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Polycyclic Aromatic Hydrocarbons and Their Effects on the Occurrence of Chronic Obstructive Pulmonary Disease (COPD): A Review

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Abstract

Background: Polycyclic aromatic hydrocarbons (PAHs) are among the most important compounds that cause adverse health outcomes in humans, such as poor lung function, bronchitis, asthma, shortness of breath, circulatory disorders, lung cancer, cardiovascular diseases, and mortality.
Objectives: This review aims to investigate the effects of PAHs on the occurrence of chronic obstructive pulmonary disease (COPD).
Methods: A narrative review of the literature was done from 1979 to 2021 in various databases: Science Direct, PubMed, Web of Science, Springer, and Google Scholar. We found 76 and 14 articles by searching the databases and other sources, respectively. Twelve articles were included after screening. The literature indicates the significant adverse effect of PAHs on the occurrence of COPD.
Results: Heavy industries (oil, steel, gas, and petroleum) are the primary sources of PAHs. Polycyclic aromatic hydrocarbons induce respiratory diseases, as they are destructive to the lung, leading to COPD. Sex, age, nutritional status, health, duration of exposure to PAHs, and body response to the pollutants affect the complications.
Conclusions: High PAH levels can increase the risk of COPD, respiratory diseases, and incremental lifetime cancer risk (ILCR).

Keywords: Polycyclic Aromatic Hydrocarbons, Health Effect, Chronic Obstructive Pulmonary, Cancer

1. Background

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds with two or more aromatic fused rings. These compounds can be divided into two categories based on the structure, including light (1 - 2 rings) and high molecular weight (2 - 4 rings) (1, 2). These compounds have low solubility in water and are very lipophilic. Besides, PAHs have low vapor pressure and are adsorbed on particles (3, 4). Polycyclic aromatic hydrocarbons are produced because of the incomplete pyrolysis of fossil fuels and enter the environment through various combustion processes.

Among the PAHs, 16 compounds are most important due to the lack of rapid biological decomposition by microorganisms and toxicity to the environment. The most important PAHs include benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, fluorene, phenanthrene, anthracene, naphthalene, acenaphthylene, acenaphthene, fluoranthene, and pyrene (1, 5, 6). Power plants, home heating systems, petroleum and oil industries, fuel combustion (diesel, coal), forest fires, tanker and ship accidents, cigarette and tobacco smoke, coke ovens, coal, asphalt, casting, volatile ash particles, solid waste incineration, and traffic exhausts are the primary sources of PAHs emissions (7-13).

Based on the USEPA classification, PAHs are among the main compounds that cause carcinogenicity in humans and animals (3, 14, 15). The route of exposure (inhalation, skin, and food), exposure duration, age, sex, nutritional status, and personal health are the most critical factors affecting the health effects of these compounds (16, 17). As known, PAHs in the body have short-term and long-term effects. The primary health effects are eye irritation, nausea, diarrhea, thrombosis, seizures, genotoxicity, mutagenicity, cancer risk, cardiovascular disease, neurological disease, respiratory disease, cataracts, kidney damage, and chronic obstructive pulmonary disease (18-24). Chronic obstructive pulmonary disease (COPD) is a lung disease chronically identified by a few airway signs (25, 26). The main symptoms of COPD include shortness of breath, cough, and sputum production (27-30). Diagnosis of COPD is based on shortness of breath, measured by lung function tests (31, 32). Treatments of COPD include smoking cessation, long-term oxygen therapy, vaccination, rehabilitation, bronchodilators, and corticosteroids (33, 34). The main factors that cause COPD are smoking and exposure to disease factors due to occupation and indoor fires (27, 35-37). Cold weather can also play a role, as most exacerbations usually occur in winter (38, 39).

Due to the importance of respiratory system function to other systems of the human body and the effects of PAHs on respiratory health function, leading to and exacerbating COPD, this narrative review aimed to investigate PAHs and their impact on the occurrence of COPD.

2. Method

2.1. Evidence Acquisition

This narrative review study was conducted on references available in various databases: Science Direct, PubMed, Web of Science, Springer, and Google Scholar (Table 1). Years of publication (1979 - 2021) and English language were the main criteria for search limitation.

2.2. Data Collection

The study was performed with 225 articles retrieved by keywords "chronic obstructive pulmonary disease," "polycyclic aromatic hydrocarbons and respiratory systems," "health effect," "polycyclic aromatic hydrocarbons and chronic obstructive pulmonary disease," and "polycyclic aromatic hydrocarbons and lung." Relevant papers were reviewed to establish the possible link between PAHs and COPD.

2.3. Search Strategy

According to the criteria mentioned above, after an initial screening of 225 titles, 135 were duplicated and excluded. There were 76 articles found through database searching besides 14 articles found in other sources. In the next stage, 34 studies were screened after review, and 18 full-text articles entered the analysis process. Finally, 12 articles were selected for this study.

2.4. Ethical Approval

Ethical approval was acquired from the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (code of ethics: IR.AJUMS.REC.1400.667). According to the national guidelines, such studies do not require individual consent.

3. Result and Discussion

3.1. Air Pollution

Increasing air pollution in recent decades due to economic development and the dramatic progress of human societies has significantly endangered the health outcomes of humans (40, 41). The emission of a large amount of particulate matter and gases into the atmosphere due to excessive burning of fossil fuels, increasing use of vehicles, and failure to use solutions to reduce gases emitted from industries has caused adverse economic and health effects (42). The US Environmental Protection Agency (USEPA) has determined carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), and sulfur dioxide (SO_2) as criteria pollutants whose daily amounts are expressed by air quality index (AQI) (43). The most important sources of air pollution are fixed sources (power plants and industries) and mobile sources (personal and public vehicles) that emit primary and secondary pollutants. Unlike primary pollutants, including SO_2, NO_2, ground-level O_3, CO, $PM_{2.5}$, PM_{10}, Pb, volatile organic compounds (VOCs), and hydrocarbons (HC) that enter ambient air with no changes, secondary pollutants, including photochemical smog, O_3, formaldehyde, and peroxyacetyl nitrate (PAN), enter the atmosphere after producing from reactions between primary pollutants and UV radiation and atmospheric components (44). Air pollution in terms of emission sources is classified into two categories of natural resources (volcanic and forest fire activities, natural dust, smoke, and burning of minerals) and human resources (motor vehicles, factories, and industrial manufacturers with quality and poor construction activities) (45-48). The emission of toxic air pollutants can cause health effects, including high or partial respiratory irritation, chronic heart, and respiratory disease, lung cancer, acute respiratory infections in children, chronic bronchitis in adults, and exacerbating previous lung disease and asthma attacks (49-51). In addition, long-term and short-term exposure to pollutants is associated with premature death and decreased life expectancy (52).

Table 1. Search Terms and Query Results

Term	Google Scholar	Web of Science	Springer	Science Direct	PubMed	Unique Results
Chronic obstructive pulmonary disease	78	33	10	23	25	76
Polycyclic aromatic hydrocarbons and respiratory systems	70	30	15	20	22	54
Health effect	38	17	10	14	16	36
Polycyclic aromatic hydrocarbons and chronic obstructive pulmonary disease	25	14	8	12	13	34
Polycyclic aromatic hydrocarbons and lung	20	10	4	8	11	25
Total	231	104	47	77	87	225

3.2. Chronic Obstructive Pulmonary Disease

The lung is among the most critical organs in the human body, which plays a vital role in protecting the organs and cell function. It is an organ intermittently exposed to pollutants. As a critical organ in the respiratory system, the lung plays a vital role in the proper functioning of the body organs. Because humans depend on respiration for survival, their lungs are active every second, so maintaining their health is especially important. Chronic obstructive pulmonary disease is an excessive inflammatory response of the lung to respiratory pollutants that, with irreversible obstruction of the airways, causes progressive, gradual, and irreversible restriction of pulmonary airflow (53). Besides, COPD reduces the flow of air through the airways in the lung. The classification of these diseases, which are the most common causes of death due to respiratory disorders, includes diseases that close the airway in or out of the lungs and reduce respiratory capacity by various action mechanisms, such as the destruction of lung parenchymal tissue (54). This disease causes the airways to become narrow, damaged, and filled with secretions. As a result, the exhaled air, which requires the natural elasticity of bronchi to escape, is trapped inside the lungs during the reduction of elasticity in air sacs and the dilation of bronchi (55). Inflammatory cells are activated in the airways following contact with disease-causing agents, especially cigarette and tobacco smoke, and the destructive enzymes caused by these cells cause damage to lung tissue, loss of cilia of epithelial cells, and airway obstruction, and restrict air passage through these ducts. As a result of immunodeficiency in the airways and alveoli, especially phagocytic dysfunction of macrophages, a person becomes prone to recurrent lung infections (56).

Diseases such as chronic bronchitis, emphysema, and asthma, which are classified as COPD and occur after exposure to stimulants, suspended particles, or occupational exposure such as mining or textile industry over a long time, are diagnosed by imaging, blood tests, and lung function tests (spirometry) (55, 56). Other risk factors include lung infections and exposure to allergens (such as pet skin and dust), cigarette smoke, and air pollution (57). Many people worldwide who suffer from chronic lung disease experience common symptoms, one of which is a persistent cough with chest pain that does not improve even after medication. Coughing helps protect the airways from inhalation stimuli and clear the sputum (mucus) in the airways, but a persistent cough with sputum and blood is a sign of abnormal lung function. Other symptoms include shortness of breath (even during daily activities), increased or discolored color, increased concentration, amount and smell of mucus (if the mucus changes color from clear to yellow or green or contains blood, it is a clear sign of a problem in the lungs), persistent wheezing (which is a sign of narrowing the airways that does not allow the air to flow fast enough), swelling in the lower body, fatigue, and headaches in the morning (58-60). These symptoms can be a sign of the disease in people that, if not appropriately treated, cause increasingly severe and irreversible damage to the lungs and the risk of lung cancer (28, 61). Although there is no definitive cure for these diseases, prescribed drugs, oxygen therapy, and surgery are methods for the relative improvement of the symptoms. However, if no action is taken for patients, reducing blood-oxygen damages the heart and brain and causes ischemic heart disease, cerebrovascular disease, and eventually death (3).

3.3. Polycyclic Aromatic Hydrocarbons and Their Effects on COPD

Polycyclic aromatic hydrocarbons are colorless to white or pale yellow lipophilic organic compounds with different isomers, consisting of two or more fused aromatic rings (30, 62). Some, including anthracene, chrysin, triphenylene, pentacene, and benzo [a] pyrene, are used in paints, plastics, pesticides, and road asphalt. These compounds are often present in the environment as complex mixtures; for example, soot is one of these complex compounds (63). These compounds are environmental pollutants and a large group of carcinogens found in the environment, including air, water, soil, and food. Besides, PAHs are a serious threat to human health due to cytotoxic and mutagenic effects (62).

Human activities such as maritime transport, tankers, refineries, oil and gas industries, and incomplete combustion of fossil fuels and tobacco smoke are the sources of petrogenic and pyrolytic-created PAHs. They are a combination of cyclic polyaromatic compounds in the environment that are rapidly oxidized during adsorption on dust particles and airborne particles by reaction with the sun's ultraviolet rays, and their chemical half-life is increased by exposure to zinc. They also react with ozone, nitrous oxide, and sulfur dioxide. Hence, due to their very high resistance, exposure to these suspended particles is more dangerous than contact with primary PAHs (64). Polycyclic aromatic hydrocarbons are mostly insoluble in water and, after entering the body for excretion, are converted into more soluble compounds. These secondary compounds can form derivatives of polycyclic aromatic compounds, which are persistent organic pollutants, 16 of which have been identified as hazardous carcinogenic compounds by the International Environmental Protection Agency. Through skin contact, eating, drinking, and breathing, they enter the body and bind to DNA to cause mutations and carcinogenesis, although the absorption of PAHs by eating is usually slow (65). The effects of PAHS on humans depend on the rate at which they enter the body and the compounds to which a person is simultaneously exposed. Although polycyclic aromatic compounds can be present in all fatty tissues, they tend to be stored in the kidneys and liver, and small amounts are stored in the spleen and adrenal glands (5). These compounds are converted in body tissues to some less dangerous compounds and some more harmful compounds than the original PAHs. Laboratory studies have shown that PAHs do not tend to stay in tissues for long periods, and most of them are excreted in feces and urine after a few days. The type and severity of the effects of PAHs on human health depend on several factors, such as the amount of these compounds entering the body, the duration of contact with these compounds, the body response that varies with age, sex, nutritional status, and health, and the source or route of exposure to such compounds (66).

In our study, PAHs were linked to the occurrence of COPD. However, further studies with more pollutants and complications are required to attain more definite results. Due to the increasing trend of chronic diseases, especially COPD, and their influential factors, the findings of this study can be helpful and practical for health system decision-makers and politicians.

3.4. Conclusions

This study assessed the effects of PAHs on COPD. The results demonstrated that PAHs could cause significant loss of life and affect millions of people because of synergistic effects on the lung and respiratory systems. Also, COPD has had an increasing trend in recent years. The findings can have broad applications for increasing knowledge of the relationship between PAHs and respiratory disease, especially asthma and COPD. Actions to decrease PAHs emissions can reduce the incidence rate of COPD.

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Footnotes

Authors' Contribution: M-J. M, G. G, B. F-D, K. Z, M. H, M. T, and F. K. conceived and designed the study and drafted the manuscript. M-J. M, M. T, and F. K. participated in designing the study, performed parts of the statistical analysis, and helped draft the manuscript. M-J. M, G. G, B. F-D, K. Z, M. H, and F. K. re-evaluated the clinical data, performed the statistical analysis, and revised the manuscript. M-J. M, H, M. T, and F. K. collected the clinical data, interpreted them, and revised the manuscript. G. G, B. F-D, K. Z, and F. K. re-analyzed the clinical and statistical data and revised the manuscript. All authors read and approved the final manuscript.

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