COMPARISON OF DUST SAMPLING IN THE PERSONAL BREATHING ZONE WITH AREA SAMPLING USING THE VERTICAL ELUTRIATOR IN LANCASHIRE SPINNING MILLS

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Abstract

Four methods of dust sampling were compared in three cotton spinning mills in Lancashire. Two of these measured personal breathing zone dust (total inhalable dust and size-selective dust fractions). The other two methods estimated dust levels in the workzone (vertical elutriator and lint-free dust). No fixed convesion factors were identified between the various methods of dust sampling. The ratios between the various fractions varied with the mill and type of process. Generally, however, personal dust was greater than workarea dust, and elutriated levels were lower than other fractions. In the clean mill, however, elutriated dust levels were very similar to lint-free workarea levels and the thoracic fraction of personal dust.

Introduction

The association between dust levels in the textile workrooms and respiratory disease is well established. However, while there is agreement that a reduction in dust levels results in a corresponding decline in byssinosis and other respiratory symptoms, there is a lack of consensus about the method of dust sampling. Gravimetric analysis of textile workroom dust involves measurement of one or more of the following fractions: coarse dust, more than 2mm; medium dust, 7um - 2mm; fine dust, <7um. Roach and Schilling using a modified Hexhlet technique, estimated all three fractions in a cotton facility in 1960 (Roach 1960), and found that total dust correlated the best with symptoms (r=0.93). The relationship between fine dust and symptoms was weak (r=0.10). On the basis of these findings, they recommended cotton dust standards in the workroom , based on measurement of the total dust fraction. Since then, the total dust fraction has formed the basis of surveillance of the textile industry in the United Kingdom. To begin with, dust levels were estimated in the workroom. In the 1970's, the Hexhlet was replaced by Rotheroe and Mitchell pumps. The latter measured dust by trapping it on filters after air had been pre-filtered through 2mm square wire mesh. Large fibres or lint, being considered biologically inert, were excluded. The dust thus collected mainly consisted of medium and fine fractons mentioned above, although some larger particles were also represented. Large epidemiological studies (Molyneux and Tombleson 1970, Fox et al 1973) showed a good correlation between lint-free dust and symptoms. Cinkotai et al (1988) reported that levels of lint-free dust in the personal breathing zone correlated better with symptoms than workzone sampling. They also found a poor correlation between respirable dust and symptoms.. Later studies used a sampling head with known characteristics (Mark and Vincent 1986), to measure total dust in the personal breathing zone. Unlike the earlier methods, this sampler measured total dust without pre-filtration through 2mm wire mesh. Once again, a good correlation was observed between symptoms/impaired lung function and dust levels estimated with this device (Fishwick et al 1994, Fletcher et al 1990). Later on, it was demonstrated that for the same workroom, dust samples collected in the personal breathing zone could be several times as high as those estimated in the workzone (Niven et al 1992). Hence current United Kingdom standard of cotton dust in the workroom (2.5 mg/m3) is based on personal breathing zone dust sampling (HSE 1997). Recently, it has been stressed that exposures in the workplace should ideally be carried out using size-selective personal dust sampling. A personal sampling instrument, using porous foams, can select the thoracic and respirable subfractions of the inhalable fraction of total airborne particulates. This instument is based on the personal inhalable aerosol sampler developed by the Institute of Occupational Medicine, Edinburgh and comprises an inhalable entry and two selection foams in series between the entry and the collection filter (Aitken et al 1993). This device has not been used for the monitoring of the cotton workplace in the past.

In the USA, the recommendation of Roach and Schilling (Roach 1960) was adopted by the American Congress of Government Industrial Hygienists and was considered as the threshold limit value for cotton dust till the early 1970's (ACGIH 1971). However, the present method of cotton workroom dust sampling employs a vertical elutriator, which collects dust particles with a mass median diameter of 15 um and less (OSHA 1993). This is based on the assumption that larger particles are unlikely to be inhaled. Merchant et al (Merchant 1973) using this technique, showed a dose-response relationship for byssinosis upto elutriated dust levels of 1.0 mg/m3. The curves tended to flatten at higher levels. Jones et al1 (Jones 1979), however, concluded that mill effect and job category, rather than current dust exposure levels (elutriated dust), accounted for the distribution of byssinosis prevalence rates. Also, current levels of exposure did not have a significant effect on baseline lung function. In a more recently reported longitudinal study of a large textile workforce (Glindmeyer 1991), a dose response relationship was demonstrated for

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lung function decline, using elutriated dust. Thus, individually, both dust fractions (total dust and dust consisting of paticle size <= 15 um) have been reported to be associated with byssinosis and lung function decline in cotton textile workers manning processes upto and including winding. However, the performance of these four methods has never been directly compared in a cotton mill.

The pesent study, applied all four methods in a single workplace to define the relationship between them.

Methods

Population Surveyed

Three mills (clean, moderately clean and dirty)were surveyed. This ensured a comparison over a range of dust levels (low to high).

Personal Breathing Zone Dust Sampling

This was carried out on a random sample of openers, card room workers, doublers, winders and spinners. Each operative was sampled twice. The personal sampler developed by the Institute of Occupational Medicine (IOM), Edinburgh was used. It has a single barrel, in which an aluminium cassette is retained during sampling. The cassette and barrel are open faced with no pre-filter and the dust measured is "total inhalable dust". Dust collects on a 25 mm Whatman GFA micro-glass fibre, contained inside the cassette. A microbalance, with a readability of 0.001 mg was used to weigh the cassettes before and after mill visits. Control cassettes (not exposed in the mills but treated in the same way, otherwise) were used to provide a correction factor. This was added to or subtracted from the weight change of the test cassettes. In the mills, the cassettes were pinned to the lapels of the workers. These were connected to Casella AFC 123 pumps (flow rate 2 litres/min), worn on the waist for the duration of the shift. Pumps were switched off during breaks. The dust level in the personal breathing zone (total inhalable dust) was calculated from the corrected weight change, flow rate and sampling time.

For size selective sampling, a random sub-sample of workers from each occupational group were chosen in all three mills. Workers undergoing this method of sampling wore the IOM sampler for total inhalable dust on one lapel and the size-selective sampler on the other lapel. Size-selective sampling was carried out with the IOM sampler incorporating a thoracic selecting foam (45 pores per inch) in the barrel (the greater the number of pores per inch, the finer the fraction trapped on the filter paper). The same methodology as described above was used. Dust trapped in the foam was called the extrathoracic fraction and that collecting on the filter paper the thoracic fraction.

Workzone Sampling, Measuring Lint-Free Dust

Whatman GFA micro-glass fibre filters (37mm) were weighed before and after the sampling exercise, using a precision microbalance. The correction factor was obtained from the weight change of "blank filters". The test filters were placed in large volume dust samplers (60 litres/min, Rotheroe and Mitchell). A cage with 2mm pitch gauze mesh encases the sampling face after insertion of the filter paper into the filter clip. The gauze cage is believed to prevent dust fibres greater than 2 mm (the dust known as "fly") from being included in the sample. This is an inaccurate assumption as fibres of greater than 2 mm will pass through the gauze if they have a smaller "effective" diameter. These samplers were positioned in the work room at working height (1.5 metres) on aluminium ladders. Sampling time was approximately 4 hours. Flow rates were measured at the commencement of sampling and at approximately 10, 30 and 60 minutes and then hourly. This is to measure the early drop off of flow rate as the machine warms to full running temperature. Dust levels were calculated from available data (HSE 1980).

Workzone Sampling with the Vertical Elutriator

This method measures fine dust of particle size <= 15 um aerodynamic diameter. Methodology recommended by the Occupational Safety and Health Admin (OHSA 1993). Air was drawn through a plastic cassette (incorporating a filter membrane). A flow-limiting orifice, included in the circuit, generated a pressure drop of 17 inches of mercury. A pump (MCS 10, SKC instruments Ltd.) generating a flow rate of 7.4 litres/minute across the filter membrane was employed. The filter membranes were weighed before and after the mill visit (blank membranes provided the correction factor). The vertical elutriators sampled for 6 hours. Each wokarea was sampled with both methods at the same time.

Statistical Analysis

The geometric mean dust exposure was calculated for each identified workarea/worker in each mill (because dust exposure is not normally distributed). The values obtained by the different techniques were directly compared. The relative performance was assessed as a simple ratio for each site and mill.

Results

Three mills were studied. Mill 1 processed almost pure (85-90%), coarse cotton, mill 2 handled medium cotton blend and mill 3 fine cotton blend. Mill 1 was dirty, mill 2 moderately clean and mill 3 clean. Total inhalable dust in the personal breathing zone was measured in 47 workers (2 visits and 94 samples). Size-selective sampling in the personal breathing zone was performrd on 31 operatives. All individuals undergoing size-selective sampling also had total inhalable dust sampling performed on them. These two methods were grouped by work process for comparison with workarea sampling. 50 sites were used for area sampling (both methods simultaneously). Table 1 lists the geometric mean dust levels obtained from the four methods. In table 2, comparison of ratios derived from personal sampling are presented. Table 3 shows the ratios of dust estimation, using the two workarea sampling methods. Tables 4 and 5 list ratios obtained from comparison of workarea (vertical elutriator) with personal breathing zone dust.

Discussion

Levels obtained from personal breathing zone dust measurement were generally higher than workarea dust levels. Most of the personal breathing zone dust consisted of the extra-thoracic fraction. Ratios were compared across a range of dust exposures and work processes. No fixed conversion factor emerged. Total inhalable dust in the personal breathing zone was several times higher than that measured with the vertical elutriator. The disparity between the two was greater in the coarse mills and in the early processes. In such a setting, the symptoms are more common.

Lint-free dust levels in the workzone were generally 1-5 times greater than elutriated dust levels. Like personal levels, the difference was more obvious in mill 1. In the clean mill, on the other hand, the ratio was greater than 1. In the less dusty processes, the thoracic fraction was very similar to the elutriated levels. In the dusty processes, this relationship was lost.

In conclusion, therefore, the relationship between the various dust fractions varied with the dustiness of a mill, fibre type, cotton grade and workroom.

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Table 1. Mean dust levels by workarea and mill (mg/m^3).

	Area (VE)	Area (LF)	Personal (Total)	Personal (Thor)	Personal (E-Thor)
Mill 1					
Carding	0.38	1.79	6.25	0.80	4.04
Spinning	0.15	0.62	2.06	0.24	1.53
Winding	0.21	0.76	2.36	0.32	1.18
Open/blow	0.72	2.96	-	-	-
Mill 2					
Carding	0.12	0.31	0.90	0.20	0.69
Spinning	0.04	0.12	-	--	-
Winding	0.21	0.56	0.99	0.32	0.85
Open/blow	0.24	1.28	5.61*	2.85*	26.83*
Mill 3					
Carding	0.11	0.18	0.88	0.34	0.94
Spinning	0.18	0.25	0.90	0.11	0.97
Winding	0.21	0.07	0.38	0.24	0.41
Open/blow	0.11	0.28	-	-	-

*=single worker handling waste cotton in one mill.
VE=Area sampling with the vertical elutriator
LF=Area sampling, measuring lint-free dust
Personal=Personal dust sampling
Total=Total inhalable dust in the personal breathing zone
Thor=Thoracic fraction on size selective sampling in the personal breathing zone
E-Thor=Extrathoracic fraction on size selective sampling in the personal breathing zone
Mill 1=coarse cotton/dirty. Mill 2=medium cotton blend/moderately clean
Mill 3=Fine cotton blend/clean

Table 2. Ratios of dust levels obtained by the two personal breathing zone dust sampling methods (ratios of geometric means).

	Number sampled	Thoracic /Total	E-thoracic /Total	Thoracic/ E-thoracic
By mill				
Mill 1	8	0.16	0.68	0.23
Mill 2	6	0.23	0.85	0.27
Mill 3	13	0.40	1.27	0.38
By workarea				
Carding	10	0.32	0.93	0.34
Spinning	9	0.19	1.15	0.20
Wind/Doub	8	0.37	0.93	0.42

Thoracic= Thoracic fraction by size selective personal sampling.
E-thoracic= Extra-thoracic fraction by size selective personal sampling.
Total= Total inhalable dust in the personal breathing zone.

Table 3. Ratio of dust levels obtained by the two workzone sampling methods (ratios of geometric means).

	Number compared	Ratio (VE/LF)
By mill		
Mill 1	14	0.27
Mill 2	17	0.40
Mill3	18	1.29
By workarea		
Cardroom	20	0.48
Spinning	10	0.51
Winding/Doubling	12	1.39
Opening/Blowing	7	0.37

Ratio=Ratio of geometric mean of dust level by Vertical Elutriator (VE) and Lint-free area sampling (LF)

Table 4. Ratio of (geometric mean) elutriated dust and total inhalable dust in the personal breathing zone.

Area	Mill 1	Mill 2	Mill 3
Opening	-	0.05	-
Cardroom	0.07	0.12	0.11
Spinning	0.08	-	0.20
Winding	0.09	0.20	0.55

Table 5. Ratio of (geometric mean) elutriated dust and thoracic fraction by personal breathing zone size-selective sampling.

Area	Mill 1	Mill 2	Mill 3
Opening	-	0.10	-
Cardroom	0.45	0.60	0.35
Spinning	0.60	-	1.62
Winding	0.61	0.61	0.85