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Exposure and acute exposure-effects before and after modification of a contaminated humidification system in a synthetic-fibre plant

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Abstract Objective: Follow-up study of exposure and acute exposure-effects after modification to steam humidification of a contaminated cold water system which had caused an outbreak of humidifier fever in a synthetic-fibre plant. Methods: Before and after modification of the system aerobiological measurements were performed. Concentrations of fungi and bacteria, in colony forming units (cfu) per m$^3$, were measured by stationary air sampling with an Andersen sampler. Endotoxin levels (pg/m$^3$) were determined by Limulus Amoebocyte Lysate (LAL) assay in pooled dust from personal air sampling. An indication of exposure levels of oil-mist was obtained by monitoring with a direct reading optical photometer. Changes as acute exposure-effects in spirometry and white blood cell count, during an afternoon shift were compared in exposed and non-exposed workers before and after modification. Results: Measured levels of fungi, total bacteria, Gram-negative bacteria and endotoxins both before and after modification were below levels which would be expected to be associated with the exposure-effects. However, after modification, we found that the statistically significant differences in levels of bacteria and endotoxins with a department without humidification no longer existed. Mean oil-mist concentrations were below 1 mg/m$^3$, with short-time peak exposure during certain tasks of up to 5 mg/m$^3$. Before modification, in exposed workers there was significantly more decline of spirometry, and more increase of white blood cell count during the first afternoon shift, compared with non-exposed workers. In exposed workers, the white blood cell count increase was positively associated with decline of spirometry. After modification, differences between exposed and non-exposed workers no longer existed. Conclusion: Follow-up investigation of acute exposure-effects demonstrated the effectiveness of remedial actions taken against a contaminated humidification system. Follow-up of exposure-effects in particular is recommended when there is doubt about the interpretation of exposure measurements.

Key words Humidifier fever · Endotoxin · White blood cell count · Spirometry · Intervention · Oil-mist

Introduction

After an outbreak of humidifier fever in a department of a synthetic-fibre plant, remedial actions were taken. Patients were transferred to another department, but more importantly, the humidification system was changed after cleaning operations proved to be unsuccessful. The cold water system was transformed to a steam humidification system. Effectiveness of this modification may be evaluated by follow-up of exposure levels [29], but even more important is the follow-up of exposure-effects.

As far as we know, there are only few studies with this type of follow-up data [8, 11, 12, 26, 29]. In previous papers [18, 28] we showed data of exposure-effects such as lung function (changes), sensitisation parameters (skin tests, serology) and changes in white blood cell counts, of exposed workers in plants with contaminated humidification systems, before remedial actions took place.

In this paper we describe the results of a follow-up investigation which compares changes of lung function and white blood cell count during an afternoon shift, in
workers before, and 1 year after installation of a steam humidification system. Follow-up data of the serology and skin tests of workers in another plant have already been published [22].

### Subjects and methods

**Study population**

In the department of the fibre plant where the outbreak of humidifier fever took place, polyester technical yarn is wound, heated and stretched by various machines. In one area of the department, at the time of the humidifier fever outbreak, the air was already humidified with a steam humidification system, but there was open access to the air of another part of the plant which was humidified with a recirculating cold water system. Job-rotation for workers within this department was on a weekly basis.

On two occasions before (4 and 2 years), and 1 year after replacement of the cold water system with a steam humidification method, spirometry and/or white blood cell count changes during an afternoon shift were investigated in a random sample of exposed and non-exposed workers. Non-exposed workers in the same plant worked in a winding department where air was not humidified. Table 1 shows the number of workers in the various subgroups, who participated in the investigations.

All three investigations took place in December and January, the first in 1985, the second in 1987, and the third in 1991, 1 year after the modification. Because of the previously mentioned job-rotation within the exposed group, it was not possible to perform the investigations on each occasion on the same worker working at the same machine. In addition, the non-exposed group did not consist of the same workers at each investigation. There was no transfer from the exposed to the non-exposed category in the study population between the three investigations.

Data about respiratory symptoms and smoking habits were derived from a self-administered shortened Dutch version of the British Medical Research Council (BMRC) standardised questionnaire, at the first two investigations. At the first session, some items about work-related symptoms were added, and at the third, only smoking habits were recorded.

At all three investigations, spirometric measurements were performed with a Vici-test-5 dry rolling seal spirometer (Mijnhardt, The Netherlands). Workers were studied during a 5 day afternoon shift (2–10 p.m.) at the first investigation on day 1 (2 p.m., 6 p.m., 10 p.m.), day 2 (2 p.m.) and day 5 (2 p.m.); at the second on day 1 (2 p.m., 10 p.m.), day 2 (2 p.m., 10 p.m.) and day 5 (2 p.m., 10 p.m.); at the third on day 1 (2 p.m., 10 p.m.) and day 5 (2 p.m., 10 p.m.). On each occasion the results of the spirogram with the highest forced vital capacity (FVC) and one-second forced expiratory volume (FEV1) of at least three acceptable tests were used for analysis.

**Exposure measurements**

During the period of the second and third investigations in December and January, aerobiological investigations were performed. The levels of viable fungal spores, total numbers of bacteria and Gram-negative bacteria were expressed as colony forming units/m³ (cfu/m³).

Air samples were taken by Andersen sampler (sampling time 8–10 min, flow 33.5 l/min). Stages were loaded with Petri dishes containing different culture media for total bacteria, Gram-negative bacteria and fungi.

Endotoxin concentrations were determined per work area from pooled personal dust samples (PAS-6 2 l/min, Whatman CF/A glass-fibre filters) using the Limulus Amoebocyte Lysate (LAL) assay according to a previously described procedure [17].

In the 3 years between the second and third investigations, levels of bacteria and fungi were also measured outside of winter months. These measurements were performed to evaluate the effectiveness of the cleaning operations of the cold water humidification system.

During the process of heating and stretching of the yarn, the applied lubricating oil-film is partly released as mist and vapour within the machine. Oil-mist monitoring with an infrared scatter-detector (Hund TM data) was carried out in the neighbourhood of the yarn machines at air breathing height during the performance of different tasks.

**Statistical analysis**

Differences in mean exposure levels of fungi, bacteria and endotoxins before and after modification and between departments were tested by t-test (two-sided) after logarithmic transformation.

Changes of lung function and white blood cell count were tested univariately by t-test and with multiple linear regression analysis using time (2 p.m., 10 p.m.), day (1, 2, 5) and exposure group as independent variables.

Correlation between changes of lung function – expressed in percentages of their predicted values – and white blood cell count was tested with univariate linear regression.

Data were analysed with Statistical Analysing System version 6.09 (SAS).

### Results

**Exposure measurements**

Levels (cfu/m³) of total bacteria and Gram-negative bacteria were significantly lower after the humidification system was changed, and were no longer different from those in the department without humidification (Table 2). Before and after modification, measured levels of fungi did not differ between the cold water area and the department without humidification. Surprisingly, both in the cold water area and in the department

<table>
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<tr>
<th>Table 1 Number of workers participating in the various investigations</th>
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<tbody>
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<td>Before modification</td>
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*a Only changes in white blood cell count were investigated*