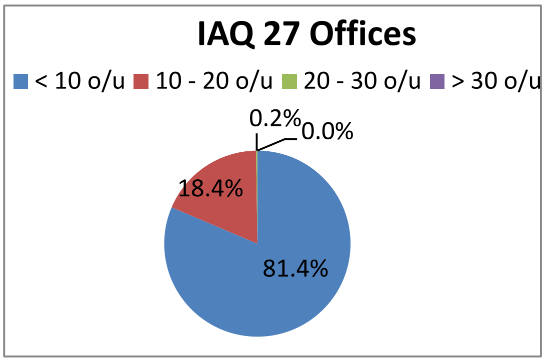


Diagram 3: Frequency distribution VOC'S (indicative)

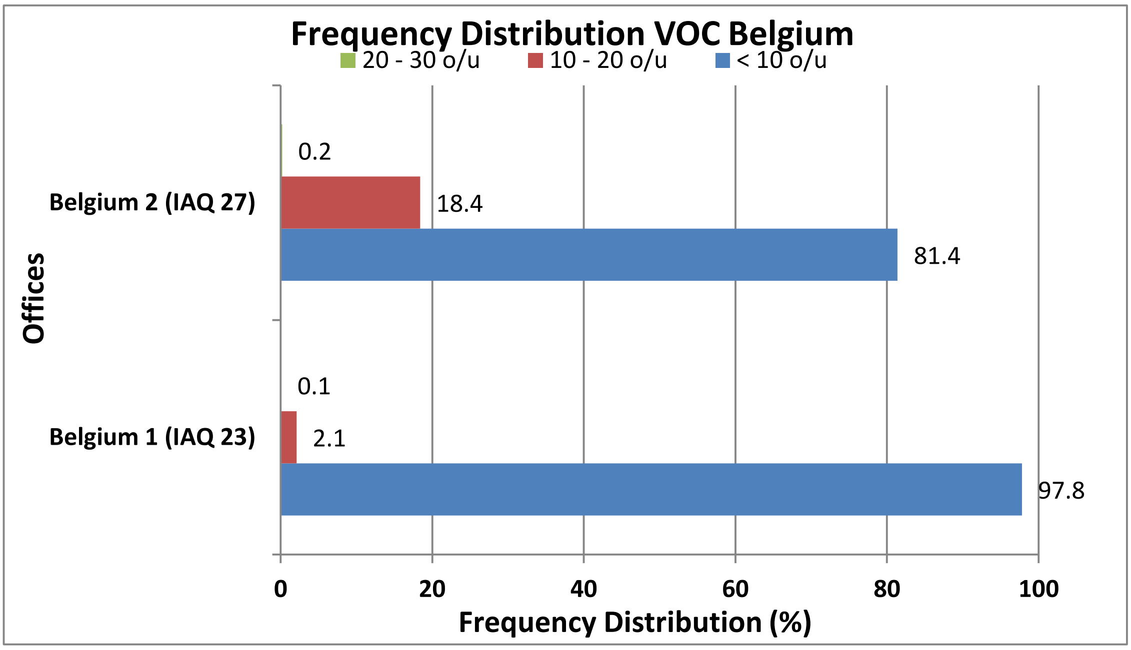


Diagram 4: VOCs Frequency distribution

3 MONTHLY VARIATIONS

At the following diagrams, the monthly morning and the 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 office buildings are 8:00 – 18:00.

3.1 CO_2

There is a steady trend at the monthly CO_2 measurements for the system IAQ 23 with the maximum of these exceeding the limit of 1000 ppm.

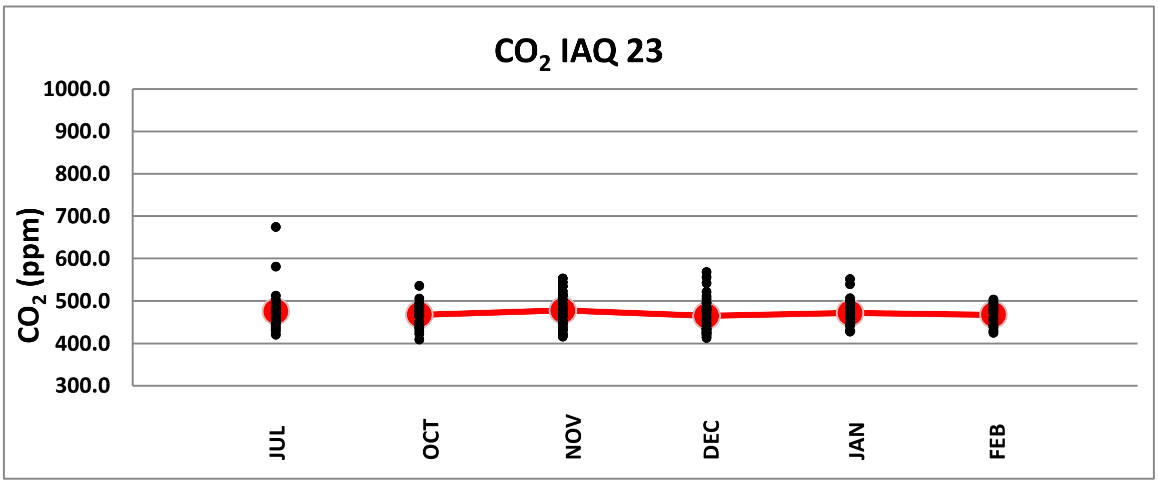


Diagram 5: Monthly CO2 measurements

3.2 VOC's

There is a steady trend at the monthly VOC'S rates for the systems IAQ 23 and IAQ 27 and the indoor air quality could lead to no irritation or discomfort, while some days the limit of 10 o/u was overcome.

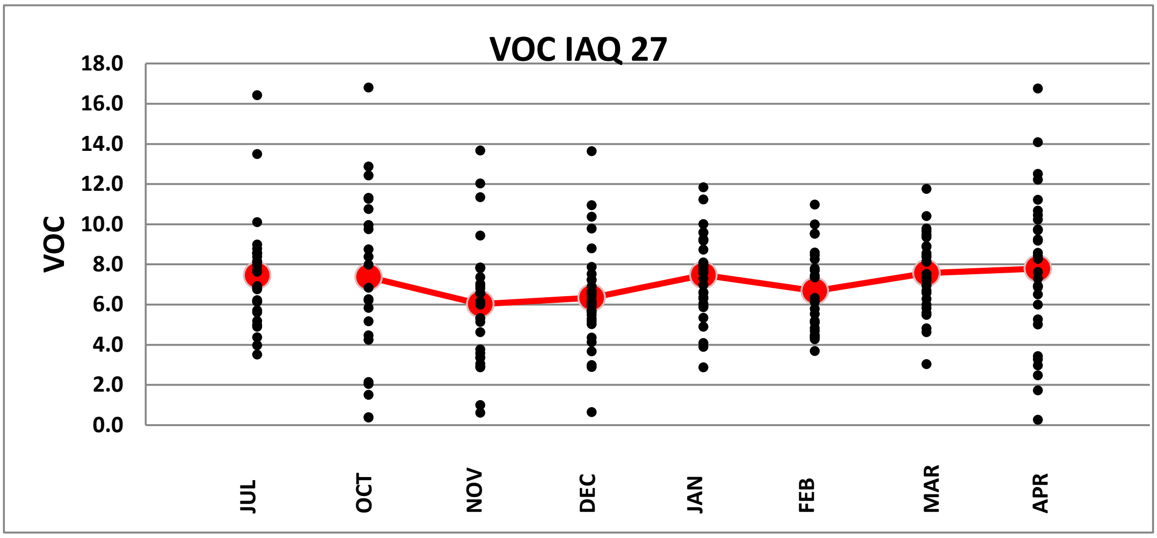


Diagram 6: Monthly VOC measurements

4 CONCLUSIONS

In conclusion, the building's air quality is considered to be good, since the recorded CO_2 values were 0 - 600 ppm. Moreover, both buildings recorded the majority of the hourly VOC's measurements between 0 – 10 o/u (0 - 0,05 of the Molhave scale), so they might be able to cause no irritation or discomfort. The percentages and the diagrams of values for CO_2 and VOC's from Frequency distributions for each building are given below:

CO_2 (%)					
IAQ No	Building Type	< 600 ppm	600 - 1000 ppm	>1000 ppm	Category
23	Office	96.8	3.2	0	Good
27	Office	-	-	-	-
VOC's (%)					
IAQ No	Building Type	< 10 o/u	10 - 20 o/u	20 - 30 o/u	Category
23	Office	97.8	2.1	0.1	No irritation or discomfort
27	Office	81.4	18.4	0.2	No irritation or discomfort

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

CONCLUSIONS FROM THE HVAC INSPECTIONS

IAQ 27

The building is conditioned using three AHUs which can use fresh and recirculated air as required and 155 Fan coil terminal units all supplied by two water cooled liquid chillers each with a nominal cooling capacity of 75kW.

AHU CP1 supplies FCUs on the south side of the "A" building and balances the proportion of re-circulated and fresh air supplied, depending on CO_2 levels in the return air duct. It was calculated using data gathered from the inspection 3.97m^3/S of air was being supplied from this AHU

AHU CP3 supplies laboratories on the north side of the "A" building and is a full fresh air system, working in conjunction with the GE extract fan to maintain a negative pressure and the required air changes within the laboratories. It was calculated using data gathered from the inspection 1.77m^3/S of air was being supplied from this AHU

AHU CP2 supplies FCUs in "B" building and balances the proportion of re-circulated and fresh air supplied, depending on CO_2 levels in the return air duct. . It was calculated using data gathered from the inspection 3.78m^3/S of air was being supplied from this AHU

Installed capacity

There is total installed water cooled water chillers' nominal cooling capacity of 150kW (103.8W/m^2) although we have re-calculated this to 143.17kW (101.37W/m^2), in respect of the chillers having been modified, from the outset, with the inclusion of a dual circuit air cooled condenser and condenser pressure regulating valve with which to optimise the condensing pressure in order to maintain higher than normal condensing temperatures for a water cooled condenser - to enable heat recovery by the building hot water system.

Maintenance

Maintenance is carried out regularly and response to any alarms by in-house personnel and by a specialist contractor for the chillers

Operation, Control and Monitoring

The BEMS control system controls both heating and cooling functions - single liquid chiller being enabled on cooling demand between 08:00 and 18:00 Monday to Friday,

The second chiller is enabled when the ambient temperature is above 24^oC, whilst the secondary pumps operate constantly at high speed during these normal operating hours.

Outside of these hours night time cooling operates on a single liquid chiller to maintain relaxed conditions between 23^oC and 24^oC, the secondary pumps are operated at low speed.

AHU CP1 supplies FCUs on the south side of the "A" building and balances the proportion of re-circulated and fresh air supplied, depending on CO_2 levels in the return air duct.

AHU CP3 supplies laboratories on the north side of the "A" building and is a full fresh air system, working in conjunction with the GE extract fan to maintain a negative pressure and the required air changes within the laboratories.

AHU CP2 supplies FCUs in "B" building and balances the proportion of re-circulated and fresh air supplied, depending on CO_2 levels in the return air duct.

Air from the relevant AHUs is supplied the local terminal fan coil units at 23°C, mixing with the discharge air.

The FCUs have a pre-set room set-point of 23°C (return air temperature) which can be adjusted by +/-3 degrees using an adjacent controller.

Fault conditions are detected by the BEMS system which alerts the building manager and the maintenance engineer by e-mail.

The liquid chillers are furnished with a single semi-hermetic, reciprocating motor/compressor, each of which have two offloading solenoid valves, giving three capacity stages, controlled by three stages of a four stage electro/mechanical thermostat, of 33%, 66%, and 100% and overall, six stages from the two chillers, of 17%, 34%, 51%, 68%, 84%, and 100%. Each compressor is also equipped with an unloaded start valve, greatly reducing the starting current.

The water cooled packaged liquid chillers are also connected to remote external air cooled condensers. The water shell and tube condenser (described as a 'Winter Condenser) has interconnecting pipe-work with a hot water cylinder, within the plant room, where it apparently pre-heats the main LPHW water buffer tank, recovering heat from the high temperature refrigerant. Once the optimum cylinder temperature is reached, the refrigerant is diverted to the remote air cooled condenser. This function appears, although it's not certain, to have been withdrawn during the renewal of the control/BMS protocol.

Condenser pressure control is carried out using a condenser pressure regulator, to maintain a pre-set value, within the condenser with all of the fans operating, and at full speed.

Efficiency

There would be a 4.6% reduction in straight chiller efficiency operating in air cooled condenser mode rather than water cooled, but when making the comparison with the condenser fans operating, with the former, and the pump with the latter, there would be a 6.6% reduction.

This reduction in efficiency would have been off-set by the benefits of heat recovery feature of the system, which we understand is no longer used. Should this be the case the condensing pressures could be reset to 'normal' by adjustments to the regulating valve and by controlling the condenser fans appropriately.

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There are proposals for a single replacement air cooled packaged chiller which has a 15.84% superior energy efficiency rating at peak demand, but as, at part load, the input power of the reciprocating compressors of the existing chillers, would reduce proportionally, there would be an increased efficiency of the chillers in respect of the increased evaporating temperature and the lower condensing temperature; and therefore, by comparison with the 'loss' of four capacity stages, a single chiller with only two compressors operating at 100%, on or off, the benefit of its superior EER would be diminished – the likelihood of there being no net gain.