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The possibilities of energy consumption reduction and a maintenance of indoor air quality in doctor's offices located in north-eastern Poland

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ABSTRACT

The main problem observed in doctor's offices is a good air quality, especially after thermal modernization. The present research involved 15 rooms belonging to 6 different medical practices located in north-eastern Poland. The observed minimum air change rate in a room equalled 0.55 ACH with the flow of ventilation air amounting to 25.20 m^3/h, which according to standards provides a ventilation air stream sufficient for a single person. It has been proved that the temperature and humidity were conformed to the standards, whereas the CO_2 concentration was close to the permissible upper limit or in some cases exceeded it.

In all rooms energy consumption has been simulated for three air change rates: the real one and two recommended values: 1.5 and 3 ACH. The calculation results showed that thermal modernization could bring 18–53% energy reduction for heating without changing air quality. However in order to improve air quality it is recommended to increase air change rate in some offices so the achieved effect would be lower: only 19–28% energy consumption reduction in some tested offices or even the energy consumption would be 9–34% higher that actual in the others.

The energy consumption could be reduced about 23–38% by using mechanical ventilation with recuperation.

1. Introduction

Indoor air quality of small doctor's offices is important for staff and patients health, although engrossed as the patients during the medical appointment are, they often fail to notice inconveniences of the surrounding environment. Because usually no one controls the quality of air inside the office, the conditions prevailing inside are arbitrarily dictated by the doctor occupying it.

The role of a good ventilation and air-conditioning system in health centres was investigated by Cheong and Phua [1]. They claimed that an effective ventilation system is crucial to protect doctors, nurses and other health-care workers from patients with infectious disease and paid attention to an isolation room, where clean air is required. The authors suggested that it was possible to achieve it by an extraction airflow rate higher than the actual one.

In Poland, the Directive of the Minister of Health [2] concerning sanitary and technical requirements which have to be met by rooms and devices in medical care centres specifies the conditions that should be fulfilled by doctor's offices, both in individual medical practices and in large health-care clinics. In particular, this regulation [2] makes clear that every room in a health care institution, like hospitals or doctors' offices, should be fitted with a ventilation system that should ensure at least 1.5 air changes per hour (ACH). The minimum sanitary requirements are understood differently in different countries and by various standards, although the climate in Poland, Germany and the UK seems to be similar. For instance, in Germany, according to DIN 1946-2 [3] this minimum amount equals 50 m^3/h per person (14 l/s per person). On the other hand, WHO [4] generally recommends the amount of 36 m^3/h per person (10 l/s per person), and ASHRAE [5] – 35 m^3/h per person (9.7 l/s per person). The Polish standard PN-83/B-03430 [6], which is still in effect, determines the minimum value at 20 m^3/h per person (5.5 l/s per person), but at the same time the PN-EN 13779 [7] standard suggest the values between 22 and 54 m^3/h per person (6–15 l/s per person). Again, Swedish regulations admit the value as low as 9 m^3/h per person, and English opt for 25 m^3/h per person (7 l/s per person) [8].

American Society of Heating, Refrigerating and Air-Conditioning Engineers' Instructions included in [9] recommend the natural or mechanical ventilation for buildings like "primary outpatient

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Nomenclature

a_H	dimensionless numerical parameter depending on the time
$b_{tr,l}$	adjustment factor for the adjacent unconditioned space with internal heat source
Δp	stack effect [Pa]
$\Delta \rho$	difference in outside and inside air density [kg/m^3]
Φ_i	total heat losses [W]
$\Phi_{sol,mn,u,l}$	time-average heat flow rate l from solar heat source k [W]
$\Phi_{sol,mn,k}$	time-average heat flow rate from solar heat source k [W]
$\Phi_{V,i}$	heat losses for ventilation [W]
g	gravity acceleration [m/s^2]
h	stack duct height [m]
$H_{ve,adj}$	overall heat transfer coefficient by ventilation [W/K]
n	air change rate [l/h]
$\eta_{H,gn}$	dimensionless gain utilization factor
$Q_{H,gn}$	total heat gains for heating mode [kWh/month or GJ/month]
$Q_{H,ht}$	total heat loss during heating mode [kWh/month or GJ/month]
Q_{int}	internal heat gains [kWh/month or GJ/month]
Q_{sol}	gains from the sun [kWh/month or GJ/month]
$Q_{H,nd}$	energy need for heating [kWh/a]
Q_{ve}	The overall energy consumption for ventilation [kWh/month or GJ/month]
R	thermal resistance [m^2 K/W]
t	length of the period [Ms]
τ	time constant of the building zone [h]
$\tau_{H,0}$	reference time constants [h]
U	heat transfer coefficient [W/m^2 K]

Acronyms

ACH	air changes per hour
CFD	computational fluid dynamics
ECG	electrocardiography
IAQ	indoor air quality
HVAC	heating, ventilation and air condition
PM	particulate matter
SPBT	simple payback time
ECG	electrocardiography

facilities", but they do not give values of minimum ACH or air quality. The principles [10] developed by U.S. Department of Defence for Medical Military Facilities are more or less the same like for the outpatient facilities.

The impact of CO_2 concentration inside public buildings on human health has been investigated and showed in [11]. The maximum level of CO_2 concentration in the air that do not affect human health was established at 800 ppm. It has to be remarked that this value is lower than described in the ASHRAE [5], WHO [4], PN-EN 13779 [7] standards. However, the present research will rely on the Polish standards only.

The recommended air parameters were shown in Table 1 [7,12]. Too high values of carbon dioxide concentration in the air could increase partial blood pressure (hypercapnia), which results in breathing difficulties and increased frequency of breaths or even cause headaches, dizziness, hearing disorders, perception disorders and tachycardia. When the level of CO_2 concentration exceeds 10%, people could have hallucinations and suffer from various types of consciousness disorders. The CO_2 concentration higher than 20% results in death within several minutes [13].

Economic considerations force the designers and users of buildings to optimize objects' shape and parameters and one of ways to do it is a thermal modernization. The study shows the theoretical savings coming from the reduction in heat loss through transmission and ventilation and ecological effects of modernization for a building is located in Bialystok, north-eastern Poland. The calculated values were compared with the achieved ones. The actual savings were estimated based on data from measurements carried out in several heating seasons before and after modernization. All the theoretically calculated values were higher than the achieved ones [14].

The energy consumption in health centres is important too because it depends on a ventilation stream and influences operating costs. Another very important thing worth mentioning is that patients should be provided with maximum thermal comfort, so it is possible to apply modern technologies and management strategies that can keep the same level of comfort with significant savings in consumption [15–19] but it is not possible to decrease indoor temperature or an air change rate. Great part of energy goes for heating – about 40% [20–23].

The present study, for that matter, was inspired by information received from patients and doctors working in modernized buildings, who complain about the IAQ but on the other hand they are glad because of low energy costs. This study investigates the air quality in doctor's offices and energy used for space heating. Nowadays the thermal modernization of buildings is very popular and the potential savings are often relatively high, but in most cases investors do not care about a minimum flow of ventilation air and low CO_2 concentration in rooms. The aim of this work is to show the potential energy consumption changes in buildings, where the thermal modernization is planned or has been just carried out, without deterioration of the inside climate parameters, like temperature and CO_2 concentration. In offices where the air flow before modernization was too low the increasing of air change rates was recommended and the modernization effect is shown.

2. Description of the investigated offices

In Poland in most doctor's offices natural ventilation works, also in all of the examined doctor's offices natural ventilation was present; most often it was gravity ventilation. Several doctor's offices located in different facilities and used by various number of personnel have been subject to analysis.

Office no. 1: single-person practice (for just one doctor, a dentists) (1), consisting of a sanitary room, corridor, reception desk, and the office proper, all of which are conjoined (there are no doors, the rooms are separated by partition walls). The whole office occupies the ground floor of a tenement house. The natural ventilation system is masked by a perforated ceiling, and the window frames, which were installed in 1996, are airtight.

Office no. 2: small family practitioners clinic consisting of 2 doctor's rooms (2a, 2b), a nurses' room (2c), and an ECG room (2d). The facility is situated on the ground floor of a ten-storey building built in the 1970s. Natural ventilation is present only in the doctor's offices only. The remaining rooms are ventilated by means of airing through open windows and doors. Window frames were installed in 2006 and are airtight.

Office no. 3: independent medical practice in a huge state-owned clinic, comprising a doctor's room (3a), and another doctor's room (3b) connected with a reception desk (3c). The doors between these rooms are permanently open. The facility is situated on the first floor of a building which underwent a renovation in 2006. Natural ventilation is present in all the rooms, and the window frames are airtight.