Sick building syndrome symptoms caused by low humidity

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ABSTRACT

Sick building syndrome (SBS) symptoms were investigated in a laboratory study of low humidity environments: 30 subjects were exposed to clean air at 22°C with 5%, 15%, 25% and 35% RH and 30 were exposed to polluted air at 18°C, 22°C and 26°C with a constant moisture content of 2.4 g/kg dry air and at 22°C/35%RH. The subjects were exposed to each condition for 5 h and reported the intensity of SBS symptoms. Five hours of exposure to clean air at 5% RH caused only eye symptoms, while 5 h of exposure to polluted dry air at 15% RH aggravated a number of symptoms of the skin, nose, throat and lips. Increasing indoor air temperature from 18°C to 26°C aggravated nose and throat symptoms and the sensation of dryness. The effect of low humidity was found to have significant effects on SBS mainly for the environmentally sensitive subjects.

INDEX TERMS

Low humidity; Temperature; Air pollution; SBS; Indoor environment

INTRODUCTION

The most frequent complaint that is made under conditions of low humidity is the feeling of ‘dryness’, such as dry skin, eyes, nose, mouth, lips and hair. Low air humidity means dry air; it, therefore, seems logical that increased evaporative power due to low humidity will dry out skin and mucous membranes and will be perceived as a sensation of dryness. In a 48 h exposure, Carleton and Welch (1971) found that the severity of eye, nose and mouth irritation was greater at 22% RH compared to 63% RH. Andersson *et al*. (1975) re-analysed the data from Rasmussen (1971) and showed that humidity perception is strongly related to air temperature—contrary to expectation, the sensation of dryness increased with increasing absolute humidity as temperature increased at constant RH. These authors also reported a large field intervention study involving 630 subjects in Swedish offices in winter: at 21–22°C, 80% of the subjects were satisfied with the normally occurring low humidity and humidifying the air to 40% RH had the unexpected effect of significantly reducing this percentage ($P < 0.01$). At 23–24°C this key percentage was unchanged by humidifying the air to 40% RH even though the sensation of dryness was significantly reduced ($P < 0.001$), because a corresponding proportion now complained that it was too humid. In a later field intervention study in a hospital building in Malmö (south Sweden), Wyon (1992) found a positive effect on some SBS symptoms when humidity was increased from 25 to 40% RH.

Some effects of thermal or chemical stimulation may be similar to the sensation of dryness and may, therefore, be interpreted as an effect of low humidity. Mucous membrane function may also be impaired after being exposed to chemicals and this may result in different symptoms, some of which may be similar to the sensation of dryness. This has been observed in several laboratory and field studies. A large field study of office buildings in northern Scandinavia was carried out by Sundell and Lindvall (1993). They studied the correlation between relative humidity and sensations of dryness, which is a SBS symptom. This epidemiological study indicated that indoor air humidity in the range 10–40% RH was not

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significantly associated with the sensation of dryness. They concluded that the sensation of dryness might be caused by air pollutants that irritated the mucous membranes. Rhinometry measurements made by Mølhave *et al*. (1993) in a laboratory study showed that volatile organic compounds may influence the mucous membranes of the nose, resulting in changes in the cross-sectional area and volume of the nasal cavity. The same study also showed that skin humidity increased significantly with increasing air temperature and VOC exposures. However, in a well-controlled chamber study by Andersen *et al*. (1974), no change in the function of the clearance mechanism of the nose and no significant discomfort was observed when subjects were exposed for 78 h to clean air at 9% RH. In subsequent studies, with air polluted with sulfur dioxide, inert plastic dust, formaldehyde and wood dust, Andersen and Proctor (1982) showed that complaints of nasal irritation and dryness of the nose were not significantly affected by the relative humidity of air. These studies indicate that there is no physiological need for humidification of the air.

Recent studies have found that indoor air temperature and humidity significantly influence the perception of air quality (Berglund and Cain, 1989; Fang *et al*., 1998a,b; Toftum *et al*., 1998). These studies found that decreasing humidity in the range from 70 to 30% RH improves perceived air quality. Cool and dry air was found to improve the perceived air quality, probably by increased cooling of the mucous membrane in the nasal cavity by evaporation and convection (Fang *et al*., 1998a,b). This observation is important since ventilation standards and guidelines are based primarily on perceived air quality (ASHRAE, 2001; CEN, 1998). However, it is not clear whether this positive effect of low humidity can be extended to the range below 30% RH. Artificial humidification tends to increase SBS symptoms, according to the epidemiological literature review performed by Mendell (1993).

More information on the intrinsic effects of low humidity and the interaction of low humidity with air pollution and temperature on different SBS symptoms is required. The present study is designed to investigate these effects.

METHODS

In order to be able to separate the effect of low humidity from the effect of temperature and air pollution, the experiment was designed with eight different environmental conditions—six hygro-thermal conditions and two levels of air pollution. It included four levels of humidity, 5%, 15%, 25% and 35% RH at a constant air temperature of 22°C, with clean air, and three levels of air temperature, 18°C, 22°C, 26°C at a constant moisture content of 2.4 g/kg dry air (19%, 15%, 11% RH, respectively) in normally polluted air. This approach was taken to simulate normal heating systems, which often have no means of adding or removing moisture. Two levels of relative humidity, 15% and 35% RH were studied in both clean and polluted conditions, so that it was possible to compare the effect of low humidity between 15% and 35% RH at two levels of air quality.

Sixty healthy volunteers participated in the experiment. It was stipulated at the outset that they should not be on regular medication of any kind during the period of the experiment. They were then screened for environmental sensitivity, using a self-report questionnaire, and were classified into three subgroups: a sensitive group (with symptoms of hay fever in the pollen season and symptoms of dry skin), contact-lens wearers and a ‘normal’ group (not falling into either of the other two groups). Thirty subjects (17 females) were exposed for 5 h to clean air at each of the four levels of humidity. A further 30 subjects (15 females) were exposed for 5 h to four conditions with normally polluted air: the three levels of temperature and the 35%/22°C reference condition. Each exposure was for a group of six subjects.

During each 5 h exposure, the subjects performed tasks that simulated office work, mainly to prevent them from closing their eyes for long periods, i.e. text-typing, proof-reading,

reading and simple addition, as described by Wargocki *et al*. (1999). Wyon *et al*. (2003) have since reported that the performance of these tasks in the present experiment was unexpectedly reduced at lower levels of humidity. Subjective assessments of perceived air quality, thermal sensation and the reported intensity of SBS symptoms were obtained from the subjects using standard visual-analogue scales (Wargocki, 1999), which in this experiment were marked by the subjects on a PC screen, using a computer mouse. The results were quantified and stored automatically by the computer. Objective medical tests were made before and after each exposure on the eyes, nose and skin. The medical tests were a tear film stability test, a mucous ferning test, a Rose Bengal staining test for micro-damage to the corneal epithelium, blink rate measurement, nasal peak-flow measurement, nasal transit time measurement, corneometer measurement, transepidermal water loss measurement and a skin irritation challenge test. The results obtained in these tests have been published elsewhere (Wyon *et al.*, 2002).

The 5 h exposure periods were divided into two sections of 2.3–2.5 h by a 15 min break. Simulated office tasks were performed throughout each exposure. Subjective ratings were obtained upon entering the chamber and at intervals of 20–40 min throughout each exposure. The first set of objective medical tests was applied in the examination chamber before subjects entered the exposure chambers. After 5 h of exposure, the eye and nose tests were applied inside the exposure chambers and the subjects then entered the examination chamber for the skin tests. Subjects maintained thermal neutrality by self-adjustment of their clothing and were allowed to drink water whenever they required it.

RESULTS

Wyon *et al*. (2002) have reported that in the clean condition, the general sensation of humidity after the 5 h exposure to air at a low humidity of 5% and 15% RH was significantly lower than at 25% and 35% RH. However, even in the extremely dry air (e.g. 5% RH at 22°C), the sensation of humidity was not worse than ‘slightly dry’ when the air was clean. Figure 1 shows that the first perception of air quality is an extension of the results of Fang *et al*. (1998) from 30% down to 5% RH. The effect of humidity on the perception of air quality is in the expected direction, although the effect of low humidity was not significant at this low level.

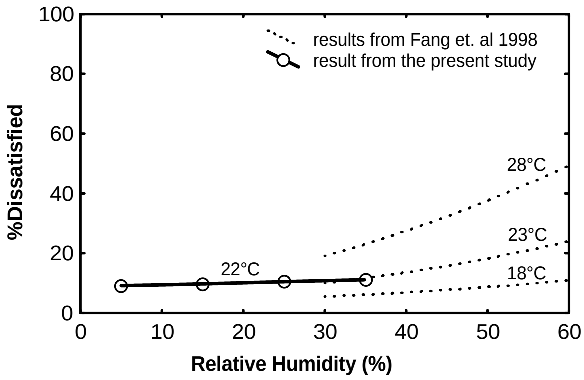

Figure 1 The positive effect of low humidity on perceived air quality extends below 30% RH

Eye symptoms were found to be exacerbated by low air humidity in the clean environment. The Mucous Ferning test showed that the mucous layer of the tear film was significantly drier at 15% RH or below than at 25% or above; subjectively perceived eye dryness also increased significantly when the humidity decreased to 15% or lower (Wyon *et al*., 2002). The SBS scales showed that the eye smarting symptom and fatigue symptom were significantly more severe after 5 h of exposure to 5% RH in comparison with 35% RH; both symptoms were alleviated at increased levels of humidity (Figure 2). Further analysis within each subgroup found that only the contact lens wearers reported severe eye smarting symptoms after 5 h of exposure to the extremely dry air at 5% RH, and only the sensitive group felt significantly more tired after working 5 h in the dry condition of 5% RH.

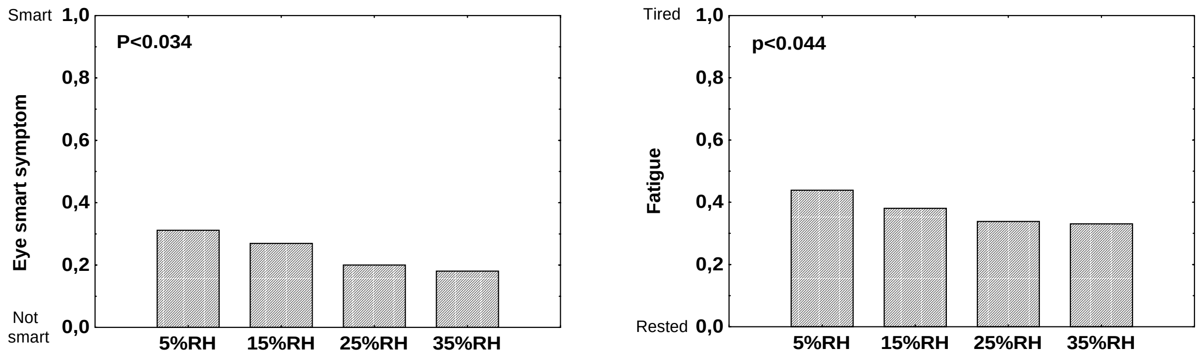

Figure 2 Eye smarting and fatigue symptoms decreased with increasing humidity after a 5 h exposure to clean air at 22°C

Except for the above symptoms, no other symptoms were found to have increased significantly with decreasing air humidity from 35% to 5% RH in the clean air condition. However, a number of symptoms became severe at low humidity when the air was polluted. Figure 3 shows that the symptoms of dry lips, skin dryness, blocked nose and throat irritation were significantly higher at 15% than at 35% RH. Among these symptoms, the skin dryness symptom of the whole group of subjects was found to be due to results obtained from the sensitive group.

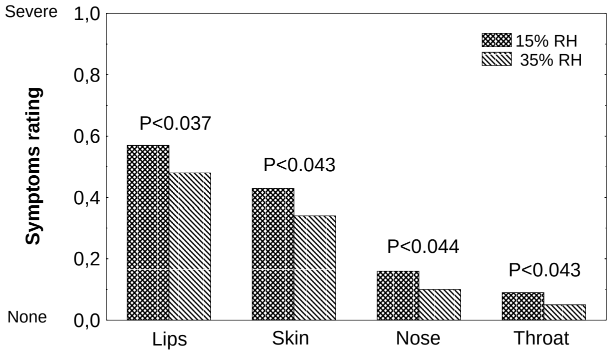

Figure 3 Lips, skin, nose and throat symptoms decreased with increasing humidity after a 5 h exposure to polluted air at 22°C.

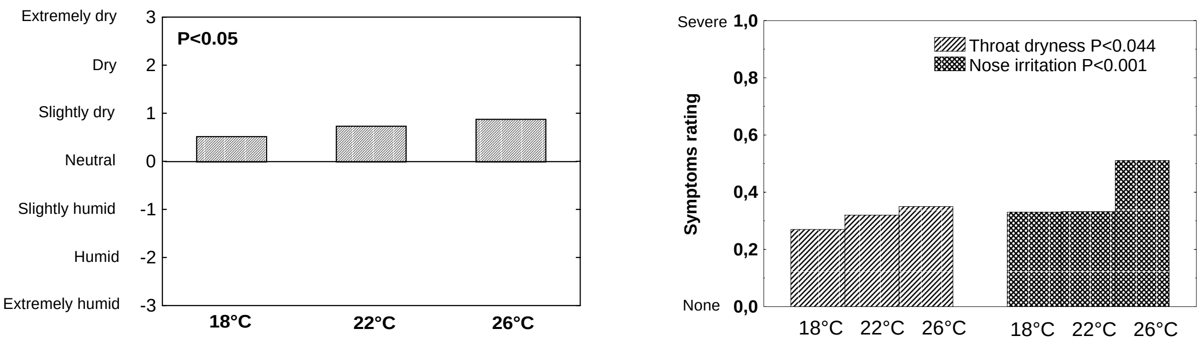

Figure 4 Sensation of dryness, throat and nose symptoms increased with increasing air temperature at constant moisture content of 2.4 g/kg dry air in the polluted condition

At a constant level of absolute humidity, increasing the temperature from 18°C to 26°C increased the sensation of dryness, throat dryness and nose irritation (see Figure 4). However, the skin dryness sensation was not affected by air temperature. An analysis of subgroup data showed that the effect of temperature on throat dryness and nose irritation was significant only for the sensitive subjects. Mouth dryness sensation was also higher at 26°C than at 18°C for the sensitive subjects.

The *P*-values shown in Figures 2 and 4 were obtained using the non-parametric Page test. The within-subjects pairwise comparison in Figure 3 was obtained using the Wilcoxon Matched-Pairs Signed-Ranks test.

DISCUSSION

The 5 h exposures indicate that air pollution plays an important role for several symptoms of the lips, nose, throat and skin at these very low levels of air humidity. Increased humidity might help to alleviate these symptoms. However, when the air is clean, low humidity does not create many problems except at extremely low levels of humidity (i.e. 5% RH). These results support the conclusions of Sundell and Lindvall (1993) following their field investigation and are similar but not identical to the results of the laboratory study by Andersen and Proctor (1982). In Andersen and Proctor's study, nasal irritation and dryness were not affected by relative humidity but were affected by air pollutants. The difference between the results of the two studies is most probably due to the differing levels of air pollution and the nature of the pollutants in the two studies. It is worth noting that the pollution levels in the present study were mild and similar to those encountered in real offices, and that the source of pollution was a carpet that had been used in normal office rooms.

Air temperature has a direct effect on relative humidity. The present study shows that high air temperature also causes mouth dryness and irritation in the nose, although these effects were mainly reported by the sensitive subjects.

The results indicate that sensitive subjects are more likely to be negatively affected by low humidity, especially when the air is polluted. Eye smarting symptoms increased at the lowest level of air humidity for contact lens wearers but not for subjects who did not wear contact lenses. The sensitive group of subjects had increased skin dryness symptoms at low levels of air humidity when the air was polluted but this was not the case for the normal group of subjects. Sensitive subjects may more easily become fatigued when working in extremely dry environments (e.g. 5% RH) even if the air is clean. The present study suggests that exposure to low air humidity for 5 h does not cause an increase in SBS symptoms for healthy subjects unless the humidity is well below 15% RH. However, contact lens wearers and sensitive people (e.g. people who suffer from hay fever in the pollen season and/or suffer from dry skin symptoms) may report more symptoms when exposed to low air humidity. Increasing humidity to above 15% RH or decreasing air temperature to 22°C or below may help to alleviate their symptoms.

CONCLUSIONS

- Exposure to low humidity for 5 h does not create severe SBS symptoms for normal, healthy people.
- Exposure to humidity at 15% RH or below for 5 h aggravates SBS symptoms for environmentally sensitive people, e.g. contact lens wearers or subjects who suffer from hay fever or dry skin.
- Exposure to high air temperature (26°C) increases dryness sensations and other related symptoms for environmentally sensitive people.
- Air pollution at normally occurring levels exacerbates the effect of low humidity on the SBS symptoms of environmentally sensitive people.

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