

# Health and Well-being Disorders in Air-conditioned Buildings; Comparative Investigations of the "Building Illness" Syndrome

P. KROELING

Institut f. Med. Balneologie und Klimatologie, L.-M. Universitaet, Marchionini Str. 17, 8000 München (F.R.G.)

## SUMMARY

Complaints about disorders of comfort, well-being and health in air-conditioned (AC) buildings have often been reported [1 - 8]. Nevertheless, there is little knowledge about their qualitative and quantitative structure, as well as their possible causes. To get detailed information, two different kinds of studies have been performed [9]: Study A: a representative Gallup poll (INFRATEST); Study B: comparative investigations in 11 "matched" buildings by questionnaire, combined with simultaneous measurements including: air velocity and turbulence, temperature, humidity, low frequency noise, CO<sub>2</sub> concentration, technical and weather conditions.

Results — study A: The Gallup poll, including 8000 representative persons older than 14 years, showed that 2.5 million residents of the F.R.G. and West Berlin are working in AC buildings. Compared to controls in conventional buildings, AC persons complained significantly more frequently of "tendency to colds" (+14.6%), "dry mucous membranes" (+13.0%), "rheumatism" (+7.5%), "headache" (+5.0%), "rapid fatigue" (+5.0%), irritability (+4.1%) and "numbness" (+3.3%). Furthermore, they felt more affected by the following environmental conditions; "missing window ventilation" (+24.4%), "draught" (+12.8%), "dry air" (+12.1%), "changing temperatures" (+11.3%) and "stale, stuffy air" (+4.8%). None of the 23 investigated parameters had favourable results for the AC group compared to controls.

Results — study B: An extended questionnaire (47 parameters) has been used for investigations in "matched" individual buildings. The investigations included a total number of ≈3000 persons in 5 administration buildings and 6 schools. As in study A, the criteria of well-being, health and comfort have been evaluated to be considerably worse by persons in AC buildings, compared to controls. Sets of typical complaints could be isolated, quantified and hypothetically related to certain conditions, e.g.:

• increase of air velocity and turbulence  
• disturbed heat budget  
• stress reactions to low frequency noise  
• allergic reactions to microorganisms and dust  
• insufficient air quality  
• insufficient AC systems, control and regulation  
• insufficient building constructions.

- increase of air velocity and turbulence
- disturbed heat budget
- stress reactions to low frequency noise
- allergic reactions to microorganisms and dust
- insufficient air quality
- insufficient AC systems, control and regulation
- insufficient building constructions.

## 1. INTRODUCTION

Complaints about disorders of well-being, health and comfort in air-conditioned (AC) buildings have been often reported [1 - 7]; we drew attention to this problem by means of a pilot study performed in 1982 [8]. However, the knowledge about the quantitative structure of the complaints — compared to natural ventilated and heated "conventional" buildings — has been poor. For most of them there seem to exist no satisfying physical or technical explanations; for this reason mainly psychological factors have been thought to be responsible by different authors.

With the help of a government-supported research program [9], two combined studies (A and B) were performed to get detailed information about the following questions:

- How many persons in the F.R.G. are working in AC buildings?
- Are there typical patterns of complaints in AC buildings, compared to those in conventional ones?
- Are the complaints relevant from an epidemiological point of view?

- Are there suspicious physical, technical or other differences between AC and conventional buildings, which may lead to reasonable explanations for the complaints, and to technical solutions?

## 2. MATERIALS AND METHODS

### 2.1. Study A

A representative Gallup poll has been performed within a monthly 'multiple theme' investigation by INFRATEST. It included 8000 representative persons older than 14 years in the F.R.G. and West Berlin. Eleven items of a short questionnaire included typical health complaints at work, another 12 items dealt with comfort and other environmental problems. Filter questions allowed the comparison of answers from persons working in AC and conventional locations (note: study A took place at the homes of the participants, not at the working place itself).

The representative study enabled us to get some general data about the well-being and comfort situation in AC and conventional locations, but it gives only little information about the possible causes of the different complaints. Therefore it was necessary to compare subjective evaluations with objective measurements in selected buildings (see study B).

### 2.2. Study B

Comparative inquiries have been performed in selected, matched buildings with and without air-conditioning, by use of an extended questionnaire (comprehending the questions of the representative Gallup poll, study A). The investigation took place in 6 schools with  $\approx 1800$  pupils (about 15 years old) and teachers, and in 5 administration buildings with about 1200 employees (München, Berlin, Heidelberg). Physical and other boundary conditions have been measured simultaneously, such as:

- air velocity and turbulence
- room temperature and humidity
- low frequency noise (10 - 100 Hz)
- carbon dioxide
- technical specifications
- weather conditions

## 3. RESULTS

### 3.1. Study A

There were 420 persons out of 8000 working in AC locations; this means, that about 2.5 million (5%) of the population ( $\geq 14$  years old), or 13.2% of indoor working places (19 million) in Germany and West Berlin are air-conditioned.

In part 1 of the questionnaire, the persons evaluated the statement: "At my working place I suffer usually from the following health disorders...". Figure 1 demonstrates the differences between the AC group and the control group. AC persons complained nearly twice as much about: "tendency to colds", "dry mucous membranes", "rheumatism", and "lack of energy". Significant differences were found also for the items: "headache", "rapid fatigue", and "numbness".

In part 2 of the questionnaire the persons evaluated the statement: "At my working

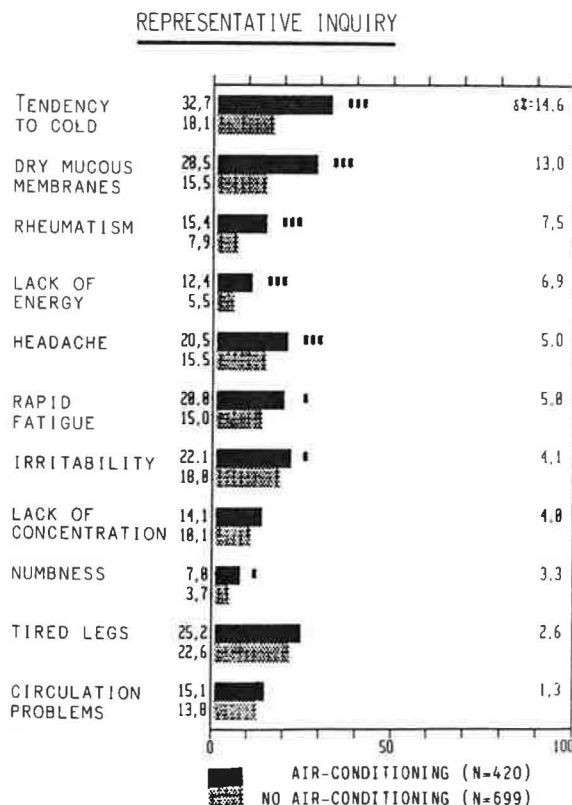


Fig. 1. Well-being disorders in air-conditioned and conventional (heated and ventilated) buildings. Representative Gallup poll by INFRATEST (study A). Random sample  $n = 8000$  persons  $\geq 14$  years. 100% represents 2.5 million persons in F.R.G. and West Berlin. Significance levels of Chi<sup>2</sup>-test:  $p \leq 0.05 = *$ ;  $p \leq 0.01 = **$ ;  $p \leq 0.001 = ***$ .

## REPRESENTATIVE INQUIRY

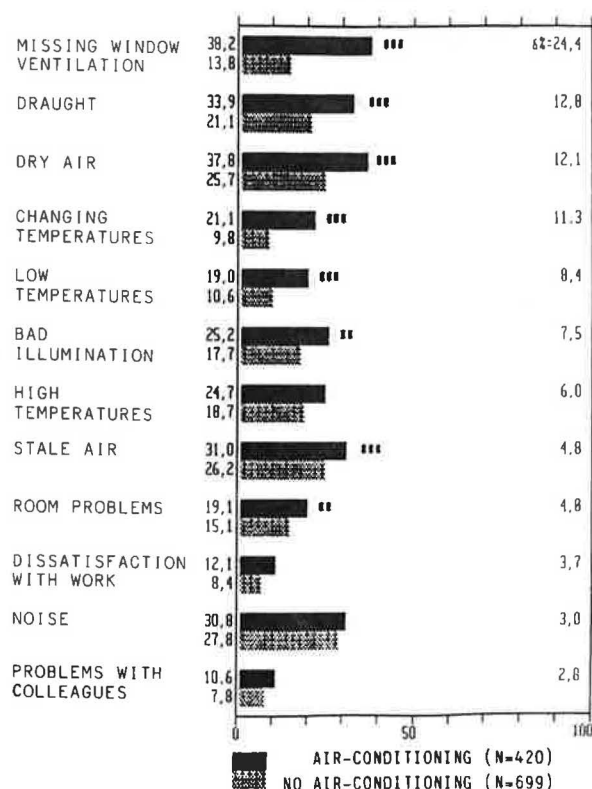


Fig. 2. Environmental problems in air-conditioned and conventional (heated and ventilated) buildings. Representative Gallup poll by INFRATEST (study A). Random sample  $n = 8000$  persons  $\geq 14$  years. 100% represents 2.5 million persons in F.R.G. and West Berlin. Significance levels of  $\chi^2$ -test:  $p \leq 0.05 = *$ ;  $p \leq 0.01 = **$ ;  $p \leq 0.001 = ***$ .

place I feel affected usually by the following conditions...". Figure 2 shows, that the AC persons were mostly affected by: "missing window ventilation", "draught", "dry air", "changing temperatures", "low temperatures" and "stale air" (all differences statistically highly significant).

### 3.2. Study B

#### 3.2.1. Questionnaire investigations

It is not possible in this contribution to give detailed information about the results of each matched questionnaire investigation. To provide an overview, however, summaries of selected data, gained in the administrating buildings and in schools, will be demonstrated.

Figure 3 is based on 724 employees in 2 AC buildings and 508 in 3 conventional ones (Berlin, Heidelberg). Nearly twice as many AC persons suffered from "rapid fatigue" and

## TOTAL OF ADMINISTRATION BUILDINGS

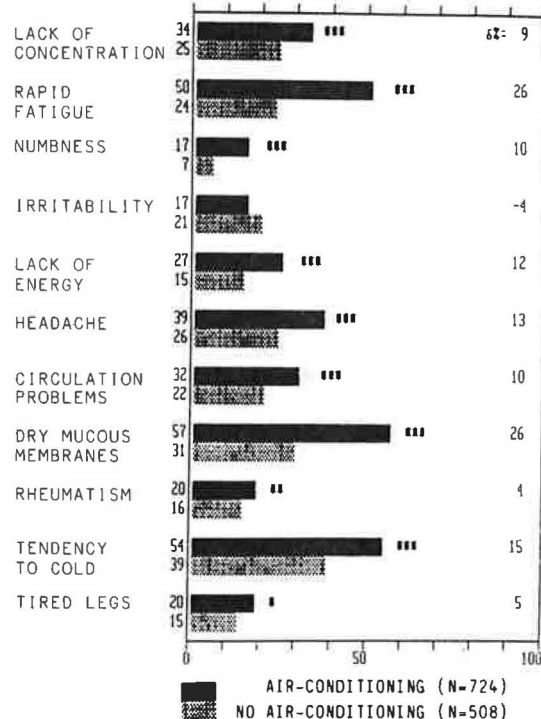


Fig. 3. Well-being disorders in 2 air-conditioned and 3 conventional (heated and ventilated) buildings. Summary results from administration buildings in West Berlin and Heidelberg. Significance levels of  $\chi^2$ -test:  $p \leq 0.05 = *$ ;  $p \leq 0.01 = **$ ;  $p \leq 0.001 = ***$ .

"dry mucous membranes". Highly significant different items were: "tendency to colds", "headache", "loss of energy" and "numbness".

As shown in Fig. 4 the persons mostly complained about: "missing window ventilation", "dry air", "stale air", "changing temperatures" and "draught".

Similar, if even worse disorders were found in 3 AC schools, compared to 3 conventional ones (Berlin, München) as shown in Fig. 5. Highly significant were the increased complaints of: "dry mucous membranes", "lack of concentration", "rapid fatigue" and "tendency to colds": furthermore "headache", "lack of energy" and "numbness" were noted.

Figure 6 demonstrates the answers concerning environmental comfort. More than 80% of the children missed the window ventilation. Other highly significant complaints, besides illumination problems, concerned "low temperatures", "changing temperatures" and "dry air".

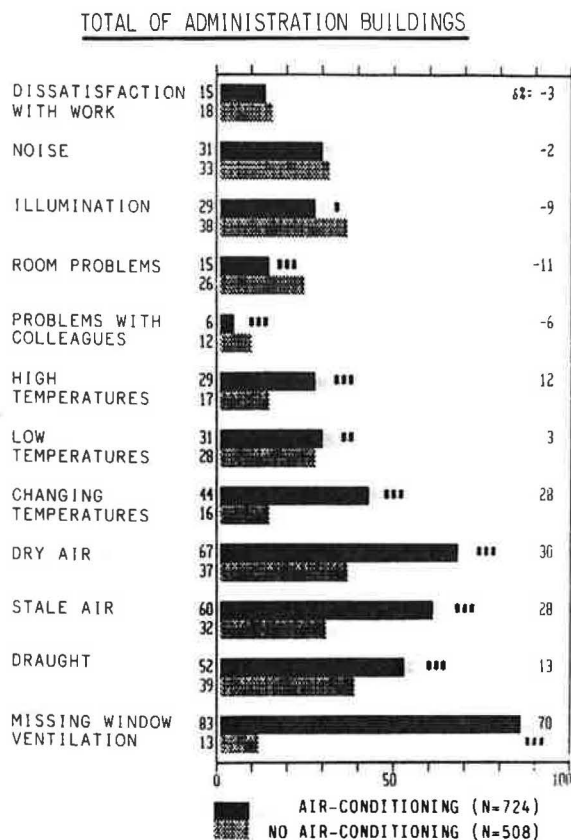


Fig. 4. Environmental problems in 2 air-conditioned and 3 conventional (heated and ventilated) buildings. Summary results from administration buildings in West Berlin and Heidelberg. Significance levels of Chi<sup>2</sup>-test:  $p \leq 0.05 = *$ ;  $p \leq 0.01 = **$ ;  $p \leq 0.001 = ***$ .

### 3.2.2. Measurements

Demonstration of the numerous measurement data is not possible in this contribution. In short, remarkable differences between AC and conventional buildings have been found, which may lead to explanations for some of the described complaints:

#### • Increase of air velocity and turbulence

Though the limits of DIN 1946 ( $\approx 0.2$  m/s) have not been exceeded, complaints about "draught" in the AC buildings were high. At the same time, complaints about "dry air" and "dry mucous membranes" were high as well. We suppose a causal connection between them, because accelerated, turbulent air can exsiccate mucous membranes and skin even at normal air humidity values. Obviously the DIN 1946 for air velocity limits is not sufficient in its actual form. Therefore we propose an air velocity limit  $\leq 0.1$  m/s (at room tem-

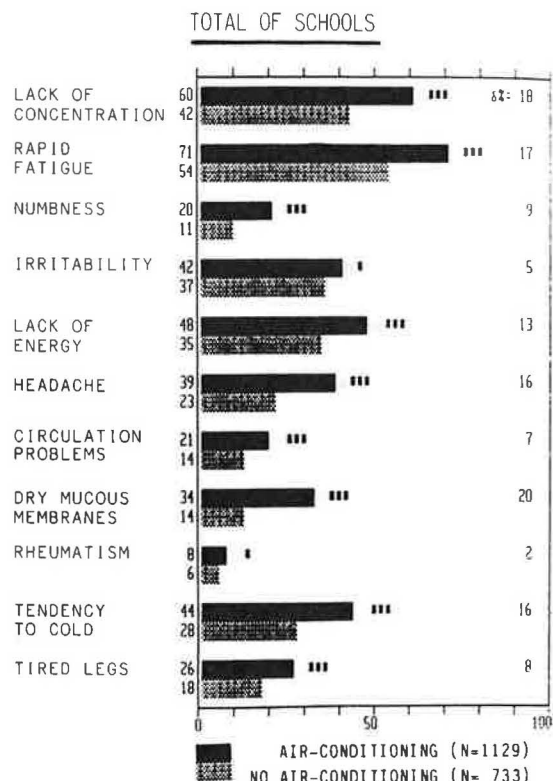


Fig. 5. Well-being disorders in 3 air-conditioned and 3 conventional (heated and ventilated) schools. Summary results from schools in West Berlin and München. Significance levels of Chi<sup>2</sup>-test:  $p \leq 0.05 = *$ ;  $p \leq 0.01 = **$ ;  $p \leq 0.001 = ***$ .

peratures of  $\approx 21$  °C) to prevent draught and dryness sensations.

#### • Instability of room temperatures

We found paradoxically much larger deviations from the ideal room temperature ( $\approx 21$  °C) in AC than in conventionally heated and ventilated buildings; the tendency is for it to be too cold in the morning time, and too warm after noon. These observations may explain the many complaints about thermal discomfort and the strong claim for openable windows.

#### • Increase of low frequency noise

The low frequency noise level (10 - 100 Hz) we found in AC buildings usually is 10 - 15 dB above controls, due to the action of ventilation systems. The hearing threshold mostly is reached or crossed at frequencies  $> 30$  Hz. Obvious annoyance has not been observed, except a strange "off-effect": many people reported to feel acoustically and physically "relieved" at the moment when ventilating



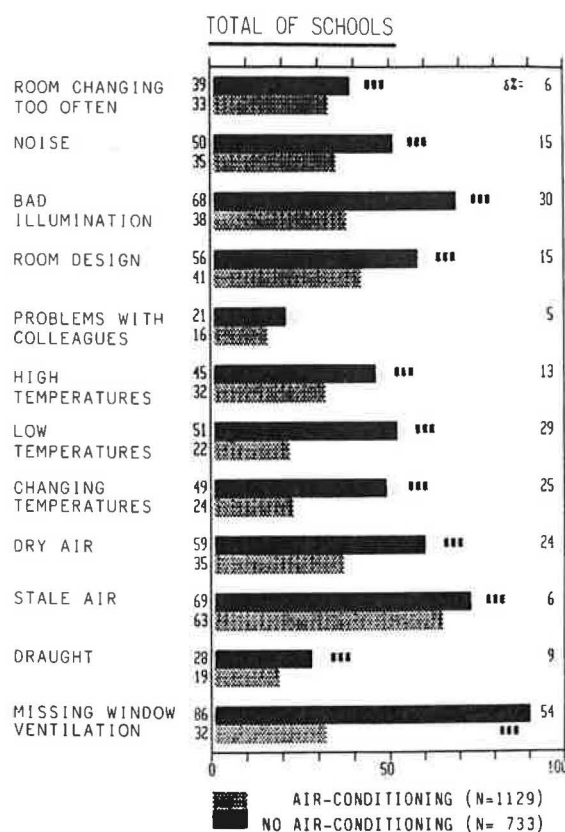


Fig. 6. Environmental problems in 3 air-conditioned and 3 conventional (heated and ventilated) schools. Summary results from schools in West Berlin and München. Significance levels of Chi<sup>2</sup>-test:  $p \leq 0.05 = *$ ;  $p \leq 0.01 = **$ ;  $p \leq 0.001 = ***$ .

systems stop. There is some evidence, that existing intensities within the hearing threshold are capable of causing unspecific stress reactions like "rapid fatigue", "headache", "lack of concentration" and "numbness" (see literature in ref. 9).

No remarkable deviations from normal carbon dioxide levels have been found, so the air exchange rates must have been sufficient in all investigated AC buildings and were not responsible for the many complaints about reduced air quality.

It was not possible within our research program to investigate the microbiological situation in the AC systems, as well as allergy-related problems of the residents. Still it must be considered, that a great number of the unspecific complaints, such as "rapid fatigue" "headache" and mucous membrane problems may be caused by constant exposure to AC-related microorganisms with high allergic potency (such as moulds).

#### 4. DISCUSSION

None of the 23 items in the first and second part of the questionnaire in study A had favourable results for persons in AC locations. Considering that these results are from persons in more than 400 different AC buildings, it can be concluded that the complaints are epidemiologically relevant and not limited to some single buildings, for example with malfunctioning AC systems. It can be roughly estimated that, in Germany and West Berlin, about 500 000 out of 2.5 million persons suffer more or less from disorders they would not have if they worked in conventional (ventilated and heated) buildings.

The results of study B varied between the different matched investigations in selected buildings; generally the findings in AC buildings were worse than in conventional ones. At the same time a number of physical factors were found to be different. Therefore it is rather improbable that mainly psychological reasons are responsible for the complaints (such as prejudice).

The described investigation program has to be understood as a first step towards a better knowledge about the so-called "building illness" syndrome ("sick building" syndrome). It cannot give definitive answers concerning the causes of the complaints. However, in combination with a systematic literature analysis (see ref. 9) the results allow the drawing of some connections between the found effects and possible reasons, as shown in Fig. 7.

Some of the listed complaints are supposed to belong together (groups within dotted lines). The arrows indicate in which way secondary connections may exist. The list is incomplete and some of the named "possible reasons" (right side) are still rather hypothetical; they may serve as a basis for specific further investigations.

#### ACKNOWLEDGEMENTS

The research program has been supported by the Bundesministerium für Forschung und Technologie, Bonn, F.R.G. FKZ Nr: 01 VD 132.

The Gallup poll (study A) investigation and the statistical comprehension in study B have been done by INFRATEST-Gesundheitsforschung, München, F.R.G.

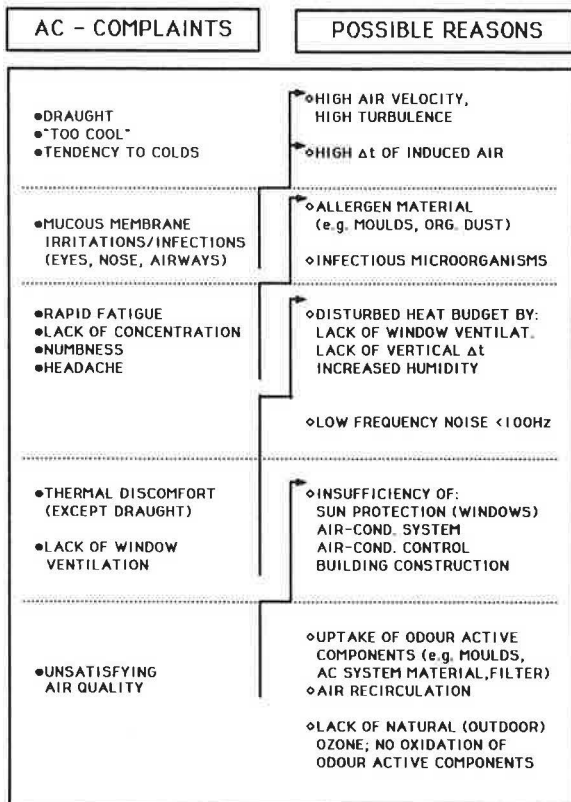


Fig. 7. The main complaints in air-conditioned buildings and their hypothetical reasons. The arrows indicate overlapping connections.

The air velocity and turbulence measurements have been performed by Dr. E. Mayer, Institut f. Bauphysik der Fraunhofergesellschaft (FhG), Holzkirchen, F.R.G.

Room temperature, radiation and humidity measurements have been supported by Dr. P.

Hoeppe, Institut f. Bioklimatologie, L.M-Universität München, F.R.G.

#### REFERENCES

- 1 A. Cakir, R. P. Franke and M. Piruzam, *Arbeitsplaetze für Stenotypistinnen*, BAU-Forschungsbericht 363, Dortmund, 1983.
- 2 C. Dick, J. Kompart, G. Reinartz, H. Schnadt and N. Tossing, *Auswirkungen der Taetigkeit in Grossraumbüros auf die Gesundheit der Beschaeftigten*, Forschungsbericht 57a; BuMi AS, Bonn, 1980.
- 3 M. J. Finnegan, C. A. C. Pickering and P. S. Burge, The sick building syndrome: prevalence studies. *Br. Med. J.*, 283 (1984) 1573 - 1575.
- 4 L. Gruen, Befeuchterfieber bzw. Montagskrankheit durch Klimaanlage, *Hygiene und Medizin*, 6 (1981) 33 - 35.
- 5 A. G. Henkel, Eine kritische Untersuchung zwölf realisierter Grossraumbüros, *Rationalisierung*, 25 (1974) 192 - 196.
- 6 A. S. Robertson et al., Comparison of health problems related to work and environmental measurements in two office buildings with different ventilating systems, *Br. Med. J.*, 291 (1985) 373 - 376.
- 7 T. D. Sterling, E. Sterling and H. D. Dimich-Ward, Air quality in public buildings with health-related complaints, *ASHRAE Trans.*, 89 (2A) (1983) 198 - 207.
- 8 P. Kroeling, K. Dirnagl and H. Drexel, Gesundheits- und Befindlichkeitsstörungen in vollklimatisierten Räumen, *Z. Phys. Med.*, 11 (1982) 241 - 244.
- 9 P. Kroeling, *Gesundheits- und Befindensstörungen in klimatisierten Gebäuden. Vergleichende Untersuchungen zum "building illness" Syndrom*, Zuckschwerdt-Verlag, München, 1985.