JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT
2008
14(1): 39–44

EVALUATION OF INDOOR ENVIRONMENT CONDITIONS IN OFFICES LOCATED IN BUILDINGS WITH LARGE GLAZED AREAS

Lina Šeduikytė[1], **Valdas Paukštys**[2]

Faculty of Civil Engineering and Architecture, Kaunas University of Technology, Studentų g. 48, LT-51367 Kaunas, Lithuania. E-mail: [1]lina.seduikyte@ktu.lt; [2]valdas.paukstys@ktu.lt

Received 14 Sept. 2007; accepted 19 Jan. 2008

Abstract. The field study was carried out during the heating season in two Lithuanian office buildings with large glazed areas. The methodology was prepared for evaluating indoor microclimate parameters while using objective and subjective evaluation. The results show that the average temperature in all tested offices was in the range of optimal zones, but in some offices the average temperature was not in compliance with the recommended temperature for offices. During the subjective evaluation, respondents working in these offices identified complains because of too high temperatures, stuffy air and irritation in eyes. The average relative humidity measured in all tested offices was not in compliance with the optimal requirements. Such SBS symptoms as irritation in eyes, cough and dry skin of the hands were identified as the most frequent symptoms in the second tested building. Main indoor microclimate problems arising in buildings with large glazed areas were related to overheating indoor spaces because of the direct sun and improper ventilation.

Keywords: indoor microclimate, glazed areas, SBS symptoms.

1. Introduction

In the last six years, there is a tendency in Lithuania to build new office buildings with glass facades. Traditions have been formed how to use the glass in buildings. However, the increase of glazed areas aroused a new problems, which should be solved with regard to energy savings and indoor microclimate requirements. Big glazed areas are always related to higher energy losses during the heating season and overheating of indoor spaces because of the direct sun (Carmody *et al.* 2004; Ramanauskas *et al.* 2005).

The explanation why higher heat losses are in the buildings with large glazed areas is that for the new buildings the normative value of the heat transmission coefficient (U-value) of large glazed areas is $U_N = 1{,}3$ W/(m^2·K). The U-value of walls of public buildings is $U_N = 0{,}25$ W/(m^2·K) (STR 2.05.01:2005), the value is fivefold lower. The heat losses through such wall are considerably lower compared with glazed areas.

There is overheating of the indoor spaces because glass is pervious to sun radiation waves of electromagnetic spectrum, which consists of visible spectrum waves, ultraviolet rays and short wave (high frequency) infrared rays. The sun emits light at all different wavelengths in electromagnetic spectrum. The part of sun radiation transmitted through the usual glass is presented in Fig. 1.

Sun radiation is heating buildings surfaces, therefore the indoor temperature is rising up. All warm bodies are eradiating thermal rays. Humans, at normal body temperature, radiate most strongly in the infrared at a wavelength of about 10 microns.

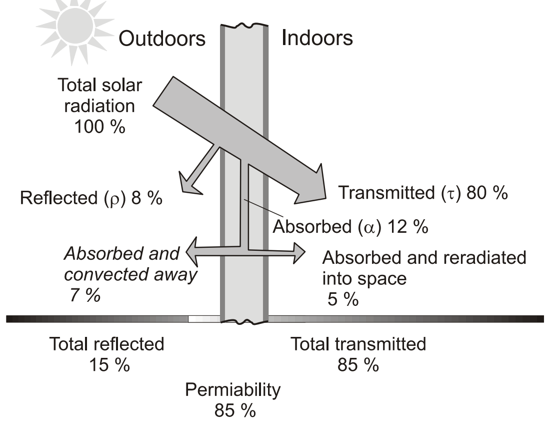

Fig. 1. The distribution of sun radiation when it gets on the transparent glass (Belgian Building… 2002)

However, they are in the long wave (low frequency) infrared rays spectrum and for present waves glass is not pervious. Transmitted sun radiation is accumulated indoors and there is a possibility for the appearance of "greenhouse" effect (Active facades …2002).

The indoor spaces are overheated by the sun not only during the summer time when it is hot outdoors and air conditioning system is on. It may happen during cold weather too, when the heating system is on and when because of the direct sun radiation some of the indoor spaces might be overheated too. This problem is very important in buildings with a centralised heating ventilating system where some parts of the buildings should be heated and some cooled at the same time. The worst thermal conditions are in these parts of the building which are under the influence of the direct sun.

The increase of glazed areas in facades enlarge the energy consumption for heating, ventilating and cooling the building as well as create indoor microclimate conditions, causing thermal discomfort for people, although the indoor parameters might meet the requirements. Different methods are used for the evaluation of the indoor microclimate parameters (thermal environment and indoor air quality). Human response to the thermal environment can be expressed in terms of the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices which predict the percentage of the occupants' feeling too warm or too cool. Normalisation of temperatures depends on different clothing habits, national traditions, the differences of subjective sensations and acclimatisation (ISO 7730:1994, CR 1752:1998, ASHRAE 55-1992).

Subjective evaluation of the indoor environment is used in many surveys. The World Health Organization (WHO) introduced the name of Sick Building Syndrome (SBS) symptoms, which characterise the health problems, related to the exposure to a particular building environment.

Indoor temperature is one of the main factors influencing work performance. It can have direct (when thermal comfort is not obtained) as well as indirect (when SBS symptoms are arising) influence (Fang *et al.* 2004; Dear 2004).

The research on people productivity, while performing usual office tasks, is one of the recent methods for evaluating indoor microclimate conditions. Niemmela *et al.* (2002) made a research in Finland on people's performance while working under different thermal conditions in the telecommunication centre. The results showed that people performance decreased by 2.2 % by every 1°C over 25 °C. Federspiel *et al.* (2002) made research in USA in a telecommunication centre. The results showed any difference while performing tasks in the comfort zone, but the performance of people decreased by 15 % when the temperature increased from 24.8 °C to 26 °C. The direct influence of thermal environment on mental performance was confirmed by the experiments by Wyon (1993, 1996, 2004). Šeduikytė and Bliūdžius (2005) presented the research in an experimental office. The results showed that people performance decreased and intensity of SBS symptoms increased while performing tasks in an experimental office where comfort parameters were not met.

There is a new philosophy: improvement of indoor microclimatic conditions is associated with a positive effect on work performance. The benefit of improved indoor microclimate conditions at working places are as follow: decrease of medical costs, increase of working days because of the decrease of days off, higher performance of people, lower costs for training new employees and keeping qualification.

After literature review it was determined that for the evaluation of indoor microclimate quality two methods can be used: measurements of indoor parameters and evaluation of people performance and well-being. There are doubts, whether measurements of indoor microclimate parameters are giving enough information about the indoor microclimatic conditions and their suitability to productive work of people.

The aim of the field study carried out in Lithuanian office buildings with large glazed areas was to test the prepared methodology in practice, to determine indoor microclimatic conditions by using objective and subjective evaluation of people, working in those spaces.

2. Methods

Two methods for evaluating the indoor microclimate were used in this survey: objective (measurements of indoor microclimate parameters) and subjective (questionnaire survey). It is important to determine indoor microclimatic quality and arising problems while using these two methods.

The prepared methodology for the evaluation of indoor microclimate parameters which was used in the field study is presented in Fig. 2.

Three stages of the research are given. Primary evaluation of the indoor microclimate is made at the first stage, where objective and subjective evaluation, determination of the air quality and "sick leave" days is made. During the objective evaluation the technical investigation of the building, measurements of the indoor microclimate parameters (temperature, relative humidity (RH) and air velocity) and primary evaluation of the pollution sources is made. A questionnaire was prepared for the subjective evaluation. The aim of the questionnaire survey is to evaluate the quality of indoor microclimate while using subjective evaluation presented by people working in the tested offices.

The second stage is identification of existing problems. At the third stage conclusions of the investigation are presented and suggestions of possible solutions for the dilution of the existing problems are given. After implementing changes in tested office building, it is suggested to make additional investigation, to evaluate the effectiveness of the implemented operations. While comparing the employees' productivity, evaluation of microclimate parameters, intensity of SBS symptoms and the number of absent days because of the illness, the estimation of the economical benefit gained because of the improved indoor microclimate conditions can be made.

Two new office buildings with large glazed areas, similar finishing building materials and ventilation systems were chosen for this survey. The field survey in office buildings was performed in the heating season. The measurements of indoor microclimate parameters (temperature, RH, air velocity) were made according to the requirements of LHN HN 42:2004 Indoor microclimate of dwellings and public houses. The duration of the measurement period was two weeks in each tested building. Measurements were made in sequence. All measurement equipment was set to record 3-minute average values during the measurement time. For the analyses data of the workday, when employees were at offices, was taken. For the evaluation of thermal parameters PMV

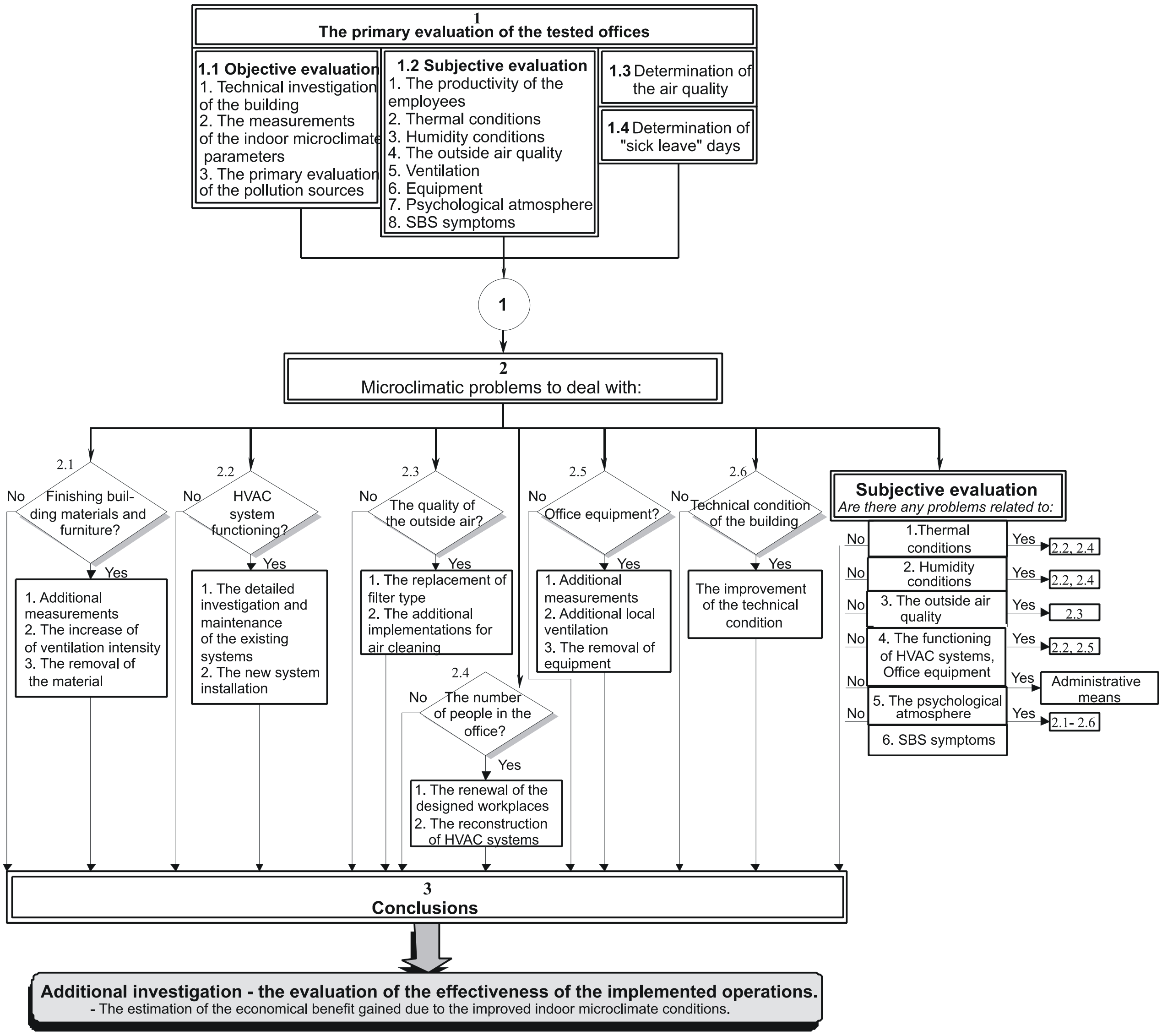

Fig. 2. The algorithm for evaluating and examining the microclimatic parameters

and PPD indexes were used. PMV index can be determined when the activity (metabolic rate) and the clothing are estimated and such environment parameters as air temperature mean radiant temperature, relative humidity and air velocity are measured. UC Berkeley Thermal Comfort program was used for calculating PMV and PPD indices.

Office buildings were coded, while giving a number to each. They were investigated and 7 representative single room offices in each tested building were chosen. All buildings were mechanically ventilated.

3. Results and discussion

Primary evaluation of the tested office buildings was made according to the first and second items of the prepared methodology. Technical investigation allowed identifying problems which would not be identified during the measurements of indoor parameters. Employees of the first tested office building were not able to control temperature in their office during the heating season – they could not lower it, as the owner of the building switched off the regulation system in order to save energy.

In an office of the second tested building the air supply devices were not "turned on", so the fresh air could not come. It should be mentioned that there was no possibility to open windows in neither of the tested office buildings.

Dark sooty spots were identified around the air supply devices in the offices of the second tested building (Fig. 3). During the investigation, technical personnel was instructed to check the quality of the used filters, the time of replacement and technical conditions of the pipes, where the air was delivered to the offices.

Technical investigation allowed identifying that in some offices of the second tested building the number of working places was bigger than planned in the project. When this number differs, employees could have complains because of stuffy air, too high temperatures or lack of space.

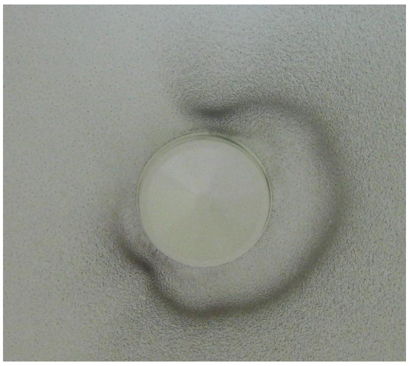

Fig. 3. Dark sooty spots around the air supply devices

It is always recommended to set up separate rooms for an additional office equipment such as copy machines and printers because of the contaminants which are spread during their work, as they are hazardous for people health. In the first tested building, the equipment was in the same office where people were working; in the second building – a separate room for the equipment. However, the door of this room was always opened so the contaminants were getting to the working zone.

Results of measurements - average temperature and RH values - in the tested offices are presented in Fig. 4 and 5. The results of temperature measurements show, that the average temperature in all tested offices was within the optimal zone. However, in the 1st office building the average temperature in 71 % of tested offices was not in compliance with the recommended temperature. This requirement was not met in 14 % of tested offices of the 2nd office building.

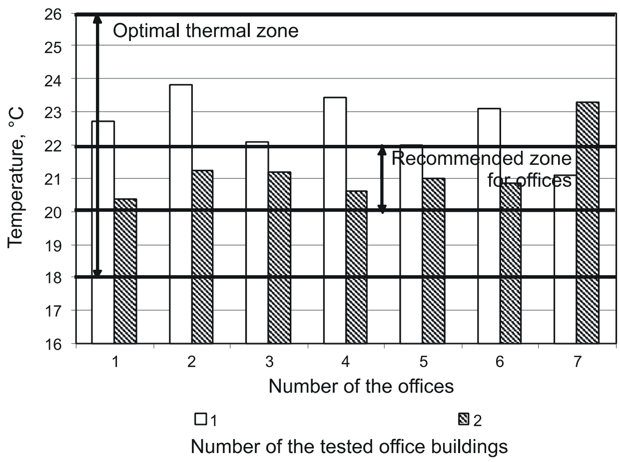

Fig. 4. The average temperature measured in tested offices

Relative humidity in non-residential buildings is often lower during the heating season. However, this parameter should be not lower than the minimum point, i.e. 30 %. The results show (Fig. 5), that the average relative humidity measured in all tested offices was not in compliance with the optimal requirements; it can be named as one of the critical parameters.

Predicted number of thermally dissatisfied people (PPD) in tested offices (calculated according to COMFORT program) is presented in Fig. 6.

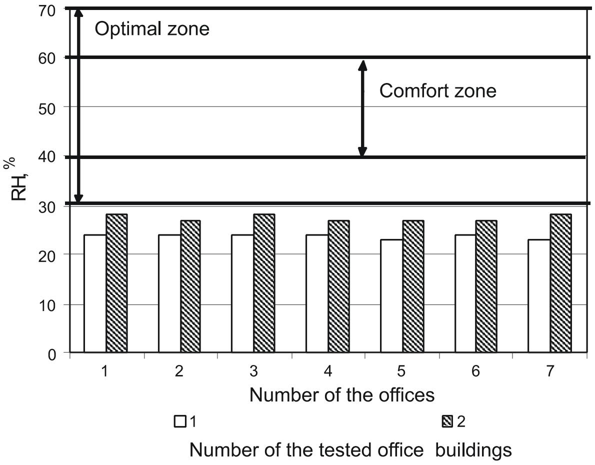

Fig. 5. The average relative humidity measured in tested offices

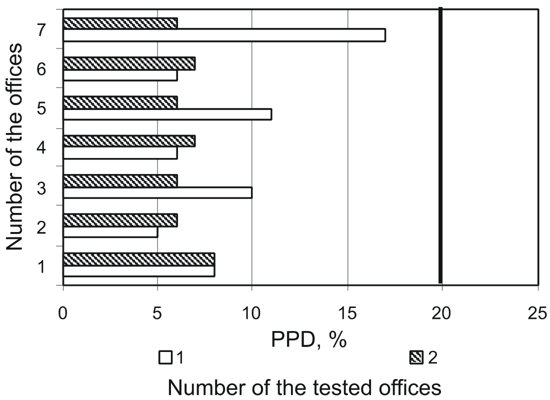

Fig. 6. Predicted percentage of the dissatisfied with thermal environment (PPD)

According to Lithuanian norms and standards, a predicted percentage of the dissatisfied with thermal environment should not exceed 20 %. It can be stated that the calculated PPD value for the tested offices did not exceed 20 %.

43 occupants working in the tested office buildings took part in the subjective evaluation – a questionnaire survey. SBS symptoms, evaluation of thermal conditions and other complains related to working indoor environment was identified by the questionnaires results. The intensity of symptoms was evaluated by the frequency of their appearance (no symptom, few times a week, every day).

The identified complaints which were related to working environment are in Fig. 7.

Discomfort caused by too high temperatures was identified by 86 % and a problem because of stuffy air was identified by 72 % of the respondents of the first tested building. Average temperature in this building was in compliance with the optimal requirements, but it did not meet the recommended temperature for offices. Only in one office the average temperature was not higher than 22 °C. There were no curtains or other sun protection in these tested offices, so occupants had no possibility to avoid direct sunshine in the first building with a glass facade. Direct sunshine and reflection in the monitors were disturbing occupants. About 50 % of employees working in this building identified that they were suffering from changing, low temperatures, dry air and unpleasant smells.

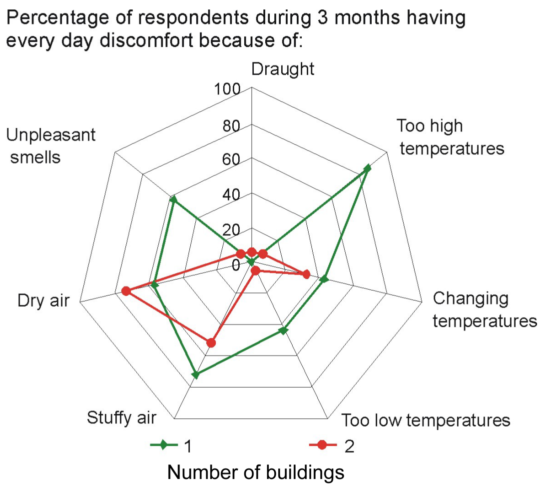

Fig. 7. The frequency of complains related to the working environment

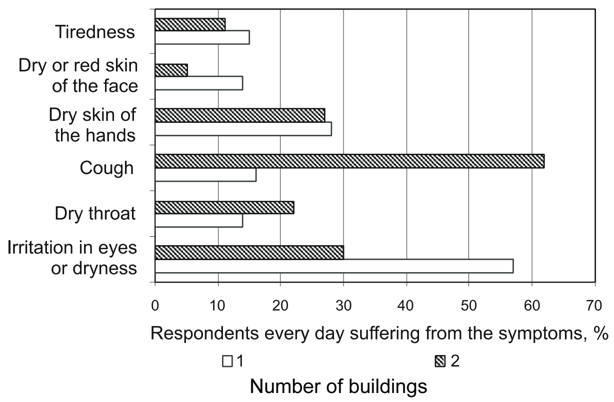

Fig. 8. SBS symptoms identified during the field survey

Dry air was the most frequently mentioned problem in the second tested building. Even 73 % of respondents identified this problem. Stuffy air was identified by 51 % of respondents every day causing discomfort in their working environment.

SBS symptoms identified during the field survey in tested office buildings with large glazed areas are presented in Fig. 8.

Respondents working in the first tested building identified irritation in eyes as the most frequent SBS symptom. 57 % of the respondents suffer these symptoms every day. One of the reasons why this symptom appeared in this building, was relative humidity, which was not in compliance with the optimal requirements, the second – indoor air temperature which sometimes reached 28,7–29,5 °C. A synthetic carpet used for finishing floor in all tested offices can be named as the third reason for appearance of the mentioned symptoms.

Such SBS symptoms as irritation in eyes, cough and dry skin of the hands were identified as the most frequent symptoms in the second tested building. Cough which was identified by 62 % respondents in the tested building could be caused by dry and polluted air. Dry air was identified by measuring RH and technical investigation of the building allowed to find dark sooty spots in the tested offices.

When summarising, it can be stated that SBS symptoms, complains with unpleasant odours, other complains related to the working indoor environment were identified by a questionnaire survey. This information would be not identified while measuring indoor microclimate parameters.

The analyses of the obtained results show that ventilation systems cannot warrant good microclimate conditions in the office buildings with large glazed areas. There are cases, when people have complains because of working environment even when optimal indoor microclimate conditions are obtained. This can be explained by the combination of several different parameters. Arising problems could be not solved only by an increase of volume of the supplied air.

4. Conclusions

1. The results of measurements show that the average temperature in all tested offices was within the optimal zone. 43 % of tested offices were not in compliance with the recommended temperature for offices. The predicted percentage of the dissatisfied people with thermal environment working in tested offices was not higher than 20 %. The most critical parameter in all tested offices was relative humidity, as in all tested offices it was lower than 30 %.

2. An inappropriate thermal control system and direct sun coming to the offices of the first tested building with large glazed areas during the heating season caused complains related to working environment: too high temperatures, stuffy and dry air. In the second tested building respondents had discomfort because of dry and stuffy air.

3. SBS symptoms identified during the survey may have been caused by a relative humidity, which was not in compliance with optimal requirements, indoor air temperature which in some offices did not pass the recommended temperature for offices. A synthetic carpet used for finishing floor in all tested offices of the first building can be named as the third reason for appearance of SBS symptoms in this building. Old or dirty filters, which were used in ventilation systems of the second tested building, could cause the appearance of SBS symptoms.

4. In order to minimise the negative effect of the direct sun, because of the overheating of indoor spaces, it is reasonable to use glass which reflects sun or to mount ventilated facades, where it is easier to ensure good indoor microclimate conditions.

5. The most accurate evaluation of indoor microclimate conditions is conducted through combined results of analyses of measurements of indoor microclimatic parameters along with a subjective evaluation of microclimate conditions. The methodology established to examine indoor microclimate combines both objective and subjective methods for an optimal evaluation of indoor microclimatic conditions.

References

ASHRAE 55-1992 Thermal environmental conditions for human occupancy. American society of heating, refrigerating and air-conditioning engineers, Atlanta, 1992. 21 p.

Belgian Building Research Institute. 2002. *Source book for a better understanding of conceptual and operational aspects of active facades.* Dept of Building Physics, Indoor Climate and Building Services, Belgian Building Research Institute. Version no. 1. Available from Internet: <http://www.bbri.be/activefacades/index2.htm>.

Carmody, J.; Selkowitz, S.; Lee, E.; Arasteh, D.; Willmert, T. 2004. *Window Systems for High-Performance Buildings*. New York: W.W. Norton & Company. 400 p.

CR 1752:1998 Ventilation for buildings – Design criteria for the indoor environment. European Committee for Standardization. Brussels, 1998. 74 p.

Dear, R. 2004. Thermal comfort in practice, *Indoor Air* 14(suppl 7): 32–39.

Fang, L.; Wyon, D. P.; Clausen, G.; Fanger, P. O. 2004. Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance, *Indoor Air* 14(suppl 7): 74–81.

Federspiel, C.; Liu, G.; Lahiff, M. 2002. Worker performance and ventilation: analyses of individual data for call-centre workers, in *Proc. of Indoor Air 2002, 9th International Conference on Indoor Air Quality and Climate. Monterey, CA, USA, 2002,* 796–801.

HN 42:2004 Gyvenamųjų ir viešojo naudojimo pastatų mikroklimatas [Indoor microclimate of dwellings and public houses]. Vilnius, 2004. 8 p.

ISO 7730:1994 Moderate Thermal Environments – determination of the PMV and PPD indices and specification of conditions for thermal comfort. Switzerland, 1994. 28 p.

Niemela, R.; Hannula, M.; Rautio, S.; Reijuka, K.; Railio, J. 2002. The effect of indoor air temperature on labour productivity in call centers – a case study, *Energy and Buildings* 34: 759–764.

Ramanauskas, J.; Bliūdžius, R.; Stankevičius, V. 2005. *Langų šiluminės savybės* [Thermal properties of windows]. Kaunas: Technologija. 135 p. ISBN 9955-09-983-6.

STR 2.05.01:2005 Pastatų atitvarų šiluminė technika [Thermal Technique of Building Envelope]. Vilnius, 2005. 104 p.

Šeduikytė, L.; Bliūdžius, R. 2005. Pollutants emission from building materials and their influence on indoor air quality and people performance in offices, *Journal of Civil Engineering and Management* 11 (2): 137–144.

Wyon, D. P. 2004. The effects of indoor air quality on performance and productivity, *Indoor Air* 14(suppl 7): 92–101.

Wyon, D. P. 1996. Individual microclimate control: required range, probable benefits and current feasibility, in *Proc of Indoor Air 1996, 7th International Conference on Indoor Air Quality and Climate. Nagoya, Japan, 1996,* 1067–1072.

Wyon, D. P. 1993. Healthy buildings and their impact on productivity, in *Proc of Indoor Air 1993, 6th International Conference on Indoor Air Quality and Climate. Helsinki, Finland.* 1993, 3–13.

BIURO PASTATŲ, TURINČIŲ DIDELIUS ĮSTIKLINTUS PLOTUS, MIKROKLIMATO SĄLYGŲ VERTINIMAS

L. Šeduikytė, V. Paukštys

Santrauka

Straipsnyje nagrinėjamos patalpų mikroklimato sąlygos pastatuose esančiuose biuruose, turinčiuose didelius įstiklintus plotus. Didelių skaidrių atitvarų plotų įrengimas pastatuose ne tik didina energijos sąnaudas pastatams šildyti, vėsinti ir orui kondicionuoti, bet ir sukuria mikroklimato sąlygas, kuriose dirbantys žmonės dažnai patiria šiluminį diskomfortą, nors aplinkos parametrai atitinka normų reikalavimus. Natūriniams patalpų mikroklimato tyrimams sukurta patalpų mikroklimato tyrimo metodika, kuri sieja objektyvius ir subjektyvius tyrimo metodus patalpų sąlygoms optimaliai įvertinti. Patalpų mikroklimato sąlygos tiksliausiai įvertinamos pagal patalpų mikroklimato parametrų matavimo, papildyto subjektyvaus mikroklimato sąlygų įvertinimu, apibendrintos analizės rezultatus.

Reikšminiai žodžiai: biuro patalpų mikroklimatas, objektyvus ir subjektyvus įvertinimas, stikliniai fasadai.

Lina ŠEDUIKYTĖ. Dr, Faculty of Civil Engineering and Architecture, KTU. Field of research: indoor microclimate conditions, thermal-comfort parameters, effect of indoor air quality on health, SBS symptoms and people performance.
Faculty of Civil Engineering and Architecture, Kaunas University of Technology, Studentų g. 48, LT-51367 Kaunas, Lithuania. Mob. tel.: +370 6 20 33467, Fax.: +370 37 300454,

Valdas PAUKŠTYS. Dr, Faculty of Civil Engineering and Architecture, KTU. Field of research: physical-technical processes in building envelopes, physical properties of building materials.
Faculty of Civil Engineering and Architecture, Kaunas University of Technology, Studentų g. 48, LT-51367 Kaunas, Lithuania. Mob. tel.: +370 6 8626812, Fax.: +370 37 300454.