

Exposure to Dust and Endotoxin in Textile Processing Workers

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Background: Inhalation of cotton-based particulate has been associated with respiratory symptoms and overt lung disease related to endotoxin exposure in some studies. This cross-sectional study measures personal exposure to inhalable dust and endotoxin in the textile industry of Nepal. **Methods:** This study was conducted in four sectors (garment making, carpet making, weaving, and recycling) of the textile industry in Kathmandu, Nepal. Personal exposure to inhalable dust and airborne endotoxin was measured during a full-shift for 114 workers.

Results: Personal exposure to cotton dust was generally low [geometric mean (GM) 0.81 mg m⁻³] compared to the UK workplace exposure limit (WEL) (2.5 mg m⁻³) but with nearly 18% (*n* = 20) of the workers sampled exceeding the limit. Exposures were lowest in the weaving and the garment sector (GM = 0.30 mg m⁻³), higher in the carpet sector (GM = 1.16 mg m⁻³), and highest in the recycling sector (GM = 3.36 mg m⁻³). Endotoxin exposures were high with the overall data (GM = 2160 EU m⁻³) being more than 20-fold higher than the Dutch health-based guidance value of 90 EU m⁻³. The highest exposures were in the recycling sector (GM = 5110 EU m⁻³) and the weaving sector (GM = 2440 EU m⁻³) with lower levels in the garment sector (GM = 157 EU m⁻³). The highest endotoxin concentrations expressed as endotoxin units per milligram inhalable dust were found in the weaving sector (GM = 165 EU mg⁻¹). There was a statistically significant correlation between inhalable dust concentrations and endotoxin concentrations (*r* = 0.37; *P* < 0.001) and this was particularly strong in the garment (*r* = 0.82; *P* = 0.004) and the carpet sector (*r* = 0.81; *P* < 0.001).

Conclusions: Inhalable dust exposures measured in the weaving, carpet, and garment sectors were all below the UK WEL for cotton dust. A significant proportion of the measurements from the cotton recycling sector were above the UK WEL suggesting that better hygiene control measures are required. Airborne endotoxin concentrations in all sectors were found to exceed the Dutch health-based guidance limit of 90 EU m⁻³ and may be associated with respiratory health effects.

Keywords: carpet; cotton; developing countries; dust; endotoxin; garment; Nepal; recycling; weaving

INTRODUCTION

Textile workers are exposed to airborne particulate from natural and synthetic fibrous materials in their work environment (Oldenburg *et al.*, 2007). Exposure to cotton dust in the textile industry has been

associated with several work-specific and non-specific respiratory symptoms (Wang *et al.*, 2003). Cotton dust is often contaminated with Gram-negative bacteria, which contain endotoxins (lipopolysaccharide) in their outer cell wall (Mayan *et al.*, 2002). Some studies suggested that endotoxin is probably a major causative agent in the adverse pulmonary effects associated with organic dust exposure (Castellan *et al.*, 1987; Mayan *et al.*, 2002). Endotoxin occurs abundantly in organic dust contaminated with animal faeces and plant

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materials (Jacobs *et al.*, 1997). Endotoxin is released into the air during cotton processing. Exposure to cotton dust and endotoxin has been implicated in the aetiology of a number of diseases, including byssinosis, chronic bronchitis and chronic obstructive pulmonary disease along with nasal and ocular irritation (Christiani *et al.*, 1994; Fishwick *et al.*, 1994; Hendrick, 1996; Niven *et al.*, 1997). On the other hand, some studies have indicated a possible protective effect of endotoxin exposure on the risk of atopic sensitization (Gehring *et al.*, 2001; Smit *et al.*, 2010).

The workplace exposure limit (WEL) for inhalable cotton dust in the UK has been set at 2.5 mg m^{-3} for an 8-h time-weighted average (HSE, 2005). Although no occupational exposure standard exists for endotoxin in the UK, attempts have been made to identify levels of exposure where there is a perceived risk to health. The process has been made difficult due to the methodological variation in collection, storage, extraction, and analysis of dust samples (Simpson *et al.*, 1999). Recently, in the Netherlands, Dutch Expert Committee on Occupational Standards (DECOS) has revised the earlier health-based occupational exposure limit and set a limit at 90 EU m^{-3} . This exposure limit was based upon a study, which showed a no-effect for selected sensitive healthy subjects in an experimental setting of 6-h work exposure (DECOS, 2010).

The cotton textile industry is one of the oldest industries in Nepal and mainly exists in the form of family-based cottage industries; the clothes produced are still called 'gharbuna' (made at home). Cotton garments accounted for more than half of Nepal's exports in 2003 and their production employs ~300 000 people (Crop watch, 2009). There are numerous reported studies of cotton workers in developed countries (Simpson *et al.*, 1999; Oldenburg *et al.*, 2007) but few in developing countries. Despite the presence of various types of cotton industries and the large population of workers employed in this sector in Nepal, there is no information about exposure to cotton dust in these populations. Given the general lack of occupational hygiene control measures in workplaces where cotton and materials are handled, it is possible that a proportion of the workforce will be suffering from the effect of cotton dust exposure.

The present cross-sectional study was designed to measure the personal exposure to cotton dust and endotoxin in cotton textile workers. This paper describes in detail how exposure information was collected and provides information on the distribution of airborne particulate and endotoxin exposure concentrations measured across the various sectors of the cotton textile industry in Nepal. The relationship

between inhalable dust and endotoxin concentrations is also examined across each sector.

METHODS

Ethical approval was obtained from Nepal Health Research Council. The study was conducted in Kathmandu, Nepal, from March 2008 to March 2009. Four different textile sectors (garment, carpet, weaving, and recycling) were chosen for the study. Meetings were held with the factory managers and the workers and the nature of the survey was briefly explained. Approval and consent were also obtained at managerial level, work council level, and individual level. During each preliminary visit, a walk-through survey of the factory was conducted and the number of workers, availability of ventilation, the use of respiratory protection, and the nature of the work and job categories were noted.

Industrial setting

Garment sector. The garment factories included in the study produced garments for western brands. Mostly cotton garments along with some hemp and linen garments were produced in the factories. Different tasks such as cutting, stitching, and packaging were carried out in the factories. Exposure assessment was carried out for the workers from cutting and stitching areas only where the workers marked and cut the clothing according to the design supplied and stitched them into finished garments.

Carpet sector. The carpet factories included in the study produced woollen carpets along with some cotton and silk carpets. Tasks such as spinning, weaving, finishing, and packaging were performed in the factories. Due to unwillingness of workers from other work areas to participate, exposure assessments were carried out only for the weavers. Carpet weaving was performed by hand on wooden looms. The woollen yarn was knotted around cotton threads stretched horizontally and vertically across frames. Depending upon the size of the carpet, three to five workers worked on a single loom.

Weaving sector. The weaving factories included in the study mostly produced cotton clothing along with mixtures of wool and polyester clothing. Workers were involved in different tasks such as dyeing, spinning, weaving and packaging. Exposure assessment was carried out only for spinners and weavers. Spinning was mostly done by twisting the cotton thread together to form yarn using an electric power supply, weaving involved interlinking a set of vertical threads with a set of horizontal threads using a semi-traditional loom run by electric power.

Recycling sector. The recycling sectors studied produced fibres using all sorts of fabric waste from nearby weaving and garment factories. The workers studied were responsible for sorting pieces, tearing it apart manually, and shredding it into fibres. Hand sorting of the fabrics was done depending upon the quality and colour of the fabrics. Tearing was carried out manually using scissors. The fabrics were then mechanically shredded to produce fine fibres.

Exposure assessment

Personal exposure to inhalable dust was measured using an Institute of Occupational Medicine sampling head attached to an Apex pump (Casella, UK) using standard gravimetric methods in accordance with MDHS 14/3 (HSE, 2000). Airflow was set at the rate of 2.0 l min^{-1} . The sampling head was attached within the breathing zone. The work shift was 8-h long. A minimum of 4-h sampling time was maintained during the study period. One field blank was retained for every five sample filters (Glass filters, Type A/E, 25 mm; Pall Life Sciences) and the blanks were treated in the same manner as those of sample filters in respect to transport, storage, and weighing (HSE, 2000). The filters were placed in a sealed tin container and were stored in the room temperature for 3 months prior to weighing (Scaltec SBC 21; Scaltec GmbH, Heiligenstadt, Germany) at the University of Aberdeen. Filter weights were blank corrected using the mean of the field blanks. The limit of detection (LOD) was set as three times the standard deviation of the mean of the laboratory blanks (0.1 mg). The two samples that provided a value less than the LOD after blank correction were assigned a value of one-half of the LOD.

Endotoxin analysis

On completion of the gravimetric analysis, the filters were sent to the University of Manchester for endotoxin analysis. Endotoxin levels were measured using the Limulus amoebocyte lysate test (LAL) assay (Charles River Laboratories BP 109 69592, L'Arbresle, Cedex, France). Briefly, the filters were extracted by shaking in pyrogen-free tubes with 5 ml endotoxin-free water (both Charles River Endosafe) for 1 h at room temperature on rollers. Following centrifugation (1420 g for 30 min), aliquots (100 μl , 1:50) were transferred to a microtitre plate (96 wells, Becton Dickinson Labware) and 100 μl LAL was added. Optical densities were read every 30 s at 405 nm for 1 h (BIO-TEK Instruments). Results were calculated from a standard curve run on each plate using Biolise software (Charles River Endosafe). Results

were calculated as endotoxin units (EU) per millilitre and expressed as endotoxin units per cubic metre of air volume and as endotoxin concentrations per gram of collected dust. The LOD for endotoxin concentration was set as 0.25 EU ml^{-1} .

Statistical analysis

Analysis of data was carried out using SPSS software version 17 (SPSS Inc., Chicago, IL, USA). Exposure levels followed a skewed frequency distribution. Hence, the dust and endotoxin exposure were log transformed. Geometric means (GMs) and geometric standard deviations (GSDs) were used to describe the data. Pearson's correlation coefficient was used to assess the relation between exposure to inhalable dust and airborne endotoxin exposure. Differences were considered statistically significant at the $P < 0.05$ level.

RESULTS

A total of 24 sites from the four sectors were surveyed during the study period. The greatest numbers of sites were in the weaving sector ($n = 12$). Personal exposure to inhalable dust was measured for a total of 114 workers across the four industrial sectors. The target sample size ($n = 50$) could not be reached in the recycling sector as some of the workers declined to wear the sampling equipment believing that it would interfere with their work. None of the filters were damaged or spoiled. Altogether 16% of the workforce was surveyed for personal exposure assessment to cotton dust and endotoxin. The average sampling duration per worker was 6.17 h, with the shortest duration being for workers measured in the recycling factories (5.73 h). The industrial sectors included along with the number of sites for each industry and the sampling rates are displayed in the Table 1.

Personal exposure to inhalable dust was lowest and similar in the weaving and the garment sector (GM = 0.30 mg m^{-3}) and highest in the recycling industry (GM = 3.36 mg m^{-3}). The exposure level in the carpet industry fell between the weaving and the recycling sector (GM = 1.16 mg m^{-3}). Comparative data across the textile sectors for inhalable dust, endotoxin, and level of endotoxin in collected dust are presented in Table 2 and 3.

There was a large variation between specific tasks in terms of inhalable dust exposures. The tasks involved in the recycling sector had the highest personal exposure to inhalable dust. Shredding of the fibres (GM = 3.67 mg m^{-3}), sorting pieces (GM = 3.30 mg m^{-3}), and tearing (GM =

Table 1. Demographic data for the different sectors of textile industries studied

Industrial sector	Number of sites	Range of workforce	Number of samples	% of workforce sampled	Mean sampling time (h) 95% confidence interval
Garment	2	26–48	10	13	6.43 (6.35–6.52)
Carpet	2	156–173	15	5	6.10 (5.7–6.49)
Weaving	12	5–45	50	22	6.46 (6.0–6.86)
Recycle	8	4–23	39	44	5.73 (5.55–5.91)
Total	24	4–173	114	16	6.17 (5.96–6.36)

Table 2. Inhalable dust and endotoxin exposure levels per sector

Sector	Inhalable dust (mg m^{-3})			Endotoxin (EU m^{-3})			Endotoxin (EU mg^{-1})		
	AM	GM (GSD)	Range	AM	GM (GSD)	Range	AM	GM (GSD)	Range
Garment	0.40	0.30 (2.94)	0.02–0.69	176	157 (1.64)	91–308	24	12 (2.85)	6–127
Carpet	1.26	1.16 (1.51)	0.58–2.16	988	678 (2.37)	271–3300	14	12 (1.72)	6–36
Weaving	0.40	0.30 (2.44)	0.01–1.72	4100	2440 (2.82)	86–15100	330	165 (3.29)	10–2705
Recycling	5.74	3.36 (2.55)	0.82–35.95	7330	5110 (2.33)	1370–26300	53	46 (4.17)	5–54 082
Total	2.34	0.81 (3.54)	0.01–35.95	4460	2160 (3.96)	86–26300	164	56 (4.82)	5–54 082

AM, arithmetic mean.

Table 3. Inhalable dust and endotoxin exposure in main job task of the textile industry

Sector and task	<i>n</i>	Dust (mg m^{-3})		Endotoxin (EU m^{-3})	
		GM (GSD)	Range	GM (GSD)	Range
Weaving					
Weaving (clothes)	40	0.26 (2.64)	0.01–1.72	2290 (3.26) ^a	86–15 100
Spinning	10	0.49 (1.37)	0.29–0.71	2840 (2.65) ^a	508–8950
Garment					
Cutting	1	0.35	—	117 ^a	
Stitching	9	0.28 (3.14)	0.18–0.59	163 (1.67) ^a	91–307
Carpet					
Weaving (carpet)	15	1.16 (1.51)	0.58–2.16	678 (2.37) ^a	271–3300
Recycling					
Tearing	21	3.02 (2.8) ^b	0.82–35.95	6060 (1.54) ^a	1740–23 300
Shredding	14	3.67 (2.71) ^b	1.26–29.51	4160 (2.45) ^a	1376–26 300
Sorting pieces	2	3.30 (1.79) ^b	2.18–5	1800 (1.11) ^a	1660–1950
All areas	2	1.32 (6.29)	0.29–14.41	6010 (3.4) ^a	1300–22 800

^aInhalable dust concentration exceeding the WEL of 2.5 mg m^{-3} .

^bEndotoxin concentration exceeding the Dutch TLL of 90 EU m^{-3} .

3.02 mg m^{-3}) tasks in the recycling sector produced dust exposure levels higher than the UK WEL limit. The lowest exposure was measured in the cloth weaving area ($\text{GM} = 0.26 \text{ mg m}^{-3}$).

The highest personal endotoxin exposure was measured in the recycling sector ($\text{GM} = 5110 \text{ EU m}^{-3}$) followed by the weaving sector ($\text{GM} = 2440 \text{ EU m}^{-3}$) and the carpet sector ($\text{GM} = 678 \text{ EU m}^{-3}$). Exposure was lowest in the garment sector (157 EU m^{-3}). The highest levels of endotoxin in collected

dust were found in the weaving sector ($\text{GM} = 165 \text{ EU mg}^{-1}$), followed by the recycling sector. The measurements were low and similar in the carpet and the garment sectors.

Overall, there was a moderate linear relationship between personal exposure to inhalable dust and airborne endotoxin exposure ($r = 0.37$, $P < 0.001$). The linear relationship was strong in the garment ($r = 0.82$, $P = 0.004$) and the carpet sector ($r = 0.81$, $P < 0.001$). However, no such relationship

was found in the weaving and the recycling sector (Fig. 1).

DISCUSSION

To the best of our knowledge, this is the first study to measure exposure to inhalable dust and airborne endotoxin of workers in the textile processing industry in Nepal. Large differences in dust and endotoxin concentration across the different sectors of the textile processing industry were observed, with the highest level in the recycling factories and lowest in the garment sector.

Contrary to expectations, personal exposures to inhalable dust concentrations in this study (0.81 mg m^{-3}) were low and broadly comparable to measurements in Chinese textile mills (0.29 mg m^{-3}), Lancashire cotton factories (1.98 mg m^{-3} ; Raza *et al.*, 1999), Turkish cotton mills (2.39 mg m^{-3} ; Bakirci *et al.*, 2007), and Dutch mills (1.32 mg m^{-3} ; Keman *et al.*, 1998). This inconsistency in the results can be explained, in part, by the methodological varia-

tion and partly by the large variation in the industrial setting and handling and processing of cotton.

Inhalation of cotton dust has been associated with increased prevalence of respiratory symptoms (Bouhuys *et al.*, 1997; Niven *et al.*, 1997). The current UK WEL for cotton dust was set at 2.5 mg m^{-3} using data from epidemiological studies of the Lancashire cotton industry before its final demise. The majority of the measurements for inhalable dust in our studies fall below the 2.5 mg m^{-3} WEL (only 18% of the samples exceeding the limit) with all the samples from the garment, carpet, and weaving sectors being below the limit. However, 50% ($n = 20$) of the samples from the recycling sector exceeded this limit with some measurements as high as 35 mg m^{-3} . The high level of dust seen in this sector might have resulted from the coarse processes involved in the conversion of fabric into fibre.

Endotoxin levels measured in this study ($\text{GM } 2160 \text{ EU m}^{-3}$) were higher than those reported in cotton mills in Germany (450 EU m^{-3} ; Oldenburg *et al.*, 2007) and Turkey (191 EU m^{-3} ; Bakirci

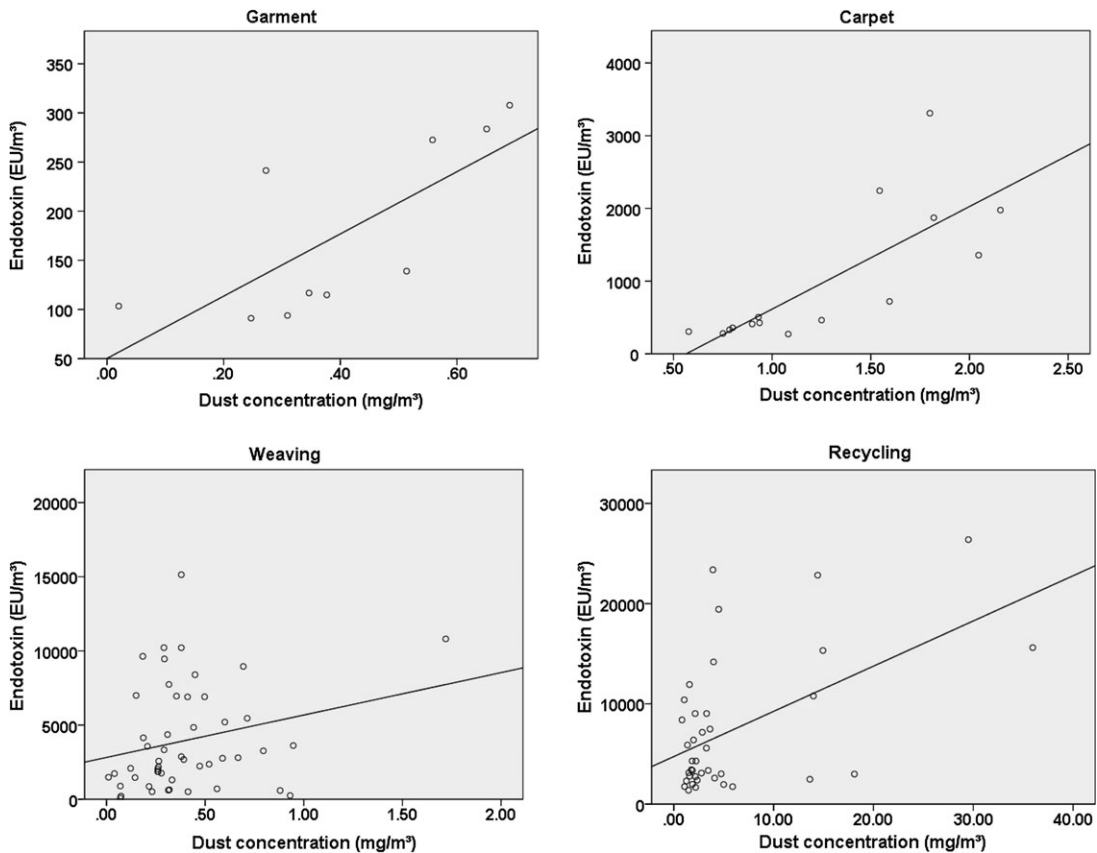


Fig 1. Correlation between inhalable dust and endotoxin concentration across the textile sectors.

et al., 2007) but lower than those observed in the UK in recent years (4380 EU m⁻³; Simpson *et al.*, 1999) and Dutch mills (2566 EU m⁻³, Keman *et al.*, 1998). Overall, the correlation between measured inhalable dust levels and endotoxin in our study ($r = 0.37$) was similar to that reported by Simpson *et al.* (1999) in cotton spinning mill ($r = 0.49$) but was not as strong as that in weaving industries ($r = 0.77$) reported in the same study. A possible explanation for this discrepancy might be due to methodological variation as well as the degree of contamination of the cotton fibres.

The endotoxin exposures derived in this study are much higher than those seen in other occupational settings, such as the animal feed industry (310 EU m⁻³, Simpson *et al.*, 1999), the wood industry (43 EU m⁻³, Mandryk *et al.*, 1999), the mushroom industry (70 EU m⁻³, Simpson *et al.*, 1999; 81 EU m⁻³, Spaan *et al.*, 2006), and in dairy farming (560 EU m⁻³, Spaan *et al.*, 2006) and are approaching the extremely high concentrations reported in pig farming (3400 EU m⁻³, Smit *et al.*, 2006) and poultry farming (84 310 EU m⁻³, Simpson *et al.*, 1999).

In cotton processing, high levels of bacteria and endotoxin are seen early in the processing, such as opening and carding, but hardly detectable by the later stages with endotoxin levels in the weaving industry were being very low (Raza *et al.*, 1999). It has been concluded that endotoxin was removed from cotton by the progressive stages of processing from raw material to finished product. High level of endotoxin despite of the low level of dust in the weaving sector may have resulted from additional contamination of cotton during the process of washing, storing, and handling. Grade of the cotton fibres used is correlated with endotoxin exposure in the textile industry (Glindmeyer *et al.*, 1991). Use of low-grade cotton fibres in the Nepalese weaving sector might have resulted in the high level of endotoxin exposure. Earlier studies have reported high level of endotoxin exposure in workers exposed to sewage (Rylander, 1999; Thorn *et al.*, 2002). Additional contamination in the weaving sector in this study may have occurred during dyeing of fibres as water from nearby river highly contaminated with sewage was used for the process of dyeing. Similarly, several determinants might have resulted in elevated level of endotoxin in the recycling sector. Fabrics were dumped in the damp floor for months before they were processed and were heavily contaminated with soil containing animal faeces. High endotoxin concentrations have been associated with moist environments and contamination with animal faeces (Jacobs *et al.*, 1997; Park *et al.*, 2000; Spaan *et al.*, 2006).

From the results of this study, it can be appreciated that the endotoxin exposure are more than 20 times the Dutch health-based guideline limit of 90 EU m⁻³. Almost all the measurements exceeded the given limit. Several epidemiological and experimental studies have shown that endotoxin exposure is associated with reduced lung function and although this is by no means invariable, endotoxin level reported in this study, indicates that the workforce are likely to be at significant risk of respiratory impairment.

There are some limitations to this study. Firstly, the workplaces were not randomly selected from all such workplaces in the Kathmandu valley. This was because there are no complete lists of all such facilities, which were largely identified by those recorded in the local telephone directory and from word of mouth. Secondly, measurements were not randomly taken for both logistical and time constraints. However, it is unlikely that either of these resulted in serious bias as local knowledge implied that the majority of such workplaces had been identified and walk-through surveys of the factories included in the study showed no important differences in infrastructure or work processes compared to those that were not revisited for practical reasons.

In summary, exposure levels for inhalable dust measured in this study are similar to those from previous studies in cotton-processing workers. However, endotoxin exposure concentrations are many times higher than the Dutch proposed health-based exposure limit. Simple control measures such as ventilation, use of personal protective equipment, regular cleaning of equipment, and good housekeeping practices should be designed in the first instance to try and reduce workers' exposure to both inhalable dust and airborne endotoxin.

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