Adverse Environmental Health Effects of Ultra-low Relative Humidity Indoor Air

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Abstract: Adverse Environmental Health Effects of Ultra-low Relative Humidity Indoor Air: Mikiya Sato, et al. Department of Hygiene and Public Health, Teikyo University School of Medicine—In Japan, relative humidity (RH) shows the lowest achievement rate among the various general air quality standards for work environment. It has been mainly contributed by airtight design of modern buildings and occurrence of dry outdoor air in winter. Furthermore, an ultra-dry air environment of nearly 0% RH is often required in sophisticated industries. In order to assess the adverse health effects of the ultra-dry air environment, using a self-reported questionnaire, we have undertaken a study of over 200 employees of a high-tech device developing laboratory having a room at 2.5% RH (ultra-dry room). Those who worked in the ultra-dry room were identified and the prevalence of symptoms was compared with the other workers. Analysis was performed by Wilcoxon’s test and Fisher’s exact test. In the ultra-dry room, all the twelve workers covered their skin with long-sleeve clothes, paper caps, paper masks and latex gloves. They reported skin symptoms more often (p<0.05) than the other workers (N=143). The prevalence of atopic dermatitis was also higher in the exposed workers (p<0.05). The complaints of workers in the ultra-dry environment were similar to preceding reports concerning moderately dry environmental exposures. The current precautions to protect the workers from the adverse effects of ultra-low RH appear to be insufficient, indicating that additional measures such as selection of appropriate clothing to mere skin coverage should be considered. (J Occup Health 2003; 45: 133–136)

Key words: Low relative humidity, Dry air environment, Adverse health effect, Skin symptom, Atopic dermatitis, Cross-sectional study

Field Study

The indoor air environment of modern buildings is customarily extremely airtight and highly controlled, though may still exhibit inadequate ventilation. Poor air-conditioning can cause adverse health effects, such as “sick building syndrome”, in workers or inhabitants. In Japan, there is legislation which regulates temperature, relative humidity (RH), air flow, and concentration of dusts, carbon dioxide and carbon monoxide in large buildings, in order to prevent diseases related to a poor indoor air environment and to ensure the comfort of workers (Table 1). With regard to the concentration of indoor dust, about 60% of buildings failed to achieve the standard in the early ‘70s, but the proportion has declined rapidly since late ‘70s. By comparison, the 30% of buildings that did not achieve the standard for RH has shown no improvement during the last three decades, mainly because of the high proportion of buildings experiencing a very dry air environment during the cold winter time. In winter, air-conditioning maintenance of an adequate RH is even more difficult to attain, and as a consequence, the RH of indoor air is less than 40% in nearly 90% of large buildings. In addition to the general problems associated with the dry air environment in buildings, specialized industries such as high-tech devices manufacturers require less than 5% RH. Workers exposed to non-physiological extreme ultra-dry environments may develop various related signs and symptoms. While preceding studies have reported that dry environment in chambers or buildings, where the RH ranged

Table 1. Six items of the legal standards for the indoor air environment for the maintenance of sanitation in building in Japan

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>17°C to 28°C</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>40% to 70%</td>
</tr>
<tr>
<td>Air flow</td>
<td>&lt;0.5 m/s</td>
</tr>
<tr>
<td>Dust</td>
<td>&lt;0.15 mg/m³</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>&lt;10 ppm</td>
</tr>
</tbody>
</table>

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between 40% and 10%, caused dry symptoms and deterioration of allergic diseases, there has been no previous report on the adverse effects of ultra-dry environments on workers health.

In order to assess the adverse health effects of exposure to the ultra-dry environment and the associated effectiveness or otherwise of current preventative measures taken, we have performed a questionnaire survey of self-reported symptoms among the workers in an ultra-dry room of a research and development (R & D) laboratory of a company.

**Materials and Methods**

The subjects of the study were workers in an R & D laboratory of a company, which consisted of several buildings and had tens of various rooms for R & D experiments of new products, paper works and administration.

The laboratory employed over 200 full-time workers, mainly working indoor. Eighty-five percent of them were men. Three quarters of them were researchers, and others were office workers or engineers. While the researchers did their own experiments regularly staying in certain rooms, the duration they stayed in each room for experiments or paper works varied very much.

If necessary, air environment of each room was tailored and maintained at a certain condition. Some rooms were kept dustless and other few rooms with melting-pots tended to rise in temperature. One room named ultra-dry room was strictly kept away from moisture at 20°C of temperature. In other rooms, temperature was not strictly controlled but moderately maintained at between 20°C and 28°C depending on the season. Relative humidity was not intentionally controlled in these rooms. Several organic solvents (mainly acetone, toluene, and some others) were widely utilized in many experimental rooms including the ultra-dry room. However, exhaust cabinets and latex gloves were used to prevent workers from their inhalation and absorption.

The ultra-dry room was kept airtight and maintained at 2.5% RH and temperature of 20°C by means of dedicated air-conditioning. To maintain the ultra-dry air, the fresh air was initially dehumidified by cooling to –30°C, followed by returning the cooled air to 20°C with no humidification. With dry air, row materials (minerals) mixed with organic solvent were dried up to make high-tech devices. These procedures were undertaken in exhaust cabinets to ensure that no organic solvent vapor was inhaled by the workers. The workers prepared the reagents in a chamber beside the ultra-dry room. For paper works, another room was used. Their duration staying in each room varied widely.

A cross-sectional study was undertaken using a self-reported survey questionnaire in late November, 2001.

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**Table 2.** Self-completed questionnaire item list provided to workers in high-tech device manufacturing company utilizing an ultra-dry room

<table>
<thead>
<tr>
<th>Demographic features</th>
<th>Age</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure</td>
<td>Whether or not worked in the ultra-dry room</td>
<td>The length of stay in the ultra-dry room (h/wk)</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Skin symptoms</td>
<td>Dry skin, itchy skin, rush, and dermal pain</td>
</tr>
<tr>
<td></td>
<td>Eye symptoms</td>
<td>Dry eye, itchy eye, ophthalmic pain, and weak vision</td>
</tr>
<tr>
<td></td>
<td>Nose symptoms</td>
<td>Nasal congestion, rhinorrhea, nasal bleeding, and impaired smelling</td>
</tr>
<tr>
<td></td>
<td>Mouth and throat symptoms</td>
<td>Sore throat, discomfort of throat, dry throat, and hoarseness</td>
</tr>
<tr>
<td></td>
<td>Lung symptoms</td>
<td>Cough, phlegm, bloody phlegm, and shortness of breath</td>
</tr>
<tr>
<td>Others</td>
<td>History of atopic dermatitis and bronchial asthma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smoking status</td>
<td>Pack-year</td>
</tr>
</tbody>
</table>
Questionnaire details included age, sex, history of exposure to ultra-dry environment, symptoms, history of illness, and life style (Table 2). The measure of exposure was the length of time worked in the ultra-dry room. A total of 20 related exposure symptoms categorized into five groups (four symptoms each) were specified. Each category was designated as a positive response if at least one symptom of the group was reported.

Additional related morbidity indicators monitored included past or present illnesses of atopic dermatitis and bronchial asthma, together with smoking status (pack-year). Statistical relationships among these variables were analyzed with non-parametric tests (Fisher’s exact test and Wilcoxon’s test). We granted it statistically significant if p value was below 0.05.

**Results**

Twelve workers were found to have worked in the ultra-dry room (exposed group) and 143 workers had never worked in the ultra-dry room (non-exposed group). The remaining 63 subjects were excluded from the analysis because of their incomplete questionnaires. In the ultra-dry room, workers wore long-sleeved clothing, paper masks and caps, and latex gloves. The latex gloves were the same as what workers wore in other experimental rooms. Except for personal glasses or contact lenses, no special glasses were worn to protect their eyes. In order to avoid the unwanted humidifying effect, water-drinking, mask-humidifying and hand-washing were prohibited in the ultra-dry room. Cigarette-smoking was also prohibited in the ultra-dry room. However, workers could freely go out of the ultra-dry room for drinking and smoking.

Response to the questionnaire was summarized in Table 3. In the exposed group, work time in the ultra-dry room per week (the length of stay) ranged from 1 h to 40 h. The exposed group reported skin symptoms more frequently than did the non-exposed group. Within the exposed group, six workers who stayed longer than 14 h/wk complained more often than did the other six who stayed less. Workers in the exposed group also tended to complain more often of eye symptoms than did the non-exposed group, though the difference between the two groups was not significant. Prevalence of nose, mouth and throat, and lung symptoms did not differ between the groups.

With regard to other subject variables, ages were younger and prevalence of atopic dermatitis was higher in the exposed group. However, while working in the ultra-dry room, most of atopic dermatitis did not appear in the exposed group. Other variables, such as the smoking pack-year, showed no significant difference between the two groups.

**Discussion**

In summary, the exposed group reported skin symptoms
more often than did the non-exposed group. Though statistically not significant, the exposed group also tended to complain of eye symptoms more often and the prevalence of atopic dermatitis was significantly higher in the exposed group.

As the number of the exposed subjects is small, our results could have arisen merely by chance. In addition, age difference between the exposed and non-exposed group could cause confounding bias. The relationship among the organic solvents, latex gloves, skin symptoms and atopic dermatitis requires consideration. Each of them by itself causes itching and dryness of skin and might fully account for the reason why the exposed group complained of skin symptoms more often. Recently, dermatitis caused by latex gloves, which are widely used among the workers handling organic solvents, has attracted attention. Likewise, allergic reaction against organic solvents and latex gloves might exist in our study. However, those in non-exposed group who used the same organic solvents and latex gloves did not show skin deterioration. Allergic reaction induced by organic solvents and latex may, if exist, exacerbated in the ultra-dry environment. Concerning atopic dermatitis, job placement to the ultra-dry room did not consider their past history of the disease. Symptom deterioration or anxiety about skin disorder may have contributed increased reporting of dermatitis in the exposed group.

Our findings are in accordance with previous research into the health effects of low RH environment. Andersen reported that about 10% RH was associated with dry symptoms affecting the eyes, mucus membrane and skin. Wyon and Nordstrom described an improvement of dry symptoms and “sick building syndrome” by humidification. Reinikainen reported a decrease in symptoms of allergic reactions in office workers consequent to an elevation in humidity from 20% to 40% RH. These results indicate that symptoms of dryness, sick building syndrome, and allergic reactions may occur even in a moderately dry environment. We assume that the exposure to the ultra-low RH air may exacerbate the skin symptoms and the disease similar to the preceding researches. On the other hand, we could not detect any signs or symptoms that are specific to the ultra-dry environment in the present study.

Despite the current skin coverage precautions to prevent the adverse effects of the ultra-dry environment, the exposed subjects complained more frequently of skin and eye symptoms. However, the exposure did not relate to reported nose, mouth, throat, and lung symptoms. In the environment at 2.5% RH, the humidifying effect of the paper mask by the self-exhaled air may be protective for the airways. Direct exposure of unprotected eyes to ultra-dry air may also cause eye symptoms.

With regard to skin protection, further consideration is required. Our survey suggests that mere coverage with long-sleeved clothing, cap and gloves was insufficient to protect the skin from the adverse health effects of the ultra-dry environment. Irritation by static electricity and allergic reaction to the fabric of the clothing may specially relate to the skin symptoms under the ultra-dry environment. To avoid these adverse effects on workers’ skin, additional counter measures such as selection of appropriate clothing or reduction of static electricity-evoking materials may be needed.

Laviana has reported that eye discomfort was most pronounced after 4 h exposure to 10% RH. Hence, for workers in an ultra-dry environment, a shortening in the duration of continuous work and provision of additional intermittent rest periods may also be an effective preventive measure to reduce the adverse health effects.

In conclusion, in order to determine the effective preventive measures to counter the adverse health effects of the ultra-dry environment, further studies are required. Detailed interviews to examine the subject history of the pertinent disease signs and symptoms and exposure to the ultra-dry environment, as well as experimental research into modifications in the duration of exposure and selection of appropriate clothing, would be informative.

References