Occupational chronic obstructive pulmonary disease: an update

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**Occupational COPD: An Update**

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Words: 4,764

References: 74

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Introduction

Chronic obstructive pulmonary disease (COPD), one of the most prevalent healthcare problems in the world, constitutes a major cause of morbidity and mortality in both developed and underdeveloped countries and accounts for over 120,000 deaths per year in the United States, representing the third leading cause of mortality.(1, 2) COPD is estimated to be responsible for the death of 250 people per hour worldwide with the annual deaths from the disease surpassing lung cancer and breast cancer combined.(2) The global economic burden of the disease is large and, according to the World Health Organization, is projected to rank fifth in burden of disease caused worldwide by year 2020.(3)

Tobacco use remains the main risk factor for development of COPD; nevertheless, this disease also develops in never smokers.(4) Occupational risk factors have been well described in previous reports in the literature and represent an important and preventable cause of COPD. For example, data from the Third National Health and Nutrition Examination Survey, estimated that 19% of all cases of COPD (31% among never smokers) were attributed to occupational factors.(5) Similarly, a study performed by the World Health Organization (WHO) in 2000, estimated that selected occupational risk factors were responsible worldwide for 13% of COPD (COPD) and 11% of asthma.(6)

A systematic review published by the American Thoracic Society (ATS) in 2003, estimated a 15% population attributable-risk for the work-related burden of COPD.(7) Several subsequent reports provide further evidence of the occupational burden of COPD. The purpose of this review is to summarize the previous studies of occupationally related COPD, and to provide an update of the most recent advances in the field.
Historic Background and Terminology

The association between dust exposure and development of chronic bronchitis dates back to the nineteenth century, when several breathing problems among workers laboring in dusty trades (coffee workers, malt workers, flax seed workers, rag paper makers, and grain millers) were reported. Although the pathology of inorganic dust exposure-caused lung disorders was also demonstrated in the 19th Century (especially among miners) and the term pneumoconiosis was introduced to describe such fibrotic interstitial lung disease, only in recent years has airway disease due to inorganic dust exposure been recognized as well. Thus, between 1940 and 1960, several reports described a link between the presence of irreversible airflow obstruction in patients with chronic bronchitis, observed among mine workers heavily exposed to inorganic dust and fumes.

Despite more than a century elapsing between the original descriptions of occupation related “dust” exposure and development of chronic bronchitis, the term “occupational COPD” has not been used frequently in the literature. In addition, the clinical spectrum of occupational exposures and obstructive lung disorders is wide, with many airway disorders overlapping or evolving into fixed airway obstruction.

COPD is defined by the World Health Organization (WHO) Global Obstructive Lung Disease (GOLD) initiative and the American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines as a disease characterized by airflow limitation that is not fully reversible and is progressive and associated with an abnormal inflammatory response of the lungs to noxious particles or gases. In addition to airflow obstruction, COPD traditionally comprises two overlapping clinical entities with different pathological characteristics:
emphysema and chronic bronchitis. Recent data, however, have emphasized the phenotypic complexity of disease and the importance of factors such as inflammation and polymorbidity.(13)

**Occupational Asthma and COPD**

Asthma is defined as a chronic inflammatory disorder of the airways characterized by recurrent episodes of coughing, wheezing and dyspnea, and characterized by the presence of reversible airflow obstruction. Work-related asthma represents a subset of patients in which asthma either develops de novo or is exacerbated in occupational environments.(7) According to a review of the literature published by the American Thoracic Society, the occupational burden of asthma is significant in the general population, with a population attributable risk of 15%.(7) Additionally, recent studies subsequent to the ATS review have reaffirmed that a substantial proportion of the new adult onset asthma cases can be attributed to occupational exposures. Even though long-standing asthma unrelated to its cause is believed to progress to poorly-reversible obstruction consistent with COPD, the contribution of occupational asthma to the overall prevalence of COPD is not well studied.(14) In contrast to “occupational asthma”, “occupational COPD” is complicated by the frequent occurrence of tobacco use and the long time between exposure and development of airflow limitation. Thus, the term “occupational COPD” is infrequently used in clinical practice.(15)

**Other Work-related obstructive airway disorders**

In addition to asthma, chronic bronchitis and emphysema, work-related exposures can be associated with other obstructive airway disorders that do not meet criteria for COPD. For example, occupational exposure to organic dusts has been associated with variable airflow
limitation and acute bronchitis. Examples of organic dust airway disease include exposure to cotton, flax, hemp, jute, sisal, and several organic grains.(16)

Byssinosis, an occupational lung disease resulting from chronic exposure to cotton dust, is characterized by episodes of dyspnea, productive cough and chest tightness accompanied by a reduction in FEV1. Prolonged exposure results in frequent and severe symptoms and functional changes that are indistinguishable from COPD.(17)

In addition, several cases of severe and progressive airflow limitation and obliterative bronchiolitis have been reported in association with diacetyl exposure and among workers of flavoring plants and microwave popcorn plans.(18) These findings suggest that many workers are at risk for development of a wide spectrum of airway disorders that can lead into fixed obstructive airway limitation, and some are at risk for rapid progression to severe obstructive lung disease.

**Epidemiological Evidence**

Ascertainment of the true incidence and prevalence of occupational COPD can be difficult due to several factors: a) a large proportion of patients with diagnosis of COPD and occupational exposures, also share other risk factors such as concomitant tobacco use; b) COPD has a multi-factorial etiology, where a clear cause and effect relationship cannot be established at short term in the majority of the patients; c) there are no pathognomonic features of occupational COPD that allow to distinguish a subcategory of COPD; d) there has been significant heterogeneity in the definitions of COPD during the last couple of decades, complicating the prevalence estimate among populations at risk.
There is substantial scientific and epidemiological evidence to support the association between work related exposure to dust, noxious gases and fumes and development of COPD. For example, longitudinal studies involving coal miners, hard rock miners, tunnel workers and concrete manufacturing workers, have found that exposures are associated with a progressive annual decline of lung function measured by spirometry (mean decrease in FEV$_1$ of 7-8 mL/year) even after adjustment for cigarette smoking.(7) While a mean decrement of 8 mL/year seems trivial, over a 40 year career this translates to a loss of over 300 mL, in addition to that attributable to smoking, aging and other factors. Furthermore, other evidence that suggests that in some cases the cumulative effect of dust exposure may exceed that from cigarette smoking in the absence of dust exposure. For example, a study that included 100 tunnel workers found that the decrease in FEV$_1$ associated with cumulative exposure to respirable dust was greater among non-smoking tunnel workers (50-60 mL/year) compared to non-exposed smokers (35 mL/year).(19)

A large number of cross sectional and longitudinal community based studies have reported an increase risk for respiratory illnesses among exposed workers. Although the major limitation of these studies is the potential for exposure misclassification and variations in the definition of COPD, these studies provide evidence to support the association between occupational exposures and the risk of developing COPD.(5, 20)

Two major studies performed in the United States including over 17,000 patients provide the largest cross sectional cohorts evaluating occupational exposures and COPD: Korn et al studied a random sample of 8,515 subjects from six major metropolitan areas in the United States and analyzed the self-reported occupational exposure to dust, gas and fumes. After adjusting for smoking and other risk factors for airflow limitation, the authors found that subjects with
reported occupational exposure had a higher prevalence of symptoms (chronic cough, wheezing and dyspnea). In addition, occupational exposure was associated with a higher prevalence of COPD defined by the presence of a FEV\textsubscript{1}/FVC ratio of < 0.6. (OR=1.53, 95% CI=1.17-2.08).(20) Similarly, Hnizdo et al analyzed data from 9,823 subjects included in the NHANES III study in the United States and concluded that approximately 19% of all cases of COPD was attributable to multiple occupational exposures (31% among never-smokers).(5)

Large community based studies describing the relation between occupation and COPD have also been performed in other countries. In a cross-sectional study from China that included 3,606 adults (40-69 years of age), dust exposure was associated with an increased risk for chronic respiratory symptoms (OR 1.30, CI 1.09-1.48) and a decline in FEV\textsubscript{1} and FEV\textsubscript{1}/FVC ratio after adjustment for smoking status.(21) Similarly, another cross sectional study in Netherlands [Dutch Population Study (ECRHS)], included 1,906 subjects and found that organic dust exposure was associated with a higher risk for asthma (OR 1.48, 95% C.I. 0.95-2.30) and lower FEV\textsubscript{1} (-59 mL, 95% C.I. -114 to -4). Mineral exposure in this study was associated with increased risk for chronic bronchitis symptoms (OR 2.22, 95% C.I. 1.16-4.23) and lower FEV\textsubscript{1}/FVC ratio (-1.1%, 95% C.I. -1.8 to -0.3).(22) A prospective longitudinal study in Italy evaluated 2,734 males as part of a surveillance program and found that self-reported occupational exposures to dust, vapor or fumes, was associated with an increased risk of COPD (OR 2.62, 95% C.I. 2.02 to 3.41).(23)

*Occupational Contribution to the Burden of COPD*
The overall work related burden of COPD at a population level has been well studied in the last decade. Blanc et al performed a systematic review of the eight studies (24) included in the ATS Statement on Occupational Lung Disease published in 2003(7), and found that the PAR% for occupationally related COPD was 15% (range 4%-24%) for chronic bronchitis, 13% (range 6%-30%) for dyspnea and 18% (range 12%-55%) for airflow obstruction(24). Weinman et al performed a case-control study involving 388 workers in a Northwest metropolitan area of the United States and estimated the occupational PAR% for COPD to be 43%.(25) More recently, Blanc performed a systematic review of eight population studies on occupational COPD, and estimated a PAR% for occupationally related COPD to be 15% for both chronic bronchitis (range 0-34%) and airflow obstruction (range 1-37%).(26)

Similarly, a recent prospective cohort study by Mehta et al evaluated the incidence of COPD in 4,267 Swiss workers exposed to biological dusts, mineral dusts, gases/fumes and vapors and found an increased risk (two to five fold) of COPD (stage II GOLD) and high level of occupational exposures. The PAR of stage II COPD was between 31% and 32% for biological dusts among smokers, and ranged between 43% and 56% for non-smokers depending on type and level of exposure.(27)

A summary of other relevant population studies evaluating the risk of COPD associated with occupational exposures that were completed after the latest American Thoracic Society statement on occupational lung diseases published in 2003(7) are shown in Table 1.

Specific Occupational Exposures
The association between exposure to chemical agents, noxious gases, dust and vapors and development of chronic bronchitis in humans has been widely demonstrated in the literature. Several occupations that result in organic and non-organic compound exposures have been associated with development of chronic bronchitis and potentially fixed irreversible airflow obstruction (Table 2).

a. Organic Dusts

Organic dusts are a major cause of respiratory disorders in agricultural industry. Several chemical compounds derived from bacterial and fungal contamination (endotoxin, mycotoxins, etc.) are responsible for organic dust toxicity, which may occur in association with silage, grain dust, straw, wood chips, and animal confinement buildings. (28)

Organic dust exposure resulting from agricultural work has been extensively associated with development of COPD. For example, Dalphin et al studied the effects of organic dust exposure in 250 dairy farmers from a province in France and found an increased prevalence of chronic bronchitis and worse pulmonary function compared to matched controls. (29) Eduard et al. compared the likelihood of chronic bronchitis and COPD among crop farmers and livestock farmers. Livestock farmers were more likely to suffer from both those conditions, with an odds ratio for COPD of 1.9 (95% CI: 1.4 to 2.6), and for COPD -1.4 (95% CI: 1.1 to 1.7). Importantly, the authors evaluated the effects of exposure to biological agents and found that exposure to most agents predicted respiratory morbidity, with a significant reduction in FEV₁ (-41 mL; 95% CI: -75 to -7), although the effects of specific substances could not be assessed. (30) Monso et al. studied 105 non-smoking animal farmers working inside confined buildings a prevalence of COPD of 17%; the authors describe a dose related relationship between COPD,
dust and endotoxin exposure, with the highest prevalence of COPD among subjects with highest exposures. (31) Finally, an analysis of the NHANES III study found that proportional mortality ratios for crop farm workers and livestock farm workers had significantly higher mortality associated with respiratory conditions; in addition, landscape and horticultural and forestry workers had elevated mortality for COPD. (32)

Industrial exposure to wood particles represents another important occupational risk for COPD. Studies estimated that approximately 3.5 million workers are exposed to wood dust in the world. Wood is processed in many industries including sawmills processing fresh wood, plywood mills, and furniture factories or smaller workshops using dry wood only. A review that included 10 cross-sectional studies found significant associations between exposure to wood dust and lung function decline, including a direct response rate between decline in FEV1 and DLCO and years of employment, and an increased risk for airflow obstruction (defined as FEV1/FVC < 0.70). The risk appears to be independent of type of wood (hardwood or softwood). (33)

b. Metallic Gases and Fumes

Industrial exposures to metals have been associated with development of airflow obstruction. Osmium is a highly volatile and highly toxic compound that may result in severe lung injury when inhaled (34). Vanadium, another metallic compound associated with lung inflammation, is released into the environment during oil and coal combustion and from metallurgic work. Occupational exposure can result from petrochemical, mining and steel industries. (35) A study that included 79 employees at a factory making vanadium pentoxide found an increase incidence of chronic bronchitis symptoms. (36)
Cadmium is a by-product of zinc production used industrially in electroplating and battery production. Common occupational exposures to cadmium may result from heavy metal mining, metallurgy, fossil fuel combustion, exposure to fertilizers, and from iron, steel and cement production. In the industry, cadmium exposure results from inhalation of toxic fumes and gases, although tobacco smoking is the most important single source of cadmium exposure in the general population.(37) Cadmium is capable of inducing alveolar cell damage in vitro, affecting several levels of cellular function including repair of DNA, cellular enzyme activity and membrane structure, and alpha-1 antitrypsin inhibitory capacity. Experimental emphysema can be induced in animals by administration of cadmium chloride, and several reports suggest that work exposure to cadmium can lead to the development of emphysema.(38, 39) Although cadmium exposure may be associated with COPD in highly exposed workers, an analysis of the NHANES III study by Mannino et al found that urinary cadmium levels were not elevated among never smokers with COPD (although very few people in this study had occupational cadmium exposure). (40)

Industrial aluminum exposure has been related to development of asthma and reduction of FEV$_1$ after long term exposure; a study of workers laboring in a Dutch aluminum production plant, showed that long exposure time was associated with low FEV$_1$% predicted at 5 years follow up even after removal from the exposure.(41) Finally, occupational diesel exhaust exposure has been associated with an increased risk of COPD. Individuals in a variety of occupations, including transportation, construction, mining, and maintenance, are routinely exposed to diesel exhausts. Data from the NHANES III study showed that the risk for COPD is elevated among workers (never smokers) exposed to diesel gases and fumes: construction (OR 3.5; 95% CI 0.9–14.0), transportation and trucking (OR 2.0; 95% CI 0.3–15.0). The risk is also
elevated for occupations such as vehicle mechanics, transportation, construction workers and motor vehicle operators. Similarly, a more recent case-control study in the United States, found that workers with diesel exhaust exposure had an increased risk for COPD (OR of 1.9 (95% CI 1.3–3.0), and the risk was higher among never smokers (OR 6.4, 95% CI 1.3–31.6).(25).

c. Mineral Dusts and Fumes

Mining and quarrying were the first occupations associated with significant reductions in lung function and development of irreversible airflow obstruction and severe parenchymal lung abnormalities (pneumoconiosis). Studies have shown the amount of dust exposure an independent predictor for developing chronic bronchitis and airflow obstruction, and that correlates to the degree of emphysema independent of cigarette smoking among coal miners and hard-rock miners.(43-45) Kuempel et al studied autopsy findings of 616 coal miners and quantitatively estimated cumulative exposures to respirable coal dust using data the U.S. Bureau of Mines surveys. In this study, the highest emphysema index was found in miners with history of smoking, but for the individuals who never smoked, the severity of emphysema for miners was almost six times that of non-miners.(47) Besides coal mining, several other mineral mining activities (gold, iron, copper, etc.), and quarrying industries (talc, potash, slate, kaolin) have been reported to result in occupational exposures associated with chronic bronchitis.(15) Finally, metal smelting activities have also been related with worsening annual decline of FEV1, suggesting that exposure to dusts and fumes arising from this activity may result in an increased risk for COPD.(48)
Recently, studies done in rescue workers, residents, clean workers and volunteers exposed to a massive dust cloud resulting from the World Trade Center site, have found evidence of bronchial hyperreactivity, bronchial wall thickening on CT scans and a significant reduction in 1-year decline in FVC and FEV\textsubscript{1}. A pathologic study of twelve local residents exposed to World Trade Center dust, gas and fumes, reported presence of emphysematous changes and small airway abnormalities, and macrophages had particles containing silica, aluminum, titanium dioxide, talc and metals.\textsuperscript{(49)} These findings suggest that a large portion of patients with massive dust exposure associated with building and construction sites debris (presumably inorganic in nature), have an increased risk of developing COPD at long term.\textsuperscript{(50)}

**Establishing the association between occupation and COPD**

As pointed earlier, the diagnosis of occupational COPD is infrequently made in clinical practice due to several factors. The clinician must be attentive to all potential occupational etiologies in patients diagnosed with irreversible airflow obstruction, particularly among never smokers or with history of atopy or asthma. The most important tool to help identify the etiology in these patients is to perform a thorough occupational exposure history, which must include a list of previous jobs listed in chronological order, a description of the job activities and potential exposures, and a detail analysis of the extent and duration of the potential exposure. In addition, the clinician must inquire about the use of protective equipment (i.e., masks and respirators) and if available should attempt to obtain a description of the ventilation system of the workplace.\textsuperscript{(51, 52)}

Induced sputum facilitated by inhalation of hypertonic saline solution generated by a nebulizer, has been used to support the diagnosis of dust burden in exposed workers. Fireman et
al, analysis induced sputum samples and bronchoalveolar lavage (BAL) samples obtained from 14 workers exposed to silica and hard metals. The authors found that mineralogical analysis of induced sputum was comparable to that of BAL samples, and concluded that induced sputum analysis represents a biological monitoring method to detect dust burden in healthy workers exposed to hazardous dusts.\(^{(53)}\) Lerman et al studied the correlation between the distribution of particle size in induced sputum and pulmonary function tests among 54 foundry workers, of whom 34 had been exposed to a variety of metals. The authors found that particle size correlated with lung function decline and helped differentiating between exposed and non-exposed workers.\(^{(54)}\)

Currently, the diagnosis of occupational COPD relies on clinical history of significant occupational exposure to gases, dusts, fumes or vapors, and the presence of irreversible airflow obstruction and/or the presence of emphysema on imaging studies of the chest.

**Prognosis**

Given the difficulties of establishing the diagnosis of occupational COPD, few studies have been able to address the prognosis of this group of patients. Nevertheless, some studies suggest that patients with occupational exposures that are diagnosed with occupational lung diseases other than COPD have a worse prognosis and excess mortality. For example, a study that analyzed risk of mortality by occupation over a 22-year period in England and Wales, found that mortality was highest among coal miners with diagnoses of COPD or coal worker’s pneumoconiosis. The largest component of excess mortality in this study was from diseases caused by exposure to dusts and fumes, and in particular from chronic obstructive pulmonary disease (COPD) caused by coal mine dust, silica dust and metal fume.\(^{(55)}\) More recently,
Jarvholm et al used population based case referent studies from Sweden and estimated that the number of work-related COPD deaths was much higher than asthma (about 90 versus 4 cases), and COPD had an attributable fraction of 15% for work related deaths from respiratory conditions. (56) Similarly, a study by Attfield and Kuempel investigated the causes of mortality in a cohort of coal miners from the United States. The authors used ICD (International Classification of Diseases) codes to define presence of chronic bronchitis and/or emphysema. Although the majority of the subjects had a history of smoking (80%), the authors found that mortality from COPD was associated with cumulative dust exposure with a relative risk of 1.0065 per mg-year/m³ (CI 1.0017–1.0054), although the association of cumulative dust exposure and mortality from emphysema as underlying or contributing cause was not statistically significant. (57)

Management and Prevention

There is a paucity of literature on the management and prevention of occupational COPD and there are no published guidelines yet for the same. This is in contrast to the management of occupational asthma, for which clear guidelines have been well-published. (58) Nevertheless, effective management should focus on medical treatment of already prevalent COPD as well as efforts to prevent/limit ongoing/further damage via reduction of exposure.

Clinical treatment of established COPD secondary to occupational exposures is not different from that of COPD from cigarette smoking. A detailed discussion of this treatment is beyond the scope of this review. However, of paramount importance is the smoking cessation as this is frequently a co-existing risk factor in many patients. Bronchodilators are the cornerstone
in the symptomatic management of COPD. Recently, novel data from controlled trials in COPD with the once-daily beta-2 agonist indacaterol have indicated superior bronchodilation and clinical efficacy at recommended doses over twice-daily long-acting beta-2 agonists, and at least equipotent bronchodilation compared with once-daily tiotropium. Similarly, roflumilast is a new phosphodiesterase 4 inhibitor which has shown promise in COPD. In addition to reversal of bronchoconstriction, treatment of chronic respiratory failure is obviously important. Long term oxygen supplementation has been shown to be beneficial in patients with chronic respiratory failure in the past but results of the Long term Oxygen Treatment Trial looking for the same in patients with mild hypoxemia at rest and desaturation with exercise is eagerly awaited. Also, reduction of acute exacerbations is of great importance as these are well-known to impact morbidity and mortality. A recent study of chronic azithromycin therapy in selected COPD patients showed that azithromycin decreased frequency of exacerbations and improved quality of life. Recent evidence also suggests that pulmonary rehabilitation is a highly effective and safe intervention to reduce hospital admissions and mortality and to improve health-related quality of life in COPD patients who have recently suffered an exacerbation of COPD.

Similar to other work-related diseases, prevention is the primary tool for decreasing the incidence of morbidity and disability from occupational COPD. Prevention must involve cooperation between employers, workers and their representatives, regulators, and medical personnel. For care providers, detailed history of occupational exposure is obviously important, but also of importance is to identify whether the patient has been adequately trained in the dangers of these exposures, early identification of symptoms, alternatives to the exposure and
the management options available. Preventative measures are generally classified into three types: primary, secondary and tertiary.

Primary prevention is designed to abate hazards before any damage or injury has occurred. In case of respiratory tract irritants, different strategies are available to reduce exposures. These strategies in the order of decreasing effectiveness but increasing ease of implementation include: (1) elimination (e.g., substitute alternate materials), (2) engineering controls (e.g., exhaust ventilation or process enclosure), (3) administrative controls (e.g., transfer to another job or change in work practices), and (4) personal protective equipment (e.g., masks or respirators)(66). In many cases, personal protective equipment may be the only option but it is the strategy with the most equivocal protection. This is because the effective use of personal protective equipment requires that the appropriate equipment be selected, properly fit-tested, maintained, and worn when there is potential for exposure. The failure to properly carry out any one of these essential tasks may cause failure of personal protective equipment to prevent exposure.

In many cases of occupational COPD, people have no alternatives to their job or deny the severity and degree of exposures for fear of loss of employment. Moreover, unlike workers with sensitizer-induced asthma, workers with occupational COPD may continue to work in their usual jobs if their exposure to the inciting agent is diminished(66). Consequently, secondary and tertiary prevention measures are also of great importance.

Secondary prevention addresses early detection so that morbidity and disability can be prevented by means of timely intervention. Examples include worker education and training in work processes, safety equipment, and procedures as well as some of the strategies mentioned in primary prevention above. Medical surveillance programs are a type of secondary prevention.
Any diagnosis of occupational COPD must be considered a sentinel event; other exposed workers are at risk and need to be identified promptly. A general approach to surveillance programs includes medical screening of co-workers as well as exposure monitoring(67). For medical surveillance of COPD, short symptom questionnaires can be administered before employment and repeated annually. They should include items such as improvement in respiratory symptoms on week-ends and holidays(66). In addition, spirometry can be performed on an annual basis and compared to baseline spirometric testing at the time of hire. Review of peak expiratory flow rate records over several weeks can also detect workers at risk for developing irritant-induced COPD(66).

Tertiary prevention applies to individuals who have already been diagnosed with occupational COPD. It includes institution of appropriate health care and an effort to prevent permanent disease by early removal from, or reduction of, exposure. (65). Furthermore, early recognition of the disease and early removal from, or reduction of, exposure, makes it more likely that the patient will have a slower progression of COPD.

Although there is lack of intervention studies in occupational COPD, data from certain other occupational or environmental lung diseases could be extrapolated to this condition. In occupational asthma for example, elimination of exposure has been shown to be associated with improvement in the health of already-diagnosed cases of work-related asthma in a plant where use of diisocyanates was halted(65). Similarly, reduction in air pollution during both Beijing Olympics and Summer Olympic games in Atlanta was associated with reduced incidence of asthma exacerbations(68, 69). In Dublin, there was a 15.5% reduction in respiratory deaths after ban on coal sales related to improvement in air pollution(69). Similarly, intervention studies for
indoor air pollution from bio-mass fuels in areas where they are heavily used have shown that improved stoves result in significant reduction in respiratory symptoms and a significantly lower decrease in FEV1(68)

Conclusion

COPD is a leading cause of morbidity and mortality globally. The contribution of occupational exposures to dust, gasses, vapors, and fumes remains an important factor in the development and progression of COPD in both smokers and non-smokers. Prevention strategies targeting occupational exposures to respiratory irritants will become increasingly important in the prevention of COPD.
Table 1: List of Population Studies of Occupational Exposure and Risk of COPD

<table>
<thead>
<tr>
<th>Reference</th>
<th>Type of Study</th>
<th>Population Type</th>
<th>Sample Size</th>
<th>Exposure Assessment</th>
<th>Diagnosis Outcomes</th>
<th>Outcomes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matheson et al., 2005(70)</td>
<td>Cross sectional cohort</td>
<td>Population study in Australia</td>
<td>1,232</td>
<td>Self-report and coding of occupation</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt;0.7 with symptoms (dyspnea and chronic bronchitis) or DLCO &lt; 0.8</td>
<td>OR 2.70 (1.39-5.23) for biological dust</td>
<td>No significant increased risks were found for mineral dust (OR 1.13; 95% CI 0.57 to 2.27) or gases/fumes (OR 1.63; 95% CI 0.83 to 3.22).</td>
</tr>
<tr>
<td>Jaen et al., 2006(71)</td>
<td>Cross sectional cohort</td>
<td>Urban industrial area of Spain</td>
<td>497</td>
<td>Self report</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt; &lt; 80% and FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt;0.7 (pre-BD)</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt; -80 ml (95% CI -186 to 26); FEV&lt;sub&gt;1&lt;/sub&gt;/FVC ratio - 1.7%, (CI -3.3 to - 0.2)</td>
<td>Textile industry was most common exposure.</td>
</tr>
<tr>
<td>Boggia et al., 2008(23)</td>
<td>Prospective</td>
<td>Population study in Italy</td>
<td>2,734 males</td>
<td>Expert review of job classification and exposures</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt;80% and FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt;0.7 with symptoms (ATS diagnosis criteria)</td>
<td>OR 2.62 (2.02 to 3.41)</td>
<td>Workers involved in a national health surveillance program. Study included only male workers.</td>
</tr>
<tr>
<td>Weinmann et al., 2008(25)</td>
<td>Case control</td>
<td>Northwestern urban and non-urban areas of US</td>
<td>388 cases and 356 controls</td>
<td>Self reported exposure plus expert review</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt; LLN and use of a validated algorithm</td>
<td>Diesel exhaust (OR = 1.9, 95% CI = 1.3, 3.0), mineral dust (OR = 1.7, 95% CI = 1.1, 2.7), irritant gases and vapors (OR = 1.6, 95% CI = 1.2, 2.2).</td>
<td>PAR% of 24% (95% CI = 5, 39) overall, 19% (95% CI = 0, 37) for ever-smokers, and 43% (95% CI = 0, 68) for never-smokers.</td>
</tr>
<tr>
<td>Blanc et al., 2009(72)</td>
<td>Case control</td>
<td>Northern area of US</td>
<td>1,202 cases and 302 controls</td>
<td>Self reported exposure</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt;0.7 and healthcare utilization</td>
<td>OR=2.11, 95% CI 1.6-2.8).</td>
<td>PAR% 13-33% Smoking and exposure to VGDF exponentially increased the risk (OR 14.1, 95% CI 9.3-21.2).</td>
</tr>
<tr>
<td>Melville et al., 2010(73)</td>
<td>Cross Sectional</td>
<td>Northern United Kingdom</td>
<td>845</td>
<td>Self reported exposure</td>
<td>Post-bronchodilator FEV&lt;sub&gt;1&lt;/sub&gt; &lt;80% of the predicted value and an FEV&lt;sub&gt;1&lt;/sub&gt;/FVC ratio &lt;0.7</td>
<td>OR 3.53 (95% CI 1.58–7.89).</td>
<td>PAR% 50%</td>
</tr>
<tr>
<td>Govender et al., 2011(74)</td>
<td>Case Control</td>
<td>South Africa</td>
<td>110</td>
<td>Self reported plus expert review</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt; &lt; 80% and FEV&lt;sub&gt;1&lt;/sub&gt;/FVC &lt;0.7 (pre-BD)</td>
<td>High dust exposure-years and high chemical, gas and fumes exposure-years of 5.9 (95% CI 2.6 to 13.2) and 3.6 (95% CI 1.6 to 7.9).</td>
<td>PAR% 25% for self reported high exposures</td>
</tr>
<tr>
<td>Mehta et al., 2012(27)</td>
<td>Prospective cohort</td>
<td>Population study in Switzerland</td>
<td>4,267</td>
<td>Self reported</td>
<td>Pre-bronchodilator GOLD and LLN criteria</td>
<td>Increase 2-5 times incidence risk ratio for COPD (GOLD Stage ≥ II) at high levels exposure.</td>
<td>PAR% 31-32% for smokers and 43%-56% for non-smokers.</td>
</tr>
</tbody>
</table>
Table 2: Common Occupational Exposures and Agents Implicated in COPD risk.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Exposure</th>
<th>Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic Dusts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carpenters, Farmers, Grain silos</td>
<td>Organic Dust</td>
<td>Cotton, Grain, Wood</td>
</tr>
<tr>
<td><strong>Metals and Fumes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welders</td>
<td>Fumes, Gases</td>
<td>Cadmium, Vanadium, Osmium</td>
</tr>
<tr>
<td>Aluminum Plant</td>
<td>Fumes, Gases</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Ammonia Workers</td>
<td>Fumes, Gases</td>
<td>Ammonia</td>
</tr>
<tr>
<td>Construction, Transportation</td>
<td></td>
<td>Diesel Exhaust (particulate and Fumes)</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Minerals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal Miners</td>
<td>Rock dust</td>
<td>Coal, Silica, Silicates, Cement, Asbestos</td>
</tr>
<tr>
<td>Highway and Tunnel Workers,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard-rock miners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tremolite Workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction Workers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure  Risk of occupational exposure for COPD from recent studies.
References


