ARCHIVES OF ENVIRONMENTAL PROTECTION
ARCHIWUM OCHRONY ŚRODOWISKA
vol. 32 no. 2 pp. 21 - 26 2006
PL ISSN 0324-8461

STUDY OF THE RELATIONSHIP BETWEEN THE PERCEIVED AIR QUALITY AND THE SPECIFIC ENTHALPY OF AIR POLLUTED BY PEOPLE

RUDOLF BUREK, BERNARD POŁEDNIK, ANDRZEJ RACZKOWSKI

Lublin University of Technology, Faculty of Environmental Engineering, Indoor Environmental Engineering Facility
ul. Nadbystrzycka 40B, 20-618 Lublin, Poland

Keywords: indoor air pollution, specific enthalpy, relative humidity, odour acceptability, perceived air quality.

BADANIA RELACJI POMIĘDZY WYCZUWALNĄ JAKOŚCIĄ I ENTALPIĄ WŁAŚCIWĄ POWIETRZA ZANIECZYSZCZONEGO PRZEZ LUDZI

Praca dotyczy akceptowalności powietrza wewnętrznego (AKC) i wyczuwalnej koncentracji zanieczyszczeń (D) emitowanych przez użytkowników pomieszczeń dydaktycznych i biurowych. Zagadnienia te przedstawiono w relacji do entalpii właściwej (h) i wilgotności względnej powietrza wewnętrznego (φ). Wyniki określania AKC/D/, opisane funkcją logarytmiczną wskazują na wyraźną ich zależność od ln h jak również od ln φ. Użytą funkcję logarytmiczną z zadawalającym skutkiem dopasowano także do danych literaturowych. Wyciągnięto stąd wniosek o przybliżonym charakterze powszechnie przyjmowanej liniowej zależności pomiędzy AKC i h. Zaproponowane w pracy równanie pozwala na wartościowanie mikroklimatu pomieszczeń oraz wskazuje, w jaki sposób można instrumentalnie określać wyczuwalną jakość powietrza wewnętrznego i w jaki sposób sterować procesem klimatyzacji pomieszczeń.

Summary

This paper deals with the acceptability (AKC) and perceived concentration of pollutants (D) emitted by occupants in relation to the specific enthalpy (h) and relative humidity (φ) of indoor air. Measurements of AKC/D/, described by semilogarithmic function depend significantly on both ln h and ln φ. The equation fits to the data published in the literature in a reasonably good way. Therefore, it indicates that the linear function between AKC and h which is commonly used in literature yields rough approximations. The proposed equation allows for the validation of the indoor microclimate and brings an idea how to make measurements of the perceived air quality instrumentally and how to control the air conditioning process.

INTRODUCTION

There is a problem of describing the pollution of air by temperature and humidity. It is now agreed that the concentration of pollutants may vary as a result of the specific enthalpy of indoor air [1, 4]. It has been realized that

$$\ln D = ah + b \tag{1}$$

where: D – is the pollution [decipols],

h – is the specific enthalpy [kJ/kg],

a, b – are material dependent empirical constants.

Equation (1) applies for mixtures containing dry air, water vapour and volatile emanations of materials. The influence of specific enthalpy on the acceptability or intensity of odour seems to be far from being clear. In the present study the applicability of the specific enthalpy for predictions of the perceived quality of air polluted by people is examined.

METHODS

Continuous measurements of air temperature, relative humidity and concentration of water vapour were performed in a classroom during lectures (Fig. 1a, b). The classroom was located on the second floor of the Faculty of Environmental Engineering building at the Lublin University of Technology. Inside the 86 m^3 cuboids room there was a teacher's desk, tables and seats for 24 students. Gravitational ventilation of the room with two double pane windows was conducted by two ventilation openings with the size of 0.15 x 0.20 m. The air temperature was defined on the basis of measurements performed in nine symmetric points inside the classroom (Fig. 1c) using silicon temperature sensors with temperature coefficient 0.79%/K at 25°C [5]. The air humidity was determined by digital thermohygrometer with accuracy 0.8% [6]. Assessments of perceived air quality were performed in a fully occupied classroom. Then, first at the beginning of the lecture and then after about half an hour and later after one hour 16 students entered the room, one by one, for a very short period of time and answered the question whether the quality of air was acceptable or not.

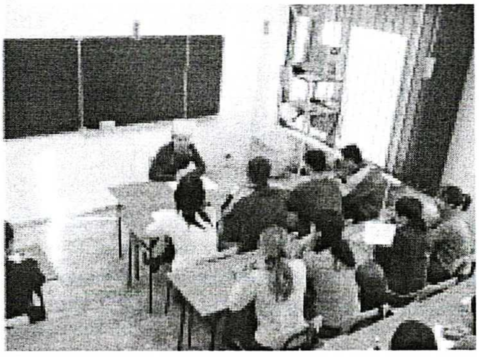
The pollution was computed from the Fanger's equation – definition [3]; the acceptability was established through the relation:

$$AKC = 0.1854 \ln D/D_o \quad \text{for } -1 \leq AKC \leq 1 \tag{2}$$

where: D_o – is the threshold concentration at AKC = 0 computed from the Fanger's equation [3] and corresponds to 50% of disappointed assessors.

Moreover, measurements performed in offices by a trained odour panel were utilized [3].

a



b

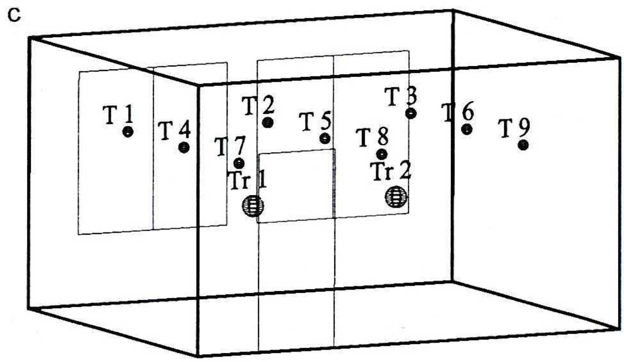


Fig. 1. Measurements of hygro-thermal parameters of classroom air
a, b – object of measurements; c – scheme of location of temperature measurement points

RESULTS

Figure 2 and 3 demonstrate the acceptability as a function of the specific enthalpy and the natural logarithm of the specific enthalpy, respectively. The points marked by squares represent results of measurements performed in offices; those denoted by triangles were obtained in classrooms. The regressions (Eqn. 3 and Eqn. 4) are listed in Table 1.

Table 1. The analysis of regressions

Eqn.	Regression	Correlation coefficient	r.s.d.	Substance
3	AKC = - 0.0178 h + 1.105	0.800	0.14	indoor air
4	AKC = - 0.7981 ln h + 3.3	0.800	0.15	indoor air
5	AKC [ln h] = AKC [h]	0.995	0.02	indoor air
6	$D/D_o = (h/61.6)^{8.32}$	0.925	–	$0.54 \leq \varphi \leq 0.64$
7	$D/D_o = (h/47.4)^{7.58}$	0.940	–	$0.25 \leq \varphi \leq 0.46$
10	AKC = - 0.029 h +1.55	0.970	0.08	pure moist air
11	AKC = -1.224 ln h + 4.87	0.950	0.09	pure moist air
12	$D/D_o = (h/51.3)^{6.52}$	0.950	0.10	pure moist air $\varphi = 0.3$
13	$D/D_o = (h/54.3)^{7.62}$	0.980	0.10	pure moist air $\varphi = 0.5$

r.s.d. – rest standard deviation

It is visible in Table 1 that the correlation coefficients and the rest standard deviations (r.s.d.) of both approximations are close to each other. The predictions of AKC obtained by means of the linear (Eqn 3) and semi logarithmic functions (Eqn 4) are almost identical (Eqn 5). Thus the empirical relationships do not signify whether the AKC is a linear or a logarithmic function of the specific enthalpy. It is important to emphasize that the empirical points are strongly scattered around the best fit line. The scattering of the empirical values is due, in part, to experimental uncertainties, and in part to the interrelations among specific enthalpy, relative humidity and relative air pollution. To get a better visualization of the above interrelationship, the dependency between the number of odour units (D/D_o) and the specific enthalpy is considered.

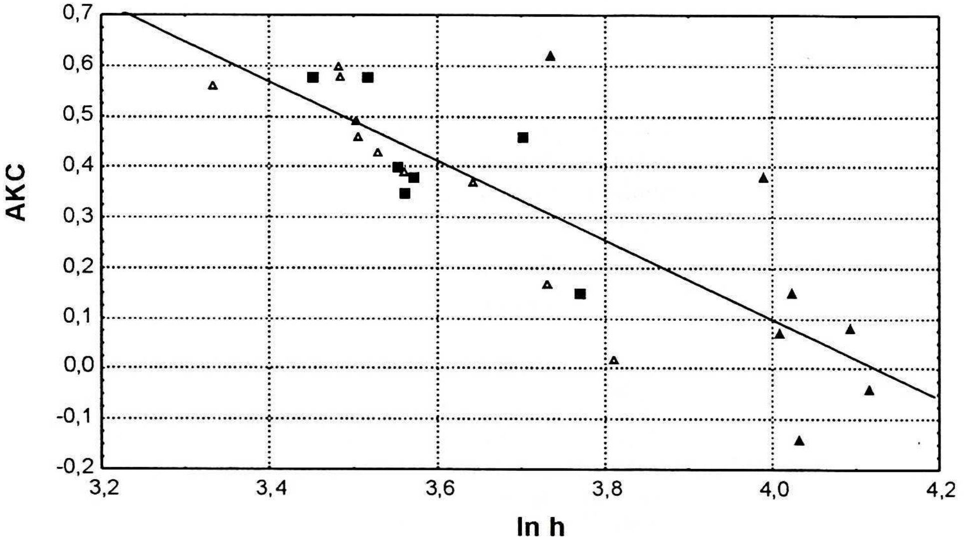


Fig. 2. The relationship between the acceptability of indoor air and the specific enthalpy
■ – measurements presented in [1]; ▲, △ – our measurements

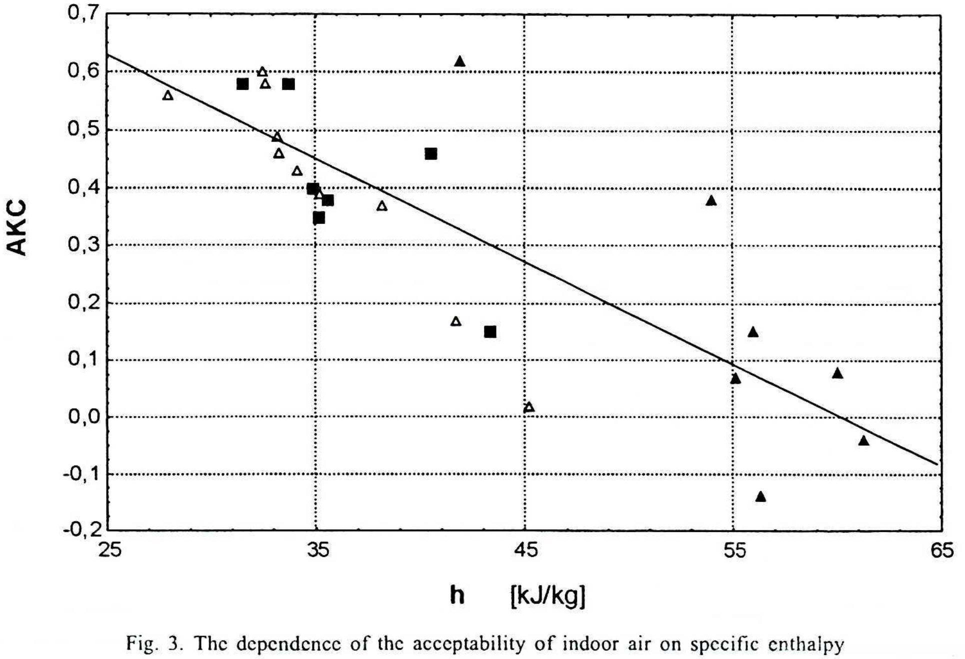


Fig. 3. The dependence of the acceptability of indoor air on specific enthalpy
■ – measurements presented in [1]; ▲, △ – our measurements

Figure 4 is the h vs. D/D_0 diagram. It shows that for the same number of odour units (D/D_0) the specific enthalpy increases as the relative air humidity increases. The scattering of the experimental points around the best fit parametric curves is strongly reduced. Thus each separate range of variations in relative humidity needs a separate curve. This interrelationship (Eqn 6 and Eqn 7) can be expressed by the following function:

$$D/D_o = (h/h_o)^n {}_{\varphi=const} \quad (8)$$

Here the relative humidity φ appears as a parameter.

The regression is statistically significant; the correlation coefficient equals about 0.93.

Figure 4 shows that the scattering of the experimental points around the best fit parametric curves is strongly reduced and that the results of measurements presented by Fanger [3] are rationally consistent with our results.

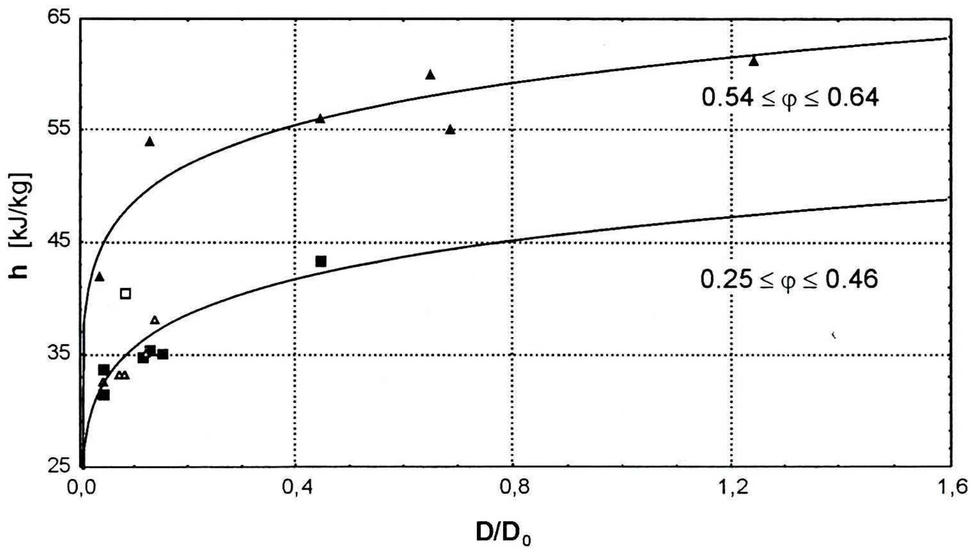


Fig. 4. The relationship between the specific enthalpy and the relative pollution of indoor air
■, □ – measurements presented in [3]; ▲, △ – our measurements

DISCUSSION

The results of this study indicate that enthalpy is a crude property for indoor air quality descriptions. The conspicuous finding is that the predictions of acceptability through the ln h (Eqn 4) and h (Eqn 3) are almost identical (Eqn. 5). The distribution of the ratings for AKC and h appears similar to the distribution of ratings for AKC and ln h. On closer inspection it is evident that the rest standard deviations of both approximations are almost identical.

A potential criticism of the presented findings may arise because the experimental assessments were obtained by various odour panels in different environments.

An important result, which confirms our findings follows from the analysis of the measurements performed by Reinikainen [4] presented originally in plots: ln D vs. h in the study of Böck and Spiess [1]. Equations (9) to (12) which refer to the mixtures of pure dry air and water vapour (pure moist air) are similar in form and accuracy to those obtained for air polluted by persons. In conclusion the relationship between the acceptability or the number of odour units, the specific enthalpy and relative humidity of indoor air would seem to make sense. Equation (8) is similar in form to that between the concentration of odorants in g/m^3 or g/kg and the number of odour units / pollution in decipoles. How this might come about and at what level of processing of the olfactory system is unknown. Whatever the case, the present findings suggest that not only the specific enthalpy but also the relative humidity of indoor air should be taken into account, if the indoor air acceptability or indoor air pollution is assessed.

The interrelationship between the AKC, specific enthalpy h and relative humidity becomes:

$$AKC = (7.93 + 0.65 \ln \varphi - 1.863 \ln h)/0.1854 \quad (13)$$

Equation (13) can be applied for determination of the perceived indoor air quality [2]. The standard error of estimated AKC amounts to $\pm$ 0.1.

CONCLUSION

In order to perform accurate determination of the perceived quality of indoor air polluted by people both specific enthalpy and relative humidity of the air should be taken into account. The development of the detailed relationship between the acceptability and the hygro-thermal parameters of indoor air requires more data from validated experiments. In practical implications such relationship brings an idea how to instrumentally measure the perceived air quality and will make the proper control of air-conditioning processes possible. Such control will assure the improvement of indoor air quality.

REFERENCES

[1] Böck R., T. Spiess: *Grundlagen zur Charakterisierung von Geruchsimmissionen in Innenräumen*, Gesundheits Ingenieur – Haustechnik – Bauphysik – Umwelttechnik, **5**, 252–256 (2000).

[2] Burek R., B. Połednik, A. Raczkowski: *Sposób pomiaru wyczuwalnej jakości i stężenia zanieczyszczeń zapachowych powietrza*, Zgłoszenie patentowe: nr 375 937 z 28 czerwca 2005.

[3] Fanger P.O., Z. Popiołek, P. Wargocki (eds.): *Środowisko Wewnętrzne*, Wydawnictwo Politechniki Śląskiej, Gliwice 2003, 117–119.

[4] Reinikainen L.M.: *The effect of humidification on perceived indoor air quality assessed by untrained odour panel*, [in:] Proceedings of Indoor Air '93, Proceedings of the 6th International Conference on Air Quality and Climate, **4**, 101–105 (1993).

[5] *Silicon sensors for temperature measurements*, Manufacturer information, Philips Semiconductors, September 06, 2000.

[6] *Świadectwo wzorcowania termohigrometru LB-701*, M63-419-220/02 issued by Laboratorium Wilgotności Zakładu Fizykochemii Głównego Urzędu Miar, December 18, 2002.

Received: December 9, 2005; accepted: April 6, 2006.