Journal Home Page:
https://e-journal.unair.ac.id/JKL

Jurnal Kesehatan Lingkungan

Vol. 13 No. 2
DOI: 10.20473/jkl.v13i2.2021.72-84
ISSN: 1829 - 7285
E-ISSN: 2040 - 881X

LITERATURE REVIEW Open Access

LITERATURE REVIEW: HEALTH IMPACT OF COAL COMBUSTION EMISSIONS IN POWER PLANT ON ADULT RESPIRATORY SYSTEMS

Basuki Rahmat[1,2]*, Cita Fitria Puri[2], Elvi Sahara Lubis[2], Endang Krisnawaty[2], Lailatul Qomariyah[2], Widyana Siregar[2]

[1]National Institute of Health Research and Development, Ministry of Health of Republic of Indonesia, Central Jakarta 10560, Indonesia
[2]Departement of Environmental Health, Faculty of Public Health, Universitas Indonesia, Depok 16424, Indonesia

Corresponding Author:
*) basukir2009@gmail.com

Article Info

Submitted : 31 December 2020
In reviewed : 11 February 2021
Accepted : 5 March 2021
Available Online : 30 April 2021

Keywords : *Coal-fired, Power plant, Respiratory, Pulmonary function status*

Published by *Fakultas Kesehatan Masyarakat Universitas Airlangga*

Abstract

Introduction: *Coal-fired power plants contribute to air pollution emissions of nearly one-third of global SO_2, 14 % of NO_x, and 5 % of $PM_{2.5}$. This condition could worsen adults' respiratory health who live close to power plants; WHO estimates that COPD and LRTI cause around 18% of premature deaths related to outdoor air pollution. This literature review aims to conduct a systematic review of the health impacts of coal-fired power plant emissions on adults' respiratory systems and explore what risk factors lead to decreased lung status. Also, to answer how risk factors influence decreased lung function in adults' respiratory system from coal-fired power plants' emissions.* ***Discussion:*** *This study used a literature study method using an online database to of various research data sources with the same topic. The searching of articles was performed based on the inclusion criteria. From an initial collection of 468 articles, after screening and considering its feasibility, four articles were obtained to serve as material for the final systematic review. The literature review showed that there had been a change in lung function of respiratory system of adults due to long-term exposure to emissions from coal-fired power plants. Factors that influence decreased lung function in adults were NO_x and SO_2 exposure levels, residence distance, wind direction, age, and smoking status.* ***Conclusion:*** *Future research should focus on improving models for assessing exposure to NO_x, SO_2, PM_{10} and $PM_{2.5}$, considering age and smoking habits in evaluating lung function.*

INTRODUCTION

Coal has been still as main fuel in electricity generation around the world. Coal fuel needs to meet global energy is expected to decline from 27% in 2016 to 26% in 2022 compared with other fuel types. The reduction of coal consumption until 2022, concentrated in India and several other countries in Asia, while decreasing coal use occurs in developed countries such as Europe, Canada, the USA, and China (1). About 37% of global electricity demand now comes from power plants that use coal as fuel (2). Coal fired electricity many use in developing countries. Its causes health risk in the community around the power plant still has the potential to be negatively impacted by the health risks associated with dust particle contamination in the air due to coal-burning (3).

Coal is formed from the coalification process of organic microorganism for thousands of years (4). The main components of coal are sulphur, small amounts of nitrogen, carbon, hydrogen, oxygen, and heavy metals. Coal burning released toxic or hazardous materials that can impact to health and environmental problems (5-6). Gas emissions such as sulphur trioxide (SO_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitric oxide (NO_x), and carbon dioxide (CO_2) are the residue from burning coal with oxygen (5). Various health problems, both directly and indirectly, are related to these gases' emission (7-8). Burning coal from power plants produces emissions of CO_2, CO, NO_x, and SO_2 gases that interact with particulate matter, change the ambient air quality to become polluted, leading to increased attacks of respiratory diseases (9–11).

Particulate Matter$_{2.5}$ is a particle material with a size below 2.5 μm in its aerodynamic diameter. The particulate matter's size is less than 2.5 μm in diameter, which is the most dangerous one. The particulate could easily to be inhaled and entered by the bronchioles and alveoli pathways where oxygen and carbon dioxide gases are happened to exchange in the lungs. In India and China, the concentration of $PM_{2.5}$ in ambient air is mostly secondary inorganic aerosols formed from nitrogen oxides and sulfur dioxide (12-13). Large amounts of NO_x and SO_2 in China and India are generated from coal-fired to fuel electricity generation. According to statistical data on the coal-fired power generation sector, NO_x and SO_2 emissions amount for 28.5% and 32.5% in China and 59.1% and 25.0% in India (14).

The process of burning coal in the boiler produces solid waste and gases. The solid waste produced is bottom ash and fly ash, while the gases waste is in the form of CO_x, NO_x, SO_x, and H_2O (15). Meanwhile, the garbage storage belonging to the power plant is generally opened so that it becomes a one source of dust particles ($PM_{2.5}$) that are carried away by the wind, potential to become air pollution. The $PM_{2.5}$ that inhaled and entered the human blood vessel, will cause variety of serious respiratory diseases (16).

The International Energy Agency estimates that coal-fired power plants contribute to air pollution emissions by nearly one-third of global SO_2, 14 % NO_x, and 5 % $PM_{2.5}$ (17). This condition worsened adults' respiratory health that live nearly power plants because they are more exposed to air pollution. In 2016, the World Health Organization estimated that Chronic Obstructive Pulmonary Diseases (COPD) and Lower Respiratory Tract Infections (LRTI) caused about 18% of premature deaths related to outdoor air pollution (18). According to research in China, COPD-related mortality was significantly and positively associated with Increased concentrations of ambient air pollutants (CO, O_3, NO_x, SO_2, and $PM_{2.5}$), susceptibility to COPD-related deaths increases with age (19). Another research in Turkey showed that, there was a relationship between exposure to SO_2 and PM_{10} with patients of COPD and Asthma (20). However, a UK study revealed an increase in $PM_{2.5}$ concentration of 5 μgm^{-3} was associated with a decrease in FVC and FEV_1, 83 mL and 62 mL, respectively, and a 52% increase in COPD prevalence (21). A study in Latin America revealed that for every 10 μgm^{-3} $PM_{2.5}$ concentration increase, the risk of death from respiratory and cardiovascular events would increase by 2% (22).

Residents around the power plant are at high risk of exposure to $PM_{2.5}$ dust, NO_x, and SO_2 (23). Appropriate information regarding to the health impacts of emissions exposure from coal-fired power plants on adults' respiratory system has not been discussed in depth using various relevant scientific literature. It is one reason for the low interest in using personal protective equipment when carrying out daily activities, especially in the residents around coal-fired power plants. This article aims to discuss the health impacts and determine the risk factors that lead to decreased pulmonary status in the adult respiratory system around power plants.

DISCUSSION

Search Strategy and Inclusion Criteria

This study used the PRISMA Protocol; research article was searched to identify eligible studies can be obtained through online databases: EBSCO, PubMed, Proquest, ScienceDirect, Springer Nature, Taylor and Francis, and Google Scholar (24). Articles were identified, screened, and eligible for inclusion criteria. Before searching the article, we build the inclusion and exclusion criteria. Inclusion criteria use English-language articles published in the last ten years (2020-2020), articles can be accessed in full, excluding predatory journals, research participants are human, the population of respondents aged 15 years and over, the primary source of exposure from coal-fired power plants, research method with a cross-sectional design, measurement of lung function in humans or using a questionnaire containing questions of respiratory symptoms, assessment of exposure to health outcomes (Table 1).

Document Selection

In order to expand coverage and minimize the loss of relevant literature, the terms "Coal-fired AND Power plant AND Respiratory," "Power plant AND Respiratory," and "Coal-fired AND Respiratory" are used. A total of 2786 titles were obtained from search results in 6 databases using these three terms and identified through other sources, 653 titles (Figure 1). After the initial identification process (similarity in title and author's name), duplicate articles (n = 2971) eliminated then proceeded to the screening stage.

Eligibility Process

A total of 468 article titles were identified from the database, including from different search results. 345 titles had complete abstracts. Complete abstracts were reviewed, and a collection of relevant articles was obtained based on the required inclusion criteria. After the screening process, the remaining 14 articles had complete and relevant texts. 4 articles were deemed eligible for input into the final review. The articles were

Table 1. Query Results and Search Terms

Term	EBSCO	Proquest	ScienceDirect	Springer Nature	Taylor and Francis	PubMed	Unique Results	Goole Scholar
Coal-fired AND Power plant AND Respiratory	31	441	265	195	105	21	1058	631
Power plant AND Respiratory	109	34	350	60	67	83	703	17
Coal-fired AND Respiratory	25	550	413	7	20	10	1025	5
Total	165	1025	1028	262	192	114	**2786**	**653**

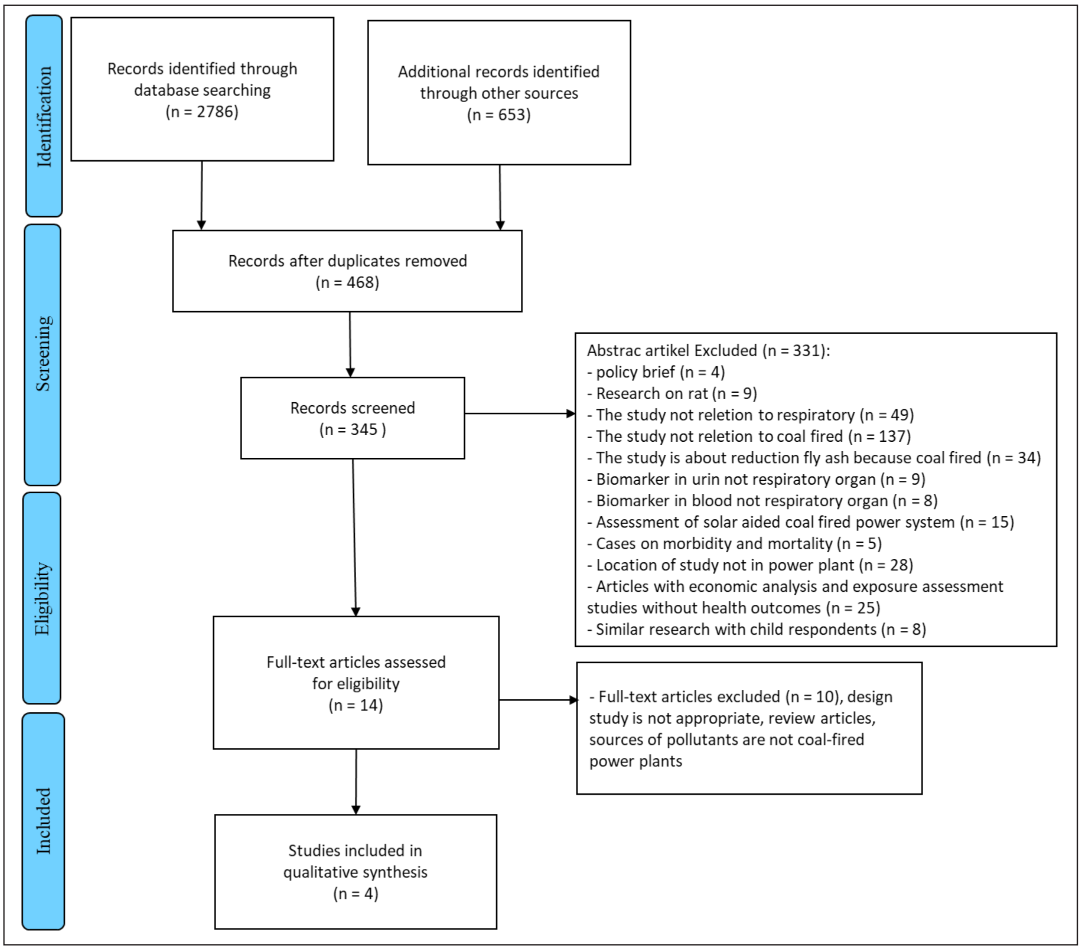

Figure 1. Preferred Reporting Item for Systematic Review

from, United States (2 articles), Turkey (1 article), and Israel (1 article).

In the final review, four articles met the inclusion criteria. Assessment of the quality of statistical tests through consideration of test power values> 85% to minimize the risk of type I or type II errors and parameter p-value with a significant value of p <0.05. However, out of the four articles that meet the inclusion criteria, there were no articles with analysis results that were not statistically related; this process minimized selection bias. Potential information bias was controlled by creating a systematic epidemiological table, including descriptions of measurement and control methods for confounding covariates

In the final literature review, there were four epidemiological articles according to the criteria. According to Table 2, of the 4 articles summarized as a whole, all articles stated the same results. Namely, there

Table 2. Journals in Review

Author	Title	Population	Method	Result	Conclusion
Kayihan P, Alpaslan T., Harika G., Erdinc O., and Hamdi A.(32)	Evaluation of Respiratory Functions of Residents Around the Orhaneli Thermal Power Plant in Turkey	This study consisted of an exposed group of 2,350 people, a non-exposed group (control) of 469 people. The research was conducted in Turkey. Exposed Group from the villages of Karıncalı, Girencik, Yurucekler, Altıntas, Gumuspınar, Danisment, and Dundar. Currently Non-Exposed from the villages of Gorukle, Irfaniye, Konakli, and Buyukbalikli.	Cross-sectional study	In the exposed group, active smokers consumed an average number of cigarettes at 17.73 ± 10.8 cigarettes, and the control group was 20.01 ± 15.75 cigarettes; Statistically, there was no difference in the number of cigarettes consumed by the exposed group and the control group. The mean number of smoking for the exposed group was 19.68 ± 11.61 cigarettes, and the control group was 24.7 ± 15.22 cigarettes, a statistically significant difference ($t = -3.335$, $p < 0.001$). The final modelling results found that living near a power plant had a statistically significant effect on the FEV_1/FVC, FVC, and FEV_1 ratios.	Further research needs to be carried out by diverting confounding factors, measuring exhaust gases from power plants, and air pollution in the surrounding ambient environment.
Eric D. A., Maayan H., Jonathan D., and David M. B.(33)	Contribution of Nitrogen Oxide and Sulfur Dioxide Exposure From Power Plant Emission on Respiratory Symptom and Disease Prevalence	The study consisted of 2244 respondents who could be confirmed, were willing to be interviewed and had an address according to their identity card. The research was conducted in Israel, Hadera District.	Cross-sectional study	There was no significant relationship between gender, age, country of origin, and asthma or COPD prevalence. Communities in power generating areas with lower education are 2.4 times more likely to develop COPD than those with higher education. Communities in power plant areas who actively smoke are at twice the risk of experiencing such as shortness of breath, respiratory symptoms, chronic phlegm, and chronic coughs than nonsmokers. The "source approach" for estimating power plant-specific exposures correlated with the "incidence approach" for NOx ($r = -0.07$) and for SO_2 ($r = 0.62$). There was a strong association between SO_2 and NO_x exposure estimates for the "source approach" ($r = 0.62$) and the "event approach" ($r = 0.97$). A statistically significant association between NOx exposure and the incidence of shortness of breath and chronic sputum after SO2 was included in the model.	Future research will need to identify clinically significant sources of pollution and consider the multiple sources in air pollution epidemiology. Calculating the proportion of pollution in ambient air from coal-fired power plants is useful for monitoring air quality for a certain period, such as planning and emission reduction programs. It is necessary to assess respondents' level of exposure to changes in lung function status and make an economic assessment by considering the benefits and disease burden suffered by respondents related to the existence of power plants.
K. M. Zierold. A. N. Hagemeyer, and C. G. Sears (44)	Health symptoms among adults living near a coalburning power plant	This study consisted of an exposed group of 231 people, a non-exposed group (control) of 170 people. Grup Terpapar di Jefferson County, Kentucky, dan Grup Tanpa Paparan Orange County, Indiana, United States.	Cross-sectional study	Based on the study results, there was a statistically significant relationship between living near a power plant and adults' respiratory problems. Meanwhile, respiratory health symptoms were significantly reported as having lung symptoms.	Future research is expected to measure exposure better, record the severity of symptoms and the frequency of occurrence in which questions are more generally asked of community members who live near coal-fired power plants.
Abby N. H., Clara G. S., and Kristina M. Z. (45)	Respiratory Health in Adults Residing Near a Coal-Burning Power Plant With Coal Ash Storage Facilities: A Cross-Sectional Epidemiological Study	This study consisted of an exposed group of 231 people, a non-exposed group (control) of 170 people. Exposed Group in Southwest Louisville, Kentucky, and Group Non-Exposed in Orange County, Indiana, United States.	Cross-sectional study	Participants felt health symptoms ($p < 0.0001$), shortness of breath, such as cough, respiratory infections, and shortness of voice. While the overall mean respiratory health score ($p<0.0001$) was statistically significant greater in exposed adults than in unexposed. Report the respiratory symptoms more often experienced by adults living near coal-burning facilities than in unexposed populations.	Subsequent research conducted an assessment of the relationship between coal ash's impact on respiratory health impacts by measuring coal dust directly (PM2.5) by taking into account smoking status, years of smoking, and other potential confounders.

was a relationship between dust exposure from coal combustion emissions in power plants with decreased lung function and respiratory health problems in adults. All studies used a spirometry test to assess lung function. The measurement results were then analyzed to see correlation with decreased lung function using statistical tests.

The four articles' main findings discuss the relationship between exposure to coal combustion emissions in power plants to the decreased lung function of respondents, but each article adds several other independent variables. Some of the most frequently cited independent variables among these articles are NO_x and SO_2 exposure levels, residence distance, wind direction, age, and smoking status. The addition of different independent variables from the four articles will affect the study's final results later. A summary of the correlation between several independent variables and lung function status due to exposure to coal combustion emissions in power plants can be seen in Table 3 below. Based on Table 3, there are differences in the number of articles that state the relationship between variables.

Table 3. Variable Relationship with Physiological Status of Respiratory Lungs in adults

Independent Variable	Related	Not Related
NO_x and SO_2 exposure levels	2	NA
Residence distance	4	-
Wind direction	2	NA
Age	2	
Smoking status	4	-

Note: Not applicable (NA)

NO_x and SO_2 Exposure Levels

Nitrogen oxide (NO_x) is a gaseous compound in the atmosphere consisting of nitrogen monoxide (NO) and nitrogen dioxide (NO_2), both of which have toxic properties. Nitrogen Oxide is a by-product of burning fossil fuels (coal and oil), coal mining, industrial manufacturing, and mineral ore smelting. Nitric acid (HNO_3) formation occurs in the respiratory pathways when nitrites reacts with water vapor. The dissociation of nitric acid produces nitrates and nitrites. In the upper respiratory tract, nitrite reacts with water vapor in low concentrations. The reaction continues to penetrate the lower respiratory tract with increasing amounts of nitrite exposure. The concentration of nitrites and other by-products will be higher due to the increased breathing rate and will reach more in-depth areas of the alveoli. Nitrite and its derivative leave the alveoli through the bloodstream, some react with hemoglobin to form methemoglobin (MetHb), and some remain in the lungs. The methemoglobin prevents oxygen binding at that site and reducing the oxygen carrying capacity which impact the circulating oxygen system that called hypoxia (25).

WHO sets the threshold limit value for exposure to NO_x gas which is safe for public health is 40 μg/m^3. Based on research results, when a person is exposed to NO_x gas in the short term with a concentration of more than 200 μg/m^3, this can cause inflammation of the respiratory tract (18). According to epidemiological studies, NO_2 exposure for the long term will increase the bronchitis symptoms in the children who have asthma. Meanwhile, European and North American cities observed an association of NO_2 exposure at concentrations currently measured with decreased lung function growth (26-27).

Sulphur dioxide (SO_2) is a type from Sulphur oxide (SO_x) which is water soluble, colorless, and has a strong odor. The primary source of SO_2 is from smelting mineral ores that contain sulfur and burning fossil fuels such as oil, natural gas, and coal. The exposure of high SO_2 concentrations into the respiratory system can cause irritation and inflammation because SO_2 can activate C-fibers and rapidly adapting receptors (RARs) in the upper airway and trachea, increasing centrally connected vegal tone resulting in distal bronchoconstriction. As well as stimulation of the C-fibers of the larynx can result in local airway narrowing. Some symptoms will occurs include pain when breathing deeply, coughing, throat irritation, difficulty breathing, SO_2 also induces local airway constriction by direct stimulation of sensory mucosal nerve endings through neurogenic inflammatory processes (28).

The concentration of SO_2 in the high risk population will worsens heart disease, asthma attacks, and decrease lung function. Similar health effects can occur when other substances in the air react to SO_2 and turn into tiny particles entering the lungs. The Environmental Protection Agency (EPA) established six air quality indices; good at SO_2 concentrations (0–0.1 ppm); moderate at concentrations (0.1–0.2 ppm) considering reduce outdoor activity for extended periods for high risk population; unhealthy for the high risk population (0.2–1.0 ppm) are children, adults, and people with lung diseases, such as asthma, should reduce prolonged outdoor activity; unhealthy category (1.0–3.0 ppm), in this condition, you should avoid prolonged outdoor activities or heavy work, especially for children, adults, and people with lung diseases, such as asthma; very unhealthy category (3.0–5.0 ppm) everyone should avoid outdoor activities, especially for people with lung diseases, such as asthma, adults, and children; hazardous category (> 5.0 ppm), the entire population must avoid outdoor activities and remain indoors. WHO said that the SO_2 exposure time should not exceed 10 minutes for SO_2 concentrations above 500 μg/m³ (18). Studies show that some asthmatics exposed to SO_2 at a concentration of 500 μg/m³ within 10 minutes will have changes in lung function and experience respiratory symptoms. The health effects of exposure to SO_2 currently known are in much lower concentrations than previously known. Although the correlation of health effects to exposure low SO_2 concentrations is not certain, efforts to reduce SO_2 concentrations are likely to reduce the amount of exposure to co-pollutants (26,29).

Nitrogen oxide and sulfur dioxide are the primary air pollutants derived from coal combustion in power plants (30). Decreased lung function and respiratory problems can occur due to SO_2 and NO_x exposure for a long periods (31). From the article review results, study that conducted in Turkey's residents with 15 years old and over who lived in areas which exposed to air pollution from coal-fired power plants, the first effect on residents was a respiratory system sympthoms. The decreased of respiratory function due to exposure SO_2 showed that the population had a significantly lower FVC and FEV_1 values, and the FEV_1/FVC values were much higher than those who lived far from the power plant (32). The FEV_1/FVC ratio increases because the decrease in FVC is relatively more significant than the decrease in FEV_1 in some patients with restrictive defects (30-31). According to a review of articles on an Israeli study, significantly, each 1 ppb increase in NO_x emissions from power generation was associated with chronic phlegm and chronic cough (33). This study did not find a statistically significant relationship between SO_2 gas emissions from power plants and asthma and COPD incidence.

A similar study in Italy supports this result, but the pollutant source is oil-fired power plants (34). The results showed that 347 workers in the field at the power plant had significantly lower FEV_1 and FVC values (P <0.001) compared to 349 administrative workers, this was because workers were in contact with NO_2 gas with an average concentration of 3.91 ± 1, 51 mg/m³ per day, where the exposure value is in the range 1.21-7.82 mg/m³. Research results in the Netherlands have shown conflicting results. The results found no association between SO_2 and NO_x exposure with decreased respiratory function (35). There may be a stronger association between estimates of exposure and prevalence of the respiratory disease in higher SO_2 and NO_x gas content. The limitation in this study's results is that the level of particulate matter is not measured in the local air quality monitoring data. Thus, the study did not include that data in the exposure assessment and cannot evaluate whether the positive correlation is due to exposure between SO_2 and NO_x emissions with particulate meters from the power plant or vice versa. Given the various recent literature's strength, many link particulate matter exposure from coal-fired power plants to respiratory health (36–38).

The particulate matter are divided into two sizes, namely PM_{10} (particles <10 μm) and $PM_{2.5}$ (particles <2.5 μm). Various studies have proven the relationship between airborne particulate meters in ambient air to various problems that are detrimental to health conditions, including respiratory health (39–41). There was a strong correlation between the health effects and the change in aerodynamic diameter size from PM_{10} to $PM_{2.5}$ (41–43). Tissue damage occured due to exposure to $PM_{2.5}$ and PM_{10} for a long time. The size of $PM_{2.5}$, which is smaller than PM_{10}, allows particles to enter the alveolus. In the alveolus, particles can enter the bloodstream and spread throughout the whole body.

Residence Distance

In four studies, proximity to coal-fired power plants was not categorized (binary variable) (32,33,44-45). However, the four studies' residential proximity classification was grouped based on area, consisting of respondents who exposed to areas nearly the source of pollution and non-exposed respondents outside from the source of pollution. The results of these four studies reported a statistically significant relationship between residence distance and pollutant sources. However, three studies did not measure lung function but only interviewed respondents. Although the use of a structured questionnaire on three articles helps answer the research objectives by obtaining complete information regarding the symptoms and respiratory diseases, suffered by the public based on personal opinions. In general, to minimize information bias in using the questionnaire as an instrument, it needs to be accompanied by a clinical examination conducted by laboratory assessment.

A review of articles on Orange County, Indiana, stated that adults living near power plants were significantly more likely to report experiencing respiratory symptoms. Respiratory symptoms that are common in adults living near power plants are shortness of breath (AOR = 2.59), allergies (AOR = 1.62), respiratory infections (AOR = 1.82), hoarseness (AOR = 4.02), and cough (AOR = 5.3). Another result was that adults living near coal-fired power plants were 5.27 times more likely to experience respiratory symptoms than those living in settlements without a power plant (44). The review conducted by Buteau et al. showed a statistically significant relationship between the proximity of housing to the industry with the incidence of wheezing and asthma prevalence. However, the heterogeneity across outcomes was considerable (I 2 = 71% and 65%) (46).

Meanwhile, a review from one of Turkey's studies with measurements of respiratory function showed that the FEV_1 / FVC, FVC, and FEV_1 values were statistically significant when living near a power plant (32). These results align with the research results in Turkey, where people who live near power plants have a lower FEV1 value than control communities (47). The results of researchers in Italy, also supporting these findings, showed that in 347 power plant workers, the FVC and FEV1 values were significantly ($P < 0.001$) lower than 349 controls (administration) (34).

Several other studies have attempted to describe the risk of the distance from residence to pollutant sources spatially. A study in Canada found an association between proximity of residence to power plants and pediatric emergency room visits rates due to asthma (48). There is no modeling for assessing sources of exposure, but the distance of the residential zip code to the power plant as a basis for determining the value of exposure. After controlling for age and gender variables, the spatial analysis showed an inverse relationship between generator distance and the visit rate of children with asthma to the hospital in the study area.

Several studies have tried to categorize the variables in the form of binary variables and continuous variables, finding a relationship between residence proximity to sources of pollution (sources other than coal-fired power plants). A cohort study said that children living close to (<7.5 km) to the primary source of pollution (releasing more than 100 tons of SO_2 and $PM_{2.5}$ per year) had a significantly greater risk of developing asthma compared to children who lived far (≥ 7.5) from a source of pollutants. Where within 7.5 km, each different distance of residence by 1 km will reduce the danger of asthma onset by 2.2% (95% CI: 1.0% - 3.3%) (49).

A study in North Lebanon reported a statistically significant association between residence distance to pollutant sources and respiratory health complaints in children (50). The study also compared the relationship between living at a distance from industry (4-7 km), versus living close to industry (distances 0-3 km), finding statistically significant increases in the ratio of sputum to colds, wheezing, colds cough, annual period sputum and cough, and annual chest colds. In a study using distance as a continuous variable, each reduction in 1 km from the pollution source had a 7% risk of hospitalization for asthma (95% CI: 2% - 18%) (46).

Adults spend more time outside the home to carry out work activities. These activities can directly increase the risk of health impacts from prolonged exposure to air pollution. According to research in the Southwest Louisville, Kentucky area, participants in the exposed group experienced more respiratory symptoms (hoarseness, respiratory infections, and shortness of breath) than the unexposed group. Also, participants who reported having respiratory tract infections in the exposed group spent more time outside (p-value = 0.0004) (45).

Distance is a variable that is closely related to health risks arising from exposure to environmental pollution. The greater the amount of particulate matter and gas emissions from polluting sources, the greater the risk of health impacts received by people living close to polluting sources. Therefore, there is a need for assistance from local health workers regarding efforts to minimize the health impacts of exposure to particulate matter and exhaust emissions to air pollution by implementing PPE for communities around polluting sources.

Wind Direction

The level of pollution and air quality were the major problems in industrial areas, urban areas, and agricultural areas. This is presumably because the spread of pollution without limits occurs following the wind's direction in the area. Wind direction and wind speed depend on climatic conditions and the current season. Some literature has looked at the effect of wind speed on decreasing air quality, which is generally experienced in smog (51). The formation of the smog phenomenon in cities occurs as a result of low wind speeds. Pollutants or smog in the atmosphere often encountered include NO_x and SO_2 gases suspended with $PM_{2.5}$ and PM_{10} particles whose presence can harm human health. One source of high particulate matter is from coal-fired power plants. This phenomenon often occurs in urban areas; much literature discusses this (52).

Research in Turkey showed at the relationship between the direction of the wind that carries pollutants from power plants and the respiratory function of people living around coal-fired power plants (32). People whose houses are traversed by wind gusts that carry air pollutants from power plants have a lower lung capacity quality than those whose houses are not traversed by the wind. People who live in the 2.6 km wind direction of the power plant chimney have the lowest average FEF 25-75% (92,389 ± 34.91), FVC (77,527 ± 24.68), and FEV_1 (82,823 ± 25.52). Meanwhile, communities that are closer to the power plant chimney (2.2 km) but located downwind, have a higher average FEF 25-75% (93.370 ± 31.11), FVC (90.51 ± 20, 24), and FEV_1

(91,943 ± 21.05). It is suspected that the pollutants released from the chimneys of power plants contributed to the decrease in lung function of the people in the Girencik area compared to the lung function value of the people living following the wind direction. A study in South Korea is in line with these results, which found that wind direction affects the transport of air pollutants from pollution sources over short and long distances, which affects ambient air quality in the surrounding area (53).

A study in Israel found a statistically significant relationship between wind direction of industrial areas and asthma prevalence (54). A recent study in Poland that looked at PM_{10} concentrations in atmospheric air during winter was affected by wind speeds; the result was that there would be a higher increment of PM_{10} particulate matter values when wind speeds were lower in the air (8). In addition to considering wind direction in mobilizing air pollution emission displacement from a region, it is also necessary to consider the wind speed, so that it can assess and predict whether air pollution emissions carried by the wind come from the same pollutant source and can estimate the distance the pollution will drop to the ground.

Age

The respiratory system has multiple functions, including a role as a place for air exchange. This system also plays a role in regulating blood pH, controlling blood pressure, and swallowing as a nonspecific mechanical immune defense (55). For example, there is a reduction of about 10% in lower bronchiolar diameter (G12 ~) between 50 and 80. Also, the alveolar sacs get bigger with age. In general, after about 30 years of age, there is a steady decrease of 1% per year in the respiratory mechanism and lung function. By the age of 50 to 80 years, the lung tissue becomes about 7% stiffer (56).

People over 30 years old have an average lung capacity of 3,000 ml to 3,500 ml, but at the age of more than 50 years, experience a decrease in lung capacity to less than 3,000 ml. A person will experience a decrease in lung function values at 30 years (57). A decrease in lung function value will occur about 20 ml every time a person gets one year old. The average age of the respondents in this scientific study was more than 30 years. At that age, a person's lung capacity has reached an optimal point and cannot develop, and even lung function tends to decrease (58).

Spirometry is a standard examination performed to assess lung function by measuring the amount of air inhaled and exhaled in one breath. The airflow limitation on spirometry was determined when the forced expiratory volume ratio in 1 second (FEV_1) to forced vital capacity (FVC) was less than 70% after bronchodilator administration (59-60). However, age or gender was not considered in this diagnostic threshold assessment and thus has drawn criticism (61-62). Changes in lung function will naturally occur when a person is ageing; this occurs due to decreased alveolar surface area for gas exchange, loss of elasticity of the lungs and weakening of the respiratory muscles. Several cross-sectional and longitudinal studies have reported decreasing with age pulmonary function parameters such as FEV_1 and FVC. In the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria, current threshold values can diagnose ordinary healthy elderly people as sick and diagnose some younger people with the disease as healthy. GOLD recommends the FEV_1/FVC threshold values adjusted for age, sex, and ethnicity to define chronic obstructive pulmonary disease. To avoid errors in the diagnosis of COPD by using spirometry (26).

Of the four studies summarized, one study measured lung function capacity using spirometry (32). The results showed that respondents who live in communities near coal-fired power plants have significantly lower FEV1 and FVC values than groups living in communities without power plants. Meanwhile, residents directly downwind from the power plant chimney show more impaired respiratory function than downwind residents. The average age of the respondents who participated in this study, both control and exposure, were both young and had not experienced a decrease in lung function in the respiratory system.

This result is in line with research in Pakistan (63), which states that increasing age affects their FEV_1 and FVC values. The respondents' FVC and FEV_1 values will decrease significantly with the increasing age of the respondent. The FVC value will continue to increase until the age of 25-30 years and decrease ten years later. However, there are different results in China's studies, where there was no relationship between age and lung function status in coal mine workers (64). It is suspected that other factors are more dominant and directly affect the status of lung function. Although age is not a fundamental factor affecting a person's decreased lung function, age can be one of the factors that worsen lung function status in someone who lives in an area with high pollution sources.

Smoking Status

Tobacco use directly causes death to 7 million people each year worldwide. At the same time, about 1.2 million results from nonsmokers who exposure to secondhand smoke (65). Tobacco smoke is high in $PM_{2.5}$ and is one of the causes of the same health problems as air pollution (66). Various research results have proven that a decrease in lung function status (FEV_1/FVC ratio), COPD, and various other respiratory diseases, one of which can occur due to exposure to tobacco smoke (67). However, tobacco use remains high and is still a significant public health problem for various respiratory diseases.

Scientific evidence has documented the effects of tobacco smoke and air pollution exposure on decreased lung function ratios, increasing the risk of ventilation defects that obstruct breathing and exacerbate existing respiratory symptoms (66,68). Review results in Tanaka et al. reported that FEV1 (Forced Expiratory Volume 1), smokers can return to normal ranges during annual periods when air quality improves (69). However, studies in Japan reported that even though the air quality improved, the patient's respiratory function did not fully recover (70). This report draws on observations of selected air pollution victims with obstructive pulmonary defects and without obstructive pulmonary defects in the long term to see the relationship between tobacco use and respiratory health. Recent literature studies have shown that exposure to air pollution accompanied by tobacco use exacerbates respiratory symptoms and lung function loss (71-72).

Of the four studies, only one study found a statistically significant relationship between smoking habits and lung function status changes. The study found that the control group's respiratory function was significantly better than that of the study group, although in the study group the mean number of years of smoking was shorter than in the control group (32). These results are consistent with recent epidemiological studies that study the relationship between decreased lung function status in workers on the effects of tobacco smoke and exposure to coal dust (73).

Airway obstruction can be caused by air pollution resulting in decreased lung function, reactive respiratory dysfunction syndrome, and asthma. However, coupled with tobacco use can cause airway hyper-responsiveness; this has been shown to have a more substantial effect on respiratory health in several studies (31,74). Cigarette smoke can reduce or even eliminate the cilia's function to prevent foreign differences from entering the body through the nose (respiratory system). The cilia can inhibit harmful chemicals from cigarette smoke from entering the body's organs. If the concentration of chemical substances from cigarette smoke and pollutant sources is too much, then the cilia have to work harder; if it lasts a long time, the cilia's function can decrease and can cause infection in the lungs (75).

Other variables influence the reduction in lung capacity, such as the length of smoking and the dosage of nicotine, in addition to the smoking habit itself. A study shows that a person has a 40 times greater risk of developing lung problems when smoking a dose of 35 cigarettes per day (76). Unfortunately, the measure of cigarette dose consumed daily was not used at all selected trial stages, so it is difficult to assess whether the respondent's cigarette dose is related to lung function status changes.

The limitation of this literature review article is that the number of recent articles obtained from systematic searches based on inclusion criteria is still insufficient (1 article), especially to break the causal relationship between NO_x and SO_2 gas emission exposure, to a decrease in lung function status. However, to overcome this limitation, the author tries to find a variety of good-quality literature sourced from journals and books, which support the justification of the causal relationship between NO_x and SO_2 gas emission exposure to a decrease in lung function status. Also, when discussing articles, the team always delivers the limitation of each paper being reviewed.

ACKNOWLEDGEMENTS

Our thanks to the lecturer (Prof. Dr. dr. Adik Wibowo, MPH) for the scientific publication course; for their guidance, this article can be published.

CONCLUSION

The health impact of coal-fired power plant emissions on the respiratory health of adults most often felt was respiratory infections, allergies, shortness of breath, hoarseness, and cough. However, the long-term impact on respiratory health in adults is a decrease in lung function. Factors that affect lung function decline in adults are NO_x and SO_2 exposure levels, residence distance, wind direction, age, and smoking. Future studies should create spatial models to assess exposure to PM_{10}, $PM_{2.5}$, NO_x, and SO_2, taking into account age and smoking habits in evaluating pulmonary function status. Geographical control is needed to make it easier to determine areas requiring health interventions to reduce the health impacts arising from air pollution emissions from power plants.

REFERENCES

1. Energy Information Administration (EIA). International Energy Outlook 2017 Overview. Int Energy Outlook 2017. United States: Energy Information Administration (EIA); 2017. https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf
2. World Coal Association. Uses of Coal. United Kingdom: World Coal Association; 2016. https://www.worldcoal.org/coal/uses-coal/coal-electricity
3. World Coal Association. Where is Coal Found?. United Kingdom: World Coal Association; 2018. https://www.worldcoal.org/coal/where-coal-found
4. Tiess G, Majumder T, Cameron P. Encyclopedia of Mineral and Energy Policy. Berlin: Springer Berlin Heidelberg; 2016. https://doi.org/10.1007/978-3-642-40871-7_92-1
5. Munawer ME. Human Health and Environmental Impacts of Coal Combustion and Post-Combustion Wastes. *Journal of Sustainable Mining*. 2018;17(2):87-96. https://doi.org/10.1016/j.jsm.2017.12.007
6. Barreira A, Patierno M, Ruiz Bautista C. Impacts of Pollution on our Health and the Planet: The Case of Coal Power Plants. Kenya: United Nations Environmental Programe; 2017. https://wedocs.unep.org/bitstream/handle/20.500.11822/22218/Perspective_No_28_web.pdf
7. Ciuta S, Tsiamis D, Castaldi MJ. Gasification of Waste Materials: Technologies for Generating Energy, Gas, and Chemicals from Municipal Solid Waste, Biomass, Nonrecycled Plastics, Sludges, and Wet Solid Wastes. Massachusetts: Academic Press; 2017. https://doi.org/10.1016/B978-0-12-812716-2.00005-4
8. Cichowicz R, Wielgosiński G, Fetter W. Effect of Wind Speed on the Level of Particulate Matter PM10 Concentration in Atmospheric Air During Winter Season in Vicinity of Large Combustion Plant. *J Atmos Chem*. 2020;77(1):1–14. https://doi.org/10.1007/s10874-020-09401-w
9. Amster E. Public Health Impact of Coal-Fired Ower Plants: A Critical Systematic Review of the Epidemiological Literature. *Int J Environ Health Res*. 2019;29(3):1–23. https://doi.org/10.1080/09603123.2019.1674256
10. Zhang X. Emission Standards and Control of $PM_{2.5}$ from Coal-Fired Power Plants. *In: Power Plant Pollutant Control MEGA Symposium (MEGA 2016)*. 2016;1(1):1-80. https://www.iea-coal.org/report/emission-standards-and-control-of-pm2-5-from-coal-fired-power-plant-ccc-267/
11. Amster E, Levy CL. Impact of Coal-Fired Power Plant Emissions on Children's Health: A Systematic Review of the Epidemiological Literature. *Int J Environ Res Public Health*. 2019;16(11):1–11. https://doi.org/10.3390/ijerph16112008
12. Singh N, Murari V, Kumar M, Barman SC, Banerjee T. Fine Particulates Over South Asia: Review and Meta-Analysis of $PM_{2.5}$ Source Apportionment Through Receptor Model. *Environ Pollut*. 2017;223(1):121–136. https://doi.org/10.1016/j.envpol.2016.12.071
13. Gao M, Beig G, Song S, Zhang H, Hu J, Ying Q, et al. The Impact of Power Generation Emissions on Ambient $PM_{2.5}$ Pollution and Human Health in China and India. *Environ Int*. 2018;121(1):250–259. https://doi.org/10.1016/j.envint.2018.09.015
14. Li M, Zhang Q, Kurokawa JI, Woo JH, He K, Lu Z, et al. MIX: A Mosaic Asian Anthropogenic Emission Inventory Under the International Collaboration Framework of the MICS-Asia and HTAP. *Atmos Chem Phys*. 2017;17(2):935–963. https://doi.org/10.5194/acp-17-935-2017
15. Youcai Z. Pollution Control and Resource Recovery: Municipal Solid Wastes Incineration. Shanghai: Elsevier Science; 2017. 369 p. https://doi.org/10.1016/b978-0-12-812165-8.00001-9
16. Lurie K, Nayebare SR, Fatmi Z, Carpenter DO, Siddique A, Malashock D, et al. $PM_{2.5}$ in a Megacity of Asia (Karachi): Source Apportionment and Health Effects. *Atmos Environ*. 2019;202(1):223–233. https://doi.org/10.1016/j.atmosenv.2019.01.008
17. Bhati P, Singh M, Issar S. Indonesia's Coal Power Emission Norms: Lessons From India and China. New Delhi: Centre for Science and Environment; 2017. https://icel.or.id/wp-content/uploads/Policy-Paper.-ICEL-CSE-REEI-2017-Indonesias-Coal-Power-Emission-Norms-Lessons-from-India-China.pdf
18. World Health Organization. Ambient (Outdoor) Air Pollution. Geneva: World Health Organization; 2018. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
19. Chen J, Shi C, Li Y, Ni H, Zeng J, Lu R, et al. Effects of Short-Term Exposure to Ambient Airborne Pollutants on COPD-Related Mortality Among the Elderly Residents of Chengdu City in Southwest China. *Environ Health Prev Med*. 2021;26(7):1–10. https://doi.org/10.1186/s12199-020-00925-x
20. Saygın M, Gonca T, Öztürk Ö, Has M, Çalışkan S, Has ZG, et al. To Investigate the Effects of Air Pollution (PM_{10} and SO_2) on the Respiratory Diseases Asthma and Chronic Obstructive Pulmonary Disease. *Turkish Thorac J*. 2017;18(2):33–39. https://doi.org/10.5152/TurkThoracJ.2017.16016
21. Doiron D, de Hoogh K, Probst-Hensch N, Fortier I, Cai Y, De Matteis S, et al. Air Pollution, Lung Function and COPD: Results from the Population-Based UK Biobank Study. *Eur Respir J*. 2019;54(1):1–12. https://doi.org/10.1183/13993003.02140-2018
22. Fajersztajn L, Saldiva P, Pereira LAA, Leite VF, Buehler AM. Short-Term Effects of Fine Particulate Matter Pollution on Daily Health Events in Latin America: A Systematic Review and Meta-Analysis. *Int J Public Health*. 2017;(62):729–738. https://doi.org/10.1007/s00038-017-0960-y
23. Morhulova V, Maremukha T, Petrosian A, Turos O. P II – 2–6 Ambient Air Pollution PM_{10} and $PM_{2.5}$ Due to Coal Tpp. *Occup Environ Med*. 2018;75(Suppl 1):1-10. http://dx.doi.org/10.1136/oemed-2018-ISEEabstracts.106
24. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred Reporting Items for Systematic Review and Meta-Analysis

Protocols (PRISMA-P) 2015 Statement. *Rev Esp Nutr Humana y Diet*. 2016;4(1):1–9. https://doi.org/10.1186/2046-4053-4-1

25. National Research Council. Assessment of Exposure-Response Functions for Rocket-Emission Toxicants. Washington (DC): The National Academies Press; 1998. https://doi.org/10.17226/6205
26. Thomas ET, Guppy M, Straus SE, Bell KJL, Glasziou P. Rate of Normal Lung Function Decline in Ageing Adults: a Systematic Review of Prospective Cohort Studies. *BMJ Open*. 2019;9(6):1–13. http://dx.doi.org/10.1136/bmjopen-2018-028150
27. Liu SK, Cai S, Chen Y, Xiao B, Chen P, Xiang XD. The Effect of Pollutional Haze on Pulmonary Function. *J Thorac Dis*. 2016;8(1):E41–E56. https://doi.org/10.3978/j.issn.2072-1439.2016.01.18
28. Tunnicliffe WS, Hilton MF, Harrison RM, Ayres JG. The Effect of Sulphur Dioxide Exposure on Indices of Heart Rate Variability in Normal and Asthmatic Adults. *Eur Respir J*. 2001;17(1):604–608. https://doi.org/10.1183/09031936.01.17406040
29. United States Environmental Protection Agency. Sulfur Dioxide Basics. United States: United States Environmental Protection Agency; 2019. https://www.epa.gov/so2-pollution/sulfur-dioxide-basics
30. Dai H, Ma D, Zhu R, Sun B, He J. Impact of Control Measures on Nitrogen Oxides, Sulfur Dioxide and Particulate Matter Emissions from Coal-Fired Power Plants in Anhui Province, China. *Atmosphere*. 2019;10(35):1–14. https://doi.org/10.3390/atmos10010035
31. Jiang XQ, Mei XD, Feng D. Air Pollution and Chronic Airway Diseases: What Should People Know and Do?. *Journal of Thoracic Disease*. 2016;8(1):E31-E40. https://doi.org/10.3978/j.issn.2072-1439.2015.11.50
32. Pala K, Türkkan A, Gerçek H, Osman E, Aytekin H. Evaluation of Respiratory Functions of Residents Around the Orhaneli Thermal Power Plant in Turkey. *Asia-Pacific J Public Heal*. 2012;24(1):48–57. https://doi.org/10.1177/1010539510363622
33. Amster ED, Haim M, Dubnov J, Broday DM. Contribution of Nitrogen Oxide and Sulfur Dioxide Exposure from Power Plant Emissions on Respiratory Symptom and Disease Prevalence. *Environ Pollut*. 2014;186(1):20–28. https://doi.org/10.1016/j.envpol.2013.10.032
34. Carbone U, Montuori P, Novi C, Triassi M. Respiratory Function in Power Plant Workers Exposed to Nitrogen Dioxide. *Occup Med*. 2014;64(8):644–646. https://doi.org/10.1093/occmed/kqu129
35. Brunekreef B, Beelen R, Hoek G, Schouten L, Bausch-Goldbohm S, Fischer P, et al. Effects of Long-Term Exposure to Traffic-Related Air Pollution on Respiratory and Cardiovascular Mortality in the Netherlands: the NLCS-AIR Study. *Res Rep Health Eff Inst*. 2009;139(1):73–89. https://pubmed.ncbi.nlm.nih.gov/19554969/
36. Burnett R, Chen H, Szyszkowicz M, Fann N, Hubbell B, Pope CA, et al. Global Estimates of Mortality Associated With Longterm Exposure to Outdoor Fine Particulate Matter. *Proc Natl Acad Sci*. 2018;115(38):9592–9597. http://dx.doi.org/10.1073/pnas.1803222115
37. Paula U De, Arbex MA, Luis A, Braga F, Futoshi R, Eduardo J, et al. Environmental Air Pollution : Respiratory Effects. *Jornal Brasileiro de Pneumologia.* 2021;47(1):1–13. https://www.jornaldepneumologia.com.br/details/3483/en-US/poluicao-do-ar-ambiental--efeitos-respiratorios
38. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and Health Impacts of Air Pollution: A Review. *Front Public Heal*. 2020;8(14):1–13. http://dx.doi.org/10.3389/fpubh.2020.00014
39. Health Organization W. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. *Clean Air J.* 2016;26(2):6. https://doi.org/10.17159/2410-972x/2016/v26n2a4
40. Gallo E, Folino F, Buja G, Zanotto G, Bottigliengo D, Comoretto R, et al. Daily Exposure to Air Pollution Particulate Matter is Associated with Atrial Fibrillation in High-Risk Patients. *Int J Environ Res Public Health*. 2020;17(17):1–10. http://dx.doi.org/10.3390/ijerph17176017
41. Orellano P, Reynoso J, Quaranta N, Bardach A, Ciapponi A. Short-Term Exposure to Particulate Matter (PM_{10} and $PM_{2.5}$), Nitrogen Dioxide (NO_2), and Ozone (O_3) and All-Cause and Cause-Specific Mortality: Systematic Review and Meta-Analysis. *Environ Int.* 2020;142(1058762):1–15. http://dx.doi.org/10.1016/j.envint.2020.105876
42. Yan H, Ding G, Li H, Wang Y, Zhang L, Shen Q, et al. Field Evaluation of the Dust Impacts from Construction Sites on Surrounding Areas: A City Case Study in China. *Sustain.* 2019;11(7):1–19. http://dx.doi.org/10.3390/su11071906
43. Zhou X, Cao Z, Ma Y, Wang L, Wu R, Wang W. Concentrations, Correlations and Chemical Species of $PM_{2.5}$/PM_{10} Based on Published Data in China: Potential Implications for the Revised Particulate Standard. *Chemosphere*. 2016;144(1):518–526. https://doi.org/10.1016/j.chemosphere.2015.09.003
44. Zierold KM, Hagemeyer AN, Sears CG. Health Symptoms Among Adults Living Near a Coal-Burning Power Plant. *Arch Environ Occup Heal*. 2020;75(5):289–296. http://dx.doi.org/10.1080/19338244.2019.1633992
45. Hagemeyer AN, Sears CG, Zierold KM. Respiratory Health in Adults Residing Near a Coal-Burning Power Plant with Coal Ash Storage Facilities: A Cross-Sectional Epidemiological Study. *Int J Environ Res Public Health*. 2019;16(3642):1–10. http://dx.doi.org/10.3390/ijerph16193642
46. Buteau S, Geng X, Labelle R, Smargiassi A. Review of the Effect of Air Pollution Exposure from Industrial Point Sources on Asthma-Related Effects in Childhood. *Environ Epidemiol*. 2019;3(e077):1–15. http://dx.doi.org/10.1097/ee9.0000000000000077
47. Karavuş M, Aker A, Cebeci D, Taşdemir M, Bayram N, Çali Ş. Respiratory Complaints and Spirometric Parameters of the Villagers Living

Around the Seyitomer Coal-Fired Thermal Power Plant in Kütahya, Turkey. *Ecotoxicol Environ Saf*. 2002;52(3):214–220. https://doi.org/10.1006/eesa.2002.2158

48. Rodriguez-Villamizar LA, Rosychuk RJ, Osornio-Vargas A, Villeneuve PJ, Rowe BH. Proximity to Two Main Sources of Industrial Outdoor Air Pollution and Emergency Department Visits for Childhood Asthma in Edmonton, Canada. *Can J Public Heal*. 2017;108(1):e523–e529. https://doi.org/10.17269/cjph.108.6136
49. Buteau S, Doucet M, Tétreault LF, Gamache P, Fournier M, Brand A, et al. A Population-Based Birth Cohort Study of the Association Between Childhood-Onset Asthma and Exposure to Industrial Air Pollutant Emissions. *Environ Int*. 2018;121(1):23–30. http://dx.doi.org/10.1016/j.envint.2018.08.040
50. Kobrossi R, Nuwayhid I, Sibai AM, El-Fadel M, Khogali M. Respiratory Health Effects of Industrial Air Pollution on Children in North Lebanon. *Int J Environ Health Res*. 2002;12(3):205–220. https://doi.org/10.1080/09603/202/000000970
51. Turner DB. Workbook of Atmospheric Dispersion Estimates. Workbook of Atmospheric Dispersion Estimates. London: CRC Press; 2020. http://dx.doi.org/10.1201/9780138733704
52. Godish T, Davis WT, Fu JS. Air Quality. Florida: CRC Press; 2020. http://dx.doi.org/10.1201/b17341-8
53. Chen X, Yang T, Wang Z, Hao Y, He L, Sun H. Investigating the Impacts of Coal-Fired Power Plants on Ambient $PM_{2.5}$ by a Combination of a Chemical Transport Model and Receptor Model. *Sci Total Environ*. 2020;727(138407):1–11. http://dx.doi.org/10.1016/j.scitotenv.2020.138407
54. Karakis I, Kordysh E, Lahav T, Bolotin A, Glazer Y, Vardi H, et al. Life Prevalence of Upper Respiratory Tract Diseases and Asthma Among Children Residing in Rural Area Near a Regional Industrial Park: Cross-Sectional Study. *Rural Remote Health*. 2009;9(3):1–16. https://www.rrh.org.au/journal/article/1092
55. Lakshmipathy D. Biomedical Engineering and its Applications in Healthcare. Singapore: Springer Nature Singapore Pte Ltd; 2019. http://dx.doi.org/10.1007/978-981-13-3705-5_1
56. Kim JW, Heise RL, Reynolds AM, Pidaparti RM. Aging Effects on Airflow Dynamics and Lung Function in Human Bronchioles. *PLoS One*. 2017;12(8):1–20. https://doi.org/10.1371/journal.pone.0183654
57. Suroto S, Jayanti S, Oviera A. Faktor-Faktor Yang Berhubungan Dengan Kapasitas Vital Paru Pada Pekerja Industri Pengolahan Kayu Di PT. X Jepara. *J Kesehat Masy*. 2016;4(1):267–276. https://ejournal3.undip.ac.id/index.php/jkm/article/
58. Aini SQ, Saftarina F. Hubungan Karakteristik Individu dengan Nilai Kapasitas Vital Paru Pekerja di PT . Bukit Asam (Persero) Tbk Unit Tarahan Lampung. *J Agromed Unila*. 2017;4(2):244–250. https://juke.kedokteran.unila.ac.id/index.php/agro/article/view/1794/0
59. National Institute for Health and Care Excellence. Chronic Obstructive Pulmonary Disease in Over 16s: Diagnosis and Management. London: National Institute for Health and Care Excellence; 2018. https://www.nice.org.uk/guidance/cg101
60. Yang IA, Brown JL, George J, Jenkins S, McDonald CF, McDonald VM, et al. COPD-X Australian and New Zealand Guidelines for the Diagnosis and Management of Chronic Obstructive Pulmonary Disease: 2017 Update. *Med J Aust*. 2017;207(10):436–442. https://doi.org/10.5694/mja17.00686
61. Miller MR, Levy ML. Chronic Obstructive Pulmonary Disease: Missed Diagnosis Versus Misdiagnosis. *BMJ*. 2015;351(3021):1–5. https://doi.org/10.1136/bmj.h3021
62. Gao C, Zhang X, Wang D, Wang Z, Li J, Li Z. Reference Values for Lung Function Screening in 10- To 81-Year-Old, Healthy, Never-Smoking Residents of Southeast China. *Medicine*. 2018;97(34):1–10. https://doi.org/10.1097/MD.0000000000011904
63. Ahmed T, Waqas M, Ahmed Zuberi S, Iqbal Q. Lung Function Comparison By The Technique Of Spirometry Between Different Working Groups Of Pakistan: A Cross-Sectional Survey Based Study. *J Pharm Pharm Sci*. 2018;7(2):97–106. http://jpps.juw.edu.pk/index.php/jpps/article/view/271
64. Qian QZ, Cao XK, Qian QQ, Shen FH, Wang Q, Liu HY, et al. Relationship of Cumulative Dust Exposure Dose and Cumulative Abnormal Rate of Pulmonary Function in Coal Mixture Workers. *Kaohsiung J Med Sci*. 2016;32(1):44–49. https://doi.org/10.1016/j.kjms.2015.11.003
65. World Health Organization. WHO Report on Global Tobacco Epidemic, 2019. Geneva: World Health Organization; 2019. https://apps.who.int/iris/rest/bitstreams/1239531/retrieve
66. Ni Y, Shi G, Qu J. Indoor $PM_{2.5}$, Tobacco Smoking and Chronic Lung Diseases: A Narrative Review. Environ Res. 2020;181(108910):1–10. http://dx.doi.org/10.1016/j.envres.2019.108910
67. Sears MR. Smoking, Asthma, Chronic Airflow Obstruction and COPD. *Eur Respir J*. 2015;45(3):586–588. http://dx.doi.org/10.1183/09031936.00231414
68. Duan R-R, Hao K, Yang T. Air Pollution and Chronic Obstructive Pulmonary Disease. *Chronic Dis Transl Med*. 2020;6(4):260–269. https://doi.org/10.1016/j.cdtm.2020.05.004
69. Tanaka T, Asai M, Yanagita Y, Nishinakagawa T, Miyamoto N, Kotaki K, et al. Longitudinal Study of Respiratory Function and Symptoms in a Non-Smoking Group of Long-Term Officially-Acknowledged Victims of Pollution-Related Illness. *BMC Public Health*. 2013;13(766):1–10. https://doi.org/10.1186/1471-2458-13-766
70. Kotaki K, Senjyu H, Tanaka T, Yano Y, Miyamoto N, Nishinakagawa T, et al. Tobacco Use Among Designated Air Pollution Victims and its Association with Lung Function and Respiratory Symptoms: A Retrospective Cross-Sectional Study. *BMJ Open*. 2014;4(7):1–9. https://doi.org/10.1136/bmjopen-2014-005393

71. Wang J, Li Y, Zhao P, Tian Y, Liu X, He H, et al. Exposure to Air Pollution Exacerbates Inflammation in Rats with Preexisting COPD. *Mediators Inflamm*. 2020;2020(4260204):1–12. https://doi.org/10.1155/2020/4260204
72. Fernandes AGO, De Souza-Machado C, Pinheiro GP, De Oliva ST, Mota RCL, De Lima VB, et al. Dual Exposure to Smoking and Household Air Pollution is Associated with an Increased Risk of Severe Asthma in Adults in Brazil. *Clin Transl Allergy*. 2018;8(48):1–11. https://doi.org/10.1186/s13601-018-0235-6
73. Dhatrak S, Nandi S, Gupta S. Comparative Study of Pulmonary Impairment Among Diverse Working Groups in Coal Mine. *Am J Prev Med Public Heal*. 2018;2(1):13–17. http://dx.doi.org/10.5455/ajpmph.20170927084148
74. Thurston GD, Balmes JR, Garcia E, Gilliland FD, Rice MB, Schikowski T, et al. Outdoor Air Pollution and New-Onset Airway Disease: An Official American Thoracic Society Workshop Report. *Ann Am Thorac Soc*. 2020;17(4):387–398. https://doi.org/10.1513/AnnalsATS.202001-046ST
75. Utiyama DMO, Yoshida CT, Goto DM, Carvalho TS, Santos UDP, Koczulla AR, et al. The Effects of Smoking and Smoking Cessation on Nasal Mucociliary Clearance, Mucus Properties and Inflammation. *Clinics*. 2016;71(6):344-350. http://dx.doi.org/10.6061/clinics/2016(06)10
76. Putri NS. Literature Review: Coal Dust Exposure and Pulmonary Physiology Status. *J Kesehat Lingkung*. 2020;12(4):292–301. http://dx.doi.org/10.20473/jkl.v12i4.2020.292-301