Respiratory disease in workers exposed to colophony solder flux fumes: Continuing health concerns

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The objectives of this study were to establish the prevalence of respiratory, eye, nose and throat symptoms of likely work-relation in workers exposed to colophony solder flux fumes and to assess their lung function. A cross-sectional study was conducted in four medium-sized electronics firms in which control measures to capture solder flux fume were absent or visibly ineffective. All female solderers and women working adjacent to soldering stations completed an administered questionnaire concerning symptoms, work history and current soldering frequency. Measurements were made of their forced vital capacity (FVC) and forced expiratory volume in one second (FEV₁) during the course of a working shift, using a Vitalograph-Compact portable spirometer. Using weekly hours of soldering as a crude index of current exposure, workers were classified into high (£ 37 h/wk) and low (≤ 20 h/wk) exposure groups, and their health responses were compared in the analysis. Individuals with symptoms suggestive of work-related asthma were also asked to provide serial peak flow measurements over a further 2-week period, and adequate returns were charted and read by two physicians experienced in the diagnosis of occupational asthma. Data were collected on 152 female workers (overall participation rate = 97%). Symptoms of recurrent, persistent wheeze and/or chest tightness were reported by 75 (49%) of interviewees; 36 (24%) gave a history typical of occupational asthma and six more (4%) a history of pre-existing asthma worsened at work. Twenty-one (14%) of the workforce complained of recurrent breathlessness on moderate exertion; 41 workers (27%) had work-related symptoms of the nose or throat and 25 (16%) had work-related eye symptoms. The odds ratios for 'all wheeze', shortness of breath, and work-related eye symptoms were all significantly greater (raised about 4-5 fold) in women who soldered £ 37 h/wk when compared with those soldering ≤ 20 h/wk. After adjustment by logistic regression for atopy, age and smoking status even higher risk estimates were generally obtained. The odds ratios (OR) and 95% confidence intervals (CI) for high vs. low were: for 'all wheeze', OR = 7.2, CI = 2.5-20.7; for work-related eye symptoms, OR = 5.2, CI = 1.4-19.8; for work-related nasal symptoms, OR = 4.0, CI = 1.4-11.1 and for occupational asthma symptoms, OR = 5.2, CI = 1.4-14.2. Mean FEV₁ and FVC percentage difference from expected were slightly lower in full-time solderers than in part-time solderers, but the differences were not significant. Thirty-seven of the 51 workers (73%) who were asked to carry out serial peak flow measurements completed an adequate return: 27 of these records confirmed the presence of asthma, and in all of the cases the history suggested onset post-dating employment in soldering. Eleven peak flow records were indicative of occupational asthma. The health problems associated with colophony solder flux were documented over 18 years ago, but are still clearly apparent in situations where adequate control has not been achieved.

Key words: Colophony; occupational asthma; rosin; soldering.

INTRODUCTION

Soft soldering is a wide-spread industrial activity, most typically performed by hand using a cored solder wire...
containing the flux colophony. Colophony, the non-
steam volatile fraction of pine sap, is a natural product
with well-known irritant and allergenic properties. The
material is ancient (it was described by Pliny in 77
AD\(^1\)), but the first description of colophony-induced
asthma occurred as recently as 1976.\(^2\) Subsequently
in one factory, 22% of solderers or people working
near soldering processes were found to be suffering
from occupational asthma.\(^3\) From other investigations
it was concluded that occupational asthma due to
colophony fume inhalation was a significant cause of
sickness absence and labour turnover;\(^4\) hence the true
extent of ill-health was suspected to have been even
higher. As many as 67% of female solderers exhibited
respiratory symptoms in a study of five electronics
facilities.\(^5\)

Sensitization is likely to apply in only a proportion
of sufferers, as colophony fume can also cause direct
bronchial irritation, and in five of 21 patients in one
study it was noted that asthma was pre-existing but
had been exacerbated.\(^2\)

The capacity of colophony-based solder fume to
cause occupational asthma is widely accepted: data
from the SWORD surveillance scheme\(^6\) records it as
one of the foremost causes of occupational asthma
noted by occupational and respiratory physicians in
the UK; the linkage has been accepted for DSS compensa-
tion purposes for several years; colophony solder
fume is listed as one of the top tier respiratory sensi-
tizers in Health and Safety Executive (HSE) literature;\(^7,8\) and at least one HSE publication\(^8\) suggests
that Regulation 11 of the Control of Substances to
Health (COSHH) Regulations 1988 is likely to require
a programme of health surveillance in solderers with
potential exposure to colophony fume. Unfortunately
it is still common experience for the Executive to
encounter companies that do not provide fume control
measures (COSHH Regulations 7 and 8), health sur-
veillance (Regulation 11) or information, instruction
and training in relation to this hazard (Regulation 12).
This report describes a survey of respiratory health
conducted by HSE’s Employment Medical Advisory
Service (EMAS) in four medium-sized electronic
companies where such concerns existed.

COMPANIES AND PROCESSES

Company A manufactured electrical hardware for the
automotive industry. In October 1993 an EMAS visit
identified inadequacies in the local exhaust ventilation
(LEV) provided to capture the solder fume. Nearly
all of the solderers soldered full-time (\(\geq 37\) h/wk). At
three-quarters of work stations there was visible failure
of the LEV to capture the solder fume. The use of
solder appeared excessive, and the extraction system
filter sometimes became blocked in the course of a
single day.

The survey at factory A followed discovery of these
deficiencies in the extraction system. Factories B, C
and D were selected as premises at which extraction
facilities were also identified as substandard. These
factories were all within a 10-mile radius of Factory
A. They were identified during a routine programme
of HSE inspection visits, and surveyed within 18
months of each other.

Company B manufactured domestic electrical appli-
cances. Hand soldering was undertaken routinely in
the assembly of printed circuit boards, coil windings
(non-polyurethane) and allied operations. LEV was provided
at approximately one-quarter of the work stations but
fume capture appeared ineffective at most of the
extraction points. A majority of the workers soldered
full-time, but two-fifths soldered less frequently (\(\leq 20\)
h/wk).

Companies C and D produced printed circuit
boards, telecommunication and cash handling equip-
ment. At company C no extraction was provided; and
in company D it functioned poorly. A third of the
employees in these companies soldered full-time. Tack
soldering was widely employed as a prelude to auto-
mated flow soldering, and the manual assembly of
circuit board components further curtailed actual
exposure times, so that employees in companies C and
D appeared to be less heavily exposed than those from
A and B.

OBJECTIVES

The objectives in these two surveys were: (1) to
establish the prevalence of respiratory, eye, nose and
throat symptoms in workers exposed to colophony
solder fumes, and to estimate the proportion that
appeared to be work-related and (2) to assess lung
function in these workers as compared with normalized
or expected values, and to determine the relation
between abnormalities and exposure. As the solderers
were with few exceptions female, this report is confined
to health effects in women exposed to solder fume.

METHODS

Subjects and symptom enquiries

All female solderers from these companies, including
those initially absent from work, were asked to par-
ticipate in the investigation. In addition, walk-through
surveys at each of the companies identified women
working in close proximity to soldering processes and
these were included in the study population. Each
participant attended a medical interview at which a
health questionnaire was completed and a measure-
ment made of lung function. The clinical assessments
were performed by two doctors and two nurses from
EMAS who had previously attended a training session
aimed at standardizing interview and measurement
techniques.

Chronic respiratory symptoms were recorded using
a modified version of the Medical Research Council questionnaire on respiratory symptoms\(^9\) with additional questions on occupational asthma and work-related eye and nose symptoms. The questionnaire was similar to the World Health Organization model,\(^10\) and included detailed enquiries concerning occupational history, smoking habits, precipitants, seasonal pattern, and the onset and temporal pattern of symptoms in relation to work activities. In particular, the following questions were asked concerning chest tightness and shortness of breath:

- Are your symptoms worse at any particular time of the day or night? (Separate answers were recorded for working and non-working days; times were recorded in relation to meals and/or work)
- Do your symptoms occur on any particular day/bedays of the week? (Responses were recorded using a 0–3 severity rating for each day)
- Is there a difference in your symptoms when you are on holiday for a week or more? (If yes, whether better or worse).

Broadly similar questions were asked concerning the relation of nasal and ocular symptoms to work.

Subjects with wheeze/chest tightness were classified as belonging to one of four categories — namely, wheeze/chest tightness that was:

- long-standing and stable ('always wheezed, not worse now' or more simply 'old wheeze');
- long-standing but exacerbated with apparent work relationship ('always wheezed, worse now at work' or 'worse wheeze');
- of maturity onset, post-dating work in the vicinity of soldering fume but with no clear occupational time pattern ('new wheeze in a solderer' or 'new wheeze');
- new, post-dating work as a solderer with clear temporal association with work activity ('history suggestive of occupational asthma').

The presence and pattern of eye, throat and nasal symptoms (gritty eyes, sore eyes, epiphoria, rhinorrhoea, sneezing, nasal blockage) were also identified, and were classified as work-related if worse at work and better away from it. Finally, enquiry was made concerning chronic cough and sputum (cough or sputum present on most days for at least 3 months) and significant exertional dyspnoea (taken to be: breathlessness walking with other people of the subject's own age on level ground; and/or having to stop for breath when walking at her own pace on level ground).

Lung function measurements

Two parameters of lung function were measured: forced vital capacity (FVC) and forced expiratory volume in one second (FEVi). Subjects were seen during the course of a working shift. Assessments were conducted over a similar period of the working day at each company site, and individuals were processed in an order that was independent of prior assessments of exposure. Measurements were made using a Vitalograph-Compact portable spirometer calibrated for volume on a twice daily basis. Procedures were performed in accordance with the American Thoracic Society Standards for spirometric measurements,\(^11\) and the results were compared with the predicted normal values defined by Quanjer.\(^12\)

Individuals were instructed in the use of a Wright's mini peak flow meter and asked to provide serial peak flow readings at 2-hour intervals over waking hours during two consecutive weeks if they had one of the following clinical attributes:

- 'history suggestive of occupational asthma';
- 'always wheezed, worse now at work' or
- 'new wheeze in a solderer' with either work-related eye, nose or throat symptoms or FEVi/FVC\% \(\leq\) 75%.

Adequate records were charted and read by two occupational physicians experienced in the diagnosis of occupational asthma.

Evidence of asthma was taken to be diurnal peak flow variability regularly exceeding 15% over the 2-week period. A peak flow diagnosis of occupational asthma was based on work-related changes, such as diurnal declines exceeding 15% in the working week as compared with weekends, holidays or other periods away from work.

Exposure estimation

No detailed hygiene estimates of exposure were available for these workplaces. However, questionnaire information was collected on individuals' weekly hours of current employment in soldering (or in the vicinity of soldering operations), and workers' own estimates were checked against those of their managers (there was close agreement). Current intensity of exposure was thus crudely categorized as 'high' (\(\geq\) 37 h/wk; \(n = 88\)), 'intermediate' (21–36 h/wk; \(n = 14\)) or 'low' (\(\leq\) 20 h/wk; \(n = 44\)). For six subjects exposure information was missing. As the intermediate exposure group was much smaller than the other two groups, analyses by exposure category have been restricted to comparisons between the 'high' and 'low' exposure groups (comprising 90% of those for whom exposure information was available).

Statistical methods

Data from the study were analyzed using the SPSS statistical software package. In comparing the frequency of reported symptoms in 'high' and 'low' exposure groups, odds ratios (ORs) and 95% confidence intervals (CI) were calculated. The risk estimates for eye and nose symptoms, breathlessness, wheeze, chronic
cough and chronic sputum production were adjusted by logistic regression to allow for the potential confounding influence of smoking status (current smoker, ex-smoker and non-smoker), age (in five bands: ≤ 20, 21-30, 31-40, 41-50, > 50 years) and allergic predisposition (as indicated by personal history of hayfever or eczema, or a prior history of wheeze, chest tightness or asthma). Since subjects with pre-existing asthma, wheeze or chest tightness were considered ineligible for a diagnosis of occupational asthma or new asthma of recent onset, comparative risk estimates for these two conditions were confined to those with no such prior history (n = 131), and adjustment was made for age, smoking status and a past history of eczema/hayfever only.

RESULTS

Participation rate, and subject characteristics
The overall participation rate was 97% (152 subjects). Table 1 provides further information on the characteristics of the study sample, overall and in high and low exposure categories. Full-time solderers (≥ 37 h/wk) were slightly older on average than part-time solderers (≤ 20 h/wk), but had been employed in soldering for fewer years; they more commonly had a personal history of hayfever or eczema and were somewhat more likely to be smokers, although the prevalence of lifetime non-smoking was similar in the two groups.

Symptom prevalence
Table 2 details the prevalence of chest, eye, nose and throat symptoms, overall and in high- compared with low-exposure groups. Complaints of recurrent, persistent wheeze and/or chest tightness were identified in 75 (49%) of women. Of these, 36 (24%) appeared to have symptoms suggestive of occupational asthma, and a further six (4%) had pre-existing symptoms worsened by work. The overall prevalence of work-related nose and throat complaints was 27% (41 cases), and that of work-related eye symptoms was 16% (25 cases). Twenty-one subjects (14%) complained of breathlessness when walking at their own pace or with other people at an ordinary pace on level ground, and 33 (22%) complained of current cough lasting more than 3 months.

Wheeze commonly co-existed with other symptoms. Thus, among those with a complaint of recurrent or persistent wheeze 30% also complained of work-related eye, nose or throat symptoms; 14% had dyspnoea; and 20% complained of a chronic cough or chronic sputum production.

Symptoms were generally more common in the high exposure group than in the low exposure group (Table 2). The ORs for 'all-wheeze' (OR = 4.2, CI = 1.9-9.3), occupational asthma symptoms (OR = 4.7, CI = 1.5-14.3), dyspnoea (OR = 5.0, CI = 1.1-22.9) and work-related eye symptoms (OR = 4.0, CI = 1.1-14.3) were all significantly raised. The relative risks of work-related nasal complaint, new unexplained wheeze and chronic sputum were also higher, but pre-existing wheeze occurred with similar frequency in the two groups.

In the logistic regression model, after allowance for the effects of age, smoking and a history of allergic tendency, higher risk estimates were obtained for 'all wheeze' (OR = 7.2, CI = 2.5-20.7), occupational asthma symptoms (OR = 5.2, CI = 1.8-14.2) and work-related symptoms of the eyes (OR = 5.2, CI = 1.4-19.8) and nose (OR = 4.0, CI = 1.4-11.1); other estimates not significantly elevated (Table 2).

Lung function assessments
The mean FEV1 and FVC (expressed as a percentage of their predicted values), were slightly lower in the high exposure group when compared with the low, but differences were small and not clinically or statistically significant (Table 3). Nor was there a significant difference between those with and without wheeze, with the exception of a significant decrement in FEV1 (mean = -12.7%, CI = -21.3 to -4.1) in those with a prior history of asthma. A single measurement of lung function did not correlate well with symptom or exposure category.

Table 1. Characteristics of participants by exposure intensity category

<table>
<thead>
<tr>
<th>Age in yrs: mean (range)</th>
<th>Weekly hours of soldering*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n = 152)</td>
<td>≤ 20 h/wk (n = 44)</td>
</tr>
<tr>
<td>Age in yrs: mean (range)</td>
<td>35.6 (17-63)</td>
</tr>
<tr>
<td>Yrs employed in soldering: median</td>
<td>5.0</td>
</tr>
<tr>
<td>Smoking status</td>
<td>No. %</td>
</tr>
<tr>
<td>Current smoker</td>
<td>69 45.4</td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>28 18.4</td>
</tr>
<tr>
<td>Non-smoker</td>
<td>55 36.2</td>
</tr>
<tr>
<td>History of eczema, hayfever or wheeze</td>
<td>51 33.6</td>
</tr>
</tbody>
</table>

* Excludes 20 subjects with intermediate exposure or absent exposure information.
Table 2. Frequency of symptoms by exposure category

<table>
<thead>
<tr>
<th>Symptom category</th>
<th>All</th>
<th>Weekly hours of soldering</th>
<th>Crude odds ratio (95% CI)</th>
<th>Adjusted ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 152)</td>
<td>≤ 20 h/wk (n = 44)</td>
<td>≥ 37 h/wk (n = 88)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Work-related eye symptoms</td>
<td>25</td>
<td>16.4</td>
<td>3</td>
<td>6.8</td>
</tr>
<tr>
<td>Work-related nose symptoms</td>
<td>41</td>
<td>27.0</td>
<td>7</td>
<td>15.9</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>21</td>
<td>13.8</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Chronic cough</td>
<td>33</td>
<td>21.7</td>
<td>8</td>
<td>18.2</td>
</tr>
<tr>
<td>Chronic sputum</td>
<td>18</td>
<td>11.8</td>
<td>3</td>
<td>6.8</td>
</tr>
<tr>
<td>All wheeze</td>
<td>75</td>
<td>49.3</td>
<td>12</td>
<td>27.3</td>
</tr>
<tr>
<td>Occupational wheeze</td>
<td>36</td>
<td>23.7</td>
<td>4</td>
<td>9.1</td>
</tr>
<tr>
<td>New wheeze (? cause)</td>
<td>18</td>
<td>11.8</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Old wheeze, worse at work</td>
<td>6</td>
<td>3.9</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Old wheeze</td>
<td>15</td>
<td>9.9</td>
<td>4</td>
<td>9.1</td>
</tr>
</tbody>
</table>

a As defined in the text.
b Excludes 20 subjects with intermediate exposure or absent exposure information.
c Figures are generally adjusted for smoking status (current, ex- and non); age (in five bands, ≤20 yr, 21–30 yr, 31–40 yr, >50 yr), and past history of eczema, hayfever and prior wheeze.
d These figures are adjusted for smoking status and age (as above), and for past history of eczema and hayfever. Analysis is confined to subjects with no prior history of wheeze (n = 131, see text).

Table 3. Lung function parameters by exposure category

<table>
<thead>
<tr>
<th>Exposure group</th>
<th>FEV1% difference from predicted</th>
<th>FVC% difference from predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Mean (95% CI)</td>
</tr>
<tr>
<td>≤ 20 h/wk</td>
<td>42</td>
<td>1.94 (-3.25–7.12)</td>
</tr>
<tr>
<td>≥ 37 h/wk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptom category</td>
<td>No wheeze</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>All wheeze</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Occupational wheeze</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>New wheeze (? cause)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Old wheeze</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Old wheeze, worse at work</td>
<td>6</td>
</tr>
</tbody>
</table>

a Eight missing observations.
b Nine missing observations.

Serial peak flow meters were offered to 51 employees, and 37 (73%) completed a return that was adequate for charting. In the others, the most common reason for rejection was insufficient information (10 individuals). Four workers resigned their post before peak flow data could be collected.

The peak flow returns of 27 subjects showed evidence of asthma, and in all of these cases the history suggested maturity onset of disease, post-dating work as a solderer. Sixteen of these came from company A (27% of its entire soldering workforce). The charts of 11 workers showed evidence of definite or likely occupational asthma. Given the compliance difficulties inherent in obtaining adequate peak flow returns, these are likely to represent minimum estimates of the size of asthmatic health problems in these workers.

DISCUSSION AND CONCLUSIONS

Our survey had several limitations. We were not able to make direct measurements of airways reactivity by challenge testing (generally regarded as the gold standard). Nor did we make direct measurements of colophony fume in the workplace. The number of hours per week spent soldering is a crude proxy for
exposure, and imperfectly reflects the personal variation in exposure. The study also suffered the disadvantage of being cross-sectional: irritant health effects are likely to depend on current exposure, but other outcomes may depend on previous rather than current exposure.

However, we attach weight to our findings because of the consistent picture that they provide. Symptoms of wheeze and chest tightness were often associated with cough and dyspnoea, the expected accompaniments of asthma and work-related symptoms of the chest and the eyes, nose and throat tended to occur in association. Work-related symptoms were most evident in individuals who spent more hours a week using a solder iron, so despite its inherent limitations, our proxy exposure estimate correlated well with the presence of symptoms. The findings are further underpinned by serial peak flow evidence of occupational asthma; and are of a very similar magnitude to those in previous published reports.

The size of effect nonetheless bears comment. In an essentially similar survey of blue collar American workers from workplaces vetted and deemed to be sensitizer-free, after allowance for differences in smoking habit, complaints of wheeze and chest tightness were approximately six times less common. Furthermore, our data suggest that labour turnover may be acting here, as in other studies, to obscure the true extent of the problem. Thus, the high exposure group, despite being somewhat older, had spent fewer years in soldering and the median duration of employment in subjects with wheeze (4 years) was also significantly less than in subjects without wheeze (6 years, \( p = 0.01 \)). It should also be noted that health complaints in this survey were not only frequent, but sometimes severe and career threatening.

The effects of colophony are well known. The surprise, perhaps, is that we can still discover them so readily 18 years after the report of Burge et al., and with a frequency little diminished by the passage of time. Our investigation highlights the health problems arising from a known but sometimes neglected hazard. The health issues are not new, but they are still with us. It behaves health and safety professionals to continue to remind managers of the need for vigilance in the use of this common industrial material.

ACKNOWLEDGEMENTS

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