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Industrial hygiene, occupational safety and respiratory symptoms in the Pakistani cotton industry

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ABSTRACT

Objectives: In the cotton industry of Pakistan, 15 million people are employed and exposed to cotton dust, toxic chemicals, noise and physical hazards. The aim of this study was to determine the prevalence of health symptoms, particularly respiratory symptoms, and to measure cotton dust and endotoxin levels in different textile factories of Faisalabad, Pakistan.
Methods: A cross-sectional investigation was performed in a representative sample of 47 cotton factories in the Faisalabad region in Punjab, Pakistan. Respiratory symptoms of 800 workers were documented by questionnaire. Occupational safety in the factories was assessed by a trained expert following a checklist, and dust and endotoxin levels in different work areas were measured.
Results: Prevalence of respiratory disease symptoms (fever, shortness of breath, chest tightness and cough) was generally high and highest in the weaving section of the cotton industry (20–40% depending on symptoms). This section also displayed the poorest occupational safety ratings and the highest levels of inhalable cotton dust (mean±SD 4.6±2.5 vs 0.95 ±0.65 mg/m^3 in compact units). In contrast, endotoxin levels were highest in the spinning section (median 1521 EU/m^3), where high humidity is maintained.
Conclusions: There are still poor working conditions in the cotton industry in Pakistan where workers are exposed to different occupational hazards. More health symptoms were reported from small weaving factories (power looms). There is a dire need for improvements in occupational health and safety in this industrial sector with particular focus on power looms.

Strengths and limitations of this study

- This is a cross-sectional study with all its inherent limitations.
- Although great care was given to a balanced selection of factories of different size and from different parts of the cotton production processes, examination of factories depended on the consent of factory owners, and thus a bias (possibly leading to an underestimation of health hazards) cannot be excluded.
- The study surveyed a large number of factories and an even larger number of workers. For the first time, workers from small weaving factories (power looms) in Pakistan were investigated.
- Industrial hygiene measurements are point measurements over a short time period only. Thus, measurements cannot be linked to personal exposure of individual workers, but overall they provide a good estimate of exposure in different sectors of the industry.
- The findings also form the basis for additional clinical examinations in a random sample of the workers from the factories described in this paper. The results of these clinical studies (that generally support the findings from the questionnaire) will be reported in separate papers.

INTRODUCTION

Approximately 60 million workers are employed in the textile industry globally[1] and the figure for Pakistan is 15 million, drawing nearly 30–35% of the 49 million unskilled work force.[2] Workers in the textile industry are exposed to airborne dust containing infectious, allergic and toxic substances.[3] Hazardous effects in the cotton industry, particularly on the respiratory tract, were reported 300 years ago.[4] A specific respiratory syndrome in that industry was called byssinosis and Schilling[5] first classified byssinosis based on respiratory symptoms. Organic cotton dust contains endotoxins that are believed to cause most of the symptoms,[6] disturbed lung functions,[7 8] organic dust toxic syndrome[9] and obstructive pattern of lung diseases having features of asthma and chronic obstructive pulmonary disease.[10] There is still unprotected and persistent exposure to cotton dust, endotoxins and different ergonomic hazards in the Pakistani cotton industry, resulting in severe public health problems.[11]

Working conditions in the developing world are often very poor and the textile industry is not an exception to this rule. Increasing awareness of consumers through civil society campaigns has contributed to some relevant improvements, especially in large factories delivering directly to the European and American markets. However, working conditions in smaller factories that either produce for the local market or are employed by the large factories in case of higher demand are not well known, although a high proportion of the workers are employed in these small enterprises.

A comprehensive study of this setting is not an easy task. This study set out to examine 800 workers by questionnaire and to investigate occupational exposure to airborne dust, endotoxins and other work-related risk factors in a sample of 47 industrial plants. Working conditions and safety measures in the selected plants were rated by trained researchers and dust was measured and analysed for endotoxin and pesticides. Thus, this is the first study to examine working conditions, occupational hygiene and safety, especially of workers in small factories, with a focus on small weaving factories, the so-called 'power looms'. Although each power loom is small in size, in total a huge number of workers are affected.

METHODS

Plants and workers

A stratified sample of plants from the cotton industry in the Faisalabad region in Punjab, Pakistan was selected. Care was taken to investigate a broader variety of different types of plants ranging from small weaving (power loom) to large spinning and compact units, representative of the different types of mills in the area. The Faisalabad Chamber of Commerce and Industry provided a list and contact information about different mills in the district. From that list, factories were chosen randomly, the owner or manager of the mill was contacted by telephone, and on permission the mill was visited. In each plant, available workers on duty were randomly chosen from the list of employees provided by the administrative/human resource section and accessed to fill in a structured questionnaire either by themselves or (in case of illiteracy) with the help of the researcher (AWK). Only those workers were selected who had a recent minimum of 6 months of experience in the cotton industry. Written or oral informed consent was sought.

Since workers in that industry setting are usually male, only male workers were approached. The questionnaire was first prepared in English and then translated into Urdu. The first draft of the questionnaire was pilot tested with the help of friends and local contacts before finalisation. The questionnaire contained questions on age, years of occupational history (less than 1, 1–5, 6–10, 11–15, 16–20, and more than 20 years), educational level (illiterate, primary: 1–5 years of schooling, middle/elementary: 6–8 years of schooling, secondary/matriculate: 9–10 grades, intermediate/higher secondary and above: 11–12 grades and above), duration of working shift (8, 10 or 12 h), ethnicity, smoking habits (current, non-smoker or ex-smoker), use of personal protection devices (mask, earplugs, caps), as well as a list of medical symptoms mostly typical for respiratory diseases or more specifically for byssinosis (table 2). Both 'current symptoms' and 'symptoms ever' were asked in the questionnaire. This paper focuses on 'current symptoms' of fever, shortness of breath, chest tightness and cough, the latter further subspecified as either a dry or mucous cough. The type and size of factory was also entered into each questionnaire.

While visiting each plant, a structured checklist was filled in by the researcher (AWK) indicating the type and size of the plant, total number of workers, and a list of items relevant for occupational safety and industrial hygiene (table 1).

Monitoring of dust and endotoxins

During these visits, the following measurements were also performed. Suspended fine dust was measured with two instruments. The Grimm Portable Aerosol Spectrometer 1108 (Grimm Aerosol Technik, Germany) counts airborne particles in 16 size channels using laser scatter technology. From these data particle masses in standardised size ranges were calculated (environmental standards: PM2.5 and PM10, occupational standards: inhalable, thoracic and alveolic). Real-time measurements averaging over 6 s were performed.

The MiniDiSC (matter aerosol, Switzerland) is a diffusion size classifier that can determine three quantities simultaneously with a high time resolution (1 s): particle number concentration, average particle diameter and lung-deposited surface area. The instrument is based on charging and current detection. For analysis, data were averaged over 10 s.

Suspended dust was collected with an Aircheck Sampler Model 224-52 (SKC Inc, USA) with an SKC IOM sampler head and a flow rate of 2 L/min. Dust was collected on glass fibre filters (25 mm diameter, pore size 1 μm). Sampling duration (approximately 1 h) was documented. Sampling of dust was performed throughout the fieldwork (February–April 2014) and filters were stored each day under dry conditions in a refrigerator (at approximately 2°C), remaining there until the end of the fieldwork. After the fieldwork was completed, all filters were brought to Europe in the flight baggage and were again stored in a refrigerator on arrival in Vienna. Owing to a misunderstanding with the first laboratory, the samples could not be processed for another 2 months and it was only in early July that the samples were brought to Munich, Germany and analysed at the laboratory of the Institute of Occupational, Social and Environmental Medicine, University Hospital Munich.

Endotoxin concentrations in airborne dust samples were determined according to the European Guideline EN 14031 using the chromogen-kinetic LAL (limulus amoebocyte lysate) assay (Lonza, Lot No 410350, expiration date 29 July 2016). Each filter was extracted by rapid shaking with 4 mL of endotoxin-free water for

Table 1 Overview of the visited factories and expert assessment of occupational hazards by type of factory (2 pages)

Type of factory	Small weaving	Medium weaving	Spinning	Compact	Total
Number	19	7	5	16	47
Employees (total)	571	703	3600	9567	14 441
Employees per factory: mean (range)	30 (12–41)	100 (50–200)	720 (300–1000)	598 (20–2500)	307 (12–2500)

Hazard	Small weaving	Medium weaving	Spinning	Compact	Fisher's exact p/total
Dirty working area	17	4	1	3	25
Factories %	**89.5%**	**57.1%**	**20.0%**	**18.8%**	**<0.001**
Persons affected	503	443	1000	415	2361
Persons %	88.1%	63.0%	27.8%	4.3%	
Leaking valves/fittings	14	2	0	4	20
Factories %	**73.7%**	**28.6%**	**0.0%**	**25.0%**	**0.002**
Persons affected	431	180	0	355	966
Persons %	75.5%	25.6%	0.0%	3.7%	
Heat	19	7	4	9	39
Factories %	**100.0%**	**100.0%**	**80.0%**	**56.3%**	**0.002**
Persons affected	571	703	2800	2059	6133
Persons %	100.0%	100.0%	77.8%	21.5%	
Noise	19	7	2	8	36
Factories %	**100.0%**	**100.0%**	**40.0%**	**50.0%**	**<0.001**
Persons affected	571	703	1300	1967	4541
Persons %	100.0%	100.0%	36.1%	20.6%	
Vibrations	19	7	3	9	38
Factories %	**100.0%**	**100.0%**	**60.0%**	**56.3%**	**0.001**
Persons affected	571	703	2200	2267	5741
Persons %	100.0%	100.0%	61.1%	23.7%	
Not enough safety distance	19	5	0	3	27
Factories %	**100.0%**	**71.4%**	**0.0%**	**18.8%**	**<0.001**
Persons affected	571	590	0	463	1624
Persons %	100.0%	83.9%	0.0%	4.8%	
Unsafe fuels backup	6	1	1	5	13
Factories %	31.6%	14.3%	20.0%	31.3%	0.777
Persons affected	228	63	900	5100	6291
Persons %	39.9%	9.0%	25.0%	53.3%	
No healthcare facility	19	7	3	11	40
Factories %	**100.0%**	**100.0%**	**60.0%**	**68.8%**	**0.008**
Persons affected	571	703	2200	4167	7641
Persons %	100.0%	100.0%	61.1%	43.6%	
No first-aid box/kit	17	5	2	3	27
Factories %	**89.5%**	**71.4%**	**40.0%**	**18.8%**	**<0.001**
Persons affected	496	490	1900	255	3141
Persons %	86.9%	69.7%	52.8%	2.7%	
No masks	19	7	4	13	43
Factories %	100.0%	100.0%	80.0%	81.3%	0.102
Persons affected	571	703	2800	4867	8941
Persons %	100.0%	100.0%	77.8%	50.9%	
No earplugs	19	7	5	14	45
Factories %	100.0%	100.0%	100.0%	87.5%	0.438
Persons affected	571	703	3600	5267	10 141
Persons %	100.0%	100.0%	100.0%	55.1%	
No fire alarm	19	7	0	4	30
Factories %	**100.0%**	**100.0%**	**0.0%**	**25.0%**	**<0.001**
Persons affected	571	703	0	663	1937
Persons %	100.0%	100.0%	0.0%	6.9%	
Insufficient ventilation	16	7	0	4	27
Factories %	**84.2%**	**100.0%**	**0.0%**	**25.0%**	**<0.001**
Persons affected	477	703	0	663	1843
Persons %	83.6%	100.0%	0.0%	6.9%	

Continued

Table 1 Continued

Type of factory	Small weaving	Medium weaving	Spinning	Compact	Total
No proper lighting	19	5	1	2	27
Factories %	**100.0%**	**71.4%**	**20.0%**	**12.5%**	**<0.001**
Persons affected	571	453	900	55	1979
Persons %	100.0%	64.4%	25.0%	0.6%	
No smoke detector	19	7	1	3	30
Factories %	**100.0%**	**100.0%**	**20.0%**	**18.8%**	**<0.001**
Persons affected	571	703	900	255	2429
Persons %	100.0%	100.0%	25.0%	2.7%	
No emergency exit	17	5	1	4	27
Factories %	**89.5%**	**71.4%**	**20.0%**	**25.0%**	**<0.001**
Persons affected	470	390	900	663	2423
Persons %	82.3%	55.5%	25.0%	6.9%	
No exit lights	19	6	2	5	32
Factories %	**100.0%**	**85.7%**	**40.0%**	**31.3%**	**<0.001**
Persons affected	571	653	1900	963	4087
Persons %	100.0%	92.9%	52.8%	10.1%	
No washrooms	2	0	0	0	2
Factories %	10.5%	0.0%	0.0%	0.0%	0.719
Persons affected	55	0	0	0	55
Persons %	9.6%	0.0%	0.0%	0.0%	
No kitchen	19	7	2	6	34
Factories %	**100.0%**	**100.0%**	**40.0%**	**37.5%**	**<0.001**
Persons affected	571	703	1900	972	4146
Persons %	100.0%	100.0%	52.8%	10.2%	
No sitting place	18	4	0	6	28
Factories %	**94.7%**	**57.1%**	**0.0%**	**37.5%**	**<0.001**
Persons affected	537	443	0	972	1952
Persons %	94.0%	63.0%	0.0%	10.2%	

Bold typeface indicates significance at p<0.05.

1.5 h. An aliquot of 100 µL was added to a microtitre plate (96 well, Falcon) and assayed with LAL. To obtain information about the possible enhancement or inhibition reactions of the LAL assay, a replicate of each sample was spiked with an endotoxin standard. A standard calibration curve (0.05–0.5–5–50 EU/mL), a laboratory blank and an internal laboratory standard were included on each plate. As recommended by the manufacturer, optical density at 405 nm was measured by an automatic reader (PowerWaveTM, MWG Biotech Inc, Mendelhall Oaks Parkway, North Carolina, USA). If spike recovery was below 50%, the suspension was further diluted and the analysis was repeated. The intra-assay variability (EU/mg dust) was less than 10%, whereas the interassay variability was lower than 20%. As the LAL assay measures the activity of different types of endotoxin, the results are expressed in Endotoxin Units (EU). Endotoxin levels for airborne endotoxin were expressed in EU per 1 m^3 (EU/m^3), accounting for the total sampled volume (sampling time in minutes times 2 L).

Statistical analysis

Industrial plants were grouped according to type: some plants (spinning) receive cotton from the ginners and only produce threads and yarns (blowing, carding, twisting and spinning operations). Other plants buy threads and produce raw cloth (weaving operations). Many small plants in the study area, the so-called 'power looms', constitute this type of factory. There are also some medium-sized plants dedicated to weaving. Large compact cotton enterprises perform the whole production including spinning, weaving and processing (eg, knitting, bleaching, dyeing, drying, stitching and packing). These large factories also purchase additional material from the small spinning and weaving factories for further processing and manufacturing. Thus, plants were grouped as spinning, small-sized or medium and large-sized weaving and whole compact units.

Types of factories were compared by Fisher's exact t test. The following possible predictors of symptoms in workers were analysed by logistic regression: type of factory, age of worker, smoking, education, years of occupation, hours per shift, ethnicity and use of personal protection devices. Non-significant parameters were dropped in a stepwise fashion. All analyses were performed with STATA V.13.1 (StataCorp LP, College Station, Texas 77845 USA).

RESULTS

In a total of 47 industrial plants, 19 small and 7 larger weaving factories, 5 spinning factories and 16 factories that followed the whole production process were visited and evaluated (table 1). The latter 16 factories, termed "compact" in Pakistan, were mostly large with up to 2500 employees. However, three processing (specific production) factories were small with 20–100 employees each. The number of these small processing factories was not sufficient for separate statistical analysis. Since at least two of the three processing factories were relocated processing departments of larger compact factories, they are listed among the latter.

Many hazards and indicators of poor working conditions were noted during this evaluation. Noise, vibration and danger of accidents were more prevalent in industries with fast-moving heavy machines (looms). Chemical hazards might be more prevalent in other processes of cotton production, for example, in dyeing. However, a detailed analysis of the specific toxicological properties and of individual exposure to specific chemicals was not possible and out of the scope of that study. Although some differences in the prevalence of hazards (table 1) can be explained by the special conditions of the very process, it is noteworthy that in general small power looms were rated the worst.

In total, 800 workers were successfully accessed and asked to answer a short questionnaire. Participation rate was high (>90%). Workers were grouped according to the process in cotton production. So workers from large compact industries were either working in weaving, spinning or other types of processing and production (including dyeing, finishing, knitting, bleaching, stitching, drying and packing). Therefore, finally, five groups could be formed (table 2: small weaving, 289 workers; medium weaving, 125 workers; big weaving, 110 workers; spinning, 80 workers; and compact, 196 workers).

Of the 800 workers, 537 reported being non-smokers, 228 smokers and 35 ex-smokers. The rate of smokers decreased significantly with educational status. Of current smokers, 54% of workers were illiterate, 22% had primary education (grades 1–5), 19% had middle education (grades 6–8), 4% had matriculate secondary/high education (grades 9–10), and 0.5% had intermediate/higher secondary education and above (grades 11–12 and above). Education was also linked to age and total number of working years following a U-shaped form. Workers with the highest education (intermediate and above) were rare (12 workers only) and they were the oldest (mean±SE 36.3±2.4), followed by illiterate workers (33.5±0.5), workers with primary education (30.3±0.6), matriculates (29.5±1.2) and workers with middle education (28.4±0.6). Duration of working shift differed by working group: in spinning, compact and large weaving factories, most people (85%) worked 8 h shifts. In small and medium-sized weaving factories, most of the people worked either 10 h shifts (25–28%) or 12 h shifts (74% and 61%, respectively). Poorer education was clearly associated with longer working shifts. Use of personal protection devices was not very widespread overall. Of the 800 workers 404, 609 and 592 reported never using a mask, earplugs or cap, respectively. Again, the use of protective devices was especially uncommon in small weaving factories also for ear plugs, even though noise levels were often exceptionally high in that setting. Respiratory symptom rates were lowest in compact units. Therefore, this sector was chosen as the reference. Most of the symptoms were significantly higher in all other sectors and in smokers and increased with age (table 3). Ethnicity, education, duration of working shift and working duration after controlling for age never reached significance.

Dust levels were generally high in most of the plants investigated (figure 1). The various measures of particle mass (PM2.5, PM10, alveolic, thoracic and inhalable) were all strongly and significantly correlated with each other, both overall and in each type of factory, namely spinning, weaving and compact. Expressed in terms of the smallest fraction (PM2.5), the average concentration of PM10 was 1.98×PM2.5 plus 917.68 μg (R^2=0.8), of inhalable dust it was 2.06×PM2.5+1579.3 (0.7), of thoracic dust it was 2.12×PM2.5+1044.76 (0.78), and of alveolic it was 1.66×PM2.5+280.9 (0.94). Coarse particles (larger than 2.5 μm) therefore amounted to more than 50% of the total mass. Nevertheless, only results for PM2.5 are reported in detail because of the high correlation between the size classes.

In compact factories, PM2.5 concentrations were lowest (mean±SD 102.3 μg/m^3±71.7). Large and small enterprises did not differ significantly from each other when controlling for factory type. Concentrations in spinning factories were non-significantly higher than in compact mills, while in weaving factories they surpassed those in compact mills strongly by 1258 μg/m^3 (p=0.001).

Table 2 Results of the questionnaire

	Small weaving	Medium weaving	Big weaving	Spinning	Compact	Total p value
Worker	289	125	110	80	196	800
Symptoms %						
Fever	22.5	24.8	11.8	12.5	6.1	p (χ^2)<0.001
Shortness of breath	28.7	22.4	10.9	17.5	5.6	p (χ^2)<0.001
Chest tightness	41.5	36.8	32.7	31.2	10.7	p (χ^2)<0.001
Dry cough	30.1	36	26.4	31.3	12.2	p (χ^2)<0.001
Mucous cough	6.9	4	5.5	8.8	0.5	p (χ^2)<0.001

Table 3 Determinants of symptoms in multiple logistic regressions: OR (p Value)

Predictor	Fever	Shortness of breath	Chest tightness	Dry cough	Mucous cough
Small weaving	**3.81 (<0.001)**	**6.43 (<0.001)**	**6.46 (<0.001)**	**2.41 (0.001)**	**8.19 (0.045)**
Medium weaving	**4.72 (<0.001)**	**4.12 (0.001)**	**5.12 (<0.001)**	**3.27 (<0.001)**	4.46 (0.185)
Big weaving	1.70 (0.247)	1.44 (0.462)	**4.76 (<0.001)**	**2.23 (0.014)**	7.54 (0.07)
Spinning	**2.90 (0.031)**	**5.15 (0.001)**	**5.59 (<0.001)**	**3.49 (<0.001)**	**21.0 (<0.001)**
Compact	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Age (year)	**1.14 (<0.001)**	**1.17 (<0.001)**	**1.16 (<0.001)**	**1.05 (<0.001)**	**1.13 (<0.001)**
Smoker	**2.30 (<0.001)**	**3.95 (<0.001)**	**6.25 (<0.001)**	**3.29 (<0.001)**	**3.77 (0.002)**
Ex-smoker	1.56 (0.339)	**2.81 (0.025)**	**4.45 (0.001)**	1.29 (0.528)	**4.36 (0.012)**

Bold typeface indicates significance at p<0.05.

Contrary to particle mass, the particle numbers (per cm^3) were highest in compact factories (81 736±47 627). In spinning (17 548±11 871) and, to a lesser extent, also in weaving (53 578±20 729), particle numbers as a measure of ultrafine particles were significantly lower. Again, factory size did not significantly affect particle number. On the other hand, the average size of particles only differed by factory size with 54.9 nm in big factories and 64.4 nm in small factories.

Endotoxin concentrations were neither correlated with particle mass nor number (p always >0.5). Concentrations were high in spinning (1521±2974 EU/m^3) and substantially lower in production sections of compact (18±17) and weaving (21±17) mills. Factory size had no influence on endotoxin concentrations.

DISCUSSION

In this cross-sectional study, a high prevalence of respiratory symptoms among workers in the cotton industry was found. The highest symptoms frequency was seen in weaving factories, especially those of small and medium size. These findings were consistent with results of previous studies in Karachi, Pakistan,[12 13] where they also reported high respiratory symptoms in weaving and spinning mills.

Symptoms reported by questionnaire cannot entirely be interpreted as byssinosis clinically. Nevertheless, the combination of symptoms makes it likely that most of the reported symptoms are indeed linked to byssinosis. This would indicate that byssinosis is still very prevalent in these workers.

The cross-sectional approach and the possibility of a selection bias are weaknesses of this study. However, assuming that factories with the poorest conditions would most likely not have been available for (voluntary) inspection, selection bias would rather lead to an underestimation of the problem.

Weaving factories displayed many hazards considered in the checklist and they also had the highest dust levels. Similarly, high dust levels in small weaving mills in Hafizabad, Punjab were also reported by Tahir *et al.*[14] However, neither endotoxins nor ultrafine particles were exceptionally high in weaving factories. Owing to logistics problems, processing of dust samples for endotoxin analysis was delayed so that the reported values might under-represent the true exposure.[15 16] However, the fact that the highest values were found in the spinning section is plausible. Humidity was generally high in these sections for technical reasons, and consequently mould growth was visible on many sites. In the cotton

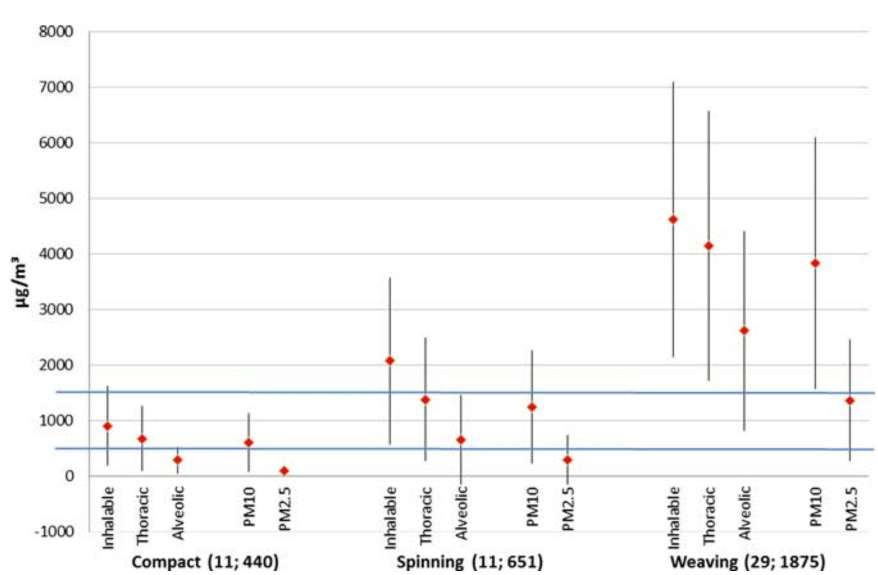

Figure 1 Dust levels (mean±SD) in three types of factories (number of factories; number of measurements). Blue lines: (upper line) German and Austrian limit value for inhalable cotton dust: 1500 µg/m^3; (lower line) US limit value for respirable dust in weaving section: 500 µg/m^3 (section with highest limit value according to OSHA guidelines for cotton dust; PM, particle mass; OSHA, Occupational Safety and Health Administration).

industry, high levels of endotoxin are detected in the early stages like opening and carding (spinning) compared with the later finishing stages such as weaving.[17 18] These poor conditions would most likely also increase the load of β-glucans (from fungi) and lipopolysaccharides (from Gram-negative bacteria). Both substance classes give a signal in the limulus assay.[19–32]

Endotoxins are generally considered the main reason for byssinosis. However, a high concentration of endotoxins is also observed in other industries such as agriculture, food industry and waste disposal. Also, in these industries, respiratory diseases are described,[30–32] but they do not fully resemble byssinosis. Symptoms of byssinosis can generally be considered similar to those of non-IgE-dependent occupational asthma observed among garbage workers, farmers and others types of workers exposed to endotoxin-contaminated organic dust.[30] The source of endotoxin can be of importance in relation to its type and composition, and research provides indications that even within a specific industry different endotoxin chain lengths can be associated with different toxicities.[31 32] This could also potentially explain the lack of full resemblance of byssinosis symptoms in non-cotton-related industries. In this study, the highest endotoxin concentration did not coincide with the highest symptom rates. Occupational hazards and dust levels were quite high in small weaving factories. Subjective respiratory symptoms were also high in workers in small and medium weaving mills. Cotton dust by itself (through toxic and/or allergic properties of parts of the cotton plant itself and through agricultural chemicals as well) might also add to the respiratory toxicity.

The majority of all spinning and weaving sections displayed high dust levels compared with European occupational limit values for inhalable cotton dust 8 h averages (UK: 2500 $\mu g/m^3$; Austria, Germany: 1500 $\mu g/m^3$). Furthermore, personal protective devices were mostly missing in these workplaces.

CONCLUSION

There are still poor working conditions in the cotton industry of Faisalabad, Pakistan and cotton workers are exposed to multiple ergonomic hazards and high respiratory dust due to lack of practising simple preventive measures. Complaints were more reported from small-scale weaving factories and power looms.

There is a need of regulations both at government and private (factories owners) levels to improve the working conditions, effectively control dust levels and create awareness among cotton workers, particularly at small weaving factories. Simple preventive measures, for example, ventilation, proper lighting, first-aid box, compulsory use of personal protective equipment (eg, masks, earplugs) and periodical medical check ups are warranted. Further studies to quantify the ergonomic hazards, especially noise and heat, are recommended.

Contributors AWK planned and performed the fieldwork. HMM assisted with the planning, helped with the dust measurements and demonstrated spirometry. AWK and HMM wrote the manuscript together and analysed the data. MK helped with some statistical analyses and checked the final text and suggested improvements.

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Competing interests None.

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Data sharing statement Extra data are available by emailing hanns.moshammer@meduniwien.ac.at.

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