



THE AGA KHAN UNIVERSITY

eCommons@AKU

---

Community Health Sciences

Department of Community Health Sciences

---

August 2016

# Available interventions for prevention of cotton dust-associated lung diseases among Textile workers.

Asaad Ahmed Nafees

*Aga Khan University*, [asaad.nafees@aku.edu](mailto:asaad.nafees@aku.edu)

Zafar Fatmi

*Aga Khan University*, [zafar.fatmi@aku.edu](mailto:zafar.fatmi@aku.edu)

Follow this and additional works at: [http://ecommons.aku.edu/pakistan\\_fhs\\_mc\\_chs\\_chs](http://ecommons.aku.edu/pakistan_fhs_mc_chs_chs)



Part of the [Family Medicine Commons](#), and the [Public Health Commons](#)

---

## Recommended Citation

Nafees, A. A., Fatmi, Z. (2016). Available interventions for prevention of cotton dust-associated lung diseases among Textile workers.. *Journal of the College of Physicians and Surgeons Pakistan*, 26(8), 685-691.

**Available at:** [http://ecommons.aku.edu/pakistan\\_fhs\\_mc\\_chs\\_chs/236](http://ecommons.aku.edu/pakistan_fhs_mc_chs_chs/236)

# Available Interventions for Prevention of Cotton Dust-Associated Lung Diseases Among Textile Workers

Asaad Ahmed Nafees and Zafar Fatmi

## ABSTRACT

The authors reviewed literature on interventions for cotton dust-associated lung diseases among textile workers. Internet sources (PubMed, Cochrane Library, Google and Google Scholar) were accessed and interventions were categorized into: Engineering or administrative controls, or personal protective equipment (PPE). Ten relevant articles were shortlisted, five related to engineering controls (pre-processing, bactericidal treatment of cotton, improved workplace design, machinery and dust control measures). Administrative controls may involve setting standards, environmental surveillance, periodic medical examinations, and workers training. Although specific guidelines are available regarding the use of PPEs, but there was little literature on their effectiveness. It was concluded that there is a dearth of literature regarding field-based assessment of interventions for control of cotton dust associated respiratory diseases and the available studies primarily focus on pre-processing of cotton. This review highlights the uncertainties that remain; and recommends several areas for future research on respiratory health of textile workers.

**Key Words:** Cotton dust. Lung diseases. Byssinosis. Textile workers. Preventive measures. Pneumoconiosis.

## INTRODUCTION

The textile industry over the years has gone through many modifications in its operation; with the most important change being large-scale mechanization. For cloth manufacturing, various steps that cotton has to go through after its harvesting are outlined in Figure 1.<sup>1</sup> The process of ginning, spinning and weaving generates large amounts of dust referred to as cotton dust.<sup>2</sup> Cotton dust is the dust, present in air during the handling or processing of cotton. It contains a mixture of many substances including ground-up plant matter, fiber, bacteria, fungi, soil, pesticides, non-cotton matter, and other contaminants.<sup>2,3</sup> Gram negative bacterial endotoxins within the cotton dust have been hypothesized to be the etiological agents for byssinosis – the disease associated with cotton dust exposure among textile workers.<sup>4,5</sup>

Schilling, in 1963, described criteria for grading of byssinosis, based on symptoms of chest tightness.<sup>6</sup> Lung function measurements may also be used to assess byssinosis among textile workers.<sup>7</sup> Other respiratory symptoms prevalent among textile workers include; cough, phlegm, wheezing, shortness of breath, chest tightness and chronic bronchitis.<sup>8-10</sup>

In China, 32% of workers in textile mills were found to be suffering from byssinosis.<sup>5</sup> Studies conducted in other developing countries found byssinosis prevalence of

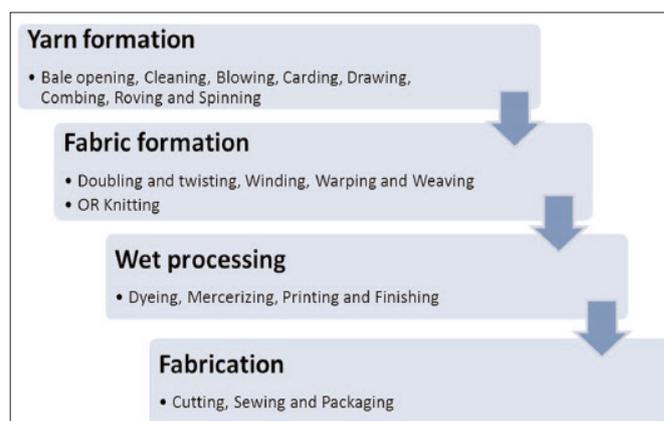


Figure 1: Flow diagram of various processes at textile industries.

14.2% among cotton processing workers in Turkey,<sup>11</sup> 43.2% among blowers and 37.5% among carders in Ethiopia.<sup>12</sup> In Bangladesh, the prevalence of chronic bronchitis and/or asthma was 5.7% and chest tightness or breathlessness was 4.3%.<sup>13</sup> In Pakistan, a recent study found prevalence of byssinosis to be approximately 10.5% among spinning and weaving workers in Karachi, with the spinning workers having a higher prevalence of approximately 18%.<sup>9</sup>

Although there is a large body of empirical evidence regarding the burden of lung diseases or symptoms among textile workers exposed to cotton dust, there is limited data to support possible protective measures for these workers. Among various causes of chronic lung diseases, occupational dust exposure may be considered as high priority area for further research due to its potential to prevent respiratory morbidity.<sup>14</sup> In this context, the present review will add important knowledge regarding possible intervention strategies in the occupational setting of textile mills. Specifically, this

Department of Community Health Sciences, The Aga Khan University, Karachi.

Correspondence: Dr. Asaad Ahmed Nafees, Assistant Professor, Department of Community Health Sciences, The Aga Khan University, Stadium Road, P.O. Box 3500, Karachi 74800. E-mail: [asaad.nafees@aku.edu](mailto:asaad.nafees@aku.edu)

Received: September 15, 2014; Accepted: April 14, 2015.

review aimed to evaluate the availability of different approaches of control of cotton dust exposure for decreasing risk of respiratory diseases in Pakistan and other developing countries.

## METHODOLOGY

The review was conducted between June 2012 to April 2013, and included literature in English language available through internet sources including PubMed, Cochrane Library, Google and Google Scholar. Peer reviewed original articles and technical reports were included in the review. Non-peer reviewed articles, review articles, commentaries, conference proceedings, editorials, newspaper reports and letters to the editor were excluded. Interventions, specific to processes in textile mills other than those related to cotton, were also excluded.

Key words used in different combinations included 'textile workers, cotton dust, prevention, intervention, respiratory illnesses/symptoms, lung function, cotton pre-processing, and washed cotton'. Cotton dust associated lung diseases included respiratory illnesses and symptoms such as byssinosis, chronic bronchitis, chronic obstructive pulmonary disease (COPD), asthma, occupational asthma, cough, phlegm, shortness of breath, wheezing and chest tightness.

The initial search identified 2,469 entries which were shortlisted to 70 after adjusting for duplication and reviewing the titles only. Further articles were excluded because they were not in English language, were not directly addressing objectives of the review or were letters to the editors. Remaining 40 articles were separately reviewed by each of the authors and 30 were excluded because they did not consider any specific preventive strategy, which resulted in selection of 10 shortlisted articles, which are included in the review (Figure 2 flowchart, Table I).

**Framework:** For the organization of results of this review, we followed a simple framework for 'control of health hazards in the workplace' which categorizes control measures into three possible categories: Engineering controls, administrative controls, and personal protective equipment (PPE).<sup>15,16</sup> This framework is based on hierarchy of control methods or strategies in the shape of a pyramid, where most preferred and effective category is placed on the top. Engineering controls were defined as measures meant for eliminating the hazard at the point of origin. This may also include substitution with safer materials or chemicals. Administrative controls were defined as measures that the management of a facility has influence over through manufacturing method or employee work assignment activities and PPEs were defined as a barrier employed for the protection of an employee from health hazard.

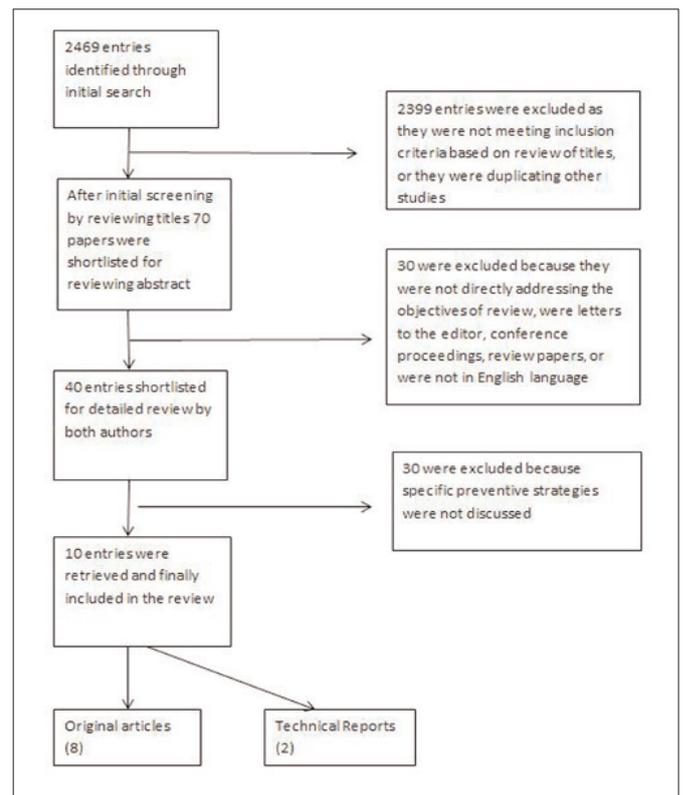


Figure 2: Flow diagram of various steps of the review process and number of excluded articles at each step.

## RESULTS AND DISCUSSION

**Engineering controls:** Engineering controls are the priority hazard control methods at workplace, four articles related to this category were found where focus was drawn on pre-processing of cotton (Table I). Pre-processing may include autoclaving, heating, steaming, and washing of cotton before use in textile units.<sup>17-21</sup>

Merchant *et al.* conducted several experimental tests in controlled settings to assess the effects of heating, washing, and steaming on cotton dust levels and lung function of 16 textile workers. This was a 'before-after' study, which comprised a total of 33 trials. Their work demonstrated a worsening of lung function due to heating of cotton, while steaming led to comparatively smaller decline in lung function. Washing of cotton did not result in decline in lung function. However, the cotton proved to be difficult to process.<sup>18</sup> These findings were not statistically significant, although further regression analysis was done. Possible confounders such as age, smoking status, section, and duration of work were not adjusted. In addition to a small sample size the findings of this study have limited external validity. Based on these findings, another study was conducted for further evaluation of the steaming method (n=62). Results of these intervention studies show that whatever benefit of steaming, which was achieved, was not long-lasting and the intervention led to delayed release of fine dust particles which could be even more hazardous compared to no intervention at all.<sup>17</sup>

**Table I:** Description of studies included in the review.

First author [year of publication]	Title	Type of paper/method	Type of intervention/preventive method
Committee members [1972]	Hygiene standards for cotton dust. British Occupational Hygiene Society Committee on Hygiene Standards Sub-committee on Vegetable Textile Dusts.	Report	Standards enforcement
Merchant JA, <i>et al.</i> [1973]	Preprocessing cotton to prevent byssinosis	Original article	Pre-processing (heating, washing and steaming)
Merchant JA, <i>et al.</i> [1974]	Intervention studies of cotton steaming to reduce biological effects of cotton dust	Original article	Steaming
Imbus HR, <i>et al.</i> [1974]	Steaming of cotton to prevent byssinosis - a plant study.	Original article	Steaming
Fawcett IW, <i>et al.</i> [1978]	The effect of sodium cromoglycate, beclomethasone dipropionate and salbutamol on the ventilatory response to cotton dust in mill workers	Original article/double-blind placebo controlled trial	Effects of bronchodilator drugs on lung function
Olenchock SA, <i>et al.</i> [1983]	Endotoxins in cotton: washing effects and size distribution	Original article	Cotton washing
Petsonk EL, <i>et al.</i> [1986]	Human ventilatory response to washed and unwashed cottons from different growing areas	Original article	Cotton washing
Task Force for byssinosis prevention [1995]	Washed cotton. A review and recommendations regarding Batch Kier washed cotton	Report	Cotton washing
Hend IM, <i>et al.</i> [2003]	Bactericidal treatment of raw cotton as the method of byssinosis prevention	Original article/ Laboratory based study	Bactericidal treatment of cotton
Boubopoulos NJ, <i>et al.</i> [2010]	Reduction in cotton dust concentration does not totally eliminate respiratory health hazards: the Greek study	Original article	Standards enforcement

Intervention studies by Imbus *et al.* (n= 167) also found that although steaming of cotton led to less decline in lung function, and decreased concentration of cotton dust levels, there was no significant difference in frequency of byssinosis before and after steaming.<sup>19</sup> This finding may also be attributed to delayed release of dust particles as was the case with previous studies and no further research was carried out on steaming of cotton.

Later work focused on washing of cotton to prevent byssinosis; and in this regard, Olenchock *et al.* conducted a study in a model cardroom where they assessed cotton samples (n=17) for dust concentration. Their work demonstrated that washing leads to significant decline (up to 95%) in endotoxins level in the airborne cotton dust.<sup>22</sup> Petsonk *et al.* conducted another before and after study on 30 volunteers in a model cardroom. They demonstrated that exposure to washed cotton led to reduced decline in lung function as compared to exposure to unwashed cotton, and a similar decline in airborne endotoxin levels. These findings were statistically significant; however, there was a small sample and possible confounders were not adjusted.<sup>20</sup>

Similar findings were observed from the work of 'Task Force for Byssinosis Prevention', which found that the more severe the washing conditions, the more reduction in airborne cotton dust. Since severely washed cotton (at 100°C for 30 minutes) led to processing difficulties in textile manufacturing, further research was done on mild washing (essentially water rinsing) of cotton dust on batch kier systems.<sup>21</sup> Their work demonstrated that mild washing of cotton leads to reduction in airborne cotton dust level by 50% and a statistically significant 19 - 55 fold reduction of endotoxin levels. They concluded that mildly washed cotton may lead to prevention of acute

and possibly chronic respiratory effects among exposed workers.<sup>21</sup> Although washing of cotton seems to be a promising option for prevention of byssinosis, to date there is lack of clear evidence regarding two important aspects: Whether this leads to prevention of chronic respiratory effects; and more importantly how feasible it is for the textile industry (since mildly washed cotton is more difficult and costly to process).<sup>3</sup>

An alternate option to washing is the bactericidal treatment of cotton before use. In this regard spraying of benzododecinium bromide (a bacteriostatic chemical used for hand sanitation and disinfection of medical instruments) solution was found to be effective in decreasing the endotoxins content of cotton.<sup>23</sup> This assessment was done on bactericidal treated cotton samples and not on samples of airborne cotton dust and we are not aware what would happen to the actual respirable cotton dust concentrations.

In addition to pre-processing, improved workplace design and machinery are other important sectors to be considered. Dust control measures are possible at various stages in the production and processing of cotton. In the field factors that may affect the dust concentration include climatic conditions, plant disease or pest infestations, use of chemicals, harvesting methods and mechanism for storage after harvesting.<sup>3</sup> At the gin, use of lint cleaners have been found to reduce the amount of respirable dust in the later processes.<sup>3</sup> Jacobs *et al.* have described possible dust control methods at each stage of processing in the mills including automation at the time of bale opening, enclosure at the time of bale opening and carding, oil overspraying at the time of carding, humidifying at the time of spinning and winding, and applying air cleaning devices at the time of winding.<sup>3</sup>

**Administrative controls:** Administrative controls may involve setting and implementing standards and guidelines for dust control, environmental surveillance, periodic medical examinations like spirometry, worker training and smoking cessation programmes. However, we could not find direct empirical evidence regarding the effectiveness of such measures in actual setting of the textile mills.

In the US, the Occupational Safety and Health Administration (OSHA) has the mandate to set and enforce workplace standards for cotton dust exposure.<sup>24</sup> The agency initially developed the standards in 1978 and these were later revised in 1985.<sup>3</sup> Such permissible exposure limits (PEL) are average exposures as measured over an 8-hour workday. For yarn manufacturing, the limit is 200 micrograms of cotton dust per cubic meter of air; for textile waste houses, 500 micrograms; for slashing and weaving operations, 750 micrograms; and for waste recycling and garneting, 1000 micrograms. Hygiene standards for cotton dust were also developed by a Committee of the British Occupational Hygiene Society.<sup>25</sup>

Various measures recommended for dust control include: (1) cleaning floors with a vacuum; (2) disposing of dust in such a way that little dust scatters; (3) using mechanical methods to stack, dump or handle cotton; (4) checking, cleaning, and repairing dust control equipment and ventilation systems. Employers must supply employees with respirators, if other measures are not sufficient. In addition, employers are required to provide free annual medical exams, and conduct a training programme at least annually. Such standards have been postulated to be largely successful in reducing cotton dust exposure over the years while improved health status of workers has also been documented. However, we do not have direct empirical evidence to assess the effectiveness of these standards. Moreover, the textile industry had to bear costs for implementation of these standards, and there were far-reaching economic implication of this social regulation as documented by Yandle.<sup>26</sup>

A recent study by Boubopoulos *et al.* found that reduction in cotton dust concentration to levels below the OSHA standards did not totally eliminate respiratory health hazards.<sup>27</sup> This study (n=443) from Greece found a high prevalence of asthma (57%) and byssinosis (8%) with mean cotton dust level of 0.16 mg/m<sup>3</sup>. This study included workers who have been employed for a year or more in the same mill. Therefore, we are neither aware of the previous occupational exposures nor of the cotton dust standards in the industry. It is possible that there have been some recent improvements in the industry which would take few years to reflect a change in the health effects. However, based on the findings of this study, we may establish more comprehensive and

country-specific standards for cotton dust within different sections of the industry. Moreover, standards are also required for monitoring the bacterial endotoxins.<sup>28,29</sup>

**Environmental surveillance:** A focused framework for environmental public health surveillance has been described which considers three types i.e. hazard, exposure and outcome surveillance.<sup>30,31</sup> In textile industry, hazard surveillance may involve the continuous monitoring of cotton dust through personal or area air sampling (Lumsden-Lynch Vertical Elutriators (VE)).<sup>32</sup> In terms of the exposure surveillance, no biomarker is currently available.

As part of outcome surveillance, baseline and periodic spirometry is essential for maintaining a healthy workforce. Periodic spirometry is generally recommended on an annual basis. However, in low-income settings this may be repeated every 3 years.<sup>33,34</sup> Various risk factors were found to be associated with lung function decline such as smoking, occupational exposures, pre-existing lung disease, and abdominal fat deposition.<sup>34</sup> Therefore, appropriate worker training and educational programmes supported by an enabling environment are essential. The additive effect (statistical interaction) of smoking on respiratory symptoms among textile workers has long been known.<sup>35</sup> Furthermore, there is evidence that educational programmes for smoking cessation among textile workers may at least lead to a positive intention and preparation for quitting.<sup>36</sup> However, we could not find any specific intervention being implemented among textile workers for smoking cessation.

Wegman suggested specific components of respiratory disease surveillance programme for cotton processing workers which include: (1) regular evaluation of health status, (2) education of employees, (3) maintenance of health records, (4) evaluation of protective devices, (5) training and performance of personnel and equipment, (6) epidemiological evaluation of results, and (7) regular evaluation of exposures.<sup>37</sup> These components are useful for designing a surveillance programme for textile workers. However, an ethical concern which may arise with the initiation of such programmes, especially in developing countries, is that of job insecurity for workers diagnosed with respiratory impairment and it is imperative that worker's rights should be ensured within such programmes.<sup>37</sup>

Although worker training and education are essential components of any occupational safety and health programme, there is little data regarding various training methodologies and their relation with health outcomes among textile workers. Further research is needed in order to assess the effectiveness of various learning theories, such as the 'adult learning theory', for designing appropriate training methods.<sup>38</sup> A recent systematic review found that though there is strong evidence to support the role of training effectiveness in

behaviour change; however; there is inconsistent and insufficient evidence to relate the training effectiveness with health outcomes.<sup>39</sup>

Bowden *et al.* mentioned the role of trade unions relating to the decline of byssinosis in UK in the 20th century.<sup>40</sup> Their work highlights a social aspect of this disease which was an important factor in increasing the momentum for greater awareness regarding the control of byssinosis at that time. Although due to large scale advocacy and resulting stringent regulations the textile industry in UK practically ceased to exist, the involvement of trade unions may still be considered pertinent. Participatory approach has been found to have good results for improving occupational safety and health in various informal sectors;<sup>41,42</sup> this approach needs to be explored further in textile industry which may lead to improvement in the ownership by textile workers.

**Personal protective equipment:** Although PPEs are the least preferred methods, their use is necessitated in certain emergency situations or at any time when the engineering and administrative control methods are inadequate. Different types of respirators are available depending on the exposure level and corresponding efficiency of the respirator in providing effective protection (determined by the Assigned Protection Factor or APF).<sup>43</sup> These respirators range from simple N95 disposable respirators to self-contained breathing apparatus (SCBA). Appropriate training of workers should be an essential component of the respiratory protection programme in order to maximize efficiency.<sup>43</sup> Although specific guidelines are available regarding the use of respirators and face pieces by textile workers, there is lack of field-based studies testing their effectiveness. Surgical facemasks have been found to have 95% or greater efficiency in terms of providing effective protection against H5N1 associated outbreak of SARS (severe acute respiratory syndrome).<sup>44</sup> A recent study found that facemasks may offer protection against flour dust exposure among bakers, demonstrating a reduction in inhalation of wheat allergens by up to 96%.<sup>45</sup> Whether these masks can be used in textile mills in developing countries as cost-effective alternatives in low resource settings needs to be assessed.

Besides PPEs, some research has been done to explore the possible preventive potential of bronchodilator drugs. However, these are not found to be effective as a preventive strategy and their use may be limited to relief of symptoms in workers with respiratory impairment.<sup>46</sup>

## CONCLUSION

This study reviewed the available literature on preventive strategies for protection against cotton dust associated respiratory symptoms and illnesses among textile workers. We found limited data addressing the

possible interventions for improving respiratory health outcomes of textile workers; especially, there was a lack of randomized controlled trials addressing this research question.

In engineering control methods, the authors could not find studies assessing improved workplace design and machinery having an impact on the health outcomes of textile workers. There is some literature available on pre-processing of cotton through various means; however, the effects on yarn quality and the reluctance of textile mill administrators to adopt this method remain a major hindrance. The use of bactericidal insecticides is another possibility; however, there is limited data on its effectiveness in the workplace settings.

Administrative controls, such as environmental surveillance and periodic medical examinations, are essential in any cotton dust exposed workplace in order to protect the respiratory health of workers. Although specific standards and guidelines are available for cotton dust monitoring, the authors could not find studies specifically assessing the environmental and medical surveillance programme and its effects on the health outcomes. Similarly, guidelines are available regarding the type of respirator required in different sections of the textile industry; however, the authors were unable to find studies assessing the effectiveness of respirators in workplace settings.

Over the last few years, there has been an increasing focus in the global priorities for occupational health research towards effective and economically feasible interventions.<sup>47</sup> Moreover, there is a need to combine various training methodologies with appropriate engineering control methods in order to design multifaceted interventions for the prevention of respiratory diseases associated with cotton dust among textile workers. Occupational health services with multifaceted interventions are needed to address the new challenges being faced by the workforce today.<sup>48</sup> With increasing population growth and globalization, the global workforce is expected to keep rising and so is the health risk associated with different occupations including the textile workers.<sup>47</sup>

The authors believe that although cotton dust-associated respiratory morbidity has a huge burden, especially in the developing countries, however this area has somehow been unable to capture the attention of occupational and environmental health researchers. Therefore, further research is required to confirm the pathogenesis of byssinosis, which in turn should lead to new standards related to monitoring of bacterial endotoxin levels, effectiveness of training, and education programmes in improving knowledge, practices as well as health outcomes of textile workers. Participatory approaches to improve ownership of workers in such training and educational programmes are also

recommended. Engineering controls methods such as workplace design and machinery improvement need to be assessed scientifically in order to determine their effectiveness. Further research is required to assess feasibility and practical applicability of pre-processing of cotton to reduce airborne cotton dust levels in later processes in the textile industry. Use of low-cost intervention, such as facemasks for protection against cotton dust associated respiratory morbidity and mortality, needs to be assessed.

**Acknowledgement:** We are highly indebted to Professor Dr David Coggon (University of Southampton, UK) for his support throughout this work including at the time of conception of the review, finalization of objectives, and a review of the included articles and the final draft. This was a non-funded study.

## REFERENCES

- Environmental Protection Agency (EPA, US). EPA Office of Compliance Sector Notebook Project: Profile of the Textile Industry. Office of Compliance, Office of Enforcement and Compliance Assurance, U.S. Environmental Protection Agency: Washington, DC; 1997.
- Kilburn KH. Byssinosis and other diseases of textile workers. In: Rom WN, editors. Environmental and occupational medicine. Philadelphia: Lippincott-Raven; 1998. p. 449-55.
- Jacobs RR. Strategies for prevention of byssinosis. *Am J Ind Med* 1987; **12**:717-28.
- Noweir MH. Studies on the etiology of byssinosis. *Chest* 1981; **79**:62S-7S.
- Wang XR, Zhang HX, Sun BX, Dai HL, Hang JQ, Eisen EA, *et al.* A 20-year follow-up study on chronic respiratory effects of exposure to cotton dust. *Eur Respir J* 2005; **26**:881-6.
- Schilling RS, Lammers B. A report on a conference on byssinosis. Spain: Proceedings of the 14th International Congress on Occupational Health, Madrid; 1963.
- World Health Organization (WHO). Recommended health-based occupational exposure limits for selected vegetable dusts. Report of a WHO study group. Geneva: WHO; 1983.
- Nagoda M, Okpapi JU, Babashani M. Assessment of respiratory symptoms and lung function among textile workers at Kano Textile Mills, Kano, Nigeria. *Niger J Clin Pract* 2012; **15**:373-9.
- Nafees AA, Fatmi Z, Kadir MM, Sathiakumar N. Pattern and predictors for respiratory illnesses and symptoms and lung function among textile workers in Karachi, Pakistan. *Occup Environ Med* 2012; **70**:99-107.
- Niven RM, Fletcher AM, Pickering CA, Fishwick D, Warburton CJ, Simpson JC, *et al.* Chronic bronchitis in textile workers. *Thorax* 1997; **52**:22-7.
- Altin R, Ozkurt S, Fisekci F, Cimrin AH, Zencir M, Sevinc C. Prevalence of byssinosis and respiratory symptoms among cotton mill workers. *Respiration* 2002; **69**:52-6.
- Abebe Y, Seboxa T. Byssinosis and other respiratory disorders among textile mill workers in Bahr Dar northwest Ethiopia. *Ethiop Med J* 1995; **33**:37-49.
- Ahsan MR, Ahmad SA, Khan TP. Occupational exposure and respiratory illness symptoms among textile industry workers in a developing country. *Appl Occup Environ Hyg* 2000; **15**:313-20.
- Bouhuys A, Beck GJ, Schoenberg JB. Priorities in prevention of chronic lung diseases. *Lung* 1979; **156**:129-48.
- OSHA. Job hazard analysis. U.S. Department of Labor. Occupational safety and health administration. OSHA 3071. 2002. Available from: <http://www.osha.gov/Publications/osh3071.pdf>
- Friend MA, Kohn JP. Fundamentals of occupational safety and health. 4th ed. Lanham, Maryland: Government Institutes, an imprint of the Scarecrow Press, Inc; 2007.
- Merchant JA, Lumsden JC, Kilburn KH, O'Fallon WM, Copeland K, Germino VH, *et al.* Intervention studies of cotton steaming to reduce biological effects of cotton dust. *Br J Ind Med* 1974; **31**:261-74.
- Merchant JA, Lumsden JC, Kilburn KH, Germino VH, Hamilton JD, Lynn WS, *et al.* Pre-processing cotton to prevent byssinosis. *Br J Ind Med* 1973; **30**:237-47.
- Imbus HR, Suh MW. Steaming of cotton to prevent byssinosis: A plant study. *Br J Ind Med* 1974; **31**:209-19.
- Petsonk EL, Olenchock SA, Castellan RM, Banks DE, Mull JC, Hankinson JL, *et al.* Human ventilatory response to washed and unwashed cottons from different growing areas. *Br J Ind Med* 1986; **43**:182-7.
- The task force for byssinosis prevention. Current intelligence bulletin 56. Washed cotton. A review and recommendations regarding Batch Kier washed cotton. National Institute of Occupational Safety and Health (NIOSH). August 1995 [internet]. 2012. Available from: [www.cdc.gov/niosh/washcot.html](http://www.cdc.gov/niosh/washcot.html)
- Olenchock SA, Mull JC, Jones WG. Endotoxins in cotton: Washing effects and size distribution. *Am J Ind Med* 1983; **4**:515-21.
- Hend IM, Milnera M, Milnera SM. Bactericidal treatment of raw cotton as the method of byssinosis prevention. *AIHA J (Fairfax, Va.)* 2003; **64**:88-94.
- OSHA. OSHA Laws and Regulations. U.S. Department of Labor. Occupational safety and health administration [Internet]. 2013. Available from: <http://www.osha.gov/law-regs.html>
- Hygiene standards for cotton dust. British occupational hygiene society committee on hygiene standards sub-committee on vegetable textile dusts. *Ann Occup Hyg* 1972; **15**:165-92.
- Yandle B. A social regulation controversy: The cotton dust standard. *Soc Sci Q* 1982; **63**:58-69.
- Boubopoulos NJ, Constandinidis TC, Froudarakis ME, Bours D. Reduction in cotton dust concentration does not totally eliminate respiratory health hazards: the Greek study. *Toxicol Ind Health* 2010; **26**:701-7.
- Shi J, Mehta AJ, Hang JQ, Zhang H, Dai H, Su L, *et al.* Chronic lung function decline in cotton textile workers: Roles of historical and recent exposures to endotoxin. *Environ Health Perspect* 2010; **118**:1620-4.
- Liebers V, Raulf-Heimsoth M, Bruning T. Health effects due to endotoxin inhalation (review). *Arch Toxicol* 2008; **82**:203-10.
- Thacker SB, Stroup DF. Future directions for comprehensive public health surveillance and health information systems in the United States. *Am J Epidemiol* 1994; **140**:383-97.

31. Thacker SB, Stroup DF, Parrish RG, Anderson HA. Surveillance in environmental public health: Issues, systems, and sources. *Am J Public Health* 1996; **86**:633-8.
32. OSHA. Occupational Safety and Health Standards, Toxic and hazardous substances. Regulations (Standards - 29 CFR). Air sampling and analytical procedures for determining concentrations of cotton dust. U.S. Department of Labor. Occupational Safety and Health Administration [Internet]. 2013. Available at URL: [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10054](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10054)
33. Harber P, Levine J, Bansal S. How frequently should workplace spirometry screening be performed?: Optimization via analytic models. *Chest* 2009; **136**:1086-94.
34. Hnizdo E, Glindmeyer HW, Petsonk EL. Workplace spirometry monitoring for respiratory disease prevention: A methods review. *Int J Tuberc Lung Dis* 2010; **14**:796-805.
35. Su YM, Su JR, Sheu JY, Loh CH, Liou SH. Additive effect of smoking and cotton dust exposure on respiratory symptoms and pulmonary function of cotton textile workers. *Ind Health* 2003; **41**:109-15.
36. Gunes G, Ilgar M, Karaoglu L. The effectiveness of an education program on stages of smoking behavior for workers at a factory in Turkey. *Ind Health* 2007; **45**:232-6.
37. Wegman DH. Objectives for health monitoring and surveillance. *Am J Ind Med* 1987; **12**:699-709.
38. Robson L, Stephenson C, Schulte P, Amick B, Chan S, Bielecky A, *et al.* A systematic review of the effectiveness of training & education for the protection of workers. Toronto: *Institute for Work & Health*; 2010.
39. North Carolina Department of Labor (NCDOL). A guide for persons employed in cotton dust environments. Occupational Safety and Health Division, N.C. Department of Labor [Internet]. 2013. Available from: <http://www.nclabor.com/osha/etta/indguide/ig5.pdf>
40. Bowden S, Tweedale G. Mondays without dread: The Trade Union response to byssinosis in the Lancashire Cotton Industry in the twentieth century. *Soc Hist Med* 2003; **16**: 79-95.
41. Henning R, Warren N, Robertson M, Faghri P, Cherniack M. Workplace health protection and promotion through participatory ergonomics: An integrated approach. *Public Health Rep* 2009; **124**:26-35.
42. Manothum A, Rukijkanpanich J. A participatory approach to health promotion for informal sector workers in Thailand. *J Inj Violence Res* 2010; **2**:111-20.
43. CDC. NIOSH Pocket Guide to Chemical Hazards. Cotton dust (raw). Centers for Disease Control and Prevention, USA [Internet]. 2013. Available from: <http://www.cdc.gov/niosh/npg/npgd0682.html>
44. Li Y, Wong T, Chung J, Guo YP, Hu JY, Guan YT, *et al.* *In vivo* protective performance of N95 respirator and surgical facemask. *Am J Ind Med* 2006; **49**:1056-65.
45. Renstrom A, Mattsson ML, Blidberg K, Doekes G, Bogdanovic J, Tovey E. Nasal air sampling for measuring inhaled wheat allergen in bakeries with and without facemask use. *J Occup Environ Med* 2006; **48**:948-54.
46. Fawcett IW, Merchant JA, Simmonds SP, Pepys J. The effect of sodium cromoglycate, beclomethasone dipropionate and salbutamol on the ventilatory response to cotton dust in mill workers. *Br J Dis Chest* 1978; **72**:29-38.
47. Rosenstock L, Cullen M, Fingerhut M. Occupational health. In: Jamison DT, editor. *Disease control priorities in developing countries*. New York: *Oxford University Press*; 2006. p.1127-46.
48. World Health Organization (WHO). *Global strategy on occupational health for all, the way to health at work. Recommendations of the second meeting of the WHO collaboration centers in occupational health*. Beijing, China: *WHO*; 1994.

