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Case Study of Ventilation Strategy in a Room with Gas Appliances

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Abstract

The paper is focused on indoor environment in a kitchen of a family house. Kitchen equipment consists of a gas stove and a gas water heater. The schedule is following: a regular everyday use of a gas stove and a gas water heater for washing the dishes. The study aims at the ventilation issues during a 3 day time period in summer conditions. The ventilation appliances available are the following: a kitchen hood and a window opening. The family house has been refurbished recently with new wooden windows and thermal insulation of 100 mm thickness. It is investigated how such a space is capable of ventilation and if all pollutants produced by such gas appliances are ventilated away. The study investigates whether the ventilation strategies are sufficient for air change, whether occupant`s behavior has a significant influence on ventilation, whether the ventilation is efficient enough to enough to get rid of properly of all pollutants emitted by gas appliances.

Keywords - indoor environment quality, indoor air quality, ventilation rate, gas appliances, air change

1. Introduction

According to the last trends of energy savings in building services operation and building envelope insulation, the minimum air change rate is calculated considering heat retention. Ventilation system control is usually based on the CO_2 measured concentration. The air change rate is dependent on the occupant behavior. This paper is focused on experimental description of the investigated pollutants in a naturally ventilated room during unoccupied hours.

In this kitchen operation typically many pollutants are produced during cooking - gas combustion. The real question is which pollutant is the most important and decides the exact ventilation need rate. The ventilation need is highly dependent on the real use of the room. These are two main challenges for is sort of operation.

2. Gas Appliances in the Investigated Room

In the investigated kitchen the following appliances are used: a gas stove and a gas water heater. The stove has four burners. These burners have three following wattages:

1 kW; 1. 75 kW and 2. 7 kW. The gas water heater has following characteristics: no flame: 0 kW, flame on: 0. 87 kW and wattage during heating of water: 17. 3 kW.

3. Ventilation Strategies

Possible ventilation strategies are natural ventilation and forced ventilation (Tab. 1.). Natural ways of used ventilation strategies are partly opened window and open door to the corridor. The forced ventilation possibility is a digester located above the kitchen stove. The digester output characteristics are 3 scales. The highest scale enables the ventilation rate of 205 m^3 / h. The wattage of digester engine is 120 W. The outlet duct diameter is Ø 120 mm. The digester is used only during times of cooking. The occupants use mostly only 1st characteristics if the scale. The estimation of this ventilation rate was determined as 130 m^3 / h.

Tab. 1. Ventilation strategies used

	yes	no
partially open window	x	
open window		x
closed window	x	
door to corridor open	x	
door to corridor closed	x	
digester on	x	
digester off	x	

4. Methods

Following methods were used to investigate indoor environment in the kitchen. Measurements were taken of carbon dioxide, carbon monoxide, TVOC and formaldehyde. All these pollutants were measured in 3 selected standpoints. The standpoints were chosen to determine air flows in a room.

Temperature and relative humidity were measured in the kitchen and outside in the stairs. A tracer gas was used to calculate air exchange in time when every window and door is closed and when there is some sort of ventilation schedule. The occupants wrote down their schedule of a kitchen use and ventilation behavior – the schedule of their ventilation habits, their presence in the room, their activity – for better comprehension.

The tracer gas SF_6 was dosed into the investigated kitchen in the beginning of the measurement. The concentration uniformity was provided by the use of mixing fan. The tracer gas concentrations were measured.

5. Measurements

There were 2 kind of COMET data loggers used in the investigated region: temperature-humidity sensors and Innova air quality sensors. For indoor air quality three standpoints (Fig. 1) were located closed to freezer I1, sink I2 and door to pantry

I3. The temperature sensors were located in the following places: a kitchen hood (digester), a gas water heater, a window, a freezer, a sink, a door to pantry and an outdoor stairs.

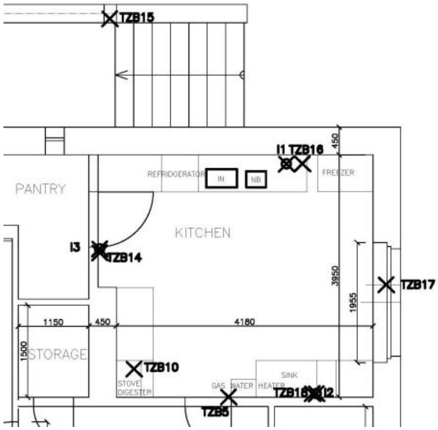

Fig. 1 Scheme of measurement standpoints in the investigated kitchen

Outdoor conditions and measured temperatures

The measurements were taken during 2015 summer extreme conditions in July. Those days were in July from 14 to 16. The temperatures (Fig. 2) were taken in the 6 standpoints inside and in 1 standpoint outside. Outdoor temperature is during the night lower down to 17, 5 °C. Indoor temperatures during the day were measured in an interval from 23, 5 °C to 31, 5 °C.

Measured relative humidity

Measured relative humidity is shown in Fig. 3. The measured indoor highest humidity is close to the sink because of doing the dishes. The outdoor measured humidity is higher during nights than during days. The other courses are close to each other which represent the state in the whole room – values were measured between 45 – 60 %.

IAQ measurements and gas appliances

CO, formaldehyde and TVOC concentrations were measured (Fig. 4, 5, 6). For better understanding the stove schedules and included. Gas combustion influences the measured concentrations. CO_2 concentration is often used as an indoor air quality indicator for g. e. lecture rooms. This CO_2 value is an average value of these 3 standpoints. (Fig. 7) According to [1] the acceptable CO_2 concentration is in the value of 1500 ppm. According to the opening schedule the open door can better the situation only a little. The window helps much more.

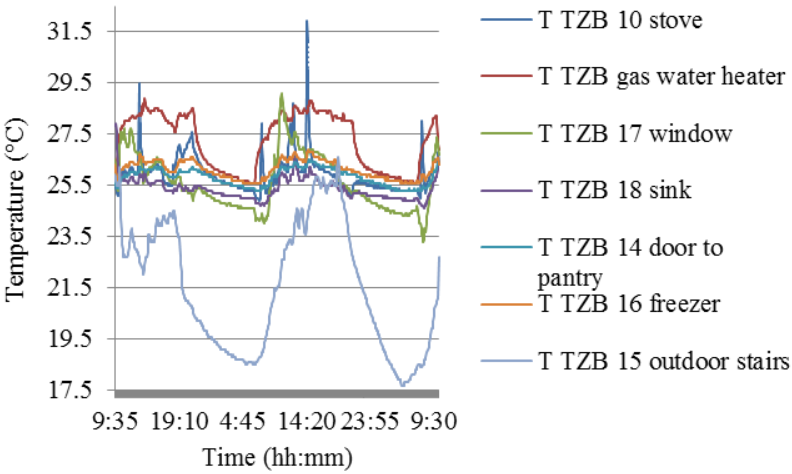

Fig. 2 Measured indoor temperatures and outdoor temperature on stairs

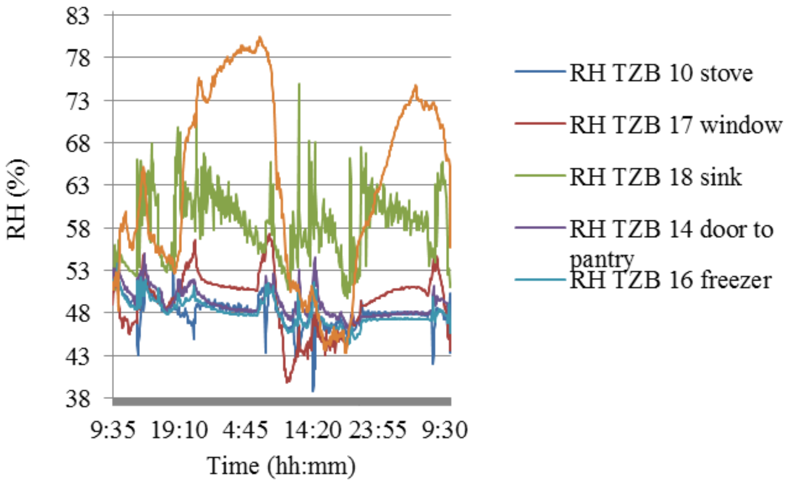

Fig. 3 Measured humidity

6. Occupational Behaviour

Occupants were present during the days for a couple of times. Their presence is shown in the Fig. 7. Mostly just one occupant is present. For only one time two occupants were present. During those times occupants produce pollutant CO2 and they also use gas appliances. Occupant presence influences the indoor environment and its

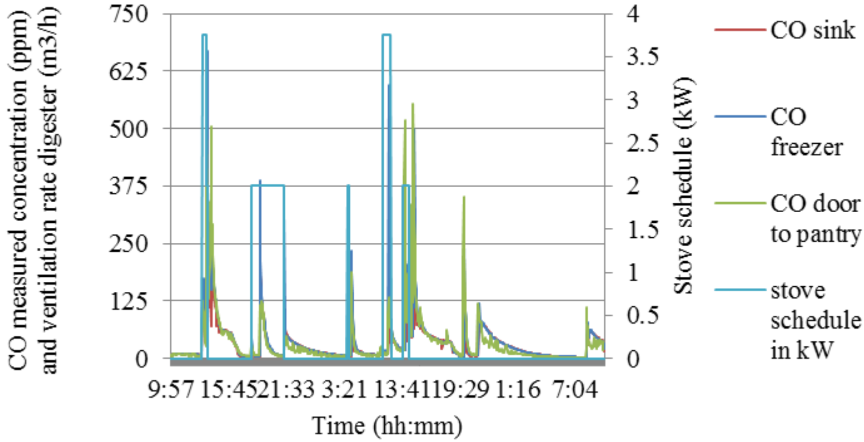

Fig. 4 CO: measured standpoints, digester and stove

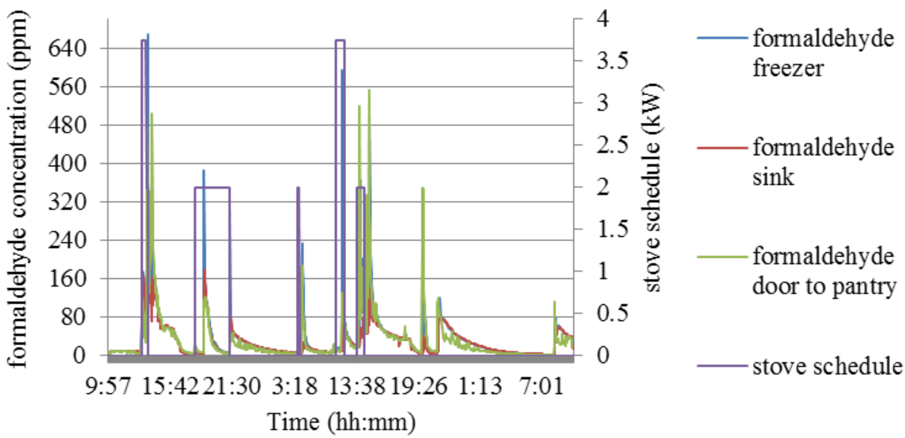

Fig. 5 Formaldehyd: 3 measured standpoints and stove schedule

requirements on ventilation rate. On the following graph there is an occupancy profile. Mostly one occupant present, exceptionally two of them are present. Occupant usually cooks or does the dishes. Cooking produces pollutants and water vapour. Doing dishes produces water vapour.

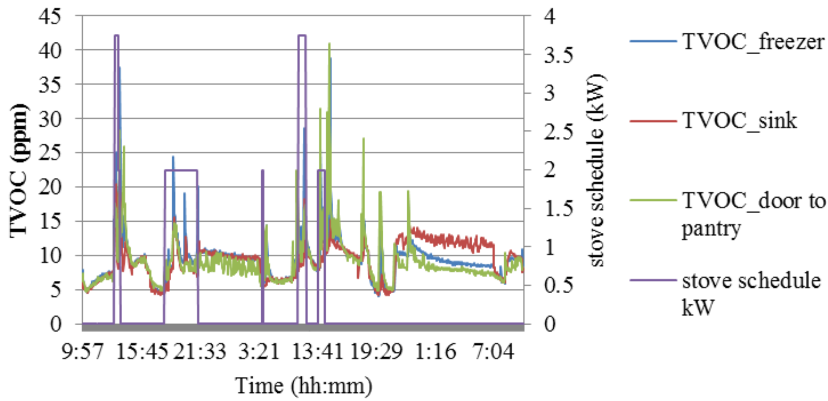

Fig. 6 TVOC: 3 measured standpoints and stove schedule

There is this relation between occupancy presence and the requirements on ventilation. Also the occupant behavior can very much influence the indoor air and indoor environment quality. According to their behavior in terms of using different ventilation strategies the indoor environment can very much be changed into more satisfactory state.

7. Schedules of Gas Appliances Use and Kitchen Use

The investigated kitchen is used every day through the whole because of occupants. Occupants are elderly retired persons who stay at home usually for most of the time of a day. They work partly during the day at home. During cooking time digester is turned on. Most of the day a window is partially opened. Gas appliances are in operation for a few times a day. For the following calculations all the values were chosen properly on the safe side of values for the biggest burners.

8. Calculations

Air change calculation

Recently the plastic windows were installed to this family house. This family house has also thermal insulation of 100 mm thickness. These factors give the assumption that the building envelope was changed to tighter one. The question was how effective can the building envelope ventilate? This assumption also brings out the hypothesis that the indoor air quality would change for the worse.

The idea was to investigate this issue with the use of a tracer gas SF_6. Tracer gas concentrations were measured (Fig. 8) during the whole day. That means during the period of closed openings and during the period of open window and door. The rate was calculated from the measured concentrations of SF_6. The air change was calculated according to the following equation. [2]

$$AC = \frac{\int_0^{\infty} C(\tau)d\tau}{C(0)} \left[\frac{1}{h}\right] \quad (1)$$

AC air change rate [1/h]
C (τ) measured concentration at τ = ∞ [ppm]
C (0) measured concentration at τ = 0 [ppm]
τ time of measurement [h]

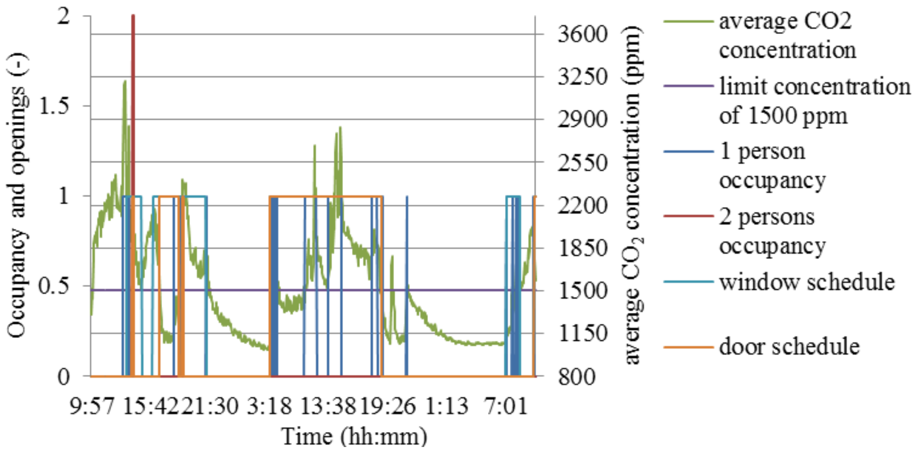

Fig. 7 Occupancy, openings and CO_2 concentration

Natural ventilation rate

Temperature difference between outdoor temperature and average indoor temperature was calculated. In order to find out natural ventilation efficiency the temperature difference was calculated. This difference shows that the natural ventilation is possible and efficient during these times of measurement. That means that ventilation through the partially open window is not negligible. Thus the strategy of ventilation with open window was effective and should be taken into the consideration.

Formulation of required ventilation rate according to occupant´s presence

Calculations of required ventilation rates were done. According to the [3] the required ventilation rate per person is 25 m^3 / h. Analogically the rate for two present

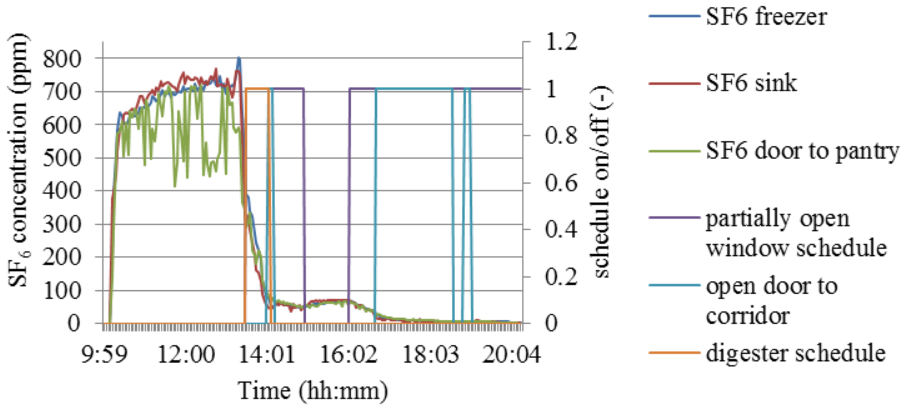

Fig. 8 SF_6: 3 measured standpoints and ventilation schedule – day 1

occupants is then supposed to be 50 m^3 / h. Also during unoccupied hours there is this required value according to standard [3] of multiple air change n = 0.1 1 / h. Then the required rate is calculated as:

$$V_{unocc} = n * V_m \ (m^3 / h) \tag{2}$$

V_{unocc} – ventilation rate for occupied hours (m^3 / h)
n – multiple air change (1 / h)
V_m – volume of investigated room (m^3)

Calculation of required ventilation rate according to gas appliances

Every used gas appliance has its own known installed wattage. The ventilation rate needed to get rid of these pollutants emitted by gas appliances was calculated. Every watt of this wattage is known and the use was written down during the measured time. The relation between wattage used and rate required was estimated as following:

$$1 \text{ kW} \approx 2 \text{ m}^3 / \text{h} \tag{3}$$

Into the calculations following appliances and their schedule were taken: stove and gas water heater. Operation of digester was also considered. The digester was used just once. Its ventilation rate was estimated as 130 m^3 / h. Balance calculations were taken in order to find out the real ventilation rate needed during the occupied hours and occupants activities in the kitchen. The balance was calculated from gas appliance output and its conversion to carbon dioxide and to ventilation rate of fresh air.

9. Results

Air change results

The calculated value was taken from concentration measured during the period of closed window and door. In the Tab. 2 initial values can be seen and also calculated results. These concentration values are taken from the period of time with no occupancy and all openings closed. These values were measured during day 1 of the measurement.

Tab. 2. Air change calculated results

standpoint	freezer	sink	door to pantry
day	10. 7. 15	10. 7. 15	10. 7. 15
T1 (hh:mm)	10:21	10:21	10:21
T2 (hh:mm)	13:05	13:05	13:05
C1 (ppm)	637	589.4	579.53
C2 (ppm)	713.9	707.7	712.4
AC (1/h)	-0.04	-0.07	-0.08

According to the measured values the measured concentrations of pollutants are higher than it is required. There was no ventilation strategy applied during this time. The calculated air change through the building envelope with closed window and door from SF_6 concentrations in three standpoints was calculated as - 0. 04; - 0. 07 and - 0. 08.

Required ventilation rate results according to occupancy

The required ventilation rates for times during occupancy are 25 and 50 m^3 / h (one person and two persons present). The calculated result with no occupancy is 5, 41 m^3 / h according to the standard multiple air change. This value was calculated according to standard requirements. These requirements were added into the Fig. no. 9. The calculated rates changes over a 50 %. The rate is very variable.

Required ventilation rate results according to occupancy and gas appliances use

In the following Fig. 9 all ventilation requirements can be seen through time. The required ventilation rate was calculated according to the appliances operation and the above mentioned equation (3). After the 13:05 there were openings (partially opened window, open door) open in a various arts. The openings schedule was graphically illustrated but due to a lack of space it was not published. The ventilation rates are time dependent and occupancy dependent. The highest requirements are during time of 2 occupant´s presence and cooking. The required ventilation rate changes according to the occupant´s activity in the kitchen and appliances operation schedule.

10. Discussion

Air change through the building envelope is not sufficient when the door and window are closed. The calculated values are negative which means that the air is mixed inside the room and doesn´t move at all despite of the fact that outdoor temperature is lower than indoor temperature. There is a solution needed to find an effective way to cope with this issue. The ventilation rate is negatively influenced by the summer conditions so it is an extreme state.

Four pollutants were measured. It is interesting to observe pollutants movement inside room volume and its meaning to the occupant. Different measured values for three different places make a good question of how one correct point should be chosen and how the exact concentration measurement should be done.

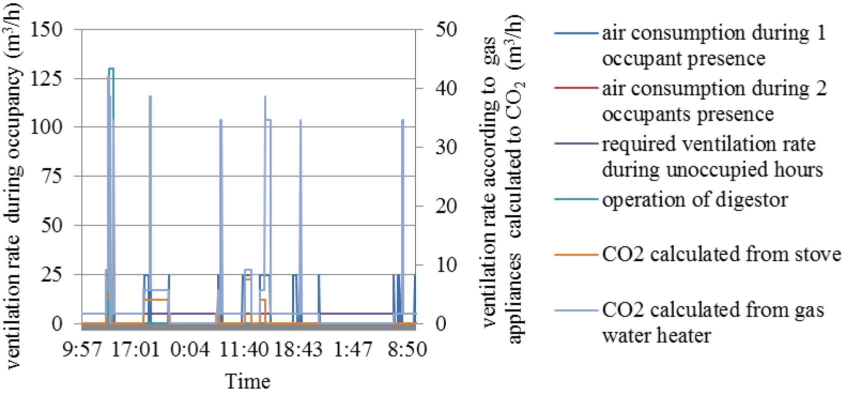

Fig. 9 Required ventilation rate and CO_2 production calculated to m^3/h

The following questions are if there is a way how the occupants can change the environment for themselves? Is there a way how to ventilate the volume efficiently and with the favorable operation costs?

11. Conclusion

The ventilation rate is not sufficient. The pollutants weren't able to be ventilated away sufficiently. This room with tight windows and gas appliances is high-risky. The carried out measurements show that use of gas appliances increases dangerous pollutants concentrations and worsen environmental quality. This room with episodic operation is a complicated case of indoor environment. The air change solution based on the episodic appliances schedule and assumed behavior of pollutants is neither sufficient nor safe. A sophisticated smart solution should be designed which is shouldn´t be dependent on human factor.

Acknowledgment

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References

[1] Directive No. 268/2009 Sb. About technichal requirements on buildings. Source: http://www.tzb-info.cz/pravni-predpisy/vyhlaska-c-268-2009-sb-o-technickych-pozadavcich-na-stavby se změnami 20/2012 Sb. In: Czech Standards Institute. Prague, 2012. Avaiable from: http://www.tzb-info.cz/pravni-predpisy/vyhlaska-c-268-2009-sb-o-technickych-pozadavcich-na-stavby

[2] Innova Air Tech Instruments. Ventilation Measurements And Other Tracer – gas Applications, Appendix A, Age of Air Measurement Equations, Concentration decay method: Innova booklet. p. 29, 1997

[3] CSN 73 0540:2002. [Thermal protection of buildings] in Czech. Prague: Czech Standards Institute, 2002