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MICROCLIMATE IN A FLAT WITH ADDITIONAL AIR INTAKES

Abstract

The relation between the gravitational ventilation and distribution of intake openings are presented here. The possibility of installing additional openings to provide sufficient quantity of indispensable air is presented here. These are essential to gas combustion in heating devices. Two different ways of localization of such openings are discussed. The first one is based on making openings supplying the air to external barriers. This results in the limitation of backward duct in ventilating ducts. Simultaneously, the decrease of comfort zone in flats is noticeable. Placing the opening directly in the external barrier causes rapid cooling of flats. This results in feeling of draught. The second solution dealt with placing identical opening in an internal barrier, bordering with the staircase. The effect of such solution was similar to the first one. It was also based on limiting the occurrence of backward ducts inside ventilating ducts. However, in the latter case, we did not notice the deterioration of microclimatic conditions in examined flats.

Keywords: Building's microclimate conditions, ventilating air, ventilating ducts, carbon dioxide concentration

1. Introduction

In Poland in the past 20 years or so, there has been a growth of interest in energy saving construction. They were mainly: constructors, developers and investors planning modernization of existing buildings. They used energy saving technologies essential to heating of the buildings. They were focused on hermetic woodwork and warming of external walls. The hermetic woodwork was accomplished through the exchange of door's and window's woodwork. The warming of external walls was done with foamed polystyrene. The measurable benefits of these solutions were: less costs in heating of the building and in renovation of the facade Due to such solutions, they qualified for so called "thermo modernizational bonus" from nation's budget. Unfortunately, they did not pay enough attention to the air exchange. As they considered it to be too expensive, not profitable enough and of little importance. In these buildings constructors planned the necessary minimum (following only the national norm guidelines). In case of thermo modernization they totally ignored this problems. It resulted in good building lagging without the inflow of the right quantity of ventilating air. But that (i.e. the right quantity of ventilating air) is essential to sanitary conditions, conditions of living and to gas combustion in gas-fired boilers. Sufficient quantity of air intake flow is necessary for combustion process. It is supplied through air intakes and untightness in external lining. Lack of that flow causes the phenomenon of backward duct in ventilating ducts. Its occurrence causes deterioration of microclimatic conditions in the flats.

2. Requirements of national norms

All requirements pertinent to gravitational ventilation are to be found in three legal acts. In the decree (Dz.U. Nr 75, poz. 690) the outline of the general requirements which buildings, their technical conditions, their location, and ventilation, is presented. Detailed requirements pertinent to individual solutions regulates norm (PN-83/B-03430), together with its supplement (PN-83/B-03430:Az3:2000). This norm says, that windows with infiltration coefficient smaller than 0.3 $m^3/(mhdaPa^{2/3})$ mounted in habitable buildings of public usefulness should be equipped in air intakes. They should provide the right quantity of an air necessary for ventilation. In case of the lack of air intakes, mechanical supply ventilation has to be installed. In other cases, the coefficient of infiltration of woodwork has to be within 0.5 – 1.0 m^3 $(mhdaPa^{2/3})$. However the definition of the range of coefficient of air penetration through the window and the differential pressure, for which the values are given rises some concern. According to valid regulations the value $\Delta p = 10$ Pa, is set regardless of the shape or size of the building. The specifications of requirements in selected countries are presented in Table 1.

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Table 1. The comparison of window tightness (Miśniakiewicz, 2002; Nowakowski, 2002) – part one

No.	The country and the name of the norm	The description of the building	Required coefficient of air penetration	Single quantity of air for Δp = 1 Pa
1.	Belgium STS 52.0	H = 0 – 18 m H > 18 m	3.0 m^3/mh for 100 Pa 2.0 m^3/mh for 100 Pa	0.040 dm^3/ms 0.027 dm^3/ms
2.	Denmark DS. – 417	For all buildings	0.50 dm^3/ms for 30 Pa	0.053 dm^3/ms
3.	Finland SFS 3304	Class 1 (max) Class 2 (min) Class 2 (max) Class 3 (min)	0.50 m^3/m^2h for 50 Pa 0.5 m^3/mh for 50 Pa 2.50 m^3/mh for 50 Pa < 7.0 m^3/mh for 50 Pa	0.011 dm^3/m^2s 0.011 dm^3/m^2s 0.053 dm^3/m^2s 0.093 dm^3/m^2s
4.	France NF P20 302	Class A1 Class A2 Class A3 (tight buildings)	20 – 60 m^3/m^2h for 100 Pa 7 – 20 m^3/m^2h for 100 Pa < 7 m^3/m^2h for 100 Pa	0.266 – 0.789 dm^3/m^2s 0.093 – 0.266 dm^3/m^2s < 0.093 dm^3/m^2s
5.	Holland NEN – 3661	The „normal“ terrain: H ≤ 15 m H = 15 – 40 m H = 40 – 100 Terrain close to the sea: H ≤ 15 m H = 15 – 40 m H = 40 – 100 m	 2.50 dm^3/ms for 75 Pa 2.50 dm^3/ms for 150 Pa 2.50 dm^3/ms for 300 Pa 2.50 dm^3/ms for 300 Pa 2.50 dm^3/ms for 300 Pa 2,50 dm^3/ms for 450 Pa	 0.145 dm^3/ms 0.092 dm^3/ms 0.058 dm^3/ms 0.058 dm^3/ms 0.058 dm^3/ms 0.044 dm^3/ms
6.	Canada 3–A440–M84	Small buildings A1 Medium buildings A2 Tall buildings A3	2.79 m^3/mh for 75 Pa 1.65 m^3/mh for 75 Pa 0.25 m^3/mh for 75 Pa	0.045 dm^3/ms 0.027 dm^3/ms 0.004 dm^3/ms
7.	Germany DIN-18055	A – H = 0 – 8 m B – D – H > 8 m	6.00 m^3/mh for 50 Pa 3.00 m^3/mh for 50 Pa	0.126 dm^3/ms 0.063 dm^3/ms
8.	New Zeland NZS N42211:87	Tight buildings Buildings of medium tightness Buildings of low tightness	0.60 – 2.00 dm^3/ms for 150 Pa 2.00 – 8.00 dm^3/ms for 150 Pa 8.00 – 17.00 dm^3/ms for 150 Pa	0.022 – 0.073 dm^3/ms 0.073 – 0.147 dm^3/ms 0.147 – 0.623 dm^3/ms
9.	Poland PN-EN ISO 6946:1998	All buildings	0.5 – 1.0 m^3/mh for 10 Pa	0.03 – 0,06 dm^3/ms
10.	Switzerland SIA 331	H ≤ 8 m H = 8 – 20 m H = 20 – 100 m	5.65 m^3/mh for 150 Pa 8.95 m^3/mh for 300 Pa 14.25 m^3/mh for 600 Pa	0.056 dm^3/ms
11.	Sweden	Tight buildings Untight buildings Buildings of H > 8 m	1.7 m^3/m^2h for 50 Pa 5.6 m^3/m^2h for 300 Pa 7.9 m^3/m^2h for 500 Pa	0.036 dm^3/ms
12.	Great Britain BS 6375	Open area, External pressure. < 1600 Pa As before, but^3 1600 Pa Building site Internal pressure < 1600 Pa As before, but^3 1600 Pa High tightness Open area As before, but building site	 6.34 m^3/mh for 50 Pa 4.84 m^3/mh for 50 Pa 1.00 m^3/mh for 200 Pa 1.00 m^3/mh for 300 Pa 1.00 m^3/mh for 600 Pa 6.60 m^3/mh for 600 Pa	 0.133 dm^3/ms 0.102 dm^3/ms 0.008 dm^3/ms 0.006 dm^3/ms 0.004 dm^3/ms 0.02 dm^3/ms
13.	USA/ASHRA E 90 – 80	All buildings	0.77 dm^3/ms for 75 Pa	0.045 dm^3/ms

Apart from the difference of pressure, in the majority of countries listed above other factors such as: the height of the building, its tightness or location in the area are also considered. One may notice (Table 1) that Polish requirements are one of the strictest.

3. Carbon dioxide as the indicator of an air quality

The relation between the quantity of ventilating air and the concentration of carbon dioxide is the recognized criterion of an air quality evaluation. The frequent occurrence of carbon dioxide in typical conditions is not dangerous. This gas causees the feeling of air stuffiness. The growth in carbon dioxide concentration comes from external and internal sources. The level of carbon dioxide concentration in the atmosphere steadily grows (as the consequence of industrialization). At present, its value oscillates between 400 – 600 ppm. Living organisms and gas devices are the source of carbon dioxide inside the rooms. Its concentration depends on organism's activities. For individuals (people) it varies. It depends (among others) on their diet, the mass of their body and their physical condition. Naturally, the concentration of carbon's dioxide inside the room depends on other factors as well. These are (among others): the number of people inside the room, not sufficient air exchange (i.e. the fall of the content of oxygen in the air) and intensification of combustion processes in the room (e.g.: smoking tobacco, or preparing the meals). That is why carbon dioxide was chosen as an indicator of the microclimate quality inside considered flats.

According to Hodgson (Liddament, 1996) the upper limit of carbon dioxide concentration which is not harmful to the man is in the range of about 8500 ppm. The present standards for the internal air, assume the admissible level of carbon dioxide concentration on the level of 1000 ppm. This coefficient was proposed already in the nineteenth century by Max von Pettenkofer (Nantka, 2004).

Table 2. Emission of carbon dioxide for different levels of activity (Fanger, 1980)

A type of activity	Emission of carbon dioxide [dm^3/h]
Dream (motionless recumbent position)	10 – 12
Sitting position (without doing any work)	12 – 15
Sitting posture – easy office works	18 – 25
Doing work of average difficulty	32 – 44
Doing hard work	> 55

Table 3. The influence of carbon dioxide on human organisms (Sowa, 1995)

No.	Concentration of carbon dioxide in the air [ppm]	The symptoms
1.	300 – 450	Dry external air
2.	1000	Basis for the qualification of most standards concerning the quantity of ventilating air for a single person
3.	1550 – 500	The growing feeling of stuffiness
4.	5000	Limitations concerning working posts
5.	7000 – 10000	The growth of breathing capacity
6.	15000	The appearance of metabolical stress
7.	20000	The increased frequency of breathing and headaches
8.	40000 – 52000	Carbon dioxide concentration in the air breathing out from the lungs
10.	60000 – 80000	The possibility of partial paralysis
11.	> 80000	Losing of consciousness in a few minutes

4. Object of researches

The object of researches were typical parameters of the internal microclimate: the temperature, the humidity of the air, the number of exchanges and carbon dioxide concentration. The research was conducted in habitable buildings. They were three and four – storied, semi – detached buildings, built in years 2000 – 2003. These buildings were equipped with the channel system of natural ventilation. In flats there were installed gas cookers and two – functional stoves with open chamber of combustion, powered by the earth gas. Buildings had external walls. The walls were warmed with foamed polystyrene covered with a thin – layer mineral plaster. The windows' woodwork with infiltration coefficients smaller than 0.3 $m^3/mhdaPa^{2/3}$ (according to producer's data) was equipped with an air intakes.

5. Results of investigation

During the first year, all the occupants felt inconveniences of proposed solutions. In case of gas cooker, the system of gravitational ventilation worked very well. However in case of gas stove, in the majority of these flats certain inconveniences occurred. They mostly relied on the appearance of backward ducts in air grates. Also, condensing water steam on window panels were seen. Moreover, the occupants complained of headaches and the lack of fresh air in the rooms. The above mentioned phenomena were intensified in the winter. After the first year, the focus of mould was noticed in the flats. They were mostly in the kitchens and bathrooms. In some cases they were also noticeable in habitable rooms. While performing the measurements, large discrepancies in data were noticed in considered flats. There were problems with gravitational ventilation, especially in flats situated in the last two storeys. The backward ducts in air grates was noticed. The speed of ventilation near the outlet from the air grate fell down to 1.15 m/s. While the air temperatures outside were about – 10°C, the temperatures near the grate outlet were approximately +16°C in rooms with air grates and air ventilation. And the interior temperatures near heating (while turned on) equaled about +17 – +19°C (Fig. 1). During the usage of gas range and gas heating devices, the very quick growth of carbon dioxide concentration was observed (Fig. 1 and 2). These values were several times higher than the accepted standards [about 2200 – 3500 ppm (Sowa, 1995)]. None of gas devices was turned on in periods when the level of carbon dioxide concentration fell to

500 – 1150 ppm. The very interesting phenomenon occurred in all investigated flats. It was the alternating character of the stream of ventilating air in air grates. That implied, that ventilation and removing the air took place through kitchen or bathroom air gates.

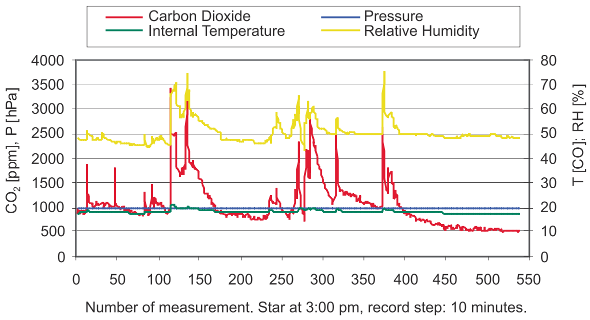

Fig. 1. The diagram of the parameters of the microclimate in selected flat with the air inflow through the ventilating duct

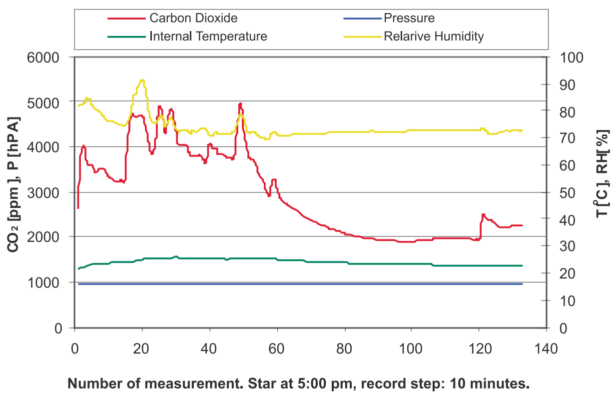

Fig. 2. The hourly diagram of microclimate's parameters in selected flat, in which users stuck some air grates

However, the air inflow occurred mostly through ventilating duct in the bathroom. That was the result of installing there two – functional stoves. They provided enough quantity of the air, necessary for gas combustion. This inflow was so large that it made impossible using the bathroom and the occupants stuck the inlets of ventilating ducts with foil. An hourly diagram of parameters of the internal microclimate for such flat is presented in Figure 2. These conditions led to a large growth of carbon dioxide concentration [up to the level of approx. 5000 ppm]. Even during the night these values didn't drop below the 2000 ppm. The relative air humidity grew up quickly. It ranged from 70% to 90%.

To solve this problem in the investigated flats and to – simultaneously – improve the microclimate conditions, making additional openings was proposed. Their diameter was that of f 120 mm was proposed for the improvement of the microclimate in considered flats. The openings had to be made in the external walls to supply the external air. Also an aspiromatic type devices on the outlets of ventilating ducts were installed. After the work was completed, the correct direction of the air flow in all ventilating ducts occurred again. Unfortunately, when the temperature fell below 0°C, the occupants noticed both: cooling of the flats and too large speed of air inflow (the feeling of draught). Considering the inhabitants safety and comfort of their living condition, the previous state was restored. The additional openings in internal walls facing the staircase and situated in the direct proximity of gas stoves were made. This resulted in better ventilation. In that way, the air was initially warmed instead of flowing directly from outside. The diagram of the parameters of microclimate in one of the selected flats where the above solutions were tested is shown in Figure 3. The analysis of this diagram shows, that there was the constant internal temperature of +20 – +22°C. The relative humidity did not exceed 65% which complied with corresponding standards. Simultaneously, the carbon dioxide concentration comprised on the level 700 – 1500 ppm. At some points it goes beyond 2500 ppm. These are however temporary values, which do not influence the health or the mood of occupants.

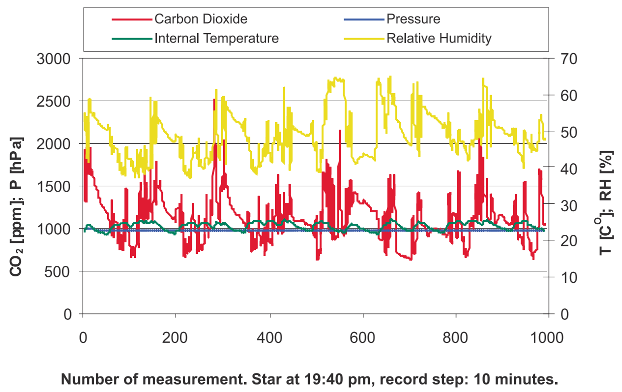

Fig. 3. Weekly diagram of microclimate's parameters in selected flat, after installing additional inflow ducts between the flat and the staircase

6. Analysis of the results

Observed irregularities are the result of the limited inflow of the external air to flats. The air inflow is indispensable for appropriate functioning of the ventilation system. And, also for the proper gas combustion in heating devices and stoves. This limited inflow is the consequence of unsuitable balance of the air flows. Additionally, gas heating devices disturb the proper functioning of ventilation system in the building. The sudden growth of carbon dioxide concentration is caused by an installment of the two – functional stoves with the open combustion chamber. After installment of this device, the sudden growth in carbon dioxide concentration appears, and turning back of duct in ventilating duct is observed. Window untightness influences air exchange up to the certain degree, too. The increase in the air inflow this way is inadequate. The occupants, especially the ones reluctant to their usage, should use it wisely. When it comes to untightness of the windows, one should accept the lack of control over the inflowing air stream. The quantity of inflowing air does not depend on the internal air parameters. Additionally, quick cooling of the rooms occurs in winter. It was was particularly burdensome after installing additional opening for air supply, directly from outside. The usage of openings through staircase for gas combustion in two – functional stoves, decidedly improved the parameters of internal microclimate. Yet, the microbiological analysis of the air is still required.

7. Conclusions

Based on the results of this research, the following conclusions may be drawn:

1. The quantity of ventilating air depends on external climate; and in particular: the air temperature, direction and speed of the wind.
2. Disorders of microclimatic conditions in flats with tight casing and installed intakes appear on upper storeys. They result in backward ducts and air exchange.
3. Working gas stoves with open combustion chamber make the proper work of ventilation's system difficult.
4. The appearance of heating device should depend on additional separate duct. It should either supply the air to this device or closed combustion chamber should be used.
5. The size and the placement of intake openings is important. Before making any decisions, the following factors should be considered:
   – placement of the flat,
   – constructional possibilities,
   – the demand for the air (balance).

Preliminary warming of ventilating air narrows down the possibility of disturbance of internal microclimate conditions.

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Warunki mikroklimatyczne w mieszkaniach z dodatkowymi nawiewnikami powietrza wentylacyjnego

1. Wstęp

W ostatnim okresie projektanci i deweloperzy zaczęli powszechnie stosować technologie dające duże oszczędności energii potrzebnej do ogrzania budynków, m.in. szczelną stolarkę oraz ocieplenie ścian zewnętrznych styropianem. Uzyskano w ten sposób dobrze izolowane cieplnie budynki bez zapewnienia napływu niezbędnej ilości powietrza wentylacyjnego, potrzebnego nie tylko ze względów higienicznych i bytowych, ale również do spalania gazu w piecach. Niewystarczająca ilość powietrza niezbędna dla procesów spalania, które dostarczane jest poprzez nawiewniki powietrza, oraz nieszczelności w obudowie zewnętrznej, uzupełniona zostaje w takim przypadku poprzez zjawisko wstecznego ciągu w kanałach wentylacyjnych.

2. Wymagania norm krajowych

W Polsce wymagania dotyczące wentylacji grawitacyjnej zawarte są w trzech krajowych aktach prawnych. W rozporządzeniu w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie przedstawiono ogólne wymagania dotyczące wentylacji. Natomiast szczegółowe wymagania dotyczące poszczególnych rozwiązań systemów wentylacji reguluje obowiązująca już od ponad dwudziestu lat norma PN-83/B-03430 oraz jej uzupełnienie PN-83/B-03430:Az3:2000. Powszechne wątpliwości budzi tutaj sposób określenia zakresu współczynnika przenikania powietrza przez okna oraz różnicy ciśnień, dla której podane są jego wartości. Według obowiązujących przepisów przyjmowana jest wartość $\Delta p = 10$ Pa, bez względu na warunki obliczeniowe oraz kształt czy wielkość budynku. Porównując wymagania polskie z wymogami innych krajów należy stwierdzić, że są jednymi z ostrzej postawionych przy jednoczesnym braku powiązania ich z rzeczywiście istniejącymi różnicami ciśnień.

3. Dwutlenek węgla wskaźnikiem jakości powietrza

Związek pomiędzy ilością powietrza wentylacyjnego a stężeniem dwutlenku węgla wewnątrz pomieszczeń jest od lat uznawanym i powszechnie stosowanym kryterium oceny jakości powietrza. Obecnie jego wartość waha się w granicach 400 – 600 ppm. Obecne standardy dla powietrza wewnętrznego zakładają dopuszczalny poziom stężenia CO_2 na poziomie 1000 ppm.

4. Przedmiot badań

Przedmiotem badań były typowe parametry mikroklimatu wewnętrznego, tj. temperatura i wilgotność powietrza, krotność wymian oraz stężenie dwutlenku węgla. Badania prowadzono w budynkach mieszkalnych, 3- i 4-kondygnacyjnych, wielorodzinnych wykonanych w technologii tradycyjnej, wybudowanych w latach 2000 – 2003. Budynki wyposażone były w kanałowy system wentylacji naturalnej. W mieszkaniach zainstalowane były kuchenki gazowe oraz piece dwufunkcyjne z otwartą komorą spalania, zasilane gazem ziemnym z sieci. Budynki posiadały ściany zewnętrzne ocieplone styropianem pokrytym cienkowarstwowym tynkiem mineralnym. Stolarkę okienną o współczynnikach infiltracji mniejszych niż 0,3 m^3/mhdaPa$^{2/3}$ (wg danych producenta) wyposażono w nawiewniki powietrza.

5. Wyniki pomiarów

W rozpatrywanych mieszkaniach w trakcie pomiarów zanotowano bardzo duże zaburzenia w działaniu wentylacji grawitacyjnej zwłaszcza w mieszkaniach zlokalizowanych na dwóch ostatnich kondygnacjach. W kratkach wentylacyjnych zanotowano wsteczne ciągi, a prędkość nawiewu przy wylocie z kratki wentylacyjnej wynosiła nawet 1,15 m/s. Sytuacja była o tyle niekorzystna, iż przy temperaturze zewnętrznej osiągającej –10°C temperatura przy wylocie kratki wynosiła około +16°C. W trakcie korzystania z kuchni gazowych oraz gazowych urządzeń grzewczych odnotowano bardzo szybki wzrost stężenia CO_2 do ok. 2200 – 3500 ppm.

Charakterystycznym zjawiskiem niemal we wszystkich badanych lokalach był przemienny charakter przepływu strumienia powietrza wentylacyjnego w kratkach, tzn. nawiew i usuwanie powietrza odbywało się naprzemiennie kratką w kuchni i łazience. Napływ ten był tak duży, że uniemożliwiał swobodne korzystanie z łazienki i użytkownicy mieszkań zaklejali wloty kanałów wentylacyjnych folią. Działania te doprowadziły do bardzo dużego wzrostu stężenia CO_2 do poziomu ok. 5000 ppm, który nawet w okresie nocnym nie spadał poniżej wartości 2000 ppm. Podobnie szybko wzrosła wilgotność względna, która wahała się pomiędzy 70% a 90%.

Dla poprawy mikroklimatu w rozpatrywanych mieszkaniach zaproponowano wykonanie dodatkowych otworów o średnicy ϕ120 mm w ścianach zewnętrznych, które doprowadzałyby dodatkowe ilości powietrza zewnętrznego, a na wylotach kanałów wentylacyjnych zainstalowano urządzenia typu aspiromatic. Po wykonaniu prac, we wszystkich kanałach wentylacyjnych odnotowano prawidłowy kierunek przepływu powietrza. Niestety, w dniach, kiedy temperatura zewnętrza spadała poniżej 0°C mieszkańcy zauważyli nadmierne wychładzanie mieszkań oraz zbyt duże prędkości przepływu powietrza (odczucie przeciągu). Mając na uwadze komfort użytkowników oraz ich bezpieczeństwo, przywrócono stan poprzedni. Jednocześnie wykonano dodatkowe otwory doprowadzające powietrze wentylacyjne w ścianach wewnętrznych wychodzących na klatkę schodową i zlokalizowanych w bezpośrednim sąsiedztwie pieców gazowych. W ten sposób do mieszkań, dla potrzeb spalania gazu w piecach, doprowadzono powietrze nie bezpośrednio z zewnątrz lecz wstępnie ogrzane. Z analizy danych wynika, iż bez trudu utrzymywano temperaturę wewnętrzną na poziomie +20 – +22°C. Poziom wilgotności względnej nie przekraczał 65% co odpowiada wymogom normowym. Jednocześnie stężenie CO_2 mieściło się w przedziale 700-1500 ppm. Jedynie w kilku punktach przekracza wartości 2500 ppm, jednak są to wartości chwilowe, niemające wpływu na zdrowie i samopoczucie mieszkańców.

6. Analiza wyników

Zaobserwowane nieprawidłowości są wynikiem ograniczonego napływu powietrza zewnętrznego do mieszkań niezbędnego do prawidłowego działania systemu wentylacji oraz do właściwego przebiegu procesu spalania gazu w urządzeniach grzewczych i kuchniach. Ograniczenie to jest konsekwencją nieodpowiedniego zbilansowania przepływów powietrza. Zbyt małe ilości powietrza doprowadzanego poprzez nawiewniki uzupełnione zostały powietrzem czerpanym poprzez jeden z kanałów wentylacyjnych.

7. Wnioski

1. Zaburzenia warunków mikroklimatycznych w mieszkaniach ze szczelną obudową i zamontowanymi nawiewnikami występują szczególnie na górnych kondygnacjach i przejawiają się występowaniem wstecznych ciągów oraz zmniejszeniem wymiany powietrza.
2. Zastosowanie pieców grzewczych z otwartą komorą spalania dodatkowo utrudnia działanie systemu wentylacji.
3. Pojawienie się urządzenia grzewczego w mieszkaniu powinno być uzależnione od wykonania osobnego kanału, odpowiednio obudowanego, doprowadzającego powietrze do urządzenia lub zastosowania zamkniętej komory spalania.
4. Wielkość otworów nawiewnych i ich rozmieszczenie ma decydujące znaczenie dla prawidłowego działania wentylacji grawitacyjnej oraz zapewnienia właściwych parametrów mikroklimatu wewnętrznego. Decyzja o wielkości oraz rozmieszczeniu otworów nawiewnych powinna być poprzedzona analizą:
   - warunków lokalizacyjnych mieszkania,
   - możliwości konstrukcyjnych,
   - zapotrzebowaniem powietrza (bilans).
5. Wstępne ogrzanie powietrza wentylacyjnego ogranicza zaburzenia warunków mikroklimatu wewnętrznego.