A SYSTEMATIC REVIEW ON RISK FACTORS FOR REDUCED LUNG FUNCTION DUE TO OCCUPATIONAL RESPIRABLE DUST EXPOSURES; 2005 - 2015

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ABSTRACT

Background: Occupational exposures to respirable dust includes various hazardous substances were commonly associated with acute and chronic health effects especially on respiratory system and lung function performance among workers in various industries.

Objective: The purpose of this review was to identify the risk factors that lead to reduced lung function among workers due to occupational respirable dust exposure in the industry.

Materials and Methods: A systematic review of articles related to occupational exposure and its effects on lung function among workers was compiled using a series of keywords in databases (ProQuest, PubMed and ScienceDirect). Studies that were conducted between 2005 to 2015, written in English and used a quantitative design that focus on occupational respirable dust exposure were included in this review.

Result: Most of the studied reviewed concluded that there were at least two associated factors that caused the reduction of lung function among the subjects studied. These factors were later classified into two major factors namely occupational related factors and non-occupational related factors.

Conclusion: Risk factors influence the lung function test results among exposed workers in many ways, either through direct effect or due to combination effect such as synergistic action.

Keywords: *Respirable Dust, Reduced Lung Function, Risk Factors*

1.0 Introduction

Occupational exposures to respirable dust includes various hazardous substances such as steel dust, cement dust, black carbon and rubber dust were associated with acute and chronic health effects especially on respiratory system and lung function performance (Attarchi et al., 2013; Fell et al, 2010; Yanagi et al., 2014; Zeleke et al., 2010). Respirable dust exposures are likely to vary based on the type and size of the industry. An example, in cement manufacturing, workers might be exposed to as high as 30.18 mg/m3 of personal respirable dust (Kakooei et al., 2012) or as low as 0.6 mg/m^3 (Fell et al., 2010). In addition, in agricultural based industry, the exposure to respirable dust varies according to a season and local climate condition (Prado et al., 2012).

The health risk posed by respirable dust through inhalation are influenced by the deposition region and biological response (Zeleke et al., 2010). Studies done by Kakooei et al., (2012); Mohammadien et al., (2013); and Prado et al., (2012) were able to explain the relationship between exposure and health effects, including respiratory symptoms and changes in lung function among the subjects studied. Among the most common health conditions caused by respirable dust exposure are Chronic Obstructive Pulmonary Disease (COPD), impaired lung functions and ischaemic heart disease (da Silva et al, 2012; Hnizdo & Vallyathan, 2003; Sjögren, 1997). In mice, there is evidence that exposure to respirable carbon black dust caused an increase of pro-inflammatory cytokines in lung tissue (IL-6 and IL-8 level in serum and lung homogenate) (Zhang et al., 2014).

In human body, respirable dust in a fine fraction (<0.1μm) are capable to transcytose epithelial/endothelial cells into the systemic circulation before reaching sensitive target tissues. It also able to generate reactive oxygen species which have been linked to inflammatory lung diseases and invade systemic circulation which lead to cardiac dysfunction (BéruBé et al, 2007; Schins & Borm, 1999)

Measuring workers lung function is widely accepted as the most important diagnostic tool for early recognition of pulmonary dysfunction especially in studies associated with workplace exposure (Mohammadien et al., 2013). As workers might portray a normal lung function clinically, but test on lung function will provide an exhibit of workers' lung health providently

A comprehensive approach is vital in ensuring a good and reliable data. The researcher should be able to explain the relationship between the causative agent and the health effect while considering the confounding risk factors that may affect the final results. Many of the studies conducted have taken this point into consideration. Moreover, with various type of research approaches, identifying the risk factors that link the cause and effect are crucial.

Therefore this systematic review exercise were carried out by adopting a structured methodology for evaluating the literature and evidence aiming at the risk factors that lead to reduced lung function due to occupational exposures.

2.0 Materials and Methods

2.1 Research Strategy

Journal articles from the year 2005 to 2015 that are related to the occupational exposure to respirable dust were compiled using a series of keyword. The keywords used were source for such information*, respirable dust,* lung function,*Occupational,*respiratory function,*spirometry, with an exclusion on *,biomass,*lung cancer*,silicosis*. Three major databases namely ProQuest, PubMed and ScienceDirect were used. The search is only limited to both full original paper and titles which published in English available within the year 2005 to 2015.

A total of 2643 publication related to topic of interest was identified. The final full report of 53 publications were reviewed to identify the risk factors which reduced lung function performance due to occupational exposure to respirable dust.

2.2 Quality of Assessment

The methodological quality of all relevant full text articles were retrieved using from well-known database and were cross check for reliability of the database provider.

2.3 Selection of Publications

The articles selected for final selection were screened based on the following criteria; the article published between the year 2005 until 2015, publish in English, contain research done using human subject in occupational setting (not from domestic exposure) focussing on lung function performance and used a quantitative design that report on the performance of the workers lung function due to occupational exposure to respirable dust. Articles published in books or book chapters as well as research report were not considered. Based on such practice, there were a total of 33 usable articles that met all of the selection criteria as illustrated in Figure 1.

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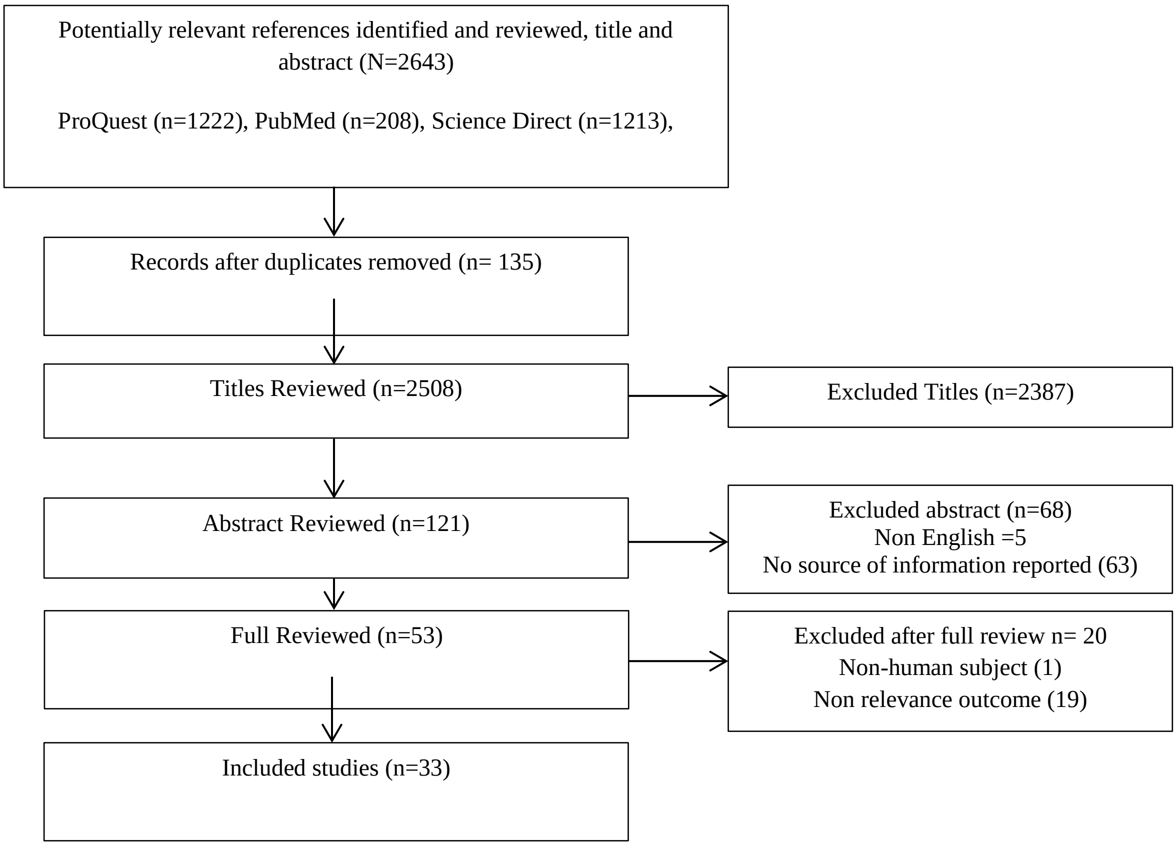

Figure 1: Flowchart of the systematic review process. Abbreviation (n) Number

2.4 Analysis strategy for the selected publication

A detailed analysis was used to extract two major categories of information from the selected articles:

a) Occupational Exposure; First step was to define the occupational exposure (the exposure were directly due to occupational setting and not from other environmental hazards.)
b) Risk factors: The second step was to determine the risk factors for occupational exposure in all selected articles.
c) Finding: The last step was to assess the findings from selected articles.

The following characteristic were extracted from each study; first author, year, location, type of study, sample size, type of industry, results and risk factors

3.0 Result

3.1 Literature research

In order to complete this exercise, a total of 2643 records were identified from the literature search and later been screened as shown in Figure 1. The number of records was later downsized to 2508 after duplicates were removed. An exclusion of title were later made because it was evident that they addressed non-occupational based on exposures and qualitative studies only.

The remaining 121 abstracts were identified as potentially relevant to the purpose of this exercise and later 68 were excluded. The abstracts were excluded when it contains one of these exclusion categories: (1) published before the year of 2005 and (2) non-occupational setting (domestic exposure).

The remaining abstracts for full review were 53 articles, but 19 were excluded due to non-relevant outcome, which was not clear based on the abstract alone and one due to non-human subject. The final 33 articles were reviewed after all relevant articles retrieved by the search were assessed according to the inclusion criteria. The outcomes were later presented and discuss systematically.

3.2 Analysis of included studies

Table 1 summarized the finding of the risk factors which led to reduced lung functions among workers exposed to respirable dust at the workplace. Majority of the studies adopted a cross-sectional approach to identify the relationship between exposures, health effects and associated risks.

Table 1: Summary of Systematic Review on Risk Factors for Reduced Lung Function Due To Occupational Exposure to Respirable Dust Exposure; 2005 To 2015.

Author/Year/ Location	Method	Type of study	Sample size	Type of Industry	Results	Risk factor
(Yanagi et al., 2014) Japan	Spirometry Test For FEV_1	Cohort study	n=40 (exposed) n=29 (non-exposed)	Manufacturing (Black Carbon)	1. No significant different in lung function for both group (control and exposed) due to availability of LEV and usage of PPE	Smoking, Availability Of Engineering Control, Usage Of PPE
(Zhang et al., 2014) China	Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), And Brunauer-Emmett-Teller Spirometry Test,	Cross-setional	n=81 (exposed) n=104 (non-exposed)	Manufacturing (Carbon Black)	1. The reduction of lung function parameters including FEV1%, FEV/FVC, MMF%, and PEF% in CB workers was observed	Smoking, Workplace Concentration (carbon black)
(Hamzah, Bahri, Tamrin, & Ismail, 2014) Malaysia	Questionnaires, Spirometry	Cross-sectional	n=402	Manufacturing (steel)	1. Smoking and cumulative respirable metal dust were negatively associated with FEV1. 2. Age and smoking were among the factors associated with respiratory symptoms (OR: 0.92 – 1.78).	Smoking, Workplace Concentration (metal dust)
(A & Majumder, 2014) India	Dynamic Pulmonary Function Parameters Were Carried Out Including Physical Parameters, Respiratory Abnormalities, Year Of Exposure And Smoking History	Cross-sectional	n=203 (exposed) n=141 non-exposed)	Manufacturing (Jute)	1. FVC, FEV1, FEF 200-1200 and PEFR values of higher age group non-smoker of low dust zone were significantly higher in comparison to the non-smoker of high dust zone. 2. Prevalence of all the above respiratory abnormalities was higher among smokers than non-smokers	Smoking, Working Duration, Workplace Concentration (Jute dust)
(Mohammadien et al., 2013) Eygpt	Questionnaires, Interview And Spirometry Test	Cohort study	n=200 (exposed) n=200 (non-exposed)	Manufacturing (Flour)	1. Highly significant decline in FEV1%, FVC% and FEV1/FVC% was noticed regarding the duration of exposure to flour dust ($p<0.0001$) 2. Additive effect of smoking was noticed as there was a highly significant decline of FVC%,FEV1%, FEV1/FVC%, FEF25% and FEF75% in smokers compared to non-smokers ($p < 0.0001$).	Smoking, Site Of Work, Years Of Employment
(Mahmoud El-Prince, 2013) Egypt	Questionanires, Chest Examination, Spirometry, Skin Prick Test, Histamine Challenge	Cross-sectional	n=43 (exposed) n=64 (non-exposed)	Manufacturing (bakery)	1. Significant different for FVC, FEV1/FVC among bakers as compared to control group	Workplace Concentration (Flour dust)
(Meo et al, 2013) Pakistan	Interview, Spirometry	Cross-sectional	n=50 (exposed) n=50 (non-exposed)	Manufacturing (cement)	1. Significant reduction was observed in the mean values of Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Peak Expiratory Flow (PEF) and Maximal Voluntary Ventilation in cement mill workers who had been working in the cement industry for more than 10 years compared to their matched un-exposed group	Years Of Employment
(Rathod & Sorte, 2013) India	Spirometry	Cross-sectional	n=120	Quarry (Stone crusher)	1. Pulmonary function test bears relationship with duration of exposure, as the duration of exposure increases the pulmonary function tests goes on decreasing	Working Duration, Years Of Employment

(Singh, Bhardwaj, & Deepak, 2013) India	Interview, Spirometry, Personal Sampling	Cross-sectional	n=309 (exposed) n=74 (non-exposed)	Manufacturing (steel)	1. The spirometric parameters such as FVC, FEV1, FEV1/FVC ratio, FEF25−75, PEFR, PIFR, and FIVC were significantly lower in exposed group than in controls.	Working Duration
(Attarchi et al., 2013) Iran	Questionnaires, Clinical Examination, Spirometry, Environmental Monitoring	Cross-sectional	n=453 (exposed) n=178 (non-exposed)	Manufacturing (rubber)	1. A significant correlation was found between occupational exposures in the rubber industry and abnormal spirometric findings ($p < .05$). 2. The synergistic effect of cigarette smoking and occupational exposures on lung function was significant (SI = 2.25; $p < .05$).	Smoking, Years Of Employment
(Kakooei et al., 2012) Iran	Personal Sampling, Spirometry Test, Respiratory Symptom Questionnaires, XRF For Silica	Cross-sectional	n=94 (exposed) n=54 (control)	Manufacturing (Cement)	1. Significant reduction in Forced Expiratory Volume in one second (FEV1), Forced Vital Capacity (FVC), and Forced Expiratory Flow between 25% and 75% of the FVC	Availability Of Engineering Control, Smoking
(Prado et al., 2012) Brazil	Spirometry Test, Respiratory Symptoms And Oxidative Stress Markers Among Two Different Exposed Group Of People	Cohort study	n=113 (exposed) n=109 (non-exposed)	Agricultural (Sugarcane Harvesting)	1. Decrease in lung function and antioxidant enzyme activity was observed in both populations during harvesting; this decrease was greater among the sugarcane workers	Site Of Work, Workplace Concentration (Sugarcane dust)
(Elserougy et al, 2012) Eygpt	Spirometry, Questionnaires, Clinical Exam For Blood And Urine	Cross-sectional	n=56 (exposed) n=52 (non-exposed)	Aluminum Foundry	1. Smokers of both groups (exposed and controls) showed significantly higher ual and lower A1AT compared with nonsmokers. 2. Significant negative correlation between the duration of exposure and A1AT ($p < 0.05$). 3. Positive significant correlation between smoking index (SI) and UAI 4. There was also significant negative correlation between SI and some of the pulmonary function tests namely the percentage of predicted FVC ,FEV in the first second and peak expiratory flow in the exposed group.	Smoking
(Shieh et al., 2012) Taiwan	Questionnaire Interviews, Pulmonary Function Tests, Skin Prick Tests, And Measurement Of Specific Ige .	Cohort study	n=95 (exposed) n=40 (non-exposed)	Manufacturing (Tea-agricultural based)	1. Tea workers ball-rolling workers had a lower ratio of the 1-second forced expiratory volume to forced vital capacity (FEV1/FVC) and a lower maximal mid-expiratory flow rate expressed as% of the predicted value–MMF (%pred). 2. During the shift, significant declines in pulmonary function.	Type Of Task, Age, Workplace Concentration (Tea dust), Years Of Employment
(Masoud Neghab et al, 2012) Iran	Interview, Questionnaires, Chest X-Ray, Spirometry, Personal Sampling, XRF For Chemical Composition	Cross-sectional	n=39 (exposed) n=40 non-exposed)	Construction	1. Symptoms such as regular cough, phlegm, wheezing, productive cough and shortness of breath were significantly ($p<0.05$) more prevalent among exposed workers 2. Ratio of FEV_1/FVC in exposed subjects was significantly different from that of non-exposed individuals	Working Duration, Workplace Concentration (Dolomite dust)
(Nordby et al., 2011) Europe	Personal Sampling, Spirometry, Questionnaires	Prospective cohort study	n=4265	Manufacturing (cement)	1. Elevated odds ratios for symptoms and airflow limitation (range 1.2–2.6 in the highest quartile), but not for chronic bronchitis, were found in the higher quartiles of exposure compared with the lowest quartile.	Smoking, Usage Of PPE, Type Of Task, Age
(Masoud Neghab et al, 2011) Iran	Questionnaires, Spirometry, Personal Sampling	Cross-sectional	n=72 (exposed) n=69 (non-exposed)	Manufacturing (Rubber)	1. Significant decreases in some preshift and postshift parameters of pulmonary function of exposed workers with a spirometric pattern consistent with restrictive ventilatory disorder were found.	Years Of Employment
(Zeleke et al, 2011) Ethiopia	Interviews, Spirometry	Cross-shift	n=71 (exposed) n=20 (non-exposed)	Manufacturing (cement)	1. Forced Expiratory Volume in one second (FEV1) and FEV1/Forced Vital Capacity (FEV1/FVC) were significantly reduced from 2009 to 2010 among the cleaners ($p < 0.002$ and $p < 0.004$, respectively) and production workers ($p < 0.05$ and $p < 0.02$, respectively)	Smoking, Years Of Employment

(Jaakkola, Sripaiboonkij, & Jaakkola, 2011) Thailand	Questionnaires, Spirometry, Exposure Assessment	Cross-sectional	n=232 (exposed) n=76 (non-exposed)	Manufacturing (tiles)	1. Factory workers had lower spirometric functions than office workers. 2. The adverse effect of dust on lung function was larger in current smokers suggesting synergism between smoking and tile dust exposure	Smoking, Years Of Employment
(Fell et al., 2010) Norway	Blood Sample, Sputum And Spirometry Test	Cross-sectional	n=35 (exposed n=15 (internal low exposed) n=39 (non-exposed)	Manufacturing (Cement)	1. Significantly higher percentage of neutrophils in sputum was observed in cement production workers during the exposed period compared with the non-exposed period and with the external reference group.	Type Of Task, Age, Working Duration
(Zeleke et al., 2010) Ethiopia	Personal Sampling, Peak Expiratory Flow Before And After Working, Modified Respiratory Symptoms Score.	Cross-shift and Cross-sectional	n=40 (exposed) n=20 (control)	Manufacturing (Cement)	1. PEF decreased significantly across the shift in the high exposed group. 2. The number of years of work in high-exposure sections and current smoking were also associated with cross-shift decrease in PEF.	Smoking, Usage Of PPE, Workplace Concentration (Cement dust), Years Of Employment
(Poornajaf et al , 2010) Iran	Spirometry, Personal Sampling, XRD For Silica Phases	Cross-sectional	n=112 (exposed) n=85 (non-exposed)	Manufacturing (Cement)	1. 35.7% of the exposed workers had abnormality in lung function compared with 5.7% of those unexposed. 2. Significant reductions in forced expiratory volume in one second percent (fev1), forced vital capacity (fvc), and fev1/fvc (*p*< 0.05) in exposed workers	Type Of Task, Workplace Concentration (Cement dust)
(Kitamura et al., 2009) Japan	Questionnaires, Personal Sampling, Chest X-Ray, Spirometry, Blood Sample	Cross-sectional	n=809 (exposed) n=805 (non-exposed)	Manufacturing (toner)	1. Influence of smoking on pulmonary function indices among subject studied, however, no difference in pulmonary function indices was observed between exposed and non-exposed workers	Smoking
(Osman & Pala, 2009) Turkey	Questionnaires, Physical Examination, Spirometry	Cross-sectional	n=328 (exposed) n=328 (non-exposed)	Manufacturing (furniture)	1. The mean FEV1 and FVC values of woodworkers, among both smokers and non-smokers, were signifi cantly low, although the FEV1/FVC value was high (p < 0.05). 2. Increase both in FEV1 and FVC values among the woodworkers who had a working period less than 10 years and exposed to wood dust at concentrations over 4 mg/m3 compared to the woodworkers who were exposed to wood dust at less than 4 mg/m3 (p < 0.05)	Smoking, Years Of Employment
(Sripaiboonkij, Phanprasit, & Jaakkola, 2008) Thailand	Questionnaires, Spirometry, Environmental Sampling	Cross-sectional	n=167 (Exposed) n=76 (non-exposed)	Production (Milk)	1. Factory workers showed significantly lower forced expiratory volume in one second measured as percentage of predicted value.	Age, Gender
(Halvani, Zare, Halvani, & Barkhordari, 2008) Iran	Questionnaires, Spirometry, Environmental Sampling	Cross-sectional	n=176 (exposed) n=115 (non-exposed)	Manufacturing (tiles and Creamic)	1. Significant relationship between frequent respiratory symptoms and years of employment among exposed workers. 2. Lower Lung capacity in workers with symptoms	Smoking, Years Of Employment
(Bio, Sadhra, Jackson, & Burge, 2007) Ghana	Questionnaires, Spirometry, Personal Sampling	Cross-sectional	n=1236	Mining	1. Significant reduction in $FEF_{25-75\%}$ with increasing dust exposure and an interaction with ever smoking	Smoking, Age
(Masoud Neghab & Choobineh, 2007) Iran	Interview, Questionnaires, Chest X-Ray And Spirometry And XRF	Cross-sectional	n=88 (exposed) n=80 (non-exposed)	Manufacturing (Cement)	1. Exposed workers compared to their referent counterparts showed significant reductions in the parameters of lung function.	Years Of Employment

(Minov et al, 2007) Macedonia	Questionnaires, Skin Prick Test, Spirometry, Histamine Challenge, Asthma Diagnosis, Serial PEFR Measurement, Serial Nonspecific Bronchoprovocation Testing, Occupational Asthma Diagnosis, Environmental Measurement	Cross-sectional	n=63 (exposed) n=63 (non-exposed)	Tea processing	1. Higher prevalence of respiratory symptoms in the exposed workers, whereas spirometric parameters were significantly lower	Workplace Concentration (Tea dust)
(Mamuya et al, 2007) Tanzania	Interview, Spirometry, Personal Sampling	Cross-sectional	n=299	Mining (coal)	1. The prevalence offev1/FVC < 0.7among the workers was 17.3%. 2. Cumulative respirable exposure to coal mine dust and quartz were significantly associated with airflow limitation.	Workplace Concentration (Coal dust)
(Xiao et al., 2006) China	Questionnaires, Spirometry, Health Examination, Workplace Environment Sampling	Cross-sectional	n=1709 (788 Male, 921 female) n=661 health examination n=119 for spirometry test	Manufacturing (rush matting)	1. Prevalence of pneumoconiosis (1/0 or more correlated with cumulative dust exposure (r=0.192,p<0.0001) 2. 19.3% and 34.5% of employees suffered from respiratory impairment for FVC and FEV1 3. Dose response relationship between dust level and Pneumonosis prevalence	Availability Of Engineering Control, Working Duration, Years Of Employment, Site Of Industry
(Chen, Doyle, & Wang, 2006) Taiwan	Questionnaires, Spirometry And Personal Sampling	Cross-sectional	n=1339 (exposed for physical examination) n=277 (exposed for personal sampling)	Manufacturing (Steel)	1. Duration of employment, smoking, subjective dustiness, and past respiratory illnesses can predict these respiratory symptoms 2. Average respirable dust exposure significantly decreased the forced vital capacity (FVC) and forced expiratory volume in one second (FEV1.0) in smoking workers 3. In the non-smokers, an effect of respirable dust exposure on FEV1.0/FVC was shown	Smoking, Past Respiratory Illness, Years Of Employment
(Çöplü et al., 2005) Turkey	Dust Measurements, Serum Total Ige, Skin Prick Test, Pulmonary Function Testing And Questionnaire On Respiratory Symptoms	Cross-sectional	n=109 (exposed) n=78 (non-exposed)	Manufacturing (reed for cellulose)	1. After the adjustment for pack-years of smoking, percentage of predicted FEV1, FVC, FEV1/FVC and FEF25_75 in reed workers were significantly lower than office workers. 2. Wheezing was associated with older age (>40 years) and ever smoking, and cross-shift decline in FVC and FEV1 with shorter duration of work.	Smoking, Type Of Task, Age

3.2.1 Location of studies

Table 1 showed the location of the studies involved in this review. Majority of the studies reviewed were conducted in Asian countries namely Japan (n=2), India (n=3), China (n=2), Iran (n=7), Malaysia (n=1), Pakistan (n=1), Taiwan (n=2) and Thailand (n=2). Several studies were conducted in African countries; Eygpt (n=3), Ethiopia (n=2), Ghana (n=1), Tanzania (n=1). The remaining six studies were conducted in Europe (n=1), Macedonia (n=1), Brazil (n=1), Turkey (n=2) and Norway (n=1).

3.2.2 Type of industry

Of all the 33 studies reviewed, majority of the studies were conducted in manufacturing based industry and followed by few other industrial setting. The details of the proportion according to type of industry were presented in Table 2.

Table 2: Proportion on type of industry reviewed.

Type of Industry	Number of Industry (n)
Manufacturing	
Cement	8
Steel	2
Black carbon	3
Tile and Ceramic	2
Food based	6
Rubber	2
Agro-based product	3
Furniture	1
Foundry	1
Quarry	1
Mining	2
Construction	1
Agricultural	1
Total (N)	**33**

3.3 Respondent

Workers in each industry were the population of these studies and majority (n=28) of the studies employed a control group for comparison on the effect of exposure for two groups of people. Only a few studies (n=5) concentrate at employing all workers as the study subject without a control group. The highest number of population were carried out in a 4-years prospective cohort study in manufacturing of cement involving 4265 workers (Nordby et al., 2011). The lowest number of population were also done in the same type of industry comparing between 2 group of workers (n=50 for exposed) and (n=50 for non-exposed) (Meo et al., 2013).

3.4 Occupational Related Factors

3.4.1 Workplace

Availability of engineering control equipment is another factor that affects the lung function among workers exposed to respirable dust at workplace (Kakooei et al., 2012). The concentration of dust largely being influence by the availability of engineering control equipment. This were reported by studies done by Xiao et al., (2006) and Yanagi et al., (2014) where results have shown a non-significant different in lung function between exposed and non-exposed group due to availavility of local exhaust ventilation (LEV) system together with the use of personal protective equipment in both industry respectively.

Workplace concentration together with the site of work strongly affects the lung function of the subject. Results from Mohammadien et al., (2013) indicates that respirable dust concentration differences for each worksite resulted in different effects on workers lung function ($P<0.0001$). In addition, Prado et al, (2012) recognized the effect of an industrial site with the exposure to respirable dust among the workers and local populations.

Reduced lung function among subjects were also associated with the type of task conducted by the workers. Results between exposed and non-exposed workers indicate that reduced lung function were more obvious among the exposed group with significant value of $P<0.0001$ (Çöplü et al., 2005; Masoud Neghab & Choobineh, 2007; Nordby et al., 2011; Poornajaf et al., 2010; Prado et al., 2012; Shieh et al., 2012).

Another occupational related factor was the use of personal protective equipment among the subject studied. Osman & Pala, 2009; Singh et al., 2013 in their studies recognized that improper selection and unavailability of personal protective equipment affects the lung function of the exposed workers. In contrast, Yanagi et al., (2014) documented that personal protective equipment use reduced the black carbon dust exposure among the workers and resulted no health effect among the subjects.

3.4.2 Years of Employment and Working Duration

Chen et al., (2006); Halvani et al., (2008); Jaakkola et al., (2011); Meo et al., (2013); Masoud Neghab et al., (2011); Osman & Pala, (2009); Rathod & Sorte, (2013); Shieh et al., (2012); Xiao et al., (2006) ; and Zeleke et al., (2011, 2010) recognized that years of employment as another associated factor for reduced lung function among workers exposed to respirable dust at a workplace. Their studies indicate that numbers of years working in high-exposure environment significantly associated with reduced in the mean values of Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Peak Expiratory Flow (PEF) and Maximal Voluntary ventilation among workers (P value between <0.005 to <0.001).

Working Duration are explained by the time spend for each day working shift. Xiao et al., (2006) found a positive association between prevalence of respiratory symptoms and working duration among non-smoking worker group. Rathod & Sorte, (2013) indicated an inverse relationship between pulmonary function with duration of exposure among 120 workers in quarry.

3.5 Non-Occupational Factors

3.5.1 Smoking Behaviour

The majority (n=25) of the studies reviewed discussed at least two associated factors that cause the reduction of lung function among the subjects. These factors were later classified into four groups namely behavioural factors, workplace associated factors, employment and work duration factor and physiological factors.

Overall, more than half (n=17) of the studies reviewed described smoking behaviour among the subjects as the main associated factors that lead to reduced lung function and increased symptom prevalence of respiratory problems. Smoking habit was recognized as the major confounding behavioural factors that affects the results of the spirometry test among the subjects. Few studies recognized that smoking behaviour influences the respiratory function among subject (Elserougy et al., 2012; Mohammadien et al., 2013) even though in Yanagi et al., (2014) the overall results indicate no significant different for both exposed and non-exposed group.

3.5.2 Physiological Factor

Physiological factor such as age, gender and past respiratory illness is another associated factor which affect the lung function among workers. Çöplü et al., (2005) in their finding recognized the effects of age on workers lung function especially among senior workers.

Gender differences among the subjects also influence the spirometry results. Sripaiboonkij et al., (2008) explained that gender differences on lung function are an important factor especially for predicted value control in regression model.

Only one study reported the effect of past respiratory illness in this systematic review exercise. Chen et al., (2006) reported that past respiratory illness could be used to predict respiratory symptoms among exposed workers. However, it must be supported by results from the spirometry to explain further the condition.

4.0 Discussion

The purpose of this systematic review was to identify the risk factors that lead to reduced lung function among workers exposed to respirable dust at workplace. This exercise found that smoking was the most common factor which reduced the lung capacity of workers exposed to respirable dust. These could be explained by the fact that smoking affects a person respiratory muscle by the influence of free radical on the vascular system that leads to a reduction in respiratory muscle blood supply. Subsequently, this will have an impact on respiratory function.

A recent study by Anong et al, (2014) concluded that reduction in strength of respiratory muscle especially in FVC results was obvious among smoker as compared to non-smoker. It also explained that in normal condition, non-smoker had a better respiratory function as compared to smoker. Since majority of the subjects involved in this systematic reviews are male aged between 20 to 45 years, the intensity and duration of smoking could also explained the reason smoking habits become the most crucial factor that led to reduced lung function among subjects. This argument were also in tandem with Anong et al, (2014) in their finding where smoking habit was significantly decrease FVC/FEV1 in adolescent smokers. This was also supported by finding from Mohammadien et al., (2013) and A & Majumder, (2014) recognizing the effect of smoking behaviour significantly in decreased the FVC and FEV^1 among workers who smokes. In addition, Zeleke et al., (2010) explained that current smoking behaviour among workers was associated with cross shift decrease in PEF among workers studied.

The additive effect of smoking together and respirable dust exposure is another factor why lung function performances were lower among workers who smoked. These are commonly known as synergistic effects. The combination effect of chemicals constituents from cigarette and respirable dust potentially enhance the condition resulting in lower lung function among workers who smoker as compared to non-smoker workers. This was also supported by findings from Attarchi et al., (2013) and Jaakkola et al., (2011) where cigarette smoking and occupational exposures were significantly correlated with the reduction on lung function among studied subjects (SI=2.25; $p<0.05$)

On the other hand, majority of the subjects studied in this systematic reviewed are male and this could help to further explain why smoking behaviour was highly recognized as one of the major associated factors for reduced lung function among subjects. However, this assumption could not be deeply discussed due to a limited scope of literature search in this systematic review exercise.

The application of personal protective equipment (PPE) among workers also have an impact on workers' lung performance. The correct selection and application of PPE especially respiratory protection equipment (RPE) could reduce the workers exposure towards the inhalation of these dusts. These are based on the fact that each type of RPE especially the air purifying respirator was designed to filter specific range of dust by forcing the contaminated air through a filtering element. This argument was supported by Yanagi et al., (2014) explaining that application of dust-protective mask in high concentration workplace resulted in insignificant different for lung function performance in both exposed and non-exposed group of workers. The use of RPE in reducing respirable dust exposure among workers could be explained by answering the route that dust normally enters the human body. It is known that inhalation process through nasal and mouth are the only pathway for this respirable dust to enter the nasopharynx and later the human lung system. Therefore, applications of these devices (RPE's) were the sole protection for workers from respirable dust. Findings from Nordby et al., (2011); Osman & Pala, (2009) and Yanagi et al., (2014) also revealed that application of personal protective device especially in higher exposure group is considered to dilute the association between workplace exposure and lung functions performance. In addition, Osman & Pala, (2009) also explained that significant decrease in $FEF_{25\text{-}75}$ values for subject who did not use mask in furniture manufacturing industry ($p>0.001$). Conversely, these findings revealed that the application of RPE is important with a significant effect on workers lung function performance.

The availability of engineering control was also another important factor in reducing the exposure of respirable dust to workers. In several studies (Kakooei et al., 2012; Xiao et al., 2006), the lack of engineering control devices such as unavailability of local exhaust ventilation (LEV) was highlighted as the one of the factor for higher level of dust exposure in workplace and resulted in poor lung function among workers. In addition, Yanagi et al., (2014) concluded that the availability of local exhaust ventilation (LEV) system in the work place help to reduce the dust exposure to acceptable limits and positively affect the lung function of the workers. In certain type of industry such as cement manufacturing, engineering control was considered vital for controlling the concentration of respirable dust in surrounding environment. Requirements for dust control do exist under the environmental law in each country involved in this systematic review. However, the degree of control might be different from one country to another and closely related with the size and type of the industry, type of task and the accepted tolerable level set by each countries. Therefore, the selection and proper design of engineering control devices for each industry should be prioritized and carefully selected to reduce the exposure to workers.

This review recognised the effect of exposure duration together with duration of employment and its effect towards workers lung function performance. A large number of studies agreed that employment duration together with continuous exposure affect the workers lung function (A & Majumder, 2014; Chen et al., 2006; Fell et al., 2010; Halvani et al., 2008; Mohammadien et al., 2013; Shieh et al., 2012; Xiao et al., 2006; Zeleke et al., 2010; Zhang et al., 2014). In addition, working duration were also bears an inverse relationship with the lung function performance among workers (Rathod & Sorte, 2013; Singh et al., 2013). This could be explained by fact that longer duration of working in highly dusty environment tends to expose the workers to high level of respirable dust; cumulatively or persistent exposure which later affect their lung function. This was supported by Nilesh et al, (2006) and Zhang et al., (2014) as their findings concluded that impairment of lung efficiency increased with duration of exposure and the duration of employment. Even in some cases, it can also be used to predict the respiratory associated problem among studied subjects (Zhang et al., 2014).

However, it is noticed that this condition might also associated with age factor and its association in reduced lung function performance, among senior workers as explained by Çöplü et al., (2005). These could be explained by the fact that ageing process change the physiology of the respiratory system depicting the decrease in static elastic recoil of lung and in respiratory muscle performance resulting in increased work of breathing (Pruthi & Multani, 2012). However, in certain condition, this effect may take place earlier than the normal range of age where lung functions start to decline. It was found that based on the review, younger workers who had been exposed to higher level of respirable dust showed a lower lung function performance together with high prevalence of chronic respiratory symptoms as compared to those exposed to lower concentration of respirable dust (Zeleke et al., 2011). As for gender effect on the physiological factors, male subjects tend to have lower lung function compared to the female subject. It is suggested that this results could be due to the lung capacity as male are having larger alveoli and alveolar surface than female (Carey et al., 2008) thus resulted in a greater effects from respirable dust exposure. However, it is notice also that majority of the studies in this review employed male subject and this could affect the overall results due gender biased effect. Perhaps, a more balanced selection number of subjects could help to further explore the relationship between exposure and its effect on gender.

Another important finding was type of industry which commonly studied regarding occupational exposure to respirable dust. Manufacturing industry dominate the number of studies which explore the relationship between respirable dust exposure and its effect on workers lung function performance. These could be explained by the fact that the activities conducted in manufacturing largely deals with handling and processing of various substances which in turn expose the workers to harmful substances especially in cement and steel based industry.

5.0 Conclusion and recommendation

The systematic review exercise has identified various factors which caused reduction of lung function among workers exposed to respirable particulate at a workplace. In overall, these factors were classified into two major groups based on similarity of certain characteristic. Occupational Related Factors (workplace, employment and working duration) and Non-occupational Factors (smoking behavioural and physiological factors) were identified as having a direct relationship with workers lung function performance. These factors affect the lung function results among workers in many ways, either directly influences or due to combination effect such as synergistic action. Nevertheless, variety of results derived from this exercise could help a researcher to further understand on the cause and effect of respirable dust exposure to workers lung function performance. However, few questions remain unanswered. Therefore, the authors would like to suggest a few recommendations as follows in relation to this systematic review exercise:-

a) In designing research on exploring the relationship between respirable dust exposure and its health effects, certain consideration should be emphasize by researcher regarding the effect of these factors towards the intended results. The authors fully recommend that few factors such as smoking, gender and age should be put into special consideration during the study design and analysis stage.
b) Psychosocial component, as another potential factor which may possibly affect workers in industry
c) Attention should be given to other possible factors such as ambient exposures from surrounding environment including local traffic condition and mode of transportation among workers as these could also expose the workers to respirable dust while commuting to work.
d) Future research should be conducted to answer the possibility of adopting some intervention such as physical exercise towards reducing the health impact of respirable dust exposure to workers as its potential was well established in promoting better quality of life among silicosis and pneumoconiosis patients.
e) This systematic review also indicates that majority of the studies concerns certain type of industry only. This feedback provides a good prospect for researcher to explore other types of industry and activity in relation to occupational exposure. Finding a better solution in order to reduce the effect of workplace exposure using multiple approaches could be next step to address those concerns.

Declaration

We, the authors of the article declared that there is no conflict of interest regarding the publication of this article.

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