# THE VENTILATION RATE INFLUENCE ON INDOOR ENVIRONMENT QUALITY AND ENERGY CONSUMPTION

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**Abstract**. In modern society, there are two aspects of inhabiting indoor spaces, which are difficult to assess by their importance one against of other: indoor environment quality and energy economy. The necessity of healthier constructions is increasingly severe as we spend more and more time indoor. In the same time, it is obviously that humanity is consuming more energy that it can afford and the need of saving energy comes from the obligation to preserve our life environment. In this study, we analyze how the ventilation rate influences simultaneous the indoor environment quality and the energy consumption in buildings. The aim is to show that correct settings of the ventilation rates can bring benefits for improving the indoor environment quality while decreasing the energy consumption.

**Key words**: IEQ, energy efficiency, building operating, ventilation rate

## 1. Introduction

In the last decade, the indoor environment quality (IEQ) becomes a topic which stimulates more and more the researcher`s interest as a feed-back to an increasing number of observations related to the indubitable influence of the IEQ to the health and well-being of building occupants (Kim and de Dear, 2012). Linked to this interest it has emerged a market trend for health and well-being within the fields of architecture, engineering and constructions (Shady, 2018). Also, the designers need to project more comfortable buildings because the demand in indoor environment quality of contemporaneous people increased compared with previous generations (Câmpeanu *et al.*, 2007; Leong and Essah, 2017; Sarbu and Sebarchievici, 2013).

A possible cause in the growing awareness of new generations related to indoor environment quality is that most of our time is spent in indoor spaces like: offices, schools and homes (Di Giulio *et al.*, 2010). In fact, we spend between 60% and 90% of our time in indoor environments (Environmental

Protection Agency, 2018; European Commission, 2003; Leong and Essah, 2017; Sarbu and Sebarchievici, 2013), which is why numerous study highlights the IEQ has such impact for our health status (Al Horr *et al.*, 2017; Geng *et al.*, 2017; Heinzerling *et al.*, 2013). In many cases, the dwellers and building owners value their own health and well-being more than energy savings (Shady, 2018).

In consequence, higher demands regarding IEQ, which meant a higher living standard, led to the increase of energy demand for buildings field, especially since HVAC systems started to be very popular (Câmpeanu *et al.*, 2007; Yang *et al.*, 2014). This fact is observed preponderant in industrialized countries; for example, people from United States represent only 5% of the world's population but uses around 20% of the total energy consumed in the world (Botkin and Keller, 2011). So, we got into the situation that the energy consumed in buildings field represents about 40% of total energy used (Catalina *et al.*, 2013; Liu *et al.*, 2015; Pérez *et al.*, 2011; Tuominen *et al.*, 2014). Being one of the crucial elements in our activities (Khastar *et al.*, 2018), the energy consumption could become a problem as its production impacts the nature and change it in significant ways.

In the near future, it is expected that the average energy consumption (approximately 2055 kWh/person/year in 2010) to become in 2030 about 2200 kWh/person/year, which mean an increase of about 21% for the average consumption. Taking in account the increase of the population, results an increase by 33% of total energy consumed in the world (Botkin and Keller, 2011). In 2017 was reported the highest growth of the electricity demand (Gheorghe *et al.*, 2018), therefore, there is an urgent need to diminish buildings sector`s consumption as a means to ameliorate the living environment while providing healthy and energy efficient buildings (Koo and Hong, 2015; Ortiz *et al.*, 2017; Shady, 2018). For that were developed a series of legal rules with local or international authority (e.g.: 2010/31/EU). Although the energy regulations brought an encouraging progress to energy saving in buildings (Hong, 2009; Pérez *et al.*, 2011; Trianni *et al.*, 2014), imposing buildings which beside their main scope (protection to rain, snow and wind), also provide a sufficient indoor environment quality with lower energy consumptions, the practical realization of this concept remain a serious challenge of the researchers and building designers (Bacali *et al.*, 2018; Godish, 2016).

Indoor environment quality index ($I_{IEQ}$) is a suitable performance indicator which analyze and adjustment in relation with consumption of energy (CE) may bring up an extra economy of energy in buildings without neglect the occupant requirements.

In the scientific literature are proposed different ways to approach the $I_{IEQ}$, but majority of researchers admit it must to take in account the four most important types of comfort: thermal comfort, acoustic comfort, indoor air quality and visual comfort (Huang *et al.*, 2012; Ncube and Riffat, 2012; Pei *et al.*, 2015; Zuhaib *et al.*, 2018) to which can be added supplementary aspects with noticeable impacts on IEQ, like: amount of space, visual privacy, closeness to nature, behaviors, culture etc. (Heerwagen and Orians, 1993; Residovic, 2017; Stephen and Bill, 2018).

In this study we make an analysis of how ventilation rate, meaning the quantity of fresh air brought at indoor which affects the indoor air quality (IAQ), influences the IEQ and CE, the interaction between indoor quality factors, IEQ and CE still being a challenge within the building sector (Pereira *et al.*, 2017).

Our motivation is the unquestionable relation of the ventilation rate with both IEQ and CE. On the one hand, IAQ is ranked as one of the top five environmental risks for public health (Lai *et al.*, 2009). A poor quality of air, mostly met in urban zones (Panagopoulos *et al.*, 2018) is responsible for fatigue, heavy head, headache, difficult to concentrate, irritated nose, irritated eyes and skin diseases (Junjie *et al.*, 2018; Vasile *et al.*, 2017), which are symptoms of sick building syndrome (Wargocki *et al.*, 2000). The IAQ, and subsequently ventilation rate, influence the occupant's performance too (Hong *et al.*, 2018; Jurado *et al.*, 2014; Pereira *et al.*, 2014). In this context of addressing the sustainability and health of the built environment, inadequate ventilation strategies in buildings currently represents the through biggest challenge for the housing sector. Especially in Central and Eastern Europe (Vasile *et al.*, 2016) the building stock still predominates outdated buildings, designed without mechanical ventilation systems therefore depending on natural air circulation. On the other hand, good managing of ventilation rate can lead to important energy economies (Borgstein *et al.*, 2018; Quang *et al.*, 2014), the potential of heating and cooling energy saving by adjusting ventilation being noticeable.

We aim to understand the relationship between the air change rate and the indoor comfort categories (thermal, acoustic, visual comforts and indoor air quality). Further the scope of the study is to understand the influence of the air change rate upon the global index of indoor environment quality (IEQ) and the building energy consumption (CE). We also aim to understand if this parameter alone can be considered as a control parameter for the ventilation system.

This research work is designed as a case study for an apartment in a multilevel residential building. For the selected apartment, we evaluated the IEQ and CE in twelve different set-points of ventilation rate and two constructive variants of the ventilation system. The paper presents the analyzed building, the mathematical model for the estimation of the indoor environment quality and energy consumption, results and data interpretation.

## 2. The analyzed building

For the study of the relation between ventilation rate, indoor temperature and the indoor environment quality index we considered the architecture plan (Fig. 1) and the thermo-physical characteristics of a multi-level residential building located in Bucharest. For this purpose, we use the information and observations obtained after a thoroughly analysis of a real multi storey building, representative for the Romanian residential building stock

The building is bar-shaped and comprises four sections similar to the one presented in Fig. 1, from which we will use as a study support the section A. The height category of the building is B+GF+10L+TL, with a build area of 3920 m$^2$, the main façade being north oriented.

The levels from one to ten are part of the residential zone and they are divided as follows: one apartment of four rooms and three apartments with three rooms on every level from the residential zone of the building. The volumes of the 40 apartments form the heated space and the stairs room, basement and the technical level are not heated. The resistance structure of the building is made from continuous reinforced concrete foundations, resistance posts and reinforced concrete walls.

The thermal envelope is composed by opaque construction elements described in table 1 and transparent construction elements: 70% simple wood framework and 30 % of glazing from PVC window frame with thermo-insulating glass.

The influence of ventilation rate upon the indoor environment quality and energy consumption was analyzed using the values of comfort indices and energy consumption which corresponds to the north-east oriented apartment (marked apartment 3 in Fig. 1).

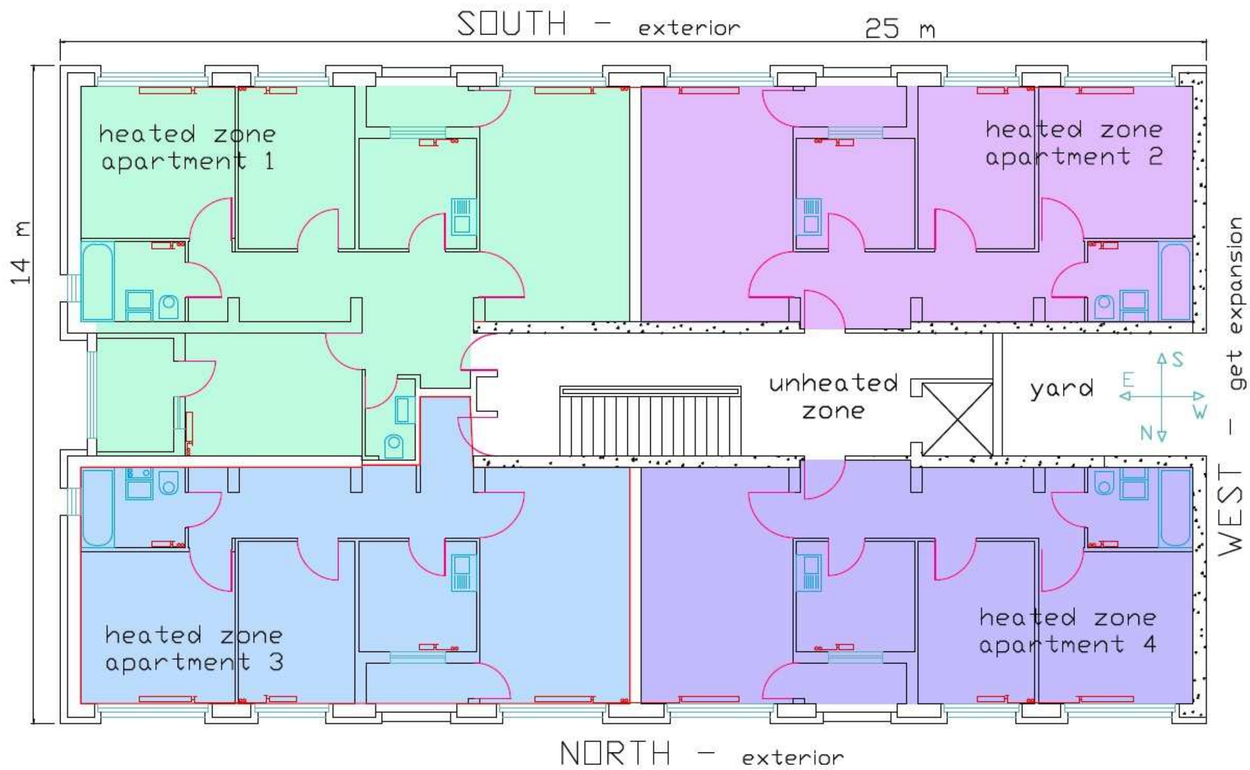



**Fig. 1**. Architectural plan of the analyzed building, section A.

**Table 1**. The structure of the opaque construction elements.

| Building element / The main materials | δ [m] | | |
|---|---|---|---|
| | **Wall type 1** | **Wall type 2** | **Roof terrace** |
| Ipsos plaster | 0,02 | 0,02 | 0,02 |
| Reinforced concrete slab | 0,2 | - | 0,3 |
| YTONG | 0,2 | 0,2 | - |
| Cellular polystyrene | - | - | 0,1 |
| Waterproofing | - | - | 0,03 |
| Plain concrete | - | - | 0,1 |
| Ipsos plaster | 0,02 | 0,02 | - |
| Waterproofing | - | - | 0,03 |

## 3. Modeling of CE and IEQ

In order to find the seasonal heating demand of the studied apartment we used the algorithm presented in „The calculation method for the energy performance of buildings. Part I - The building envelope" (MC 001/1, 2006) and „The calculation method for the energy performance of buildings. Part III - The audit and building performance certificate" (MC 001/3, 2006) which are recommended for buildings that are characterized by a glazing ratio of thermal envelope smaller than 40 percent.

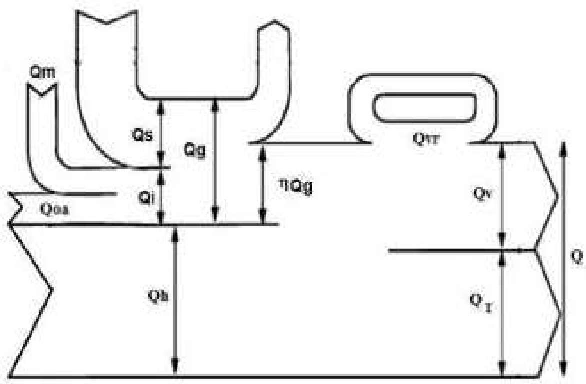



**Fig. 2.** The energy balance for heating demand

| | |
|---|---|
| $Q_h$ [W] | energy demand for heating |
| $Q_{oa}$ [W] | heat loads from indoor equipment |
| $Q_v$ [W] | heating demand for ventilation |
| $Q_{vr}$ [W] | recovered heat from ventilation |
| $Q_t$ [W] | heat loses through thermal envelope |
| $Q_m$ [W] | metabolic heat from the occupants |
| $Q_s$ [W] | passive sun heat loads |
| $Q_L$ [W] | total heat loses |
| $Q_i$ [W] | indoor heat sources |
| $Q_g$ [W] | total heat loads |
| h$Q_g$ [W] | useful heat loads |

The algorithm used for calculation of the heating demand includes: heat loss through transmission and ventilation from heated zone to outdoor space, heat loss through transmission and ventilation from heated zone to adjacent unheated zone, useful indoor heat loads and solar heat loads (Fig. 2).

The heating demand is obtained based on an iterative calculation: first, using the standardized balanced temperature are calculated preliminary heat losses, preliminary heat loads and usable ratio of the heat loads. Then supplementary iterations are made in order to identify the building balance temperature, the heat losses, the heat loads and, finally, the heat demand. The temperatures of the secondary zones of the building (the stairs room, basement and technical room) are determined with monthly thermal balance according to existing methodology (MC 001/3, 2006). The climatic parameters correspond to representative year of Bucharest city and it is used as monthly averages.

For the determination of the IEQ index we used the method described by a previous paper (Catalina and Iordache, 2012), which first requires calculation of four comfort indexes based on physical parameters of indoor space:

$$I_{CT} = \begin{cases} 28{,}57 \cdot \theta_{OP} - 514; & for\ \theta_{OP} \le 21{,}5 \\ -28{,}57 \cdot \theta_{OP} + 800; & for\ \theta_{OP} > 21{,}5 \end{cases} \quad (1)$$

$$I_{CA} = -0{,}33 \cdot L_{pi} + 200 \quad (2)$$

$$I_{IAQ} = 3{,}125 \cdot q_{ap\_S} - 12{,}5 \quad (3)$$

$$I_{CV} = 0{,}33 \cdot E \quad (4)$$

$$L_{pi} = 1{,}164 \cdot 10^{-7} q^4 - 4{,}03 \cdot 10^{5}\, q^3 + 1{,}99 \cdot 10^{-3}\, q^2 + 0{,}545 q + 0{,}218 \quad (5)$$

where:

| | |
|---|---|
| $I_{CT}$ [-] | thermal comfort |
| $I_{CA}$[-] | acoustic comfort |
| $I_{IAQ}$ [-] | indoor air quality |
| $I_{CV}$ [-] | visual comfort |
| $\theta_{op}$ [$^o$C] | operative temperature |
| $L_{pi}$ [dB(A)] | sound pressure level |
| E [lx] | illuminance level |
| $q_{ap\_s}$ [m$^3$/(h·pers)] | specific air flow |
| q [m$^3$/h] | the airflow generated by fan |

The indoor environment quality index is calculated as a weighted average of the comfort indices:

$$I_{IEQ} = \frac{I_{CT} \cdot \mu_{CT} + I_{CA} \cdot \mu_{CA} \cdot I_{IAQ} \cdot \mu_{IAQ} + I_{CV} \cdot \mu_{CV}}{\mu_{CT} + \mu_{CA} + \mu_{IAQ} + \mu_{CV}} \quad (5)$$

were $\mu_{CT}$, $\mu_{CA}$, $\mu_{IAQ}$, and $\mu_{CV}$ are weights determined by a survey study (Toderaşc and Iordache, 2016).

| | IEQ/Inputs class and star rating | | | | |
|---|---|---|---|---|---|
| | Class A | Class B | Class C | Class D | Class E |
| | ◊◊◊◊◊ | ◊◊◊◊ | ◊◊◊ | ◊◊ | ◊ |
| $\theta_{op}$ [°C]-winter | ≥ 21,5 | 20,5-21,5 | 19,5-20,5 | 18-19,5 | <18 |
| $\theta_{op}$ [°C]-summer | ≤ 24,5 | 25-26 | 26-27 | 27-28 | >28 |
| $E_{av}$ [lx] | ≥ 300 | 250-300 | 200-250 | 100-200 | <100 |
| $L_{pi}$ [dBA] | ≤30 | 30-40 | 40-50 | 50-60 | >60 |
| $Q_a$ [m³/h/pers] | ≥ 36 | 25-36 | 15-25 | 10-15 | <10 |
| IEQ index (-) | >90 | 67,5-90 | 32,5-67,5 | 10-35,5 | <10 |

**Table 2.** $I_{IEQ}$ classification scheme (Catalina and Iordache, 2012)

The influence of the ventilation rate upon IEQ and CE was revealed by variating the airflow (i.e. the fresh air delivered to indoor spaces) between 10 and 43 m³/person/h and observing the simultaneous variations of the $I_{IEQ}$ and of the specific yearly heat consume of the building. As a simplifying assumption, we neglected the energy used by a fan, in a ventilation system, in order to assure these air flows. This approach is justified as the energy consumption of the fan is strongly correlated with the ventilation system (duct type, diameters and lengths, filters etc.), therefore it is not relevant for other applications. For every value of the air flow the $I_{CA}$, $I_{IAQ}$ and $I_{IEQ}$ were calculated with equations 2, 3 and 6.

The $I_{CV}$ and $I_{CT}$ were considered constant at values suitable for class B of quality (Table 2). Because the variation of the airflow can affect the acoustic comfort as well, we consider two situations: (A) the fan is placed inside of a technical room separate from the residential rooms, which mean that airflow variations not influence the acoustic comfort, and (B) the ventilation unit is placed in the apartment which means that acoustic comfort is modified along with the ventilation flow rate.

## 4. Results

For the proposed value range of the ventilation airflow, the indoor air quality demonstrated a linear variation, advancing from the upper limit of IEQ class E (for 10 m³/pers/h airflow of fresh air) and attaining (for 43 m³/pers/h) class A (Fig. 3).

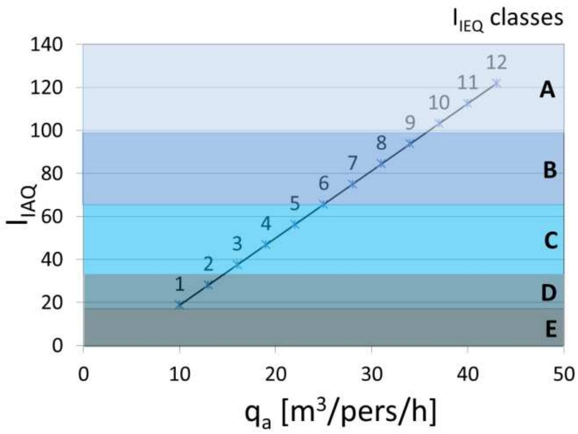



**Fig. 3.** The variation of indoor air quality index with the ventilation airflow for both (A) and (B) situation.

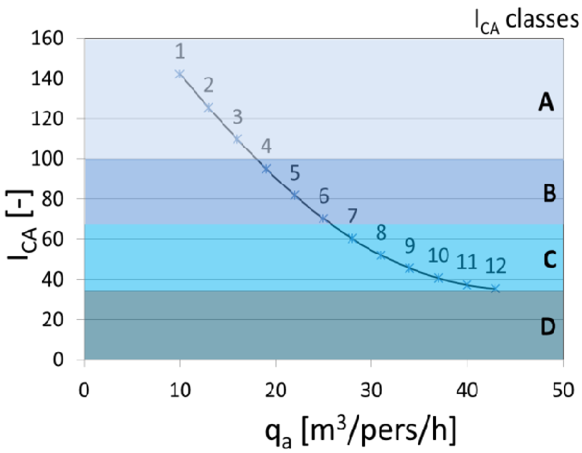



**Fig. 4.** The variation of indoor air quality index with the airflow for situation (B), respectively when the fan is placed in apartment

For these values of the fresh air flow, in the event that ventilation unit is indoor, the acoustic comfort index drops from class A up to lower limit of class C (Fig. 4), following a curve described by a polynomial function of 4th degree similar with curve described by the variation of the noise generated by the fan for different airflows (Eq. 5).

As a result of the increase in fresh air delivered by the ventilation system by 330 % from 10 to 43 m³/pers/h, the specific energy consumption for heating increase with 31 % from 179 up to 234 kWh/m²/year but this change doesn't affect the overall energy efficiency class of this dwelling unit (D, as shown in Fig. 5), as heat loses through transmission prevails in this particular case.

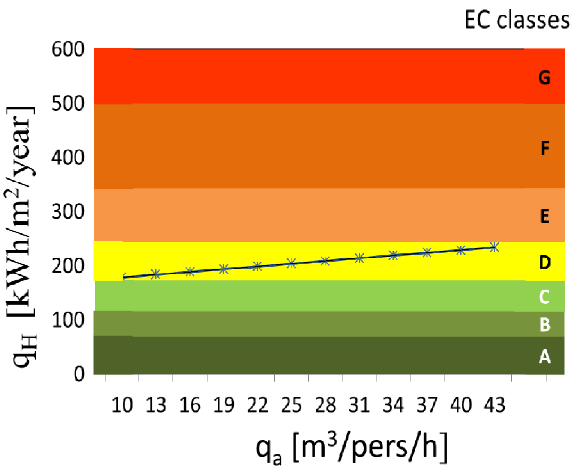



**Fig. 5**. Variation of the energy consumption for heating depending on ventilation

Overall, the indoor environment quality as shown by the IEQ index value, increase constantly for case (A) and, for situation (B) demonstrate an inflection point first decreasing with 7% and finally increase up to a value higher with 10% than the minimum value reached (Fig. 6).

For situation (B), the increase of the ventilation rate causes an increase of $I_{IAQ}$, but concomitant causes a decrease of the acoustic comfort. From the overlapped effects of the two types of comfort, for the analyzed range, results a parabolic variation of the IEQ index: it decreases for air flow lower than 19 m³/pers/h, value up to which the sound pressure level has a pronounced effect on the $I_{IEQ}$, remain relatively constant for air flow between 19 and 31 m³/pers/h, and for airflow higher than 31 m³/pers/h the $I_{IEQ}$ start to increase due to the effect of the $I_{IEQ}$ which take high values.

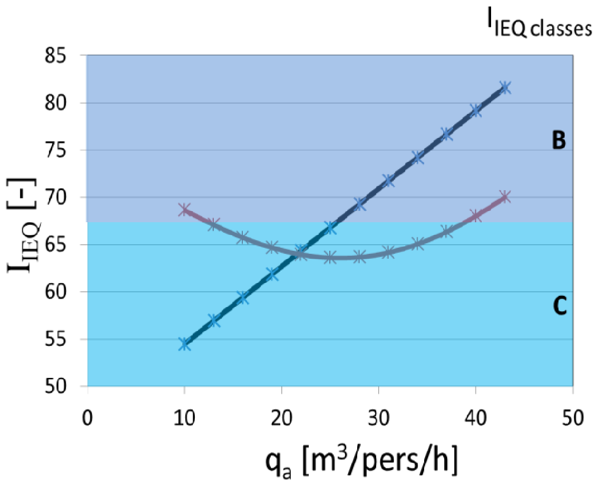



**Fig. 6**. Variation of the indoor environment quality depending on the fresh airflow:
a) the fan placed outside of the apartment
b) the fan is placed within apartment

For the situation (A) in which the fan is placed in a technical room, and the noise generated from it do not affect the acoustic comfort from the apartment, the increase of the fresh air flow causes a linear increase of indoor environment quality. We must notice that the algorithm does not include the velocity of air flow in occupied zone.

We observe that the close values for the indoor environment quality can be obtained with different energy consumptions (Table 4). For the studied apartment, the class C for IEQ can be realized with energy consumptions between 179 and 184 kWh/m²/year. For this interval, the acoustic comfort takes values which match to class A of comfort and the indoor air quality takes values which match to class D of comfort.

**Table 3.** The physical parameters for the calculation of indoor environment quality index

| case ↓ | $\theta_i$ | $I_{CT}$ | $L_{pi}$ | $L_{pi}$ | $I_{CA}$ | $I_{CA}$ | $q_a$ | $I_{IAQ}$ | E | $I_{CV}$ | $I_{IEQ}$ | $I_{IEQ}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °C | - | dB(A) | dB(A) | - | - | m³/pers/h | - | lx | - | | - |
| situation → | both | both | case (A) | Case (B) | case (A) | case (B) | both | both | both | both | case (A) | case (B) |
| 1 | 20 | 29 | 17 | 17 | 142 | 142 | 10 | 19 | 275 | 91 | 54 | 69 |
| 2 | 20 | 29 | 17 | 22 | 142 | 125 | 13 | 28 | 275 | 91 | 57 | 67 |
| 3 | 20 | 29 | 17 | 27 | 142 | 110 | 16 | 38 | 275 | 91 | 59 | 66 |
| 4 | 20 | 29 | 17 | 32 | 142 | 95 | 19 | 47 | 275 | 91 | 62 | 65 |
| 5 | 20 | 29 | 17 | 36 | 142 | 82 | 22 | 56 | 275 | 91 | 64 | 64 |
| 6 | 20 | 29 | 17 | 39 | 142 | 70 | 25 | 66 | 275 | 91 | 67 | 64 |
| 7 | 20 | 29 | 17 | 42 | 142 | 60 | 28 | 75 | 275 | 91 | 69 | 64 |
| 8 | 20 | 29 | 17 | 44 | 142 | 52 | 31 | 84 | 275 | 91 | 72 | 64 |
| 9 | 20 | 29 | 17 | 46 | 142 | 45 | 34 | 94 | 275 | 91 | 74 | 65 |
| 10 | 20 | 29 | 17 | 48 | 142 | 41 | 37 | 103 | 275 | 91 | 77 | 66 |
| 11 | 20 | 29 | 17 | 49 | 142 | 37 | 40 | 113 | 275 | 91 | 79 | 68 |
| 12 | 20 | 29 | 17 | 49 | 142 | 35 | 43 | 122 | 275 | 91 | 82 | 70 |

**Table 4.** The values of the indoor environment quality index and of the energy consumption for every analyzed case.

| case ↓ | $q_a$ | $n_a$ | $I_{IAQ}$ | $I_{IEQ}$ | $I_{IEQ}$ | $q_H$ | $Q_H$ |
|---|---|---|---|---|---|---|---|
| - | m³/pers/h | h⁻¹ | - | - | - | [kWh/m²an] | [kWh/an] |
| situation → | both | both | both | case (A) | case (B) | both | both |
| 1 | 10 | 0,214 | 19 | 54 | 69 | 179 | 9119 |
| 2 | 13 | 0,278 | 28 | 57 | 67 | 184 | 9378 |
| 3 | 16 | 0,342 | 38 | 59 | 66 | 189 | 9637 |
| 4 | 19 | 0,406 | 47 | 62 | 65 | 194 | 9894 |
| 5 | 22 | 0,471 | 56 | 64 | 64 | 199 | 10152 |
| 6 | 25 | 0,535 | 66 | 67 | 64 | 204 | 10408 |
| 7 | 28 | 0,599 | 75 | 69 | 64 | 209 | 10665 |
| 8 | 31 | 0,663 | 84 | 72 | 64 | 214 | 10921 |
| 9 | 34 | 0,727 | 94 | 74 | 65 | 219 | 11177 |
| 10 | 37 | 0,856 | 103 | 77 | 66 | 224 | 11433 |
| 11 | 40 | 0,856 | 113 | 79 | 68 | 229 | 11688 |
| 12 | 43 | 0,920 | 122 | 82 | 70 | 234 | 11943 |

The class C for IEQ can be obtained with higher energy consumptions, between 229 and 234 kWh/m²/year. For this interval, the acoustic comfort takes values which match to class C of comfort and the indoor air quality takes values which match to class A of comfort.

## 5. Conclusions

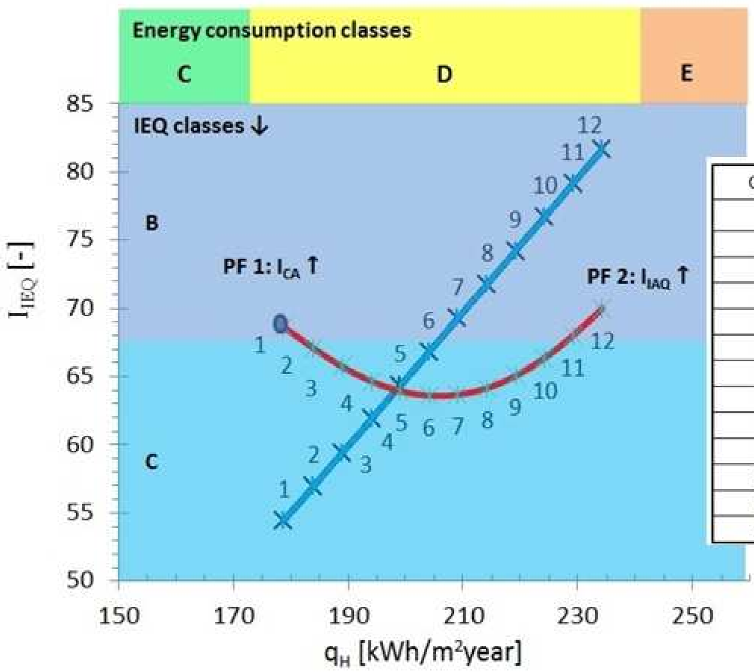
The results presented in this article are especially useful for the designing phase of a dwelling, as they show that the quantity of fresh air brought in for ventilation ($n_a$) has an important effect on the indoor air quality and therefore influences the indoor environment quality as shown by the $I_{IEQ}$ index variation in the Fig. 7.

The variation of IAQ with $n_a$ is proportionally and an increase of ventilation air flow by 330 % from 10 to 43 m³/pers/h is traduced in an increase of IAQ of 550 %, from 19 to 122 (-). At this increase in the ventilation rate, the energy consumption rises with 31% but in the analyzed case this doesn't modify the overall energy efficiency class of the dwelling.

This shows that, within limits of this study, the ventilation rate has an important effect on the overall environment quality, $I_{IEQ}$, than on the CE which means a wide range for $n_a$ set point.

For the situation in which the fan is placed outside of the apartment, or any other means that reduce its noise with a minimum of 15 dB are provided (see Table 3, $L_{PI}$ results for case (B)), any increase of the IAQ translates into an attenuated increase of the $I_{IEQ}$. E. g. an increase of 550% of IAQ corresponds to an increase of 50% of $I_{IEQ}$. In the situation when the fan is placed in the house and the noise is perceived by the residents, the increase of ventilation rate influences the IAQ but also the acoustic comfort (CA). For this situation, while the IAQ increases, CA decrease following a curve described by a polynomial function. The two combined effects produce a decrease of $I_{IEQ}$ from 69 to 64 (-) when fresh airflow rises from 10 to 22 m³/pers/h, then the $I_{IEQ}$ remains almost constant for airflow between 22 and 31 m³/pers/h and for airflow superior than 31 m³/pers/h, the $I_{IEQ}$ begin to increase.

It's worth mentioning that the correlation between CA and the airflow is specific to the ventilation unit, therefore different fans will have other influences over the CA, but the results presented show that special attention should be accorded if the ventilation unit is inside occupied area, to prevent noise generation and transmission. As the ventilation rate affects simultaneously the $I_{IEQ}$ and CE, it should be considered as a control parameter for ventilation system. If the noise generation characteristics of the ventilation unit is known (previously determined by relevant tests in an acoustic laboratory), the ventilation rate set point can be selected as to obtain an optimum balance between indoor environment quality and the energy consumption of occupied spaces. Because the same values for the indoor environment quality can be obtained with different energy consumptions, for this particular study, the class C for IEQ can be obtained with energy consumptions between 179 and 184 kWh/m²/year, the dweller must pay attention to the ventilation rate adjustment in order to choose the best option from energy consumption viewpoint.




| Case | $q_a$ | $n_a$ |
|---|---|---|
| | m³/pers/h | $h^{-1}$ |
| 1 | 10 | 0.214 |
| 2 | 13 | 0.278 |
| 3 | 16 | 0.342 |
| 4 | 19 | 0.406 |
| 5 | 22 | 0.471 |
| 6 | 25 | 0.535 |
| 7 | 28 | 0.599 |
| 8 | 31 | 0.663 |
| 9 | 34 | 0.727 |
| 10 | 37 | 0.856 |
| 11 | 40 | 0.856 |
| 12 | 43 | 0.920 |

**Fig. 7**. The covariance of $I_{IEQ}$ and CE depending on ventilation rate.
—— a) the fan placed outside of the apartment
—— b) the fan is placed within apartment

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