Literature Review

Dust Exposure and Lung Function Disorders

Mona Lestari*, Poppy Fujianti, Novrikasari, Rizka Faliria Nandini

Department of Occupational Health and Safety, Faculty of Public Health, Universitas Sriwijaya, Palembang

Corresponding Author:
Mona Lestari | Department of Occupational Health and Safety, Faculty of Public Health, Universitas Sriwijaya, Palembang | mona_lestari@unsri.ac.id

Submitted: December 5th, 2022
Accepted: January 20th, 2023
Published: June 28th, 2023

Respir Sci. 2023; 3(3): 218-30
https://doi.org/10.36497/respirsci.v3i3.80

Abstract

Dust is a particle floating in the air produced due to mechanical processes such as splitting, grinding, grinding, punching or blasting, cutting and destroying material. Dust particles in the air for a relatively long time can enter the human body through breathing. Dust less than 5 µm entering the human respiratory system can reach the inside of the lungs or alveoli can cause lung function disorders. Impaired pulmonary function is the inability to develop (elasticity) of the lungs as well as disorders of the respiratory tract both structural (anatomical) and functional which causes slowing of respiratory airflow. The International Labor Organization (ILO) defines pulmonary dysfunction as the accumulation of dust in the lung tissue and lung tissue reaction to the dust accumulation. Dust entering the alveoli can cause hardening of the tissue (fibrosis) and if 10% of the alveoli is hardening, it will reduce its elasticity in accommodating the volume of air so that the ability to bind oxygen is decreased. This condition causes a reduction in the supply of oxygen absorbed by blood capillaries to the brain tissue, heart, and other body parts.

Keywords: aluminum dust, coal dust, rice dust, lung function disorders, wood dust

INTRODUCTION

Clean air, water, and food are human rights that are considered basic needs. However, air pollution is the focus of the world's attention, is considered the largest environmental risk that affects health, and was responsible for one of nine deaths in 2012.[1] According to WHO, air pollution can cause uncommunicable diseases. There are around 24% of deaths from heart disease, 25% from stroke, 29% from lung cancer, and 43% from chronic obstructive pulmonary disease (COPD). Out of all those deaths, 3 million are caused by ambient/outdoor air pollution.[1,2]

High air pollution is caused by increasing industrial sector growth. One of the effects of industrial activities is the production of air contaminants such as dust. According to International Standardization Organization (ISO 4225 – ISO, 1994), dust is a small solid particle with a size under 75 µm that floats in the air for a long period. Dust is an aerosol formed by the mechanical subdivision of bulk material into airborne fines that have

the same chemical composition. Dust particles are generally solid and irregular in shape and have diameters greater than 1 µm.[3]

Dust is categorized into several types, such as silica dust, wood dust, mineral dust (SiO_2, SiO_3, coal), organic dust (cotton dust, leaf dust, tobacco, paddy, etc.), and metal dust (Pb, Hg, Cd, Ar).[4] Air containing dust can enter the respiratory system, especially the lung. Dust with a size of 5–10 microns will be stopped in the upper respiratory tract; 3–5 microns of dust will be stopped in the middle respiratory tract; and 1–3 microns of dust will be suspended directly on the surface of the alveoli.[2]

In the workplace, these types of dust can be found in farming activities, ceramic production, limestone, brick production, mining activities, bed production, traditional markets, street vendors, home industries, paddy grinding, etc. Data from International Labour Organization (ILO) shows that 2 million out of 2.5 billion workers in the world die every year from accidents or work-related diseases, and one-third, or 21%, of these diseases, are respiratory or lung diseases.[5,6] WHO also reported that 600 million people suffer from COPD. In 2012, around 3.1 million people died from lung problems, and it is predicted to be the third main cause of death around the world in the year 2030.[7]

The quality of air in the workplace also plays a role in occupational health, where there is a risk of respiratory issues. If the respiratory issues accumulate over a long period, lung fibrosis may form, which will cause hardened alveoli. Lung problems are commonly categorized as obstructive and restrictive respiratory disorders. Obstructive disorders are due to obstruction, narrowing, or resistance in the airways, while restrictive disorders are due to disturbances in the lung parenchyma.[8]

The risk faced by workers includes not only occupational accidents but also occupational diseases. Occupational diseases, found in various industries, are diseases that arise due to work and an unfavorable environment. One of the causes of pulmonary function disorders is exposure to dust such as wood dust, coal dust, rice dust, aluminum dust, and so on. Therefore, it is necessary to do proper handling so that there is no respiratory disease among workers.

RESPIRATORY SYSTEM DISORDERS DUE TO DUST

Work-related diseases experienced by workers can arise from the work environment that is exposed to dust, both industrial dust and dust from agricultural processing processes, and so on. Respiratory system disorders that can cause lung disease are divided into three types, namely:[9]

a. Diseases caused by organic dust, such as cotton dust (byssinosis), rice dust (grain worker's disease), and wood dust.
b. Disease caused by inorganic dust (pneumoconiosis), such as silica dust (silicosis), coal dust (coal worker's

pneumoconiosis), tin dust (stannosis), and asbestos dust (asbestosis).

c. Disease is caused by irritant gases, such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3).

THE EFFECT OF DUST SIZE ON RESPIRATORY DISORDERS

The effect of dust on respiratory disorders is distinguished by the size of the dust particles that settle in the respiratory tract. The various sizes of dust particles are as follows:[2,9]

a. Dust measuring 5-10 microns settles in the upper respiratory tract, which can cause an irritating effect characterized by symptoms of pharyngitis.
b. Dust measuring 3-5 microns settles in the middle respiratory tract, which can cause effects in the form of bronchitis, allergies, and asthma.
c. Dust measuring 1-3 microns settles and accumulates in the alveoli.
d. Dust measuring 0.1–1 micron will float on the surface of the alveoli because of its small size and weight. This dust does not stick to the alveoli but follows Brown's motion, which will hit the surface of the alveoli and can accumulate in the alveoli.

MECHANISM OF DUST COLLECTION IN THE LUNGS

The amount of dust that enters the lungs depends on the size of the dust. The size of dust particles that are harmful to health generally ranges from 0.1 – 10 µm. There are three mechanisms for the accumulation of dust in the lungs, as follows:[9]

a. Inertia Effect

   The effect of inertia will create moisture from the dust, which will be further propelled by the airflow as it moves through the bend. However, when the airway is straight, it will immediately go with a straight flow inward, while large particles do not participate in the airflow but look for an ideal place to stick or settle, such as in the grooves of the mucous membrane in the airways.

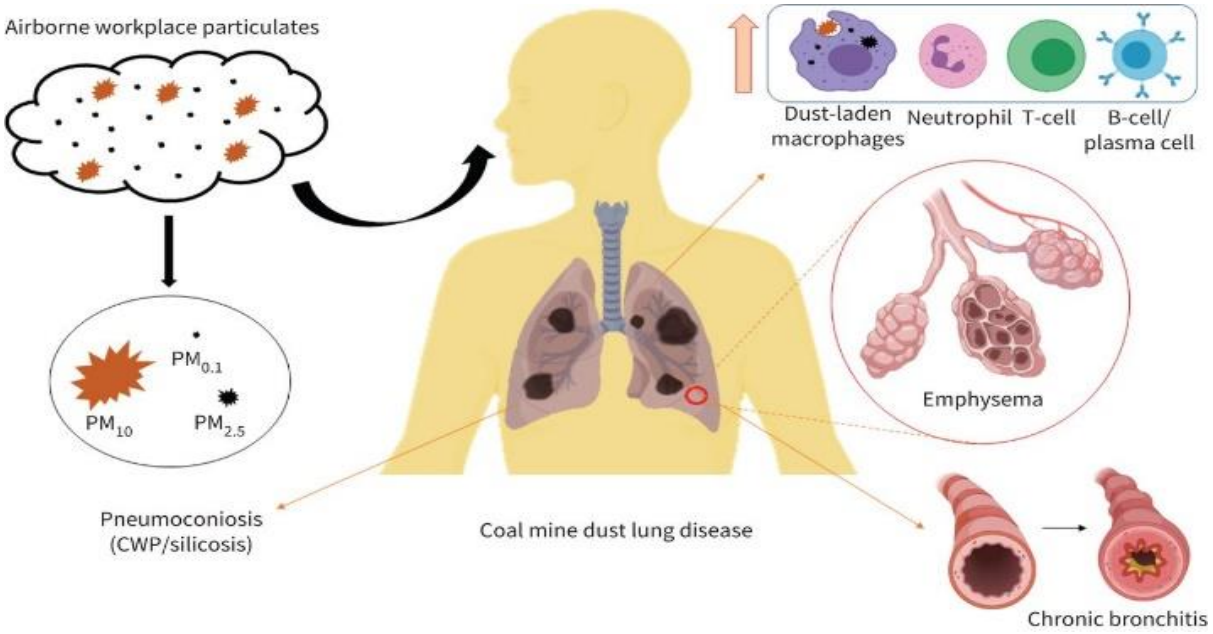
b. Effect of Sedimentation

   The effect of sedimentation occurs when the air current velocity is less than 1 cm/second so that the particles pass through gravity and settle.

c. Brown Movement

   Brownian motion applies to dust that is less than 0.1 microns in size through air movement, and dust particles that enter the body will disturb the alveoli and then settle.

Picture 1 shows an example of the dust collection mechanism in the lungs of coal miners. In the workplace, dust particles of various sizes enter the respiratory system of exposed workers through the nose. Larger dust particles will settle in the upper repiratory tract, and smaller ones will enter and settle in the alveoli. Each part of the respiratory system that is exposed to dust will react by showing symptoms of lung disorders.



Picture 1. Example of Dust Collection Mechanism in Lungs of Coal Miner[10]

In this case, the respiratory complications resulting from coal dust inhalation are the increase in cellular influx, destruction of alveolar parts (emphysema), and change in structure such as deposition of mucus and collagen, which leads to bronchitis.[11]

LUNG FUNCTION DISORDERS DUE TO DUST EXPOSURE

The cause of impaired lung function is dust exposure. Lung function disorders in the form of the inability to expand (elasticity) the lungs and respiratory tract disorders, both structural (anatomical) and functional, cause a slowdown in respiratory airflow caused by viruses, bacteria, dust, and other particles. Lung function disorders are divided into three types, namely:[10,12]

a. Obstructive Lung Disease

Obstructive lung disease is an airway disorder that is both structural (anatomical) and functional, causing a slowing of respiratory airflow. This abnormality can be detected by physical examination (auscultation found prolonged expiration), examination of FEV_1 <75% of the predicted value, and lung volume (Residual Volume (RV), Total Lung Capacity (TLC), and Functional Residual Capacity (FRC)). A study by Lange et al. stated that of 657 people who had an FEV_1 of less than 80%, 26% had COPD before they were 40 years old.[13]

b. Restrictive Lung Disease

Restrictive lung disease is a disorder of lung expansion due to any reason; it can be caused by allergens such as dust. The lungs become stiff, the inward traction is stronger so that the chest wall shrinks, the ribs narrow, and the lung volume decreases. Lung volumes decrease, namely Vital Capacity (VC), TLC, RV, FRC, and Expiratory Reserve Volume (ERV). As a parameter in spirometry, VC is measured with a value

<80% of the predicted value (normally 80-120%, whereas if the value is >120%, it is called over/hyperinflation). FEV_1 value is still above 75%.

Hutapea et al. studied the incidence of lung function disorders due to exposure to aluminum dust in CV X workers and found that 42.5% of workers had obstructive lung function disorders, 22.5% of workers had restriction disorders, and no workers had combined lung function disorders, so it could be concluded that there were 65% of workers experiencing impaired lung function (obstruction, restriction, and combination).[10] Rice mill workers in India exposed to husk dust showed significantly lower levels of FVC, FEV_1, and PEPR than controls.[14]

c. Combination of Lung Disease

Combination lung disease is a combination of obstructive and restrictive conditions that occur together due to the presence of particles that enter the lung through the top and stick together to cause pulmonary obstruction. As for the smaller size, it is not accommodated so that it can pass through and then enter the alveolus and cause lung restriction.

DISEASES DUE TO DUST EXPOSURE IN THE WORKPLACE

Various health problems can arise from the work environment. Chemical factors such as dust are very easy to find in the work environment and can expose workers. Dust is a chemical particle that can cause reduced work comfort, visual disturbances, lung health problems, and poisoning. Dust that is inhaled continuously and for a long time causes lung damage and fibrosis. The potential for impaired lung function depends on the size of the dust that can enter the alveoli or that only moves in and out of the alveoli but does not settle on the surface.[15]

Pneumoconiosis is a respiratory disease caused by dust particles that enter and settle in the lungs, causing a tissue reaction to the dust in the form of fibrosis.[16] Pneumoconiosis that is often reported in several countries includes silicosis, asbestosis, and coal pneumoconiosis. Several types of pneumoconiosis can be found in areas with industrial and technological activities caused by various types of dust and are very detrimental to the health of workers.

Diseases Due to Coal Dust and Silica

Coal is a dark organic rock with the main content of carbon, hydrogen, and oxygen atoms. It also consists of nitrogen, sulfur, and small amounts of mineral compounds.[17,18] Coal is used as a fuel to produce electrical energy. However, in its use, coal can cause air pollution by producing a mixture of earth crust dust and coal dust. Coal dust is a complex mixture of varying proportions of minerals, trace metals, and organic matter, with varying degrees of coal particulate.[19]

Coal dust can be generated from various work activities in an industry, such as mining and quarrying of coal and minerals, coal cracking, and activities at

coal stockpiles, as well as dust emissions from coal combustion.[20]

The threshold value for coal dust is seen from two angles based on the health effects caused by coal dust, namely as a cause of obstructive pulmonary function disorders and restrictive pulmonary function disorders. The threshold value based on the Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018 concerning the Threshold Value of Physical and Chemical Factors in the Workplace for coal dust that causes obstructive pulmonary function disorders is 10 mg/m^3, while for coal dust that causes restriction lung function disorders, it is 0.023 mg/m^3 (silica, crystalline).[21]

One of the compositions in coal is silica.[22]Using the threshold value of silica (crystalline) with the assumption that, based on the literature, coal dust contains 10% free silica elements and is the most dangerous substance of all substances contained in coal.[23]

Free silica elements have the potential to cause pulmonary interstitial tissue fibrosis and can reduce the phagocytic capacity of phagocytosis so that silica inhaled into the worker's body cannot be excreted, causing restrictive lung function disorders and pulmonary fibrosis.[24] A study by Cohen et al. shows that contemporary miners experience an increasing number of severe dust-related diseases due to exposure to silica. They found a high proportion of progressive massive fibrosis (PMF) caused by silica (57%) in 85 coal miners in their samples.[25]

Meanwhile, coal dust in total dust concentration can cause obstructive pulmonary function disorders in exposed workers, so workers can suffer from COPD. Therefore, coal dust can also cause combined or mixed lung function disorders (obstruction and restriction).[22]

Diseases caused by coal dust can cause silicosis. Diseases caused by coal dust are related to the nature of the dust, which is flying and easily carried by the wind. The use of coal as fuel produces a lot of SiO_2-free silica dust. When burned, silica dust will come out and be dispersed into the air along with other particles such as alumina dust, iron oxide, and carbon in the form of ash.[9] Free silica is fibrogenic; if inhaled by workers, it will cause pulmonary interstitial tissue fibrosis and restrictive lung function disorders.[26]

In addition, free silica in the crystalline form has the potential to cause pneumoconiosis, or coal worker's pneumoconiosis (CWP). Silica has an incubation period of about 5 to 10 years. The incubation period will be shorter-only a few weeks or months-if the concentration of silica is very high.[26]

Symptoms of this disease are shortness of breath and coughing without phlegm. If the disease is at a moderate level, symptoms of shortness of breath will be seen, and there will be abnormalities in the lungs during the examination. However, if the disease is at a severe level, shortness of breath will get worse, followed by right heart hypertrophy, which can lead to heart failure. The diagnosis for this disease is made by performing a

physical examination, especially on the lungs, breathing tests, a high-resolution CT scan, bronchoscopy to evaluate the inside of the lungs and a lung biopsy.[27]

There is no specific cure for silicosis. Therefore, preventive measures are the most appropriate way to avoid this disease. This is because if the worker has previously suffered from pulmonary TB, bronchitis, asthma, and other respiratory diseases, silicosis will worsen the worker's health condition. Regular health inspections and inspections for workers will help prevent and control occupational diseases in the workplace. The use of PPE, such as masks, can also help prevent infection with this disease.[9,28]

Diseases Due to Aluminum Dust

Aluminum (Al) is the most abundant metal in the earth's crust and the third most abundant element after oxygen and silicon. Aluminum is a metal that can be molded and is widely used in everyday life, causing exposure to aluminum due to its presence and use in products such as canned food and beverages, cooking utensils, the aerospace industry, food additives, and so on.[29,30]

Aluminum dust is one of the contaminants resulting from industrial processes that have a toxicological impact on the human body. Aluminum (Al) in the form of dust will accumulate in the lungs. Aluminum dust has a highly toxic nature, so in the company's hygiene practice, it needs a separate reference (TLV) to prevent its impact on health. Based on the Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018 concerning Occupational Safety and Health in the Work Environment, the threshold value of the physical and chemical factors of aluminum metal dust should not exceed 5 mg/m^3.[21]

Aluminum dust has a clinically irritating effect on respiration. The health effects of exposure to aluminum dust through inhalation can result in irritation of the upper respiratory system and interstitial lung disease, or pulmonary fibrosis.[11] Aluminum dust can form flammable or explosive mixtures with air, especially when wet, and react violently (explosively) with water, steam, and moisture to cause fire or explosion.[31]

Symptoms of pulmonary aluminosis are characterized by irritation of the respiratory tract, dyspnea, chronic cough, hemoptysis, and pleuritic pain. If exposure to aluminum dust is not addressed immediately, it will have a serious impact on the lungs and will eventually cause lung diseases in workers such as emphysema and pneumothorax. Some occupational diseases in the aluminum industry come from physical groups such as miliaria and chemical groups such as dust and steam.

In addition, exposure to aluminum dust can also cause obstructive pulmonary disorders. In addition to its effects on the lungs, aluminum exposure also has adverse effects on the skin, hematopoietic system, bones, central nervous system (Alzheimer's Disease or dementia), and cancer. This disease is diagnosed by histological examination and chest

radiography to detect dust particles in the lungs.[32]

Aluminosis can be prevented by minimizing exposure to inhaled aluminum dust particles. This disease will cause complications if not immediately followed up, causing damage to the lungs. To overcome this problem, workers must have an awareness of the importance of health and safety at work, starting with using respiratory PPE, consuming nutritious food and drinking water, and conducting medical check-ups to determine their health condition.

Diseases Due to Wood Dust

Wood dust is a solid particle (wood) produced from several natural or mechanical forces such as processing, crushing, softening, fastpacking, blasting, and others and consists of organic and inorganic materials such as wood, seeds, metal, and charcoal. Wood dust is produced from wood processing or handling such as cutting, sanding, and shaving. Although not all wood species can be harmful to health (depending on the species), workers who are exposed to wood dust every day can pose a threat to health, especially wood dust that contains toxic materials.

The wood dust threshold value based on the Minister of Manpower Regulation Number 5 of 2018 is 5 mg/m^3.[21] Wood dust is included in the hardwood dust and softwood dust classification lists that have been determined by the TWA for hardwood dust of 0.5 mg/m^3 and softwood dust of 2 mg/m^3.[33] Dust levels that exceed the TLV can reduce the ability to see, cause deposits in the eyes, nose, and airways, and cause skin damage or irritation.[34]

Wood dust is divided into two types, namely softwood and hardwood. The size of the dust is very influential on the occurrence of diseases in the respiratory tract. The large size of dust particles will be captured by the upper respiratory tract. Dust that enters the respiratory tract will cause a respiratory reaction. Wood sawdust is one of the hazardous chemicals that has a negative impact if there is a buildup.[35]

The accumulation and movement of dust in the airways can cause inflammation of the airways. This inflammation can cause blockages in the airways. Dust that enters the respiratory tract will cause non-specific defense mechanisms such as sneezing, coughing, impaired mucociliary transport, and phagocytosis by macrophages.[35]

The smooth muscle around the airway can be stimulated to cause constriction of the passageway. This situation occurs when the dust content exceeds the threshold value. High exposure to wood dust can trigger dermatitis, lung cancer, and occupational asthma.

Symptoms of disease due to wood dust and dust are generally characterized by coughing, sore throat, wheezing, chest pain, shortness of breath, nasal congestion, eye irritation, and watering.[36] A study by Neghab et al. on wood dust-exposed workers obtained an association between wood dust exposure and the rise

in respiratory symptoms' prevalence among exposed workers, where restrictive lung disorder was the dominant pattern. Other respiratory symptoms experienced ranged from wheezing (37%), coughing (28%), and chronic phlegm (14%).[37]

Prevention of this disease can be performed by identifying the type of wood used in the workplace, using the LEV (Local Exhaust Ventilation) system to control exposure to wood dust, and using hand protection and masks or respiratory protective equipment (REP). In addition, it can also provide training on handling hazardous substances to workers so that they are always careful when working.

Diseases Due to Rice Dust

Rice is a type of grain crop that is harvested for its seeds. In the process, rice can produce dust. Rice dust is dust produced from the rice milling process. Rice dust exposure was found during the drying and milling processes. The rice dust threshold value based on the Minister of Manpower Regulation Number 5 of 2018 is 4 mg/m^3.[21]

Rice dust is produced from the process of rice milling activities whose disposal has not been properly regulated. The remnants of milling are called bran. Rice bran is often allowed to accumulate and fly when blown by the wind, causing air pollution. Dust is the second-most common hazard after noise in the workplace, but dust is the number one hazard that causes occupational diseases.[38] Dust produced by the process of rice milling business activities can cause respiratory organ disorders, including lung function disorders.[39]

Diseases Due to Asbestos

Asbestos is a generic name given to six fibrous minerals that have been used in commercial products. The six types of asbestos are chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos.[40] Chrysotile, also known as white asbestos, is a magnesium silicate belonging to the serpentine group and is the most widely used (about 95% of all asbestos use).[40–42]

The other asbestos types belong to the amphibole group and include crocidolite, known as blue asbestos, amosite, also called brown asbestos, and anthophyllite asbestos. All these types have stronger mechanical and chemical resistance than chrysotile. The most commonly used types of asbestos in the industry are chrysotile, crocidolite, amosite, and anthophyllite, which are available from mining activities, whilst actinolite and tremolite are only natural pollutants.[40–42]

All forms of asbestos have the potential to cause asbestos-related lung disease (ARD). All types of asbestos fibers are carcinogenic.[42] Liu et. al. concluded in their paper that epidemiological studies have established that exposure to asbestos fibers causes pulmonary fibrosis (asbestosis), pleural abnormalities (effusion and plaque), and asbestos-related cancer (malignant mesothelioma, cancers of the lung, larynx, and ovary).[42,43] Klebe et. al. have reviewed the scientific

literature on asbestos and lung cancer, concluding that all types of asbestos can cause lung cancer, such as amphibole, anthophyllite, and the noncommercial amphibole, tremolite.[44]

PREVENTION OF DISEASES DUE TO DUST EXPOSURE IN THE WORKPLACE

Prevention of diseases due to dust exposure in the workplace is the most important action that can be taken to prevent the onset of disease and prevent it from getting worse. Some preventive measures can be taken by controlling dust exposure in the workplace to below the threshold value using health promotion, engineering control, administrative control, and procedures related to occupational health, such as medical check-ups and audits.

a. Create procedures that can be used as company guidelines in carrying out programs related to worker health, such as hazard identification, risk assessment, and risk control.
b. Rotate work on workers who are exposed to dust.
c. Isolate the source of dust exposure with the "local exhauster".
d. Provide proper and adequate ventilation in a closed work area.
e. Provide good respiratory protective equipment for all workers.

CONCLUSION

There are three types of lung function disorders, obstructive, restrictive, and combination. Impaired lung function can occur due to various types of particulates or dust exposure. Fibrogenic or carcinogenic dust or particulates can cause pulmonary fibrosis or cancer. To prevent this, it is necessary to carry out various levels of control, from elimination to the use of PPE.

REFERENCES

1. WHO. Ambient air pollution: a global assessment of exposure and burden of disease [Internet]. WHO; 2016. Available from: https://apps.who.int/iris/handle/10665/250141
2. Subramanian, Abhyankar EV. Construction Dust Causes, Effects and Remedies [Internet]. NBM&CW. 2019. Available from: https://www.nbmcw.com/article-report/infrastructure-construction/infra-real-estate/construction-dust-causes-effects-and-remedies.html
3. Lippmann M. Pathways and Measuring Exposure to Toxic Substances. In: Patty's Toxicology, 5th Edition. New Jersey: Wiley; 2001.
4. Health and Safety Executive. Construction Dust [Internet]. eLCOSH. 2013. Available from: https://www.elcosh.org/document/3689/d001228/Construction+Dust.html
5. Fuqoha IS, Suwondo A, Jayanti S. Hubungan Paparan Debu Kayu dengan Kejadian Infeksi Saluran Pernapasan Akut (ISPA) pada Pekerja Mebel di PT. X Jepara. J Kesehat Masy.

2017;5(1):378–86.
6. Cullinan P, Muñoz X, Suojalehto H, Agius R, Jindal S, Sigsgaard T, et al. Occupational lung diseases: from old and novel exposures to effective preventive strategies. Lancet Respir Med. 2017 May 1;5(5):445–55.
7. Ariza R, Soemarwoto S, Mustofa S, Sinaga F, Rusmini H, Morfi CW, et al. Hubungan Penyakit Paru Obstruksi Kronik (PPOK) dengan Indeks Massa Tubuh (IMT) di Klinik Harum Melati Pringsewu Tahun 2016-2017. J Kedokt Univ Lampung. 2019;3(1):73–7.
8. Wulandari DR, Hadisaputro S, Suhartono. Berbagai Faktor Yang Berhubungan Dengan Kejadian Gangguan Fungsi Paru Dalam Ruang Kerja (Studi Kasus Pekerja Industri Rumahan Electroplating di Kecamatan Talang Kabupaten Tegal). J Kesehat Lingkung Indones. 2013;12(1):94–8.
9. Darmawan A. Penyakit Sistem Respirasi Akibat Kerja. JAMBI Med J "Jurnal Kedokt Dan Kesehatan." 2016;1(1).
10. Hutapea RM, Novrikasari, Lestari M, Camelia A, Andarini D, Nandini RF. The Effect of Alumunium Dust Exposure on Lung Function Disorders. J Respirologi Indones. 2021;41(2):108–17.
11. Vanka KS, Shukla S, Gomez HM, James C, Palanisami T, Williams K, et al. Understanding the pathogenesis of occupational coal and silica dust-associated lung disease. Eur Respir Rev. 2022;31(165).
12. Persatuan Dokter Paru Indonesia. Gangguan Faal Paru [Internet]. Persatuan Dokter Paru Indonesia. 2013 [cited 2020 Jun 19]. Available from: https://www.klikparu.com/2013/01/gangguan-faal-paru.html#more
13. Lange P, Celli B, Agustí A, Jensen GB, Divo M, Faner R, et al. Lung-Function Trajectories Leading to Chronic Obstructive Pulmonary Disease. N Engl J Med. 2015;373:111–22.
14. Ghosh T, Gangopadhyay S, Das B. Prevalence of respiratory symptoms and disorders among rice mill workers in India. Env Heal Prev Med. 2014;19(3):226–33.
15. Ardam KAY. Hubungan Paparan Debu Dan Lama Paparan Dengan Gangguan Faal Paru Pekerja Overhaul Power Plant. Indones J Occup Saf Heal. 2017;4(2):155–66.
16. Susanto AD. Basic Principal for Reading of Chest X Ray Acording to International Labour Organization (ILO) Classification for Pneumoconiosis. J Respirologi Indones. 2019;39(4):272–9.
17. Pasymi. Batubara (Jilid 1). Padang: Bung Hatta University Press; 2008.
18. Schweinfurth SP. An Introduction to Coal Quality. Virginia: U.S. Geological Survey; 2009.
19. Simanjuntak NSR, Suwondo A, Wahyuni I. Hubungan antara Kadar Debu Batubara Total dan Terhirup Serta Karakteristik Individu dengan Gangguan Fungsi Paru pada Pekerja di Lokasi Coal Yard Pltu X Jepara. J Kesehat Masy Univ Diponegoro. 2013;2(2).

20. Lemen RA, Bingham E. Silica and Silica Compounds. In: Patty's Toxicology, 5th Edition. New Jersey: Wiley; 2001.
21. Kementerian Ketenagakerjaan RI. Peraturan Menaker Nomor 5 Tahun 2018 tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja. Jakarta: Kementerian Ketenagakerjaan RI; 2018.
22. Attfield M, Castranova V, Kuempel E, Wagner G. Coal. In: Patty's Toxicology, 5th Edition. New Jersey: Wiley; 2001.
23. Garkal KD, Shete AN. Study of Pneumoconiosis in Thermal Power Station. Int J Recent Trends Sci Technol. 2012;4(3):137–40.
24. Du Y. A Brief Talk on Coal Dust Suppression. IOP Conf Ser Earth Environ Sci. 2018;170(3).
25. Cohen RA, Rose CS, Go LHT, Zell-Baran LM, Almberg KS, Sarver EA, et al. Pathology and Mineralogy Demonstrate Respirable Crystalline Silica Is a Major Cause of Severe Pneumoconiosis in U.S. Coal Miners. Ann Am Thorac Soc. 2022;19(9):1469–78.
26. National Institute for Occupational Safety and Health (NIOSH). Crystalline Silica: Medical Monitoring [Internet]. CDC. 2019. Available from: https://www.cdc.gov/niosh/topics/silica/medical.html
27. Lung and Blood Institute National Heart. Interstitial Lung Diseases - Diagnosis [Internet]. Lung and Blood Institute National Heart. 2022. Available from: https://www.nhlbi.nih.gov/health/interstitial-lung-diseases/diagnosis
28. Hafsari D, Ramadhian MR, Saftarina F. Debu Batu Bara dan Kejadian Infeksi Saluran Pernafasan Akut pada Pekerja Pertambangan Batu Bara. J Major. 2015;4(9):35–41.
29. Choupani A, Jafari MJ, Boghsani GT, Azari MR, Zendehdel R. Biological monitoring of occupational exposure to dust among aluminium foundry workers. Russ Open Med J. 2018;7(2).
30. Shaw CA, Seneff S, Kette SD, Tomljenovic L, Oller JW, Davidson RM. Aluminum-induced entropy in biological systems: implications for neurological disease. J Toxicol. 2014;2014.
31. Taming Fires. Is Aluminum Dust Flammable? (A Comprehensive Overview) [Internet]. Taming Fires. 2022. Available from: https://tamingfires.com/is-aluminum-dust-flammable/
32. Riihimäki V, Aitio A. Occupational exposure to aluminum and its biomonitoring in perspective. Crit Rev Toxicol. 2012;42(10):827–53.
33. WorkSafe New Zealand. Workplace exposure standards and biological exposure indices - Edition 11. WorkSafe New Zealand; 2019.
34. Löfstedt H, Hagström K, Bryngelsson IL, Holmström M, Rask-Andersen A. Respiratory symptoms and lung function in relation to wood dust and monoterpene exposure in the wood pellet industry. Ups J Med Sci. 2017;122(2):78–84.

35. Pope CA, Dockery DW, Spengler JD, Raizenne ME. Respiratory health and PM10 pollution. A daily time series analysis. Am Rev Respir Dis. 1991;155(3 Pt 1):668–74.
36. Purnomo A, Anwar T. Pajanan Debu Kayu (PM10) terhadap Gejala Penyakit Saluran Pernafasan pada Pekerja Meubel Sektor Informal. J Vokasi Kesehat. 2015;1(6):181–7.
37. Neghab M, Jabari Z, Shouroki FK. Functional disorders of the lung and symptoms of respiratory disease associated with occupational inhalation exposure to wood dust in Iran. Epidemiol Heal. 2018;40:e2018031.
38. Ghaniysara, Kurniawan B, Widjasena B. Perbedaan Paparan Debu Pada Pekerja Penggilingan Padi Pregolan Desa Jetis Kecamatan Kaliwungu Kabupaten Semarang Sebelum Dan Sesudah Pemasangan Local Exhaust Ventilation. J Kesehat Masyarakat2. 2014;2(2):98–103.
39. Ansari MMH, Karim MR, Mashud I. Symptoms of Respiratory Health Problems in Rice Mill Workers of Bangladesh. KYAMC J. 2017;7(2):758–61.
40. Powell C, Cohrssen B. Asbestos. In: Patty's Toxicology, 5th Edition. New Jersey: Wiley; 2001.
41. Pira E, Donato F, Maida L, Discalzi G. Exposure to asbestos: past, present and future. J Thorac Dis. 2018;10(Suppl 2):S237–45.
42. Leong SL, Zainudin R, Kazan-Allen L, Robinson BW. Asbestos in Asia. Respirology. 2015;20(4):548–55.
43. Liu G, Cheresh P, Kamp DW. Molecular Basis of Asbestos-Induced Lung Disease. Annu Rev Pathol. 2013;8:161–87.
44. Klebe S, Leigh J, Henderson DW, Nurminen M. Asbestos, Smoking and Lung Cancer: An Update. Int J Env Res Public Heal. 2020;17(1):258.