Global perspectives of emerging occupational and environmental lung diseases

Subhabrata Moitra[a], Rajan Puri[b], Devon Paul[c], and Yuh-Chin T. Huang[c]

Purpose of review

New technologies continue to be introduced into the workplace and the environment. These novel technologies also bring in new hazards leading to evolving patterns of established occupational and environmental diseases, as well as novel conditions never before encountered.

Recent findings

Many of these emerging conditions have appeared in media outlets or in the literature as case reports. These sentinel cases often serve as a warning sign for subsequent outbreaks. This review will discuss environmental and occupational lung diseases and exposures from a global perspective. These diseases and exposures include environmental exposure to asbestos and lung diseases, accelerated silicosis in sandblasting jean workers, coal worker's pneumoconiosis in surface coal miners, health effects of indoor air pollution from burning of biomass fuels and exposures to heavy metals and potential health effects from hydraulic fracturing (fracking). Other emerging conditions are also discussed, including smog in developing countries, sand storms in Asia and the Middle East and respiratory illnesses from nanoparticles and man-made fibres.

Summary

Clinicians must remain vigilant for potential occupational and environmental exposures, especially when evaluating patients with unusual and unique presentation, so that occupational and environmental risk factors may be identified, and monitoring and preventive measures can be implemented early.

Keywords

asbestos, biomass burning, coal worker's pneumoconiosis, fracking, silicosis

INTRODUCTION

The Global Status Report on Non-communicable Diseases of the WHO has placed chronic respiratory diseases among the most prevalent diseases with severe morbidities and mortality. In 2008, of 57 million deaths worldwide, 36 million (63%) were due to non-communicable diseases. Of these 36 million deaths, 4.2 million (11.7%) were from respiratory diseases alone [1]. In low and middle-income countries, indoor smoke from solid fuel, urban air pollution and occupational airborne particulates are the major risk factors, after tobacco, for chronic respiratory diseases, and contribute to 4–8% of the mortality [2]. Most of these environmental and occupational risk factors are modifiable and preventable.

In human history, the advancements in civilization are frequently accompanied by the introduction of new hazards into the workplace and the environment. Some of these new hazards have led to the development of novel environmental and occupational lung diseases. During the industrial revolution in the 19th Century, many western European countries rose to prosperity at the cost of disastrous environmental and occupational events, including the infamous 'London killer fog' in 1880 and clusters of lung cancer in cobalt miners. In the 21st Century, many industries shifted their production to developing countries where the labour is cheaper and proper regulatory guidelines for industrial hazards and toxic substances are lacking. New technologies are also being introduced in

[a]Molecular Respiratory Research Laboratory Chest Research Foundation, Kalyani Nagar, Pune, India, [b]Division of Occupational and Environmental Medicine, University of California San Francisco Medical Center, San Francisco, California and [c]Department of Medicine, Duke University Medical Center, Durham, North Carolina, USA

Correspondence to Yuh-Chin T. Huang, MD, MHS, Department of Medicine, Duke University Medical Center, 1821 Hillandale Road, Suite 25A, Durham, NC 27705, USA. Tel: +1 919 684 3069; fax: +1 919 684 3199; e-mail: huang002@mc.duke.edu

Curr Opin Pulm Med 2015, 21:114–120

DOI:10.1097/MCP.0000000000000136

KEY POINTS

- New and old occupational and environmental lung diseases will continue to emerge and re-emerge because new technologies and chemicals continue to be introduced into the workplace and the environment.
- The occupational and environmental lung diseases and conditions of global importance include asbestos-related lung disease, silicosis, coal worker's pneumoconiosis, heavy metal-induced lung diseases, health effects associated with biomass burning, and potential health concerns related to hydraulic fracturing.
- Clinicians must remain vigilant for potential occupational and environmental exposures, especially when evaluating patients with unusual and unique presentation, so that occupational and environmental risk factors may be identified, and monitoring and preventive measures can be implemented early.

developed countries to maximize the productivity, leading to resurgence of old diseases. Although many of the emerging environmental and occupational lung diseases initially appeared in scientific journals only as case reports or small case series, they may represent a warning sign for subsequent outbreaks. In this article, we will discuss emerging occupational and environmental lung diseases from a global perspective.

Novel environmental and occupational lung diseases that have been reported over the past 5 years are listed in Table 1 with the exposure settings, responsible agents and countries where the cases were reported.

The following section will discuss a select group of emerging environmental and occupational lung diseases and exposures.

ASBESTOS-RELATED LUNG DISEASES

Although asbestos has been banned in many countries for years, approximately 125 million people continue to work with asbestos worldwide, with its use actually growing in developing countries [18■■]. The toxicity of asbestos is caused primarily by inhalation of needle-like amphibole class fibres (amosite, crocidolite, tremolite, anthophyllite and actinolite). The curly chrysotile was long thought to be relatively inert. In recent years, however, large-scale studies have shown an increased risk of lung cancer in chrysotile asbestos textile workers in the United States and China [19–21,22■,23].

Apart from occupational exposure, environmental exposure to asbestos continues to be a major issue in certain parts of the world. In Libby, Montana, town residents had an increased risk for asbestosis, mesothelioma and lung cancer [24–26]. The source of asbestos exposure was the nearby vermiculite mine that was contaminated with tremolite and other amphibole fibres. The story was first reported by the Seattle Post-Intelligencer in 1999, with the title 'Uncivil Action: A Town Left to Die'. The event subsequently gained national attention. Clean-up of the town directed by the US Environmental Protection Agency (EPA) ensued and is still ongoing. In Turkey, 219 malignant mesothelioma cases were reported in residents of the Sivas Province [3■■]. Also, 11% of the residents in Buyuktatlar, Turkey, were found to have evidence of asbestos-related pleural diseases, including pleural plaque and thickening [4]. The exposure to asbestos was most likely from the plaster materials containing tremolite used in building most of the houses. Changes in building materials will be the first step to limit environmental exposure in the affected regions.

SILICOSIS

Silicosis is the most common occupational lung disease worldwide. Exposure to silica is most abundant in sand-blasting, mining and construction-related occupations. In China, over half a million silicosis cases were reported between 1991 and 1995, with approximately 25 000 deaths annually [27]. Approximately 4.2% of the deaths (or 231 104 cases) among Chinese workers were attributable to silica dust exposure [28]. In India, over three million workers were exposed to silica dust, with 8.5 million more working in construction and building activities [29]. In Europe, more than 3 million people were diagnosed with silicosis from 1990 to 1993 [27]. In the United States, 2.2 million people have exposure to silica and among them 1.85 million are engaged in construction sectors [30]. Although occupational exposure limits to silica have been established in many countries, new cases of silicosis continue to be observed in young adults, and outbreaks of silicosis and exposures to excessive silica dusts are still being reported from different parts of the world [31■,32,33■–35■]. For example, an outbreak of silicosis was described in workers in Spain, manufacturing countertops using new construction materials such as quartz conglomerates. The median age of the cohort was 33 years, with a median exposure time of 11 years [31■]. A cohort of silicosis was reported in 170 agate grinding workers in Iran. The mean age and work duration of the workers were 31 and 13 years, respectively [33■]. In a cohort of stoneworkers in Ireland, 67% of the 8-h time-weighted

Table 1. Environmental and occupational lung diseases that have been reported since 2008

Disease	Exposure setting	Responsible agents	Country
Asbestos-related lung diseases	Home residents [3■■,4]	Tremolite	Turkey
Silicosis	Denim sandblasting workers [5–7]	Silica	Turkey
CWP	Surface coal miners [8]	Coal dusts	USA
ILD	Workers in print plant [9]	Aerosolized polyacrylate nanoparticles	China
Asthma	Home residents [10,11■]	SPF	USA
HP	Animal feed industry [12]	Phytase enzymes	Switzerland
Flock-worker's lung	Nylon workers [13]	Short length synthetic fibres	USA, Canada
Bronchiolitis obliterans	Consumers exposed to butter-flavoured microwave popcorn [14]	Diacetyl	USA
Constrictive bronchiolitis	Deployed soldiers returning from Iraq and Afghanistan [15]	Smoke from sulphur fire and burn pits (?)	USA
PAP	Indium processing workers [16]	Indium-tin oxide	USA
Sarcoidosis	WTC responders [17]	WTC dust	USA

?, may be related to; CWP, coal worker pneumoconiosis; HP, hypersensitivity pneumonitis; ILD, interstitial lung disease; PAP, pulmonary alveolar proteinosis; SPF, spray polyurethane foam; WTC, World Trade Centre.

average (TWA) exposure measurements for tasks involving sandstone exceeded the occupational exposure limit value of 0.05 mg/m^3 [34■] for crystalline silica.

More recently, the fashion of producing blue jeans with a 'distressed look' via sandblasting has brought silicosis to a new paradigm. An epidemic of aggressive forms of silicosis has been reported in denim sandblasting workers in Turkey, resulting in widespread international concerns [5–7]. Many fashion industries have since announced a ban on sandblasting denim jeans. The Turkish government also has banned jean sandblasting completely, but this technique likely is still in use in other countries, such as Bangladesh, Pakistan, China and Egypt, where the issue has received little attention (http://www.fashionnetasia.com/en/BusinessResources/5443/Health_Safety_Sandblasting_discovered_in_China.html).

COAL WORKER PNEUMOCONIOSIS

Coal worker pneumoconiosis (CWP) is one of the oldest occupational lung diseases. It was recognized as early as 1822 as 'miner's asthma'. The jobs at greatest risk for CWP are those closest to the face of the mine and the continuous miner. In the United States, since the introduction of the Coal Mine Health and Safety Act of 1969 which compensated the miners and reduced allowable dust levels in mines, the prevalence of CWP among underground coal miners has been decreasing steadily from 11.2% during 1970–1974 to 2.0% during 1995–1999 [8]. Recently, however, the incidence of simple and complicated CWP is increasing [36,37]. These cases of CWP have been noted in younger coal miners working in smaller surface coal mines in eastern Kentucky and western Virginia. A recent study by the Centers for Disease Control (CDC) showed 46 (2.0%) of 2257 miners with more than 1 year of surface mining experience had CWP, including 37 who had never worked underground. Twelve (0.5%) had progressive massive fibrosis (PMF), including nine who had never worked underground [8]. Although the majority of surface mining occurs in North America, the technique is being practiced throughout the world, including China, Australia, Russia and Africa. Surveillance programs for these surface coal miners worldwide are needed.

INDOOR AIR POLLUTION AND BURNING OF BIOMASS FUELS

Approximately 3 billion people worldwide are exposed to the smoke from burning solid fuels. Most of them are poor, and live in low and middle-income countries. They cook and heat their homes using solid fuels (e.g. wood, crop wastes, charcoal, coal and dung) in open fires and leaky stoves. The concentration of particulate matter during cooking can reach 8–10 mg/μl in the room where the stoves are located. Young children and women are particularly vulnerable because they are frequently nearest to the coal-burning stoves [38].

The health impact of biomass burning has been increasingly reported. In 2012, 4.3 million people per year died prematurely from illnesses attributable to household air pollution caused by biomass burning [39]. Biomass burning is associated with many respiratory problems, including chronic obstructive pulmonary disease (COPD), asthma, acute respiratory tract infections and lung cancer [40,41,42▪▪]. Exposure to biomass smoke doubled the risk of airflow obstruction that could be detected as early as teenage [43▪]. Women exposed to high levels of indoor smoke were 2.3 times as likely to suffer from COPD than women who used cleaner fuels [39]. Exposure to smoke from combustion of biomass fuels increased the risk of lung cancer by 2–4-fold in Chinese women [44▪]. Poor indoor air quality from burning of biomass fuels increased morbidity in existing COPD [45▪▪]. Changing the design of cooking stoves may be an effective way to reduce the exposure and its adverse health effects [46].

HEAVY METALS

Heavy metals, including cadmium (Cd), chromium (Cr), nickel (Ni), cobalt (Co) and lead (Pb), are often used in various industries including brazing/soldering, painting, chemical plants and fertilizer manufacturers. Although developed countries have implemented legislations regulating the use of heavy metals, these heavy metals are being used in many developing countries without proper safety measures. Occupational exposure to these heavy metals has been well described to be associated with lung cancer [47]. There have been recent reports on exposure to chromium and cobalt and the development of occupational asthma [48,49]. Lead and cadmium also have been shown to be potential risk factors for various lung diseases, including COPD, asthma and interstitial lung diseases. A recent study from the National Health and Nutrition Examination Survey (NHANES) showed that increased serum cadmium and lead levels were associated with obstructive airway disease [50]. Exposure to chromium in welding occupation accounted for approximately 4% of lung cancer cases in Central and Eastern Europe and the United Kingdom [51]. School children near an electronic waste recycling area in China with exposure to high levels of chromium, nickel and manganese had lower forced vital capacity [52▪]. As the use of electronics and computers continues to increase worldwide, the impact of heavy metal exposure related to electronic waste recycling sites on the health of surrounding communities will need to be closely monitored. A higher blood cadmium level was associated with COPD in Korean men, including never smokers [53]. The sources for cadmium in these never smokers were likely from food, air pollution or occupational exposure. Another large case-control study from Canada also demonstrated the relationship between cancer and occupational exposure to cadmium and lead [54]. Workers in Indian jewellery workshops using cadmium had frequent respiratory symptoms and decreased lung volumes that correlated with the extent of cadmium exposure [55▪].

Regular surveillance for heavy metal exposures to identify individuals at risk is needed, especially in developing countries, so that early interventions can be done to prevent further exposures and potential illness.

HYDRAULIC FRACTURING (FRACKING)

Hydraulic fracturing, or ‘fracking’, involves injecting large amounts of pressurized mixtures of sand, water and other chemicals deep into wells to create fractures in rock, allowing extraction of natural gas and oil. Fracking is being increasingly practiced in many countries. In the United States, it has been estimated that more than 52 000 shale gas wells have been drilled and more than 200 000 workers are employed by well servicing companies [56▪]. In the United Kingdom, more land has been offered for licence to explore since 2014. In South Africa, several companies have received permits to frack on roughly 1/5th of the country’s land. In Russia and China, fracking could grow exponentially in the coming years due to their large shale deposits.

Fracking has fuelled an economic boom and job growth, but it also raises potential environmental concerns surrounding water supplies and air quality [57▪,58▪▪]. Although some groups consider fracking to represent a health risk [56▪,59], others suggest that fracking poses little risk to the public [60]. Workers are exposed to silica, diesel exhaust and volatile organic compounds (VOCs) and, at some sites, hydrogen sulphide (H_2S) and radon, raising concerns for occupational lung diseases, including silicosis, asthma and lung cancer. In a study of 11 fracking sites in the United States, 79% of air samples obtained from employees during their shifts exceeded the relevant occupational permissible exposure limits (PELs) for silica. The magnitude of these exposures was high enough in some cases to overwhelm the purifying capacity of air filters worn by employees [61▪].

Nearby residents are exposed to air pollutants emitted during various stages of fracking, including nitrogen oxides (NOx), VOCs, ozone (O_3), hazardous air pollutants (HAPs), methane and fine particulate matter (particulate matter$_{2.5}$) [57▪,58▪▪]. NOx, O_3 and particulate matter$_{2.5}$ are known to cause cardiopulmonary health effects. In six counties near the Barnett Shale in Texas, increased concentration of ambient methane, a greenhouse gas, was found from 2008 to 2010 [62]. In Pennsylvania, significant emissions of NOx, a precursor of O_3, were attributable to various stages of fracking [63]. An O_3 level of 124 ppb was recorded in early March of 2011 in rural Wyoming, higher than the worst day in Los Angeles in the same year. High concentrations of O_3, typically a summertime phenomenon, were also recorded in the wintertime in Utah [58■■]. A recent study using a dispersion model showed that toxic concentrations of airborne hydrocarbons could spread more than half mile from the site of origin, and residents living half mile or less from wells would have higher cancer and non-cancer risks [64].

Continuous monitoring is needed since the fracking industry is a fairly recent phenomenon and the length of exposure of the workers and the residents is relatively short. Properly designed case-control and cohort studies are needed to evaluate the health risk of workers and residents living near the development.

OTHER OCCUPATIONAL AND ENVIRONMENTAL EXPOSURES

There are several other occupational and environmental exposures which have or will become important concerns. Increasing ambient air pollution (smog) has become one of the worst environmental threats in several developing countries, especially China [65■■]. Exhaust from automobile traffic and emissions from manufacturing factories are major culprits. Sand storms in the Middle East and China have been increasing in size and frequency, primarily due to poor management of the dry lands. The environmental effects also affect neighbouring countries downwind from the origin [66■■]. The adverse health effects associated with sand storms are primarily related to cardiovascular and respiratory systems [67■,68■,69]. Other novel occupational exposures that may be associated with respiratory illnesses include nanoparticles (pleural disease and interstitial lung disease) [9,70–73] and man-made fibres, for example, rock wool, fibre glass (interstitial lung disease) [74■■].

CONCLUSION

We have discussed global perspectives of emerging occupational and environmental lung diseases. As globalization continues, each new piece of technology that is introduced has the potential for bringing out new diseases at the site of application. Clinicians must remain vigilant for potential occupational and environmental exposures, especially when evaluating patients with unusual and unique presentation, so that occupational and environmental risk factors may be identified, and monitoring and preventive measures can be implemented early.

Acknowledgements

None.

Financial support and sponsorship

The study was supported by intramural funds of Duke University Medical Center, Durham, North Carolina, USA.

Conflicts of interest

The authors have no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
■ of special interest
■■ of outstanding interest

1. World Health Organization. Global status report on noncommunicable diseases. 2010. http://www.who.int/nmh/publications/ncd_report2010/en/. [Accessed 31 August 2014].
2. World Health Organization. Global surveillance, prevention and control of chronic respiratory diseases. 2007. http://whqlibdoc.who.int/publications/2007/9789241563468_eng.pdf?ua=1. [Accessed 11 September 2014].
3. ■■ Berk S, Yalcin H, Dogan OT, *et al.* The assessment of the malignant mesothelioma cases and environmental asbestos exposure in Sivas province, Turkey. Environ Geochem Health 2014; 36:55–64.

This is the most recent study from the region of Turkey where there was significant environmental exposure to asbestos. The study characterized the clinical presentatons of mesothelioma and showed that the likely culprit was the plaster materials used in most of the houses that contained small amount of asbestos fibres, including chrysotile and tremolite.

4. Koksal N, Celik M, Kahraman H, *et al.* Survey of environmental exposure to asbestos in the town of Buyuktatlar, Turkey. Int J Occup Environ Health 2012; 18:130–134.
5. Akgun M, Araz O, Akkurt I, *et al.* An epidemic of silicosis among former denim sandblasters. Eur Respir J 2008; 32:1295–1303.
6. Bakan ND, Ozkan G, Camsari G, *et al.* Silicosis in denim sandblasters. Chest 2011; 140:1300–1304.
7. Akgun M, Ucar EY, Araz O, *et al.* Prognosis of patients with silicosis due to denim sandblasting. Chest 2012; 141:831. [author reply 831-832]
8. Pneumoconiosis and advanced occupational lung disease among surface coal miners: 16 states, 2010–2011. MMWR Morb Mortal Wkly Rep 2012; 61:431–434.
9. Song Y, Li X, Du X. Exposure to nanoparticles is related to pleural effusion, pulmonary fibrosis and granuloma. Eur Respir J 2009; 34:559–567.
10. Tsuang W, Huang YC. Asthma induced by exposure to spray polyurethane foam insulation in a residential home. J Occup Environ Med 2012; 54:272–273.
11. ■ Huang YC, Tsuang W. Health effects associated with faulty application of spray polyurethane foam in residential homes. Environ Res 2014; 134C:295–300.

This is the first case series on pulmonary and extrapulmonary adverse effects from spray polyurethane foam that was applied inappropriately in home owners.

12. van Heemst RC, Sander I, Rooyackers J, *et al.* Hypersensitivity pneumonitis caused by occupational exposure to phytase. Eur Respir J 2009; 33:1507–1509.
13. Turcotte SE, Chee A, Walsh R, *et al.* Flock worker's lung disease: natural history of cases and exposed workers in Kingston, Ontario. Chest 2013; 143:1642–1648.
14. Egilman DS, Schilling JH. Bronchiolitis obliterans and consumer exposure to butter-flavored microwave popcorn: a case series. Int J Occup Environ Health 2012; 18:29–42.
15. King MS, Eisenberg R, Newman JH, *et al.* Constrictive bronchiolitis in soldiers returning from Iraq and Afghanistan. N Engl J Med 2011; 365:222–230.
16. Cummings KJ, Donat WE, Ettensohn DB, *et al.* Pulmonary alveolar proteinosis in workers at an indium processing facility. Am J Respir Crit Care Med 2010; 181:458–464.
17. Jordan HT, Stellman SD, Prezant D, *et al.* Sarcoidosis diagnosed after September 11, 2001, among adults exposed to the World Trade Center disaster. J Occup Environ Med 2011; 53:966–974.

18. Stayner L, Welch LS, Lemen R. The worldwide pandemic of asbestos-related ▪▪ diseases. Annu Rev Public Health 2013; 34:205–216.
This article is the most recent review on asbestos-related lung diseases in developed and developing countries.
19. Elliott L, Loomis D, Dement J, et al. Lung cancer mortality in North Carolina and South Carolina chrysotile asbestos textile workers. Occup Environ Med 2012; 69:385–390.
20. Loomis D, Dement JM, Elliott L, et al. Increased lung cancer mortality among chrysotile asbestos textile workers is more strongly associated with exposure to long thin fibres. Occup Environ Med 2012; 69:564–568.
21. Wang XR, Yu IT, Qiu H, et al. Cancer mortality among Chinese chrysotile asbestos textile workers. Lung Cancer 2012; 75:151–155.
22. Wang X, Lin S, Yano E, et al. Exposure-specific lung cancer risks in Chinese ▪ chrysotile textile workers and mining workers. Lung Cancer 2014; 85:119–124.
This is one of the largest studies that showed chrysotile textile workers had a higher risk of lung cancer than the mining workers at a relatively low level of exposure.
23. Wang X, Lin S, Yu I, et al. Cause-specific mortality in a Chinese chrysotile textile worker cohort. Cancer Sci 2013; 104:245–249.
24. Sullivan PA. Vermiculite, respiratory disease, and asbestos exposure in Libby, Montana: update of a cohort mortality study. Environ Health Perspect 2007; 115:579–585.
25. Dunning KK, Adjei S, Levin L, et al. Mesothelioma associated with commercial use of vermiculite containing Libby amphibole. J Occup Environ Med 2012; 54:1359–1363.
26. Whitehouse AC, Black CB, Heppe MS, et al. Environmental exposure to Libby asbestos and mesotheliomas. Am J Ind Med 2008; 51:877–880.
27. Leung CC, Yu IT, Chen W. Silicosis. Lancet 2012; 379:2008–2018.
28. Chen W, Liu Y, Wang H, et al. Long-term exposure to silica dust and risk of total and cause-specific mortality in Chinese workers: a cohort study. PLoS Med 2012; 9:e1001206.
29. Jindal SK. Silicosis in India: past and present. Curr Opin Pulm Med 2013; 19:163–168.
30. Steenland K, Ward E. Silica: a lung carcinogen. CA Cancer J Clin 2014; 64:63–69.
31. Perez-Alonso A, Cordoba-Dona JA, Millares-Lorenzo JL, et al. Outbreak of ▪ silicosis in Spanish quartz conglomerate workers. Int J Occup Environ Health 2014; 20:26–32.
The study described an outbreak of silicosis in workers in Spain manufacturing countertops using new construction materials such as quartz conglomerates. The median age of the cohort was 33 years and median exposure time was 11 years.
32. Kramer MR, Blanc PD, Fireman E, et al. Artificial stone silicosis [corrected]: disease resurgence among artificial stone workers. Chest 2012; 142:419–424.
33. Rafeemanesh E, Majdi MR, Ehteshamfar SM, et al. Respiratory diseases in ▪ agate grinding workers in Iran. Int J Occup Environ Med 2014; 5:130–136.
The study described a cohort of silicosis in 170 agate grinding workers in Iran. The mean age and work duration of the participants were 31 and 13 years, respectively.
34. Healy CB, Coggins MA, Van Tongeren M, et al. Determinants of respirable ▪ crystalline silica exposure among stoneworkers involved in stone restoration work. Ann Occup Hyg 2014; 58:6–18.
The study measured crystalline silica levels in personal air samples in a cohort of stoneworkers in Ireland. Sixty-seven percentage of the 8-h time-weighted average (TWA) exposure measurements for tasks involving sandstone exceeded the occupational exposure limit value of 0.05 mg/μl.
35. Radnoff D, Todor MS, Beach J. Occupational exposure to crystalline silica at ▪ Alberta work sites. J Occup Environ Hyg 2014; 11:557–570.
The study evaluated exposure to crystalline silica at a total of 40 work sites across 13 industries in Alberta, Canada. Potential for exposure exceeding the Alberta Occupational Exposure Limit (OEL) of 0.025 mg/μl was identified in a number of occupations where it was not expected, such as electricians, carpenters and painters.
36. Laney AS, Attfield MD. Coal workers' pneumoconiosis and progressive massive fibrosis are increasingly more prevalent among workers in small underground coal mines in the United States. Occup Environ Med 2010; 67:428–431.
37. Wade WA, Petsonk EL, Young B, et al. Severe occupational pneumoconiosis among West Virginian coal miners: one hundred thirty-eight cases of progressive massive fibrosis compensated between 2000 and 2009. Chest 2011; 139:1458–1462.
38. Kodgule R, Salvi S. Exposure to biomass smoke as a cause for airway disease in women and children. Curr Opin Allergy Clin Immunol 2012; 12:82–90.
39. World Health Organization. Household air pollution and health. 2012. http://www.who.int/mediacentre/factsheets/fs292/en/. [Updated March 2014; accessed 11 September 2014].
40. Sood A. Indoor fuel exposure and the lung in both developing and developed countries: an update. Clin Chest Med 2012; 33:649–665.
41. Kim KH, Jahan SA, Kabir E. A review of diseases associated with household air pollution due to the use of biomass fuels. J Hazard Mater 2011; 192:425–431.
42. Gordon SB, Bruce NG, Grigg J, et al. Respiratory risks from household air ▪▪ pollution in low and middle income countries. Lancet Respir Med 2014; 10:823–860.
This article is the most recent review on the respiratory health effects from biomass burning. It discussed the susceptible populations, the need for individual monitoring and potential interventions.
43. Kurmi OP, Devereux GS, Smith WC, et al. Reduced lung function due to ▪ biomass smoke exposure in young adults in rural Nepal. Eur Respir J 2013; 41:25–30.
This cross-sectional study showed exposure to biomass smoke was associated with deficits in lung function in young adults in Nepal, independent of smoking. The adverse effect was detectable as early as late teenage years.
44. Mu L, Liu L, Niu R, et al. Indoor air pollution and risk of lung cancer among ▪ Chinese female nonsmokers. Cancer Causes Control 2013; 24:439–450.
This case-control study showed that, in Chinese non-smoking women, every 10 μg/μl increase in particulate matter less than 1 μm was associated with a 45% increased risk of lung cancer.
45. Hansel NN, McCormack MC, Belli AJ, et al. In-home air pollution is linked to ▪▪ respiratory morbidity in former smokers with chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2013; 187:1085–1090.
This was the first longitudinal study to investigate the independent effects of indoor particulate matter and nitrogen dioxide (NO_2) concentrations on COPD morbidity. Increased concentrations in these air pollutants were associated with morbidity of COPD patients, including risk of acute exacerbation and respiratory symptoms. Although the sources of these pollutatn were not from biomass burning, the results implied that exposure to biomass burning, which produces much higher concentrations of these air pollutants would be quite harmful.
46. Smith KR, McCracken JP, Weber MW, et al. Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial. Lancet 2011; 378:1717–1726.
47. Spyratos D, Zarogoulidis P, Porpodis K, et al. Occupational exposure and lung cancer. J Thorac Dis 2013; 5 (Suppl 4):S440–S445.
48. Walters GI, Moore VC, Robertson AS, et al. An outbreak of occupational asthma due to chromium and cobalt. Occup Med (Lond) 2012; 62:533–540.
49. Sauni R, Linna A, Oksa P, et al. Cobalt asthma: a case series from a cobalt plant. Occup Med (Lond) 2010; 60:301–306.
50. Rokadia H, Agarwal S. Serum heavy metals and obstructive lung disease: results from the National Health and Nutrition Examination Survey. Chest 2013; 143:388–397.
51. 't Mannetje A, Brennan P, Zaridze D, et al. Welding and lung cancer in Central and Eastern Europe and the United Kingdom. Am J Epidemiol 2012; 175:706–714.
52. Zheng G, Xu X, Li B, et al. Association between lung function in school ▪ children and exposure to three transition metals from an e-waste recycling area. J Expo Sci Environ Epidemiol 2013; 23:67–72.
This case-control study showed school children from an e-waste recycling area were exposed to high levels of chromium, nickel and manganese. The blood concentrations of nickel and manganese were associated with oxidative stress and decreased forced vital capacity.
53. Oh CM, Oh IH, Lee JK, et al. Blood cadmium levels are associated with a decline in lung function in males. Environ Res 2014; 132:119–125.
54. Wynant W, Siemiatycki J, Parent ME, et al. Occupational exposure to lead and lung cancer: results from two case-control studies in Montreal, Canada. Occup Environ Med 2013; 70:164–170.
55. Moitra S, Blanc PD, Sahu S. Adverse respiratory effects associated with ▪ cadmium exposure in small-scale jewellery workshops in India. Thorax 2013; 68:565–570.
This is the most recent study showing a dose-rependent reduction in lung volumes in jewellery workers who were exposed to cadmium.
56. Kovats S, Depledge M, Haines A, et al. The health implications of fracking. ▪ Lancet 2014; 383:757–758.
This study provided an excellent review on potential health effects from fracking.
57. Moore CW, Zielinska B, Petron G, et al. Air impacts of increased natural gas ▪ acquisition, processing, and use: a critical review. Environ Sci Technol 2014; 48:8349–8359.
This study provided an excellent review on the impact on air quality from fracking.
58. Field RA, Soltis J, Murphy S. Air quality concerns of unconventional oil and ▪▪ natural gas production. Environ Sci Process Impacts 2014; 16:954–969.
This study provided an update on potential environmental and health effects of fracking on air quality.
59. Glauser W. New legitimacy to concerns about fracking and health. CMAJ 2014; 186:E245–E246.
60. Torjesen I. Fracking poses little risk to public health, but evidence is limited. Br Med J 2013; 347:f6626.
61. Esswein EJ, Breitenstein M, Snawder J, et al. Occupational exposures to ▪ respirable crystalline silica during hydraulic fracturing. J Occup Environ Hyg 2013; 10:347–356.
This study was the first to evaluate silica exposure systematically in workers at 11 sites in five states in the United States and found 79% of air samples obtained from employees during their shifts exceeded the relevant occupational PEL for silica.

62. Rich A, Grover JP, Sattler ML. An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. J Air Waste Manag Assoc 2014; 64:61–72.
63. Litovitz A, Curtright A, Abramzon S, *et al.* Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania. Environ Res Lett 2013; 8:014017.
64. McKenzie LM, Witter RZ, Newman LS, *et al.* Human health risk assessment of air emissions from development of unconventional natural gas resources. Sci Total Environ 2012; 424:79–87.
65. Xu P, Chen Y, Haze Ye X. air pollution, and health in China. Lancet 2013;
■■ 382:2067.
The study provided a brief overview of the recent disastrous air pollution events in China and their potential cardiopulmonary adverse effects.
66. Goudie AS. Desert dust and human health disorders. Environ Int 2014;
■■ 63:101–113.
The study provided the most recent review on dust storms around the world and discussed human health effects.
67. Esmaeil N, Gharagozloo M, Rezaei A, *et al.* Dust events, pulmonary
■ diseases and immune system. Am J Clin Exp Immunol 2014; 3:20–29.
The study reviewed how inhalation of dust from sand storms may affect cellular and molecular immune systems resulting in lung diseases.
68. Korzeniewski K, Nitsch-Osuch A, Konarski M, *et al.* Prevalence of acute
■ respiratory tract diseases among soldiers deployed for military operations in Iraq and Afghanistan. Adv Exp Med Biol 2013; 788:117–124.
The study found an increased prevalence of acute respiratory tract diseases among soldiers of the Polish Military Contingent deployed to Iraq and Afghanistan. The prevalence was closely related to the environmental factors, including sand storms.
69. Chan CC, Ng HC. A case-crossover analysis of Asian dust storms and mortality in the downwind areas using 14-year data in Taipei. Sci Total Environ 2011; 410–411:47–52.
70. Zhang R, Bai Y, Zhang B, *et al.* The potential health risk of titania nanoparticles. J Hazard Mater 2012; 211–212:404–413.
71. McCall MJ. Environmental, health and safety issues: nanoparticles in the real world. Nat Nanotechnol 2011; 6:613–614.
72. Gulumian M, Vallyathan V. Nanoparticles and potential human health implications: past and future directions. Preface. J Toxicol Environ Health A 2010; 73:339–340.
73. Bonner JC. Nanoparticles as a potential cause of pleural and interstitial lung disease. Proc Am Thorac Soc 2010; 7:138–141.
74. Fireman E. Man-made mineral fibers and interstitial lung diseases. Curr Opin
■■ Pulm Med 2014; 20:194–198.
This review article showed exposure of workers to man-made mineral fibres correlated with high risk for developing pneumoconiosis.