



# **Coal mine dust as a benchmark for standards for other poorly soluble dusts**

Partial Position Report

Prepared by **Institute of Occupational Medicine**  
for the Health and Safety Executive 2006

**RESEARCH REPORT 470**



# Coal mine dust as a benchmark for standards for other poorly soluble dusts

## Partial Position Report

**BG Miller, HA Cowie & CA Soutar**  
Institute of Occupational Medicine  
Research Park North  
Riccarton  
Edinburgh  
EH14 4AP

An extensive programme of research provides the legacy of an atypically comprehensive database on the respiratory health and exposure experienced by thousands of coalminers, collected at intervals during their working life. The development of generic standards for poorly soluble dusts would be greatly aided if health risks quantified for coal dust were a good surrogate for those of other low toxicity dusts.

We compared the published effects of low toxicity mineral dust exposures on lung function (FEV1) in four occupational groups (talc workers, coal miners, PVC workers and heavy clay workers), with some additional investigation of respiratory symptoms, standardising units and refitting comparable regression models where necessary.

Coalminers and talc workers had similar exposure levels on average. PVC workers had lower average exposure levels, but this may have been due, at least in part, to an underestimation of cumulative dust exposure in this population (noted at the time of the original study). Coalminers showed a decline of 0.19 standardised units of FEV1 for each 100 units increase in dust exposure, 0.26 standardised units in talc workers and 0.66 units in PVC workers. Relative risks of reporting symptoms were very similar for coalminers and heavy clay workers, but could not be calculated for talc or PVC workers.

Allowing for possible underestimation of the PVC exposures, these risks of respiratory ill health were clearly of the same orders of magnitude in the occupations studied. Further more detailed cross-sectional or longitudinal analyses on the coalminers' data sets are thus likely to be informative about risks of dusty exposures in other industries.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

© *Crown copyright 2006*

*First published 2006*

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the prior written permission of the copyright owner.

Applications for reproduction should be made in writing to:  
Licensing Division, Her Majesty's Stationery Office,  
St Clements House, 2-16 Colegate, Norwich NR3 1BQ  
or by e-mail to [hmsolicensing@cabinet-office.x.gsi.gov.uk](mailto:hmsolicensing@cabinet-office.x.gsi.gov.uk)

# CONTENTS

|     |  |    |
|-----|--|----|
| 1   | BACKGROUND   | 1  |
| 2   | AIMS   | 3  |
| 3   | DESCRIPTION OF STUDIES   | 5  |
| 3.1 | Talc workers ( <i>Wild et al., 1995</i> )                            | 5  |
| 3.2 | Coal miners ( <i>Cowie et al., 1999, SOUTAR et al. 1988</i> )        | 5  |
| 3.3 | PVC dust workers ( <i>Soutar et al., 1980, Soutar et al., 1981</i> ) | 5  |
| 3.4 | Wool textile workers ( <i>Love et al., 1988, Love et al., 1991</i> ) | 6  |
| 3.5 | Opencast miners ( <i>Love et al., 1994</i> )                         | 6  |
| 3.6 | Heavy Clay workers ( <i>Love et al., 1999</i> )                      | 7  |
| 4   | ASSOCIATION BETWEEN LUNG FUNCTION AND EXPOSURE TO DUST               | 9  |
| 4.1 | Study groups included  | 9  |
| 4.2 | Comparison of dust effects   | 9  |
| 5   | ASSOCIATION BETWEEN RESPIRATORY SYMPTOMS AND EXPOSURE TO DUST        | 13 |
| 5.1 | Study groups included  | 13 |
| 5.2 | Comparison of dust effects   | 13 |
| 6   | DISCUSSION   | 15 |
| 6.1 | Background and scope of study  | 15 |
| 6.2 | Comparability of study groups included                               | 15 |
| 6.3 | Association between lung function and dust exposure                  | 15 |
| 6.4 | Association between respiratory symptoms and dust exposure           | 16 |
| 6.5 | Implications for Workers' Health                                     | 17 |
| 6.6 | Conclusions  | 17 |
| 7   | REFERENCES   | 19 |



# 1 BACKGROUND

The Health and Safety Executive (HSE) requested a position paper that explores the potential to use coal mine dust as a benchmark for developing generic standards for poorly soluble dusts in general. In particular, two elements are required:

“

- a. Characterisation of the exposure-response relationships for coal mine dusts and COPD, using lung function and respiratory symptoms data as diagnostic markers. The lung function could be expressed in various ways, and if it is possible to use the rate of decline of FEV<sub>1</sub> over time as the index of effect then that would be desirable. It may be necessary to express the lung function values as percentages of standardised predicted values if this is the only way to allow comparisons with data sets on other dusts.
- b. Evaluation of suitable existing datasets on other dusts that have been studied by the IOM or elsewhere, comparing them with the coal mine dust data. The aim will be to see whether coal mine dust is of similar potency to other poorly soluble dusts that are not known to be intrinsically toxic.

The paper was to confine itself to epidemiological data and would be used in HSE to help judge the adequacy of the current COSHH position on dusts that are otherwise not classified.”

The broad aims of the programme of work are to review the epidemiological evidence that might justify applying quantitative risks of COPD derived from coal miners' studies to low solubility dusts in general, and to conduct some analyses of existing data to complete the picture of exposure-response relationships for COPD related to exposure to coal mine dust. This report represents the first step in the process: the production of a partial position report written on the basis of existing publications and results, with some reanalysis of IOM data for comparability with other publications.



## 2 AIMS

This position report's aim is to summarise published and available information on the exposure-response relationships between cumulative dust exposure and lung function in coalminers (IOM data) and workers exposed to other poorly soluble dusts, and to compare risk estimates. It was not expected that the risk estimates would be identical: even for dusts without specific chemical toxicity, there will be differences in risk. Causes of this variation include particle size differences, and possibly differences in peaks of exposure. Even so, the comparisons will indicate whether the risks are in the same region or not.

The tasks to achieve the overall aim were as follows:

1. Examination of a study of talc workers reported by Wild *et al.*, 1995.
2. Study of the most recent robust risk estimates (Cowie *et al.*, 1999) from IOM coal mine dust studies re-expressed in comparable forms to the talc reports. This required converting the FEV<sub>1</sub> measurements to residuals after standardising by the ECSC equations, and rerunning the IOM regression analyses on the standardised residuals.
3. Comparisons were also made with IOM studies of opencast miners, heavy clay, wool textile and polyvinyl chloride (PVC) workers (some analyses of these data had already been conducted on behalf of HSE, (Cowie *et al.*, 1995) and did not need to be repeated). In some cases the comparisons required translations of different exposure metrics into comparable forms.
4. The magnitudes of the effects were compared between coal mine and other dusts. The comparisons were not subjected to formal statistical analyses, because we did not have access to Wild's original data. The means and reported distributions are compared descriptively.

This brief report describes the risks in coal miners, and their comparability with those in other dusty industries.



## 3 DESCRIPTION OF STUDIES

### 3.1 TALC WORKERS (WILD *ET AL.*, 1995)

This was a study of 166 current workers in a talc factory in France, who participated in a medical survey in 1989, which included spirometry, respiratory symptoms questionnaire and chest radiography. In 1992 radiography was repeated for all subjects still employed at that date (n=139). Presence of chronic bronchitis was defined as cough and phlegm for at least 3 months a year for at least two consecutive years. Lung function variables included FEV<sub>1</sub>, FVC and their ratio. Lung function variables were standardised as the number of residual standard deviations from the ECSC predicted values, i.e. as (observed minus predicted) divided by residual SD. Residual SD values were extracted from Quanjer, 1983 and were equal to 0.61 for FVC and 0.51 for FEV<sub>1</sub>. Cumulative exposure to talc dust was calculated using measurements from a cross-sectional survey including 1440 samples from 52 exposure groups. Cumulative exposure ranged from under 20 to over 500 mg.m<sup>-3</sup>.years. Relatively few subjects had exposures greater than 200 mg.m<sup>-3</sup>.years.

Dr Pascal Wild was contacted to determine whether updated results were available from the follow-up study of this group of workers. He reported that no further results were available.

### 3.2 COAL MINERS (COWIE *ET AL.*, 1999, SOUTAR *ET AL.* 1988)

The association between lung function (FEV<sub>1</sub>) and cumulative exposure to respirable dust was examined in a group of over 7000 men who attended the fifth round of medical surveys as part of the UK Pneumoconiosis Field Research (PFR) programme in the late 1970s. Presence of chronic bronchitis was defined as presence of cough and phlegm for as much as 3 months in the year. Lung function values were taken as the maximum of three technically satisfactory spirometric measurements (where possible: 73 of the 7188 participants completed only one or two valid tests but were retained in the study group). Cumulative exposure to coalmine dust was estimated from the extensive sampling programme of dust sampling undertaken as part of the PFR programme. The arithmetic average cumulative dust exposure was 136 gh.m<sup>-3</sup> (approximately equivalent to 78 mg.m<sup>-3</sup>.years, assuming a 1740 hour working year) and ranged from 0.15 to 726 gh.m<sup>-3</sup> (0.1 to 417 mg.m<sup>-3</sup>.years).

The 7188 men represent the largest study group in which the association between lung function and dust exposure has been recently examined, and they provide the principal group of coalminers for this position paper. However, in a separate study, 1671 current and ex-workers from three coalmines situated in South Wales, Yorkshire and North East England were surveyed between 1981 and 1986 (Soutar *et al.*, 1988). This group, although from only a subset of coalmines, provides useful information on the association between respiratory symptoms and exposure to coal dust. Average cumulative dust exposures in this group were 205 gh.m<sup>-3</sup> (range 0 - 676 gh.m<sup>-3</sup>), 151 gh.m<sup>-3</sup> (0 - 396 gh.m<sup>-3</sup>) and 103 gh.m<sup>-3</sup> (0 - 344 gh.m<sup>-3</sup>) in the collieries in South Wales, Yorkshire and North-East England. These values were equivalent to 118 mg.m<sup>-3</sup>.years (range 0 - 388 mg.m<sup>-3</sup>.years), 87 mg.m<sup>-3</sup>.years (range 0 - 228 mg.m<sup>-3</sup>.years) and 59 mg.m<sup>-3</sup>.years (range 0 - 198 mg.m<sup>-3</sup>.years) respectively. Average dust concentrations at the three collieries were 4.3 mg.m<sup>-3</sup>, 3.1 mg.m<sup>-3</sup> and 2.2 mg.m<sup>-3</sup> respectively over total time in the industry ranging from 1 year to over 50 years, with a mean of around 25 years.

### 3.3 PVC DUST WORKERS (SOUTAR *ET AL.*, 1980, SOUTAR *ET AL.*, 1981)

This was a cross-sectional study of 818 workers exposed primarily to PVC dust; 663 were current workers, 98 pensioners and 57 leavers. The selection was designed to include a high proportion of men exposed to higher levels of PVC dust for prolonged periods, together with

samples of those men likely to have been exposed to less or no dust. An index of cumulative dust exposure to PVC was derived, based on results of an environmental survey of current dust levels (130 samples) and occupational histories gathered at the time of survey. Lung function levels were taken as the maximum of three technically satisfactory expirations. Respiratory symptoms were characterised as chronic cough, sputum and chronic cough OR sputum. Chronic bronchitis (chronic cough and sputum) was not analysed.

Cumulative dust exposure index ranged from 0 to 82.8 mg.m<sup>-3</sup>.years with an average of 13.4 mg.m<sup>-3</sup>.years for current workers, 14.2 mg.m<sup>-3</sup>.years for pensioners and 4.9 mg.m<sup>-3</sup>.years for leavers. It was noted that these values were approximate as only current (not historical) dust levels were known. A follow-up survey of 229 workers in this factory, who had not been included in the previous study, plus 127 workers from another PVC factory nearby was carried out in 1981.

### **3.4 WOOL TEXTILE WORKERS (LOVE *ET AL.*, 1988, LOVE *ET AL.*, 1991)**

A total of 2151 current workers (1655 men, 496 women) in the wool textile industry in the UK attended medical survey in the 1980s. Of those surveyed, 592 were of Asian origin, of whom 385 opted to be interviewed in Urdu. Participants in the survey completed a respiratory symptoms questionnaire, translated into Urdu where appropriate, and provided a lifetime occupational history. No lung function testing was done. Presence of chronic bronchitis was defined as presence of cough and phlegm for as much as 3 months in the year. A total of 629 measurements of current dust concentrations were made during a hygiene survey. Each individual was allocated the current mean inhalable dust concentration of the occupational group and mill in which he worked at the time of survey. Total weekly dust exposures and total time in the wool industry were also calculated. It was considered unrealistic to estimate cumulative dust exposures for each employee owing to uncertainties about previous dust concentrations in the mills and conditions in previous jobs. Nine per cent of employees were exposed to inhalable dust concentrations in excess of 10 mg.m<sup>-3</sup>, and 5% to concentrations over 25 mg.m<sup>-3</sup>.

Subsequently, a subgroup of 634 employees from 5 of the original mills participated at a second medical survey at which chest radiographs were taken and simple spirometry carried out. Lung function levels were taken from the 'best' flow volume curve from three technically satisfactory tests (where possible) with largest FVC (and largest FEV<sub>1</sub> where more than one curve had the same maximum FVC).

### **3.5 OPENCAST MINERS (LOVE *ET AL.*, 1994)**

A cross sectional study of current workers (1224 men, 25 women) was carried out at nine large and medium opencast sites in England, Scotland and Wales. Selection of sites was intentionally weighted towards longer term sites in an attempt to ensure inclusion of workers with longest exposures. Since only 25 women (mostly secretarial and catering staff) attended medical survey, they were excluded from the analysis.

A total of 626 measured concentrations of respirable dust were available, collected over a period of nearly one year covering all four seasons, from 26 occupational groups. Detailed occupational histories for each individual enabled the calculation of time in years spent in each of five exposure groups, comprising groups of occupations with similar exposure levels. However, because the spread of dust concentrations within many occupational groups was wide and for many groups the number of available samples was relatively small, it was decided there was too much uncertainty in assigning average concentrations to each occupational group. As a result estimation of cumulative lifetime exposures was not attempted. Presence of chronic

bronchitis was defined as presence of cough and phlegm on most days for as much as three months each year. Lung function levels were taken as the maximum of three technically satisfactory expirations. Four of the 1224 men did not complete the spirometric tests and were excluded from the analysis.

### **3.6 HEAVY CLAY WORKERS (LOVE *ET AL.*, 1999)**

A cross-sectional study of 1925 current employees (1852 men, 73 women) in 18 heavy clay factories in the UK was carried out in 1990-1. Since there were relatively few women, none of whom had any notable radiological abnormality, they were excluded from the statistical analysis. A total of 1407 occupational hygiene samples were taken in a cross-sectional survey, for the estimation of concentrations of dust and quartz, summarised in 12 occupational groups. These were combined with lifetime occupational histories to provide estimates of individual cumulative exposures to dust and to quartz. Presence of chronic bronchitis was defined as presence of cough and phlegm on most days for as much as three months each year. No lung function measurements were made.

Almost all cumulative dust exposures were less than 100 mg.m<sup>-3</sup>.years, with a very few between 100 and 300 mg.m<sup>-3</sup>.years. Average cumulative exposures ranged from 6.2 to 23.5 mg.m<sup>-3</sup>.years across the 18 sites surveyed, with an overall mean cumulative dust exposure of 15.5 mg.m<sup>-3</sup>.years.



## 4 ASSOCIATION BETWEEN LUNG FUNCTION AND EXPOSURE TO DUST

### 4.1 STUDY GROUPS INCLUDED

In five of the six study groups, the association between lung function and occupational factors was investigated. The exception was the heavy clay workers, where no lung function measurements were taken. In the talc workers, coal miners and PVC dust workers, FEV<sub>1</sub> was analysed in relation to an index of cumulative dust exposure and in all three of these study groups a significant association between level of FEV<sub>1</sub> and dust was found, after adjustment for age, physique and smoking.

In wool textile workers, levels of FEV<sub>1</sub> were examined in relation to mill, current dust concentration and hours worked per week in three subgroups of the population (European men, European women and Asian men). Results varied between the groups, with levels of FEV<sub>1</sub> varying by mill among European women. However, the mill differences did not reflect differences in levels of dust within the mills. There was no evidence of any other associations between FEV<sub>1</sub> and occupational factors in any of the three subgroups.

Among the opencast workers, no association was found between time in dusty jobs within or outwith the opencast industry and any measure of lung function.

Comparisons of dust effects on lung function are thus examined in detail for talc workers, coalminers and PVC dust workers only.

### 4.2 COMPARISON OF DUST EFFECTS

#### 4.2.1 Talc workers

Lung function variables were standardised as the number of residual standard deviations from the ECSC predicted values, e.g. as (observed – predicted)/residual SD. Residual SD values (0.61 for FVC and 0.51 for FEV<sub>1</sub>) were extracted from Quanjer, 1983. FEV<sub>1</sub> (expressed as numbers of residual standard deviations) showed a significant decrease with increasing cumulative exposure, with an average decline of 0.26 units associated with a 100 mg.m<sup>-3</sup>.year increase in exposure, after adjustment for smoking in the form of packyears and time since stopped smoking. A similar decrease was seen in FVC (-0.24) suggesting a mixed obstructive and restrictive effect on lung function. There was no evidence of an interaction between smoking and dust effects. It was noted that 30 subjects were excluded from the lung function analyses due to invalid spirometric tests, and that these subjects may be more ill than those who participated.

#### 4.2.2 Coal miners

FEV<sub>1</sub> was analysed using multiple linear regression models of the observed value, and adjusting for age (linear and non-linear effects), height, smoking and cumulative exposure. There was a significant association between FEV<sub>1</sub> and cumulative exposure with an average decline of 0.51ml per gh.m<sup>-3</sup>. This slope is equivalent to 0.89ml per mg.m<sup>-3</sup>.year and is of similar magnitude to effects demonstrated in earlier analyses of PFR data sets.

For better comparability of these results with the talc workers' study, the coal miners' data were re-analysed. For these analyses, observed FEV<sub>1</sub> was transformed to numbers of residual standard deviations as used in the Wild *et al* paper and cumulative dust exposure was

transformed to  $\text{mg.m}^{-3}.\text{years}$ . The regression analyses were re-run on the transformed variables, with models fitted which included a term for smoking group and a term for cumulative exposure. Because Wild *et al* had also excluded workers who were unable to complete three technically satisfactory spirometric tests, the re-analyses were also run excluding the 73 coal miners who completed fewer than three lung function tests. The results of the re-analyses are summarised in Table 1. This table is a re-expression of the results reported in Cowie *et al*, 1999 so that the magnitude of the coefficients can be compared directly with those reported by Wild *et al*.

**Table 1** Coal workers: results from regression model of FEV<sub>1</sub> expressed as number of residual standard deviations from predicted value. Table shows coefficient and the ratio (in italics) of the coefficient to its standard error. Ratio values of 2 or more indicate statistical significance at the 5% level

|  | <i>Model 1</i><br><i>Including all subjects</i> |              | <i>Model 2</i><br><i>Excluding subjects with &lt;3 tests</i> |              | <i>Model 3</i><br><i>With age/smoking interaction : all subjects</i> |             |
|--|---|--------------|--|--------------|--|-------------|
| Constant   | -0.23   | <i>-1.1</i>  | -0.03  | <i>-1.0</i>  | -0.23*   | <i>-6.3</i> |
| Age: Non-smoker  |   |              |  |              | -0.009   | <i>-3.6</i> |
| <b>Additional age slope for:</b>                       |   |              |  |              |  |             |
| Current cigarette smoker                               |   |              |  |              | -0.018   | <i>-6.9</i> |
| Current pipe smoker                                    |   |              |  |              | -0.021   | <i>-2.9</i> |
| Ex-smoker  |   |              |  |              | -0.022   | <i>-6.2</i> |
| <b>Smoking (vs Non-smoker)</b>                         |   |              |  |              |  |             |
| Current Cigarette smoker                               | -0.33   | <i>-9.0</i>  | -0.32  | <i>-8.7</i>  | -0.26*   | <i>-7.3</i> |
| Current pipe smoker                                    | -0.21   | <i>-2.9</i>  | -0.20  | <i>-2.8</i>  | 0.05*  | <i>0.5</i>  |
| Ex-smoker  | -0.11   | <i>-2.3</i>  | -0.10  | <i>-2.2</i>  | 0.04*  | <i>0.8</i>  |
| Cumulative exposure ( $\text{mg.m}^{-3}.\text{year}$ ) | -0.0046   | <i>-20.5</i> | -0.0046  | <i>-20.9</i> | -0.0018  | <i>-6.5</i> |
| Residual ss  |   | 9874         |  | 9637         |  | 9400        |
| Residual df  |   | 7169         |  | 7096         |  | 7165        |
| Residual ms  |   | 1.38         |  | 1.36         |  | 1.31        |

\* At age 40

It can be seen from this table that exclusion of those who did not complete three technically satisfactory results changed the regression model only very slightly. The decrease in FEV<sub>1</sub> was 0.46 units per 100  $\text{mg.m}^{-3}.\text{year}$  compared to 0.26 units for talc workers.

No information on packyears smoked, or time since stopped smoking were easily accessible for this study group. As a surrogate for packyears an age by smoking interaction term was included in the model. As the response variable was already standardised for age and physique, it would be expected that there would be no residual effect of age on standardised FEV<sub>1</sub> among non-smokers, and that any additional effect of age among current and ex-smokers might reflect the effect of packyears. Results from this analysis are shown in Table 1, and show that there was an unexpected residual age effect among non-smokers. The effect of age was, however, significantly steeper among smokers, perhaps reflecting an association with packyears in these groups. After inclusion of the age/smoking interaction, the decrease in FEV<sub>1</sub> with dust exposure was much less steep at 0.19 units per 100  $\text{mg.m}^{-3}.\text{year}$ , approximately comparable to the coefficient in the talc workers.

### 4.2.3 PVC workers

Both FEV<sub>1</sub> and FVC levels were significantly lower in men exposed to higher levels of PVC dust, principally among current smokers. After adjustment for age, height and weight, FEV<sub>1</sub> decreased on average by 4 ml per mg.m<sup>-3</sup>.year in the study group as a whole and by 7 ml per mg.m<sup>-3</sup>.year among current smokers. These slopes were substantially steeper than those found for coal miners, although it should be remembered that the cumulative dust index for the PVC workers was more approximate (as it was based on current dust concentrations only, rather than historical data) than for the coalminers, and was probably an underestimate of the true value. If the analysis of the PVC workers was restricted to the 356 subjects with dust exposures which were based wholly on measured dust levels (though still current and not historical concentrations), the association between FEV<sub>1</sub> and dust exposure had a less steep slope (2.4 ml per mg.m<sup>-3</sup>.year) which was statistically non-significant, but was still much steeper than for the coal miners. Analysis of standardised data showed a decrease in FEV<sub>1</sub> (expressed as number of standardised residuals) of 1.35 units per 100 mg.m<sup>-3</sup>.year, which was considerably steeper than for the talc workers or coalminers.

It was possible in this group to adjust also for the effects of packyears on the model, and for an approximate estimate of years since smoking stopped among ex-smokers. The results of these analyses are shown in Table 2. This table shows results for the PVC workers directly comparable with results already presented for the coalworkers (Models 1 and 3 in Table 2 are directly equivalent to Models 1 and 3 in Table 1). Model 2 for the PVC workers in Table 2 includes the same terms as the regression model for the talc workers, as reported in Wild *et al.*, 1995. However, as no regression coefficients were reported in the Wild *et al* paper, it is not possible to make a direct comparison of the full models.

For PVC workers, there was a statistically significant effect of packyears, with levels of FEV<sub>1</sub> decreasing with increasing numbers of packyears. There was no association between FEV<sub>1</sub> and time since stopped smoking among ex-smokers. After adjustment for these additional variables, the decrease in FEV<sub>1</sub> associated with cumulative dust exposure was less steep at 1.06 units per 100 mg.m<sup>-3</sup>.year, but still much steeper than that for the talc and coal workers.

An alternative estimate of packyears, as used for the coalworkers described above is to examine the interaction of age and smoking. In the PVC workers (Table 2; model 3), there was no effect of age amongst non-smokers but a significant association between age and FEV<sub>1</sub> among current and ex-workers which is consistent with a packyears effect. When this variable is included in the model, the association between FEV<sub>1</sub> and dust exposure is even less steep, with a loss of 0.66 units per 100 mg.m<sup>-3</sup>.year, a value which is more consistent with the other study populations.

**Table 2** PVC workers: results from regression model of FEV<sub>1</sub> expressed as number of residual standard deviations from predicted value. Table shows coefficient and the ratio (in italics) of the coefficient to its standard error. Ratio values of 2 or more indicate statistical significance at the 5% level

|  | <i>Model 1</i> |              | <i>Model 2</i> |              | <i>Model 3</i> |              |
|--|----------------|--------------|----------------|--------------|----------------|--------------|
| Constant                                       | 0.155          | <i>1.50</i>  | 0.132          | <i>1.32</i>  | 0.101*         | <i>0.31</i>  |
| <b>Age:</b> Non-smoker                         |                |              |                |              | -0.001         | <i>-0.17</i> |
| <b>Additional age slope for:</b>               |                |              |                |              |                |              |
| Current cigarette smoker                       |                |              |                |              | -0.034         | <i>-3.91</i> |
| Current pipe smoker                            |                |              |                |              | -0.046         | <i>-2.70</i> |
| Ex-smoker                                      |                |              |                |              | -0.028         | <i>-2.92</i> |
| <b>Smoking (vs Non-smoker)</b>                 |                |              |                |              |                |              |
| Current Cigarette smoker                       | -0.521         | <i>-4.39</i> | -0.176         | <i>-1.21</i> | -0.338*        | <i>-2.84</i> |
| Current pipe smoker                            | -0.301         | <i>-1.60</i> | -0.321         | <i>-1.76</i> | 0.181*         | <i>0.72</i>  |
| Ex-smoker                                      | -0.201         | <i>-1.56</i> | 0.203          | <i>1.05</i>  | -0.005*        | <i>-0.04</i> |
| <b>Packyears:</b> Current smoker               |                |              | -0.035         | <i>-4.02</i> |                |              |
| Ex-smoker                                      |                |              | -0.051         | <i>-5.64</i> |                |              |
| Time since stopped smoking (Ex)                |                |              | 0.004          | <i>0.45</i>  |                |              |
| Cumulative exposure (mg.m <sup>-3</sup> .year) | -0.0135        | <i>-3.95</i> | -0.0106        | <i>-3.16</i> | -0.0066        | <i>-1.91</i> |
| Residual ss                                    |                | 1185         |                | 1110         |                | 1093         |
| Residual df                                    |                | 813          |                | 810          |                | 809          |
| Residual ms                                    |                | 1.457        |                | 1.371        |                | 1.351        |

\*At age 40

## 5 ASSOCIATION BETWEEN RESPIRATORY SYMPTOMS AND EXPOSURE TO DUST

### 5.1 STUDY GROUPS INCLUDED

In the six key study groups, only four reported any significant associations between the presence of respiratory symptoms and exposure to respirable dust. Among the opencast coalminers and wool textile workers there was no relationship between symptoms and exposure. The comparison of dust effects on symptoms therefore includes the talc, underground coal mining, PVC workers and heavy clay workers. The underground coalminers included in this section are from three collieries studied in the 1980s (see section 3.2 above).

### 5.2 COMPARISON OF DUST EFFECTS

#### 5.2.1 Talc workers

In the study of 166 talc workers, symptoms of chronic bronchitis, chronic cough or phlegm, dyspnoea and wheeze were analysed. Overall prevalence of chronic bronchitis was 5% (9 subjects), prevalence of chronic cough or phlegm was 17% (29 subjects), prevalence of dyspnoea was 11% (19 subjects) and prevalence of wheeze was 3% (5 subjects). A significant association of symptoms with cumulative dust exposure was found only for dyspnoea. No logistic regression coefficient is reported, although it is noted that the increasing trend with increasing exposure was confirmed by the logistic regression model that included age and smoking category. Prevalence of dyspnoea ranged from 4.4% in those with  $<20 \text{ mg.m}^{-3} \cdot \text{years}$  exposure, to 8% (20 to  $50 \text{ mg.m}^{-3} \cdot \text{years}$ ), 17% (50 to  $150 \text{ mg.m}^{-3} \cdot \text{years}$ ) and 14.6% in those with  $> 150 \text{ mg.m}^{-3} \cdot \text{years}$  exposure. It is not possible to derive, even approximately, the logistic regression coefficients without knowledge of the age and smoking distributions in the exposure groups.

#### 5.2.2 Coalworkers

In the study of 1671 coal miners from three collieries in England and Wales, symptoms of chronic bronchitis and breathlessness were analysed. A comparison of the prevalences of chronic bronchitis and breathlessness for the talc workers and coalminers is given in Table 3. It should be noted that breathlessness in talc workers referred to breathlessness when walking up a slight hill, while for coal miners it referred to breathlessness when walking with people of the same age. Prevalence of both symptoms was much higher among coalminers. This may be due at least in part to the older age of the coalminers (average age 48 years) compared to the talc workers (average age 40 years). In addition, the coalminers study group included miners who had left the industry at the time of survey, whereas the talc study group comprised current workers only.

**Table 3** Prevalence (%) of chronic bronchitis and breathlessness in talc workers and coal miners

| <i>Dust exposure group</i><br>( $\text{mg.m}^{-3} \cdot \text{years}$ ) | <i>Chronic bronchitis</i> |                   | <i>Breathlessness</i> |                   |
|---|---------------------------|-------------------|-----------------------|-------------------|
|   | <i>Talc workers</i>       | <i>Coalminers</i> | <i>Talc workers</i>   | <i>Coalminers</i> |
| <20   | 0                         | 15                | 4                     | 10                |
| 20-50   | 4                         | 18                | 8                     | 13                |
| 50-150  | 13                        | 29                | 17                    | 26                |
| >150  | 2                         | 52                | 15                    | 57                |
| All   | 5                         | 28                | 11                    | 26                |

Cumulative dust exposure was significantly positively related to the occurrence of chronic bronchitis with an increase in exposure of 100  $\text{gh.m}^{-3}$  (equivalent to 57.5  $\text{mg.m}^{-3}.\text{years}$ ) resulting in a relative risk of symptoms of chronic bronchitis of 1.3, compared to an individual of the same age, physique and smoking habit. Results for breathlessness were very similar to those for chronic bronchitis, with the risk of having breathlessness significantly higher among men with higher cumulative dust exposures, with the risk increasing by a factor of 1.4 for every 100  $\text{gh.m}^{-3}$  of dust exposure.

### 5.2.3 PVC workers

Detailed analysis of respiratory symptoms in relation to respirable dust was available only for the 818 men who attended the first medical survey (Soutar *et al.*, 1980). The reported prevalence of dyspnoea in this group was 26.3% (215 subjects) who reported 'shortness of breath when hurrying on level ground or walking up a slight hill'. The authors note that 'a dust effect approached significance after adjustment for age and smoking, and this effect was pronounced in current cigarette smokers after allowing for age and lifetime cigarette consumption, but not present in other smoking categories'. They conclude that it seems unlikely that the effect of PVC dust in symptoms alone is of clinical significance. No numerical results are presented.

### 5.2.4 Heavy Clay workers

The study of 1925 employees in the heavy clay industry investigated associations between cumulative dust exposure and chronic bronchitis, breathlessness and wheeze. There was a significant effect (OR for 40  $\text{mg.m}^{-3}.\text{years}$  = 1.5, 95% confidence interval 1.1 to 2.0) of exposure to dust on the presence of chronic bronchitis for all heavy clay workers combined, and for kiln demolition work alone (OR for 40  $\text{mg.m}^{-3}.\text{years}$  = 1.6, 95% CI 1.1 to 2.7), after adjustment for smoking, site and time worked in other industries. For breathlessness, again after adjustment for factors, there was a significant effect of exposure to dust in general (OR for 40  $\text{mg.m}^{-3}.\text{years}$  = 1.5, 95% CI 1.1 to 2.2) and to dust in kiln demolition work separately (OR for 40  $\text{mg.m}^{-3}.\text{years}$  = 1.5, 95% CI 1.0 to 2.1). Table 4 (extracted from the Love *et al.*, 1999 paper) shows the prevalence of chronic bronchitis and breathlessness by dust exposure group.

**Table 4** Heavy clay workers: prevalence of chronic bronchitis and breathless by dust exposure

| <i>Cumulative dust exposure<br/>(<math>\text{mg.m}^{-3}.\text{years}</math>)</i> | <i>% with chronic bronchitis</i> | <i>% with breathlessness</i> |
|--|----------------------------------|------------------------------|
| 0 – 4.9  | 13.9                             | 4.4                          |
| 5 – 9.9  | 13.4                             | 2.9                          |
| 10 – 19.9  | 15.6                             | 2.8                          |
| 20 – 39.9  | 12.8                             | 5.8                          |
| >40  | 17.8                             | 10.2                         |
| All  | 14.2                             | 4.4                          |

## 6 DISCUSSION

### 6.1 BACKGROUND AND SCOPE OF STUDY

This partial position report aimed to compare the effects of mineral dusts on respiratory health, focusing on lung function ( $FEV_1$ ) with some additional investigation of respiratory symptoms (chronic bronchitis and breathlessness). We focused on six occupational groups exposed to low toxicity mineral dusts, five of which had been studied previously by the IOM thus allowing some limited reanalysis of existing data sets where appropriate. A search of the published literature showed many other studies of respiratory health in relation to dust exposure, but these papers tended to refer to non-mineral dusts such as carbon black, rubber and grain. It was felt that the physical and chemical differences between these and mineral dusts meant that inclusion of them in the comparisons was not warranted.

### 6.2 COMPARABILITY OF STUDY GROUPS INCLUDED

The six occupational groups that formed the core of the review included coal workers, PVC workers, wool textile workers, opencast miners, heavy clay workers and talc workers. For two of these groups, cumulative exposure indices were not analysed in the original studies. The study of opencast workers had analysed health in relation to time in dusty jobs while the principal analyses of wool textile workers were based on dust concentration in current job. Cumulative exposure levels were similar in the talc workers and underground coalminers with median cumulative exposure in the talc workers of around  $50 \text{ mg.m}^{-3} \cdot \text{years}$  (range 20 to  $>500$ ) compared to a mean cumulative exposure among the coalworkers of  $78 \text{ mg.m}^{-3} \cdot \text{years}$  (range 0 to  $417 \text{ mg.m}^{-3} \cdot \text{years}$ ). Exposures among heavy clay workers and PVC workers were lower than for the coal and talc workers, but both groups had similar levels of exposure, with mean exposures of  $15 \text{ mg.m}^{-3} \cdot \text{years}$  and  $13 \text{ mg.m}^{-3} \cdot \text{years}$  respectively.

### 6.3 ASSOCIATION BETWEEN LUNG FUNCTION AND DUST EXPOSURE

In five of the six studies, lung function measurements had been collected and in three of these five groups there was a significant association between levels of  $FEV_1$  and cumulative exposure to respirable dust. It is notable that in the two occupational populations where such an association was not apparent, opencast workers and wool textile workers, cumulative exposure indices had not been analysed in the original studies. Nonetheless, no associations between lung function levels and time in dusty jobs (opencast workers) or dust concentration in current job (wool textile workers) had been found in these groups. It should be noted that exposures among opencast workers were comparatively low, as the workers tended to work the open air, rather than in the enclosed environments of the other occupations studied.

Comparisons of results between the remaining three populations were complicated by the inclusion of several smoking-related variables in the regression models relating loss of  $FEV_1$  to cumulative dust exposure. Different smoking variables were available for the three data sets and it was necessary to recreate regression models for the PVC and coal workers that were approximately equivalent to those published for the talc workers. The talc workers analysis used as a response variable  $FEV_1$  expressed as number of residual standard deviations from the value predicted from the ECSC prediction equations (denoted 'units' of  $FEV_1$ ), and included terms for smoking habit, pack years and, for ex-smokers, number of years since stopped smoking.

Pack year data were also available for the PVC workers, although it could not be determined whether these had been calculated in the same way as for the talc workers. For this group it was also possible to recreate an approximate 'time since stopped smoking' variable. For the

underground coalminers, neither of these variables was readily available in the data sets used. Therefore, for the coalminers and for the PVC workers (because of uncertainties about the precision of the available variables), additional analyses were carried out using an age by smoking interaction as a surrogate for pack years data.

Losses of FEV<sub>1</sub> per 100 mg.m<sup>-3</sup>.years were 0.26 units in the talc workers, 0.19 units for the coal workers and 0.66 units for the PVC workers using regression models as published for the talc workers and including terms for smoking habit and an age by smoking interaction for the coalminers and PVC workers. For the PVC workers, if the estimated pack years and 'time since stopped smoking' variables were used, the estimated loss of FEV<sub>1</sub> was higher at 1.06 units. It is reassuring that in the two study groups with the most similar exposure experiences, the estimated losses of FEV<sub>1</sub> with dust exposure are also of comparable magnitude.

It is curious that the steeper loss of lung function with dust exposure occurs in the PVC workers, the group with lower exposure levels. However, it was noted in the original report for this study that the cumulative dust index was based on current dust concentrations multiplied by time in jobs in the industry. It is possible that exposures further back in time were less well controlled and hence higher than those measured at the time of survey, leading to some underestimation in the calculation of cumulative exposures in this group. In addition, it seems probable that subjects with the highest cumulative exposures would be the most likely to have worked for longer periods in dustier conditions (i.e. that their higher exposures were due at least in part to having worked longer in the industry) and so to have underestimated cumulative exposure levels. Adjustment for this underestimation would result in less steep associations between FEV<sub>1</sub> and dust exposure, and would lessen the apparent differences in slope between these workers and those from the talc and coal industries.

#### **6.4 ASSOCIATION BETWEEN RESPIRATORY SYMPTOMS AND DUST EXPOSURE**

Association between respiratory symptoms and dust exposure was found only among talc workers, underground coalminers, PVC workers and heavy clay workers. As in the analyses of lung function, no significant associations were found between respiratory symptoms and exposures in opencast workers or in wool textile workers. Again this may be due to the fact that cumulative exposures were not analysed in these two study populations, and also to the low exposures experienced by the opencast workers. In addition, for the PVC workers, an association between PVC dust and mild dyspnoea was found in smokers only, and was not thought to be of clinical significance.

Among the talc workers, an increased prevalence of symptoms with increasing dust exposure was seen only for symptoms of dyspnoea, defined as breathlessness when walking up a slight hill. Symptoms of chronic bronchitis were also analysed but no association with dust exposure was apparent. However, this was a small study of only 166 workers with correspondingly low power to detect associations with a binary response variable such as respiratory symptoms (there were only 29 cases of chronic bronchitis and 19 of dyspnoea). The results of the statistical analyses of dyspnoea were published as prevalence of symptoms in four dust exposure groups, with a p-value given for trend. It was not possible to derive from this information the odds ratio for reporting symptoms associated with a specified increase in dust exposure.

In contrast, in both the heavy clay workers and underground coalminers, significant associations were found between cumulative exposure to respirable dust and symptoms of both chronic bronchitis and breathlessness (defined in both of these studies as breathlessness when walking with other people of your own age on level ground). Odds ratios for coalminers were expressed

per 100  $\text{ghm}^{-3}$ , equivalent to  $57 \text{ mg.m}^{-3} \cdot \text{years}$  and were 1.3 for chronic bronchitis and 1.4 for breathlessness. Results for heavy clay workers showed associations of symptoms with dust that were slightly steeper than, but of similar magnitude to, those found for the coalminers, with odds ratios per  $40 \text{ mg.m}^{-3} \cdot \text{years}$  of 1.5 for both symptoms.

## 6.5 IMPLICATIONS FOR WORKERS' HEALTH

It was not a principal aim of this position paper to examine the implications of the findings for workers' health, but rather to assess the comparability of low toxicity dusts from a variety of industries. The results of the study suggest that coal mine dust can be used as a reasonable surrogate for the estimation of the health impacts of dusts more generally and so it is possible to use the results of the limited re-analyses for this paper and our previous analyses of coalminers (Cowie *et al*, 1999) to make some overview observations on the effects of dust on lung health.

In interpreting the results for coal dust exposures, it is necessary to take account of the change to the ISO/CEN sampling convention introduced in 1997. Under the new convention,  $5 \text{ mg.m}^{-3}$  as measured in the 1970s is equivalent to  $4 \text{ mg.m}^{-3}$  at the present time. As noted in section 4.2.2, a decline of 0.89 ml of  $\text{FEV}_1$ , on average, is associated with an increase in cumulative dust exposure of  $1 \text{ mg.m}^{-3} \cdot \text{year}$ . A lifetime (40-year) exposure to an average of  $5 \text{ mg.m}^{-3}$  ( $4 \text{ mg.m}^{-3}$  using the ISO/CEN sampling convention) is therefore associated with an average deficit of  $\text{FEV}_1$  of 178ml. This loss will vary across workers, with a subset of miners being more susceptible to exposure to dust. Using results from Cowie *et al* we estimate that around 17% of coalminers with a working lifetime exposure to  $5 \text{ mg.m}^{-3}$  ( $4 \text{ mg.m}^{-3}$  ISO/CEN) will have a loss of  $\text{FEV}_1$  of 0.993 litres or more, compared to around 10% of unexposed men.

These estimates are based on a cross-sectional analysis of a group of coalminers and so are necessarily approximate. Similar analyses to those carried out for  $\text{FEV}_1$  would provide valuable information on other lung function variables, such as FVC and  $\text{FEV}_1/\text{FVC}$  ratio, while additional longitudinal analyses of this group of coalminers would provide more robust estimates of lung function loss associated with exposure to coalmine dust.

## 6.6 CONCLUSIONS

This partial position paper has reviewed the associations between respiratory health and cumulative dust exposure in a number of occupational study groups exposed to different types of mineral dusts of low toxicity. At the outset it was not expected that the risk estimates would be identical, due to differences between the dusts in, for example, surface properties and particle sizes. However, the results of the study have shown good consistency in the magnitude of lung function effects in the different study groups where associations were found.

The principal comparisons were carried out in four key occupational populations. The additional two groups included in the study had not analysed respiratory health in relation to cumulative dust exposure in the original studies, and in neither case were any associations found between lung function or respiratory symptoms and the dust exposure metrics used.

Associations between lung function and dust were found in three of the four key populations, with no lung function measurements available for the fourth group. There was little difference in the estimated risks in the two populations with the most similar exposure experience. The risks in the third population tended to be higher, but this may have been due, at least in part, to an underestimation of cumulative dust exposure in this population.

For respiratory symptoms the situation was similar, with significant associations between symptoms and cumulative dust exposure in three of the four key populations, but little evidence of an association in the fourth group. In one of the groups, an association was found for breathlessness only and the available information did not allow the expression of risks per unit dust exposure. In the other two populations, significant associations were found for both chronic bronchitis and breathlessness, with odds ratios of similar magnitude in the two groups.

In summary, this report has shown that risks of respiratory ill health in relation to cumulative dust exposure calculated for underground coalminers are reasonable predictors of risks in other dust exposed populations. There is some variability among the occupational groups studied in whether or not associations are apparent between lung function or symptoms and dust exposure, with the absence of such associations perhaps due partly to lack of statistical power (because of relatively small study groups or very low levels of dust exposure). Where associations exist between lung health and dust exposure, the extensive data available from the large coal dust populations provide comparable estimates of the extent of the risks in other occupational groups, and could be used to provide information on the health risks for workers exposed to other insoluble mineral dusts.

## 7 REFERENCES

- Cowie HA, Miller BG, Soutar CA. (1999). Dust-related risks of clinically relevant lung functional defects. Edinburgh: Institute of Occupational Medicine. TM/99/06).
- Cowie HA, Prescott GJ, Love RG, Miller BG, Soutar CA. (1995). The functional implications of chronic bronchitis in populations exposed to dust. Edinburgh: Institute of Occupational Medicine. TM/95/07).
- Love RG, Muirhead M, Collins HPR, Soutar CA. (1991). The characteristics of respiratory ill health of wool textile workers. *British Journal of Industrial Medicine*; 48: 221-228.
- Love RG, Smith TA, Gurr D, Soutar CA, Scarisbrick DA, Seaton A. (1988). Respiratory and allergic symptoms in wool textile workers. *British Journal of Industrial Medicine*; 45: 727-741.
- Love RG, Waclawski ER, Maclaren WM, Porteous RH, Groat SK, Wetherill GZ, Hutchison PA, Kidd MW, Soutar CA. (1994). Cross-sectional study of risks of respiratory disease in relation to exposure to airborne quartz in the heavy clay industry. Edinburgh: Institute of Occupational Medicine. TM/94/07).
- Love RG, Waclawski ER, Maclaren WM, Wetherill GZ, Groat S, Porteous R, Soutar CA. (1999). Risks of respiratory disease in the heavy clay industry. *Occupational and Environmental Medicine*; 56: 124-133.
- Quanjer PH, ed. (1983). Standardisation of lung function tests. Report of working party. *Bulletin Europeen De Physiopathologie Respiratoire*; 19 (Supplement 5):
- Soutar CA, Copland L, Thornley PE, Hurley JF, Ottery J, Adams WGF, Bennett B. (1980). Epidemiological study of respiratory disease in workers exposed to polyvinylchloride dust. *Thorax*; 35: 644-652.
- Soutar CA, Gauld SJ, Thornley PE, Copland L, Hurley JF, Ottery J, Adams WGF, Bennett B. (1981). Epidemiological and clinical studies of polyvinylchloride workers. Edinburgh: Institute of Occupational Medicine. TM/81/8).
- Soutar CA, Campbell SJ, Gurr DC, Lloyd MH, Love RG, Cowie HA, Cowie AJ, Seaton A. Cross-sectional studies of respiratory disease in British coalminers. Final report on CEC Contract 7248-31/009. Edinburgh: Institute of Occupational Medicine, 1989. (IOM Report TM/88/06).
- Wild P, Refregier M, Aubertin G, Carton B, Moulin J. (1995). Survey of the respiratory health of the workers of a talc producing factory. *Occupational and Environmental Medicine*; 52: 470-477.



**MAIL ORDER**

HSE priced and free  
publications are  
available from:

HSE Books  
PO Box 1999  
Sudbury  
Suffolk CO10 2WA  
Tel: 01787 881165  
Fax: 01787 313995  
Website: [www.hsebooks.co.uk](http://www.hsebooks.co.uk)

**RETAIL**

HSE priced publications  
are available from booksellers

**HEALTH AND SAFETY INFORMATION**

HSE Infoline  
Tel: 0845 345 0055  
Fax: 0845 408 9566  
Textphone: 0845 408 9577  
e-mail: [hse.infoline@natbrit.com](mailto:hse.infoline@natbrit.com)  
or write to:  
HSE Information Services  
Caerphilly Business Park  
Caerphilly CF83 3GG

HSE website: [www.hse.gov.uk](http://www.hse.gov.uk)

**RR 470**