Review

Air Pollution and Lung Health: A Significant Public Health Challenge in Resource Poor Countries

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Abstract

Background: The majority of the inhabitants of today's world live in financially deprived countries with well-established high levels of air pollution. Air pollution is one of the biggest environmental threats as well as health challenges ravaging the century and is yet to be eliminated. This is particularly worse in low-middle-income countries where polluted air continues to remain a well-known menace to lung health. This paper describes the increasing effects of air pollution on the general well-being and lung health of inhabitants residing in low-middle-income countries and propose solutions and recommendations for ameliorating this significant health challenge.

Methods: A scoping review to evaluate published studies on the Air pollution and Lung Health in resource poor countries. The search was conducted on electronic databases: PubMed and Google scholar until April 2024, using the following keywords: "Air pollution", "Lung Health", "Public Health challenges", "resource poor countries". Included studies addressed the effects of air pollution on lung health in resource poor countries.

Conclusion: The prevalence of lung diseases such as pneumonia, asthma, chronic obstructive lung disease, and lung cancer is directly proportional to the burden of air pollution, resulting in high morbidity and mortality every year in resource-poor settings. This has been noted to be a far greater contributor to the burden of lung diseases even more than tobacco smoke. This problem can be combated through proper air quality monitoring, enforcement of air pollution guidelines, policy framework, and regulations, provision, and utilisation of cleaner fuel, planned urbanisation, and through health systems strengthening.

Keywords: *Air pollution, low-middle-income country, system strengthening, lung health.*

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Introduction

The multiple interactions between the biotic and abiotic components of the environment often produce substances that can influence environmental composition particularly the quality of the air. The atmosphere which is majorly air, comprises mainly nitrogen (78%) and oxygen (21%). Other minute gases such as argon, carbon dioxide, hydrogen, and water vapour also form atmospheric components. When harmful substances are produced in higher than usual concentrations and introduced into the environment, the atmosphere becomes contaminated resulting in pollution.

Air pollution, therefore, is the damaging impact of emissions from any sources which contribute to the degradation of the ecosystem and contamination of the atmosphere. It can be due to anthropogenic activities as small as tobacco smoking or more obvious emissions from vehicles and heavy-duty automobiles as well as natural occurrences like volcanic eruptions.[1] Air pollution can be in ambient air or indoors. Pollutants can be in the form of any state of matter; solid, liquid, or gas. However, the World Health Organization (WHO) states six major air contaminants.[2] Air pollution has been a source of concern to human health as far back as 400 BC. The earliest landmark study on air pollution can be traced to Europe, this study birthed the 1273 Smoke Abatement Act.[3,4]

In recent times, air pollution has become one of the greatest problems facing mankind. The World Health Organisation (WHO) Global Health Advisory air pollution data states that about 99% of world people (especially those in low-and-middle-income countries) reside in environments where the air is polluted beyond the 2019 WHO guideline limits. It also revealed that approximately 2.3 billion people did not use clean fuel or technology for cooking in the year 2021.[5]

Air pollution is a major cause of mortality, amounting to 6.7 million premature deaths with 89% of these deaths occurring in low and middle-income nations, particularly the WHO Western Pacific region, Sub-Sahara Africa, and South-Asia regions.[6] Polluted air has several detrimental health impacts on different human organ-systems but the worst hit goes to the lung. Air pollution is an inevitable consequence of global industrialization, with more occurrence in low and middle-income countries (LMICs) compared to the high-income countries seen in Europe and North America.[7] Hence, it is of great significance to discuss the problem especially as it relates to the lung health of economically disadvantaged nations because these developing nations that have limited access to clean fuel, unplanned urbanization, and non-enforcement of air quality regulations also have poorer health indices.

This article will analyse the major sources of air pollution, the whys of persistent air pollution, the general health risk of air pollution, the toxicity of air pollution on the lung and lung health in the LMICs, and also propose some achievable solutions to mitigating the problem. Thus, it will contribute to the growing body of literature and be useful to policymakers, health professionals, and environmental scientists with an interest in air pollution.

Methods

We employed a comprehensive and well detailed literature search to evaluate published studies on the Air pollution and Lung Health in resource poor countries. The search was conducted on electronic databases: PubMed and Google scholar until April 2024, using the following keywords: "Air pollution", "Lung Health", "Public Health challenges", "resource poor countries". Included studies addressed the effects of air pollution on lung health in resource poor countries. The study included a background screening of all articles, scientific conference abstracts, and editorials. Studies not written in English and not relevant to the topic of interest were excluded. Restrictions were not based on the length of the study.

Discussion

Major components/sources of air pollution

There are several sources of air pollution including but not limited to industrial waste and emissions, fossil fuels, agro-based waste, and vehicular emissions. The major air pollutants emitted into the environment from these sources are particulate matter, products of volatile hydrocarbon and nitrogenous wastes.[8]Particulate matter (PM), ground-level ozone, carbon monoxide, sulphur oxides, nitrogen oxides, and lead are particularly deleterious to human health.[9] Particulate matter (which can be formed primarily from combustive activities or secondarily from interaction with the atmosphere matter[10,11]) refers to a mixture of inhalable droplets of liquid and gases in the air. They are composed of carbonaceous particles mixed with adsorbed organic chemicals and metals. They occur as coarse particles (PM10), fine inhalable particles (PM2.5), and ultrafine particles (PM0.1).[8,12]The diameter of these particles determines their penetrability of the respiratory system and consequent adverse health effects. Hence, smaller particles (i.e. P.M2.5 and PM0.1) which can travel very

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long distances mixing with other heterogeneous substances are considered the most dangerous and damaging. The latter can reach the lower part of the airway and even the bloodstream. The level and duration of exposure are directly proportional to the harmful effect of particulate pollutants.[1,13]Ozone (O3) can be found in the troposphere and at the stratosphere and it has a protective effect on humans when in the stratosphere and a destructive effect at ground level. Sulphur dioxide is a gaseous harmful substance released from fossil fuel or industrial activities that is toxic to human, animal, and plant life. Additionally, carbon monoxide (CO) is a colourless and odourless gas that is produced by burning biomass fuel such as in burning coal and wood. Its concentration varies from 3 parts per minute (ppm) when improved stoves are used to over 2000 ppm during cooking.[14,15]The binding capacity to carboxy-haemoglobin is about 250 times more than that of oxygen. The severity of poisoning or pollution with carbon monoxide depends on the concentration and duration of exposure.[1]

The plight of air quality in low-middle-income countries

Globally, there is an uneven distribution of the above-mentioned air pollutants between the developed and developing nations.[16,17]The developing countries bear the brunt of this challenge as most polluted cities are found in these areas. For instance, from the 2020 air quality report, 37 out of 40 highest polluted megacities are in South Asia.[18] Most countries in sub-Saharan Africa, North Africa, Asia, and the Middle East were also noted to have PM2.5 greater than 44ug/m3. Rentschler J et al. further reported that of the 7.3 billion people exposed to dangerous average annual particulate matter, 80% are residents of low and middle-income nations.[19]Little wonder the impact of ambient air and indoor air pollution on lung health is felt more in these low-income regions.[14, 20, 21] Yu Shang and colleagues in a 33 time-series study in China, found an important association between air pollution and increased mortality. The study found that with an increase of 10ug/m3 in fine particles, there was a 0.38% increase in total death rate and a 0.51% rise in respiratory mortality.[22]Similarly, the ESCAPA (Estudio de Salud Contaminacion del Aire Latino America) project, a multicity study of the relationship between air pollution and death rate in Latin America discovered Mexico and Santiago had mortality rates of 1.02% and 0.48% respectively, related to polluted air. Coarse particulate matter was linked to death involving most body systems in most cities.

The study also noted that PM10 caused more mortality than outdoor ozone concentration.[9,23]Achakulwisut et al. in an estimate from a worldwide dataset, showed that the incidence of asthma among children in major urban areas in LMICs was higher as a consequence of polluted air from transportation traffic.[24] The situation is not different in Africa. Nigeria for example, had the highest air-pollution-linked pneumonia-related death in children according to the global burden of disease in 2019, as documented by the United Nations International Children Fund (UNICEF)).[25] Likewise in 2019, Blanco et al in a systemic review revealed that the south-western extremity of Africa had the highest prevalence of chronic obstructive pulmonary disease (COPD) with as high as 23% in Cape Town.[26]Additionally, in Pakistan, where more than 50% of households depend on biomass fuel (with inefficient combustion) as their main source of household fuel, indoor air pollution resulted in 28,000 deaths annually and approximately 40 million cases of acute respiratory diseases.[27] This sorry state of affairs regarding air pollution and lung health in economically challenged countries stems from various factors such as the following:

1. Poor air quality assessment and monitoring

Compared to the high-income countries, the air quality index is regularly monitored unlike in the resource-poor countries. The Europe and United States, for example, have air quality monitors readily available in most urban cities with approximately one monitor to less than a million people. Consequently, data generated from regular monitoring guide in policy and regulation generation aiming at reduction in air pollution level. The situation is different in the LMICs. According to Carvalho et al, 4.5 million people in Africa share an air monitor, and narrowing down to sub-Saharan Africa, the narrative is worse as more people share an air quality monitor or simply depend on the WHO interactive maps.[28]The installation and maintenance of air monitors require a fortune; ranging from monetary implications for purchase, constant electric supply, and functional institutional framework to maintenance and monitoring of the equipment, analytical capacity, and much more which are not readily available in some LMICs thereby hampering air quality monitoring and regulation. Whatever is not measured and monitored cannot be quantified and cannot be regulated. Hence, pollution of air in economically disadvantaged nations is at a very dangerous level.

2. Poor implementation of Air quality regulations

There is a surfeit of laws and regulations on air pollution and air quality enacted for control of both indoor and

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ambient air. Laws ranging from global regulations such as WHO air quality guidelines2 to regional regulations such as the Lusaka Agreement of 2008, by 14 Southern African Development Community (SADC) member states, the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects in South Asia[29] and those enacted by individual countries like the Bangladesh laws on brick Klin.[30] However, in most developing countries, these regulations are not strictly implemented due to the following:

a. Lack of political will and corruption: This is a front-burner issue directly related to air pollution in LMICs, the degree of enforcement of laws regulating pollutants, and the punishment of offenders. More often than not, the governments of economically challenged countries lack the political will to implement air quality laws as they are seen as a less important aspect of governance. More so, some poor nations are embodied with different levels of corruption, Hence, these countries do not strictly apply air quality guidelines nor punish offenders. In nations where corruption strives, good governance is essentially sacrificed and thus air pollution offenders are not brought to book.

b. Non-uniformity of air pollution laws and regulations: For some countries, the rules regulating air quality and pollution are made centrally by the federal government while some have central and local government rules and institutions in which case there are usually conflicting roles between different agencies regulating these laws and complacency at the level of enforcement because of overlapping functions. For instance, the federal pollution control laws may sometimes overlap with laws at the local government level.

3. Use of substandard Vehicles

Globally, there is a rise in the usage of fleets of vehicles. Vehicular emissions are a major source of air pollutants in LMICs. Combustion from vehicles contains significant amounts of pollutants such as fine particulate matter and Nitrogen oxide that are detrimental to lung health. The aforesaid rise in usage of vehicles and emissions is worse in economically disadvantaged nations particularly in the urban cities because most cars utilized in LMICs are already used vehicles. The United Nations Environmental Programme (UNEP) 2020 in its press release on "environmental impacts of export of used vehicles to developing world" reported that over 3 years, approximately 14 million used light-duty vehicles were exported globally. Most of these importations were done by developing countries, with Africa spearheading the trend. Many of these vehicles have spent several years before being sold at cheaper rates to these poor nations. For instance, the Netherlands exported vehicles that have been used for approximately two decades to African countries.[31]Majority of these second-hand vehicles are not road worthy, fall below the set standards for vehicular emissions, and have damaged automobile engines which generate more P.M 2.5 and other pollutants than new cars.

4. Substandard industries or companies

The limited availability of funds, poverty level, and little or no enforcement of laws in LMICs often result in the creation of substandard industries. These substandard companies use inferior machineries which generate all sorts of air pollutants into ambient air. The end products from these companies are below the approved minimum manufacturing quality, further worsening the already damaged air. Nigeria readily serves as a good example in this case, as the country witnessed a rise in the building of modular, illegal refineries in the southern part of the country for refining raw crude oil. The refining processes and petroleum products from these companies are below the required standards thereby generating enormous carbon soot and other air pollutants[32,33]that ultimately spread several miles from the location of production to other areas, staining floors, walls, roofing sheets and increasing in lung and other respiratory diseases.[34]

5. Predominant use of fossil fuel products/subsidies as a major source of fuel

Economically advanced nations are mindful of the fact that fossil fuel is one of the worst forms of polluting fuel. Thus, most countries with financial advantages have moved to using cleaner fuel and other sources of renewable energy for household purposes. Contrastingly, the developing world still relies largely on cheap fossil fuels like the use of firewood, kerosene stoves, and other high soot-generating sources of fuel for cooking and other household needs due to their cheaper cost as the majority of the inhabitants of these poor countries live on below six (6) United States dollars per day.[35]The consequence is an increase in household pollutants and its attendant increase in lung diseases such as chronic obstructive pulmonary disease (COPD) in the region.[36]

6. Unplanned urbanization

Over 75%[37]of the world's current population of over 8 million people reside in LMICs.[38] Consequently, more and more people move to the cities and metropolitans in search of greener pastures and education giving rise to a

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rapid shoot in urbanization in these nations. This occurs uncontrollably and haphazardly in most cases. The ripple effects are unplanned and congested housing, an increase in traffic jams, an overall increase in other human activities that produce air pollutants, and environmental degradation leading to impaired lung health. In a review of unplanned urbanization and health risks by Rahaman et al in Dhaka city[39], it was revealed that a range of public health risks including air pollution can be due to poorly planned urbanization.

7. Climate change

The contribution of climate change to air pollution cannot be underestimated and is often in a vicious cycle. The developing nations with poor air environments experience climate-induced harsh conditions such as increases in temperatures, and incidences of wide fire smoke producing high atmospheric ozone as well as black carbon (a fine particulate matter). These pollutants have been figured to lead to the release of greenhouse gases and their attendant consequences that subserve the negative cycle for the release of more air pollutants leading to the continuous negative cycle. The impact is not limited to outside air as increased outdoor ozone and particulate matter find their way into houses to cause indoor pollution. These exposures lead to poor lung health conditions. Additionally, climate-enhanced seasonal changes in LMICs worsen seasonal respiratory diseases such as bronchiolitis in children, allergic rhinitis, and bronchial asthma.

8. Weak health systems

The people's knowledge of the link between air pollution and lung health and actions taken regarding the impact of air pollution on the lungs are weak in most LMICs thereby encouraging the proliferation of respiratory diseases. Some of these countries possess weak health organisations as a result of poor funding of their health system and have had to depend mainly on financial aid and grants coming from economically rich countries to fund their healthcare system with little or no functional health insurance schemes for its citizens as most people purchase health care out of pocket leading to late presentation of air pollution-related lung challenges and poor disease outcomes.

General health effects of poor air quality

No part of the human body is immune to the effect of the poor air quality harboured by the economically disadvantaged part of the globe. Pruss-Ustun and colleagues posited that polluted air is only second to tobacco use in the aetiology of non-communicable diseases (NCDs) and is perhaps contributing to the projected risk of the NCD epidemic in developed countries.[40–42]In the cardiovascular system, it can either aid in the development of a new disease or result in the exacerbation of already existing ones. Bourdrel T et al. after a pooled epidemiological study reported that a 10μg/m3 increase in long-term exposure to PM2.5, and long-term and short-term inhalation of nitrogen dioxide were associated with increased cardiovascular mortality. Exposure to road traffic pollution was associated with an increased risk of arteriosclerosis leading to untimely calcification of the aorta and coronary arteries. Increased risk of myocardial damage and acute heart failure was also seen with short-term exposures.[43,44]43,44 Chen and colleagues in a time-stratified case crossover over a 5 year-period found an association between particulate matter, nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (CO), and acute coronary syndrome (ACS). This association was noted to occur in a crescendo-decrescendo pattern worsening in the next hour and terminating after more than half a day.[45]

Regarding the haematological system, it is a fact that pollutants like lead and fine particulate matter have been linked to the inhibition of erythropoiesis and consequent anaemia.[46, 47]The neurological system is not spared. The occurrence of Ischaemic stroke is connected to air pollution; particulate matter is recognized as a risk factor for carotid stenosis, a forerunner of ischaemic stroke.[48]Adami and colleagues described a relationship between air pollution and autoimmune diseases, in a retrospective observational study. The research reported an associated 7% increase in the risk of acquiring autoimmune disease with an increase in PM10 concentration in multiples of 10 μg/m3. Exposure to PM10 above 30 μg/m3 and PM2.5 above 20 μg/m3 were associated with a 12% and 13% higher risk of autoimmune disease, respectively. Exposure to PM10 was associated with an increased risk of rheumatoid arthritis; exposure to PM2.5 was associated with an increased risk of rheumatoid arthritis, connective tissue diseases (CTDs), and inflammatory bowel diseases (IBD).[49]Faustini et al. proposed that pollutants may be exacerbators of autoimmune diseases such as thyroiditis, lupus, arthritis, and psoriasis although there was no association with hospitalizations for the aforementioned illnesses.[50] Metabolic[51,52]and dermatological diseases[53] have also been associated with air pollution.

Relationship between air pollution and lung health

The lungs which are a part of the respiratory system function by breathing in oxygen from the atmosphere and taking out carbon dioxide from metabolic processes occurring in humans. The lungs are the major recipient

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of all gases inhaled by the airway. Hence, the deleterious effects of air pollutants are more pronounced in the lungs. There are several mechanisms through which air pollutants result in lung damage. Firstly, particulate matter causes direct toxicity to the airways by producing free radicals; these free radicals like reactive oxygen species cause oxidative damage to the lung tissues.

It is speculated that the by-products of particulate pollutants such as iron catalyses the fenton-type reaction to produce hydroxyl radicals thereby disrupting the integrity of the tight and adherence junctions of the airway epithelial barrier. Particulate matter (PM) is proinflammatory and could also serve as a carriage tool for bacterial and other microorganisms through enhancement of adsorption and inhibition of antimicrobial peptides and proteins with resultant impaired antimicrobial activities.[54–57]Secondly, the injurious impact of nitrogen oxides on the lungs is mainly mediated by the acidic form; nitric and nitrous oxide. These elements generate oxidative metabolites from reactive nitrogen by-products[58], which can result in direct structural and functional dysfunction of lung cells. Another mechanism is by oxidation and peroxidation of protein and lipids respectively amounting to cell membrane destruction. Additionally, Nitrogen oxides cause immune function dysregulation and susceptibility to infections. Furthermore, the cell membrane of the alveolar macrophages and epithelial cells of the exchange unit of the lungs alongside other lubricants of the airways are attacked by ozone. When ozone is inhaled, it sets in motion oxidative damage leading to bronchiolar inflammation and over activity of the air exchange unit.[59]Moreso, the volatile organic chemicals [60,61] lead[62] sulphur oxides[63]and carbon monoxide[64]are proinflammatory to the lungs resulting in a cascade of reactions and ultimately respiratory system impairment.

Impact of air pollution on Lung Health

The effects of air pollution on lung health are clear and have been recognised for many years. These effects could be experienced from the cradle as observed by Wang X et al and Salam et al who noted an association between poor air and low birth weight.[65, 66]Lung development in these children is hampered and may result in the subsequent presentation of adult lung impairment. Lung manifestation from exposure to poor air quality is determined by the duration of exposure. Acute exposure gives rise to irritation and symptoms such as breathlessness, wheezing, cough, phlegm, and asthma exacerbation. Longer-term exposures result in inflammation of the lung and changes in lung function. In 2013, researchers found a reduction in forced expiratory volume in the first second (FEV1) and forced vital capacity (FVC) among non-smoking adults exposed to particulate pollution, ozone, and NO_2.[67–69]Several epidemiological evidence are available on the effects of air pollution on the increased prevalence of lower respiratory tract infections such as pneumonia[70] COPD[71] and Lung cancer.[72] Indoor air pollution commonly arising from the predominant use of fossil fuel in LMICs is linked to a rising number of COPD and lung cancer cases amongst previously non-smoking adult females.[73]Black carbon and soot containing fine particulate from agricultural bush burning and illegal crude oil exploration and artisan refining are also likely to worsen respiratory symptoms and illnesses.[74]Overall, the challenges of lung health from air pollution are becoming increasingly common and could be the predominant cause (not tobacco smoking) of morbidity and mortality in LMICs since about 90% of deaths from COPD in older adults occur in LMICs.

Recommended ways to tackle the problem

Is there a way out of this environmental threat to human existence? The answer is in the affirmative. There are many opportunities and solutions to the deficiency of clean air in LMICs. It is an environmental-cum-health challenge that requires all and sundry for mollification. The enormity of air pollution can be mitigated when the following measures are put in place:

a. Proper air quality monitoring

Although air quality monitoring is capital and labour-intensive, it is the only assured way to go. The content of air must be adequately measured throughout the day and documented. Basic tools and low-cost sensors such as the WHO AirQ+[75]75 could be used and domesticated in poor resource areas. Continuous monitoring would provide daily information and trends. These long-term quantification and qualitative assessments are a reliable basis for decision-making; as whatever is not measured cannot be quantified and monitored. Furthermore, air quality measurement and monitoring will become more efficient once it becomes part of government expenditure. If budgeted for as part of government financing, the problem of procurement of air monitoring devices, maintenance of such devices, documentation, and staffing will become a thing of the past and the air quality data gap in resource-poor settings will cease to exist.

b. Enforcement of air quality regulations

The need for purified air must be seen as an emergency to be promoted especially by the legislative and judicial arms of governments in developing countries. This will enable allotment of commensurate punishment to an

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offender of clean air. When guilt sentences are attached to whatever and whoever is found guilty of polluting the air beyond safe limits, especially on a large scale, it will serve as a major deterrent to overt and wilful air contamination. Additionally, better enforcement of environmental legislation designed for the manufacturing sector and companies where business non-compliance is rampant is also sacrosanct to having cleaner air. Adequate compensation for workers and neighbours of pollution-emitting industries by the industries themselves should be enforced at all times.

c. Provision and utilisation of cleaner fuel

The benefits of the availability and utilization of cleaner fuel and migration to the use of renewable energy cannot be overemphasized. Sources of renewable energy such as solar power and wind power harness the natural sun and weather energy to generate decarbonized energy. Switching from the use of coal, petroleum products, and other fossil fuel energy to carbon-free fuel will reduce the amount of air pollution and the incidence of lung diseases.

d. Proper and balanced urbanisation

To improve air quality in economically poor countries, preventive measures must be put in place to reduce industrial emissions (since rapid industrialization heralds uncontrolled and unbalanced urbanisation). This will include proper city planning with adequate separation and spacing between residential and industrial areas, the generation of an industrial database to aid the government's decision, and the identification of public and private sector initiatives to address industrial pollution. In addition, the encouragement of more people to commute by public transport and the use of cleaner vehicular fuel in cities will reduce vehicular air pollution. The use of household energy appliances will also reduce household emissions of pollutants, reforestation of urban areas by deliberate and conscious planting of trees, and use of indoor air filters to purify household air.

e. Health systems strengthening.

Health systems in developing countries must be strengthened to ameliorate air pollution-related lung diseases. This requires a strategic approach and commitment of the various organs of the health systems, an interplay between managers to promote multi-sectorial teamwork for a functional and better health system, tailoring health services to specific needs arising from pollution-related lung diseases, provision of funded low-cost care bundles for air pollution linked respiratory illnesses to aid early diagnosis and treatment, regular quality assessment and assurance of different sectors of health care systems in LMICs aiming to improve gaps and deficient area.

In summary, the total impact of air pollution exposure on lung health has been the subject of extensive research. However, the problem persists particularly among the World Bank-designated countries with low and middle-income. These developing countries also happen to harbour the most populous cities, and depend mainly on polluting fuel, further worsening the already existing problem. This article recommends continuous regulation and monitoring of air pollution, the use of alternative sources of fuel and renewable energy, and health systems strengthening as a way to curb this menace.

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References

1. Ghorani-Azam A, Balali-Mood M. Effects of air pollution on human health and practical measures for prevention in Iran. *J Res Med Sci.* 2016;21(65).
2. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Bonn, Germany: WHO European Centre for Environment and Health; 2021. (accessed Feb 21, 2024)
3. Fowler D, Brimblecombe P, Burrows J, Heal MR, Grennfelt P, Stevenson DS, *et al.* A chronology of global air quality. *Philos Transact A Math Phys Eng Sci.* 2020 Oct 30;378(2183):20190314.
4. Fowler D, Brimblecombe P, Burrows J, Heal MR, Grennfelt P, Stevenson DS, *et al.* Correction to "A chronology of global air quality." *Philos Transact A Math Phys Eng Sci.* 2021 Jul 12;379(2201):20210113.
5. World Health Organisation. World Health Organization; Ambient air pollution data. 2021. Available from: http://www.who.int/data/gho/data/themes/air-pollution/ambient-air-. (accessed Feb 21, 2024)
6. World Health Organization (WHO). Ambient (outdoor) air pollution. World Health Organization (WHO); 2022. Available from: http://www.who.int/news-room/fact-sheets/details/ambient-(outdoor)-air-quality-and-health (accessed Feb 26, 2024)

Print ISSN: 0189-9287 Online ISSN: 2992-345X

7. Hajat A, Hsia C, O'Neill MS. Socioeconomic Disparities and Air Pollution Exposure: a Global Review. *Curr Environ Health Rep.* 2015 Dec;2(4):440–50.
8. Tran VV, Park D, Lee YC. Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality. *Int J Environ Res Public Health.* 2020 Apr 23;17(8):2927.
9. Mannucci PM, Franchini M. Health Effects of Ambient Air Pollution in Developing Countries. *Int J Environ Res Public Health.* 2017 Sep 12;14(9):1048.
10. Bonzini M, Tripodi A, Artoni A, Tarantini L, Marinelli B, Bertazzi PA, *et al.* Effects of inhalable particulate matter on blood coagulation. J Thromb Haemost. 2010 Apr;8(4):662–8.
11. Schwarze PE, Øvrevik J, Låg M, Refsnes M, Nafstad P, Hetland RB, *et al.* Particulate matter properties and health effects: consistency of epidemiological and toxicological studies. *Hum Exp Toxicol.* 2006 Oct;25(10):559–79.
12. US EPA (US Environmental Protection Agency) (2023). Available from: Available online at: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics (accessed Feb 20, 2024)
13. Bentayeb M, Simoni M, Norback D, Baldacci S, Maio S, Viegi G. Indoor air pollution and respiratory health in the elderly. *J Env Sci Health Tox Hazard Subst Env Eng.* 2013;48(14):1783–9.
14. Kurmi OP, Lam KBH, Ayres JG. Indoor air pollution and the lung in low- and medium-income countries. *Eur Respir J* 2012;(40):239–54.
15. Bruce N, McCracken J, Albalak R, Schield M, Smith K, Lopez Victorina. Impact of improved stoves, house construction and child location on levels of indoor air pollution exposure in young Guatemalan Children. *J Expo Sci Environ Epidemiol.* 2004;14(1):S26–33.
16. Yu W, Ye T, Zhang Y, Xu R, Lei Y, Chen Z, *et al.* Global estimates of daily ambient fine particulate matter concentrations and unequal spatiotemporal distribution of population exposure: a machine learning modelling study. *Lancet Planet Health.* 2023 Mar;7(3):e209–18.
17. Fuller R, Landrigan PJ, Balakrishnan K, Bathan G, Bose-O'Reilly S, Brauer M, *et al.* Pollution and health: a progress update. *Lancet Planet Health.* 2022 Jun;6(6):e535–47.
18. Abdul Jabbar S, Tul Qadar L, Ghafoor S, Rasheed L, Sarfraz Z, Sarfraz A, *et al.* Air Quality, Pollution and Sustainability Trends in South Asia: A Population-Based Study. *Int J Environ Res Public Health.* 2022 Jun 20;19(12):7534.
19. Rentschler J, Leonova N. Global air pollution exposure and poverty. *Nat Commun.* 2023 Jul 22;14(1):4432.
20. Meghji J, Mortimer K, Agusti A, Allwood BW, Asher I, Bateman ED, *et al.* Improving lung health in low-income and middle-income countries: from challenges to solutions. *The Lancet.* 2021 Mar;397(10277):928–40.
21. Ibrahim MF, Hod R, Nawi AM, Sahani M. Association between ambient air pollution and childhood respiratory diseases in low- and middle-income Asian countries: A systematic review. *Atmos Environ.* 2021 Jul;256:118422.
22. Shang Y, Sun Z, Cao J, Wang X, Zhong L, Bi X, *et al.* Systematic review of Chinese studies of short-term exposure to air pollution and daily mortality. *Environ Int.* 2013 Apr;54:100–11.
23. Romieu I, Gouveia N, Cifuentes LA, de Leon AP, Junger W, Vera J, *et al.* Multicity study of air pollution and mortality in Latin America (the ESCALA study). Res Rep Health Eff Inst. 2012 Oct;(171):5–86.
24. Achakulwisut P, Brauer M, Hystad P, Anenberg SC. Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO2 pollution: estimates from global datasets. *Lancet Planet Health.* 2019 Apr;3(4):e166–78.
25. UNICEF NIGERIA. Air pollution, especially in the home, biggest driver of child deaths from pneumonia in Nigeria. Available from: https://www.unicef.org/nigeria/press-releases/nigeria-has-highest-number-air-pollution-related-child-pneumonia-deaths-world (accessed Feb 21, 2024)
26. Blanco I, Diego I, Bueno P, Casas-Maldonado F, Miravitlles M. Geographic distribution of COPD prevalence in the world displayed by Geographic Information System maps. *Eur Respir J.* 2019 Jul;54(1):1900610.
27. Colbeck I, Nasir ZA, Ali Z. The state of indoor air quality in Pakistan—a review. *Environ Sci Pollut Res.* 2010 Jul;17(6):1187–96.
28. Carvalho H. The air we breathe: differentials in global air quality monitoring. *Lancet Respir Med.* 2016 Aug];4(8):603–5.
29. Climate and clean air coalition initiative (CCAC. In a World Full of Dirty Air, Regional Agreements on Air Pollution Offer a Glimmer of Hope by CCAC Secretariat -. UN Environment Programme. 2023 Sep 6; Available from:

Print ISSN: 0189-9287 Online ISSN: 2992-345X

https://www.ccacoalition.org/news/world-full-dirty-air-regional-agreements-air-pollution-offer-glimmer-hope (accessed Mar 24, 2024)
30. Abir AH. Role of Laws to Control Brick Manufacturing and Kiln Establishment in Bangladesh: Scope of Alternative Bricks. *VNU J Sci Earth Environ Sci.* 2019 Mar 28];35(1).
31. United Nation Environmental Programme. New UN report details environmental impacts of export of used vehicles to developing world. United Nation Environmental Programme. 2020 Oct 26; Available from: https://www.unep.org/news-and-stories/press-release/new-un-report-details-environmental-impacts-export-used-vehicles#:~:text=Nairobi%2C%2026%20October%202020%20%2D%20Millions,report%20by%20the%20UN%20Environment (accessed Mar 28, 2024)
32. Kalagbor IA, Dibofori-Orji AN, Ekpete OA. Exposure to Heavy Metals in Soot Samples and Cancer Risk Assessment in Port Harcourt, *Nigeria. J Health Pollut.* 2019 Dec;9(24):191211.
33. Yakubu O. Particle (Soot) Pollution in Port Harcourt Rivers State, Nigeria—Double Air Pollution Burden? Understanding and Tackling Potential Environmental Public Health Impacts. *Environments.* 2017 Dec 24;5(1):2.
34. Ekhator OC, Orish FC, Nnadi EO, Ogaji DS, Isuman S, Orisakwe OE. impact of black soot emissions on public health in Niger Delta, Nigeria:understanding the severity of the problem. *Inhal Toxicol.* 2023;1–13.
35. Worldbank. Poverty and Inequality Platform. World Bank. Available from: http:/pip.worldbank.org/home (accessed Mar 23, 2024)
36. Wang Y, Duong M, Brauer M, Rangarajan S, Dans A, Lanas F, *et al.* Household Air Pollution and Adult Lung Function Change, Respiratory Disease, and Mortality across Eleven Low- and Middle-Income Countries from the PURE Study. *Environ Health Perspect.* 2023 Apr;131(4):047015.
37. THE WORLD BANK IBRD.IDA. Middle Income Countries Overview: Development news, research. Available from: http://worldbank.org/en/country/mic/overview (accessed Mar 29, 2024)
38. United Nations. UN DESA Policy Brief No.140: A World of 8 Billion. Department of Economic and Social Affairs, United Nations. Available from: http://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/PB_140.pdf (accessed Mar 28, 2024)
39. Rahaman MA, Kalam A, Al-Mamun M. Unplanned urbanization and health risks of Dhaka City in Bangladesh: uncovering the associations between urban environment and public health. Front Public Health. 2023;11:1269362.
40. Prüss-Ustün A, van Deventer E, Mudu P, Campbell-Lendrum D, Vickers C, Ivanov I, *et al.* Environmental risks and non-communicable diseases. *BMJ.* 2019 Jan 28;364:l265.
41. United Nations Environmental Programme. Air. Available from: https://www.unep.org/beatpollution/forms-pollution/air (accessed Feb 22, 2024)
42. Schraufnagel DE, Balmes JR, Cowl CT, De Matteis S, Jung SH, Mortimer K, *et al.* Air Pollution and Noncommunicable Diseases. *Chest.* 2019 Feb;155(2):417–26.
43. Bourdrel T, Bind MA, Béjot Y, Morel O, Argacha JF. Cardiovascular effects of air pollution. *Arch Cardiovasc Dis.* 2017 Nov;110(11):634–42.
44. Miller MR, Shaw CA, Langrish JP. From particles to patients: oxidative stress and the cardiovascular effects of air pollution. *Future Cardiol.* 2012 Jul;8(4):577–602.
45. Chen R, Jiang Y, Hu J, Chen H, Li H, Meng X, *et al.* Hourly Air Pollutants and Acute Coronary Syndrome Onset in 1.29 Million Patients. *Circulation.* 2022 Jun 14;145(24):1749–60.
46. Fongsodsri K, Chamnanchanunt S, Desakorn V, Thanachartwet V, Sahassananda D, Rojnuckarin P, *et al.* Particulate Matter 2.5 and Hematological Disorders From Dust to Diseases: A Systematic Review of Available Evidence. Front Med. 2021 Jul 14;8:692008.
47. Malik VS, Singh M, Pradhan P, Singal K, Agarwal A, Chauhan A, *et al.* Role of environmental lead in the occurrence of anemia in Indian children: a systematic review and meta-analysis. *Environ Sci Pollut Res.* 2022 May;29(25):37556–64.
48. Lee KK, Miller MR, Shah ASV. Air Pollution and Stroke. *J Stroke.* 2018 Jan;20(1):2–11.
49. Adami G, Pontalti M, Cattani G, Rossini M, Viapiana O, Orsolini G, *et al.* Association between long-term exposure to air pollution and immune-mediated diseases: a population-based cohort study. RMD Open. 2022 Feb;8(1):e002055.
50. Faustini A, Renzi M, Kirchmayer U, Balducci M, Davoli M, Forastiere F. Short-term exposure to

Print ISSN: 0189-9287 Online ISSN: 2992-345X

air pollution might exacerbate autoimmune diseases. *Environ Epidemiol.* 2018 Sep;2(3):e025.
51. United Nations Environmental Programme. Pollution Action Note – Data you need to know. 2021. Available from: https://www.unep.org/interactives/air-pollution-note/ (accessed Feb 23, 2024)
52. Darbre PD. Overview of air pollution and endocrine disorders. *Int J Gen Med.* 2018;11:191–207.
53. Liu W, Pan X, Vierkötter A, Guo Q, Wang X, Wang Q, *et al.* A Time-Series Study of the Effect of Air Pollution on Outpatient Visits for Acne Vulgaris in Beijing. *Skin Pharmacol Physiol.* 2018];31(2):107–13.
54. Vargas Buonfiglio LG, Comellas AP. Mechanism of ambient particulate matter and respiratory infections. *J Thorac Dis.* 2020 Mar;12(3):134–6.
55. Vargas Buonfiglio LG, Mudunkotuwa IA, Abou Alaiwa MH, Vanegas Calderón OG, Borcherding JA, Gerke AK, *et al.* Effects of Coal Fly Ash Particulate Matter on the Antimicrobial Activity of Airway Surface Liquid. *Environ Health Perspect.* 2017 Jul 24;125(7):077003.
56. Liu J, Chen X, Dou M, He H, Ju M, Ji S, *et al.* Particulate matter disrupts airway epithelial barrier via oxidative stress to promote Pseudomonas aeruginosa infection. *J Thorac Dis.* 2019 Jun;11(6):2617–27.
57. Liu H, Zhang X, Zhang H, Yao X, Zhou M, Wang J, *et al.* Effect of air pollution on the total bacteria and pathogenic bacteria in different sizes of particulate matter. *Environ Pollut.* 2018 Feb;233:483–93.
58. Van Der Vliet A, Eiserich JP, Cross CE. Nitric oxide: a pro-inflammatory mediator in lung disease? *Respir Res.* 2000 Aug;1(2):1.
59. Groves AM, Gow AJ, Massa CB, Laskin JD, Laskin DL. Prolonged injury and altered lung function after ozone inhalation in mice with chronic lung inflammation. *Am J Respir Cell Mol Biol.* 2012 Dec;47(6):776–83.
60. Yoon HI, Hong YC, Cho SH, Kim H, Kim YH, Sohn JR, *et al.* Exposure to volatile organic compounds and loss of pulmonary function in the elderly. *Eur Respir J.* 2010 Dec 1;36(6):1270–6.
61. Garçon G, Dagher Z, Zerimech F, Ledoux F, Courcot D, Aboukais A, *et al.* Dunkerque City air pollution particulate matter-induced cytotoxicity, oxidative stress and inflammation in human epithelial lung cells (L132) in culture. *Toxicol In Vitro.* 2006 Jun;20(4):519–28.
62. Boskabady M, Marefati N, Farkhondeh T, Shakeri F, Farshbaf A, Boskabady MH. The effect of environmental lead exposure on human health and the contribution of inflammatory mechanisms, a review. *Environ Int.* 2018 Nov;120:404–20.
63. Wigenstam E, Elfsmark L, Bucht A, Jonasson S. Inhaled sulfur dioxide causes pulmonary and systemic inflammation leading to fibrotic respiratory disease in a rat model of chemical-induced lung injury. *Toxicology.* 2016 Aug ;368–369:28–36.
64. Ryter SW, Ma KC, Choi AMK. Carbon monoxide in lung cell physiology and disease. *Am J Physiol-Cell Physiol.* 2018 Feb 1;314(2):C211–27.
65. Wang X, Ding H, Ryan L, Xu X. Association between air pollution and low birth weight: a community-based study. *Environ Health Perspect.* 1997 May;105(5):514–20.
66. Salam MT, Millstein J, Li YF, Lurmann FW, Margolis HG, Gilliland FD. Birth outcomes and prenatal exposure to ozone, carbon monoxide, and particulate matter: results from the Children's Health Study. *Environ Health Perspect.* 2005 Nov;113(11):1638–44.
67. Mölter A, Agius RM, de Vocht F, Lindley S, Gerrard W, Lowe L, *et al.* Long-term exposure to PM10 and NO2 in association with lung volume and airway resistance in the MAAS birth cohort. *Environ Health Perspect. 2013* Oct;121(10):1232–8.
68. Rice MB, Ljungman PL, Wilker EH, Gold DR, Schwartz JD, Koutrakis P, *et al.* Short-Term Exposure to Air Pollution and Lung Function in the Framingham Heart Study. *Am J Respir Crit Care Med.* 2013 Dec 1;188(11):1351–7.
69. Adam M, Schikowski T, Carsin AE, Cai Y, Jacquemin B, Sanchez M, *et al.* Adult lung function and long-term air pollution exposure. ESCAPE: a multicentre cohort study and meta-analysis. *Eur Respir J.* 2015 Jan;45(1):38–50.
70. Zhou X, Guo M, Li Z, Yu X, Huang G, Li Z, *et al.* Associations between air pollutant and pneumonia and asthma requiring hospitalization among children aged under 5 years in Ningbo, 2015-2017. *Front Public Health.* 2022;10:1017105.
71. Rajak R, Chattopadhyay A. Short and Long Term Exposure to Ambient Air Pollution and Impact on Health in India: A Systematic Review. *Int J Environ Health Res.* 2020 Dec;30(6):593–617.
72. Berg CD, Schiller JH, Boffetta P, Cai J, Connolly C, Kerpel-Fronius A, *et al.* Air Pollution and Lung Cancer: A Review by International Association for the Study of Lung Cancer Early Detection and

Print ISSN: 0189-9287 Online ISSN: 2992-345X

Screening Committee. *J Thorac Oncol.* 2023 Oct;18(10):1277–89.
73. Shetty BSP, D'Souza G, Padukudru Anand M. Effect of Indoor Air Pollution on Chronic Obstructive Pulmonary Disease (COPD) Deaths in Southern Asia-A Systematic Review and Meta-Analysis. *Toxics.* 2021 Apr 16;9(4):85.
74. Ephraim-Emmanuel BC, Enembe O, Ordinioha B. Respiratory Health Effects of Pollution Due to Artisanal Crude-Oil Refining in Bayelsa, Nigeria. *Ann Glob Health.* 2023;89(1):74.
75. World Health Organisation. AirQ+: software tool for health risk assessment of air pollution. Httpswwwwhointeuropetools--Toolkitsairq---Softw-Tool--Health-Risk-Assess--Air-Pollut. Available from: https://www.who.int/europe/tools-and-toolkits/airq---software-tool-for-health-risk-assessment-of-air-pollution (accessed Feb 29, 2024)

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