SYSTEMATIC REVIEW

Air Pollution Emergency and Human Health Crisis – Doable Risk Reduction Strategies

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ABSTRACT

Background: The environmental devastation wrought by indoor and ambient air pollution is causing immeasurable stress and strain on the health of people and projected to increase mortality and morbidity rate specifically due to accumulation of particulate matter and ground-level ozone in the atmosphere. **Objective**: This work aims to provide a comprehensive outlook on the global death and disease burden, impact on low- and middle-income countries' population with focus on Asian countries, health vulnerability and projected hazards of particulate air pollution. **Methods**: Data pertaining to air pollution and health impacts were collected from web sources following PRISMA model, analysed and interpreted. **Results**: The authors found that the ominous environmental magnification and accumulation of air pollutants is the greatest threat questioning human existence in the near century. **Conclusion**: The interdependent augmentation of global warming and air pollution is further worsening climatic conditions and disease occurrence. Hence this work recommends evidence-based policy framework and synergistic actions to allay air pollutants thereby enhancing eco-survival.

KEYWORDS

Air Pollution; Disease Burden; Mental Health; Occupational Hazard; Geopolitical Conflicts.

INTRODUCTION

The clout of air pollution inflicted by rapid urbanization, population explosion, industrialization and the declining air quality as an ultimatum has created substantial effects on environment and the atmospheric accumulation of pollutants has made an undeniable disorder in human health influencing morbidity and mortality. Research states that the ambient or outdoor air pollution from fossil fuels account for 2.18 million deaths in India and an additional 5.13 million deaths across the world (1). Chronic or even short-term exposure to air pollution could potentially create malignant effects on human life by implicating mental, pulmonary, cardiovascular, perinatal disorders and non-communicable diseases too (2). In spite of strenuous environmental protection policies at national and global level to control atmospheric deterioration, the reemerging challenges need restructured frameworks. The paper hence will comprehend the disease prevalence and excess death rate engendered by long-term exposure to air pollution in Indian and global context and intervention strategies.

Aim: To provide a comprehensive outlook on air pollution levels and global disease burden

Objectives

- To analyse the impact of air pollution on low- and middle-income countries' population
- To suggest policy level interventions and health risk reduction strategies to prevent loss of vulnerable populations to the sweltering effects of air pollution.

MATERIAL & METHODS

Study Type and Design: Data search pertaining to ambient and indoor air pollution, global disease burden, occupational hazard of pollutants, Particulate matter 2.5 from 2020 - 2024, mortality and morbidity, impact on LMICs and war conditions were obtained from WHO, IPCC, IQAir, articles from PubMed and Google scholar.

Inclusion and Exclusion criteria: Of the 96 articles retrieved, based on PRISMA model, 20 articles relevant to current global status published from 2012 to 2024 that highlighted impacts of air pollution and disease prevalence were considered for the present study.

Data Analysis: The derived descriptive and peer reviewed data was thematically analysed and interpreted with reference to disease prevalence caused by air pollution and associated future projections on health impacts.

RESULTS

Global Disease Burden

The increasing global burden of disease (GBD) and mortality rate has raised a huge call to address air pollution effects. The Organization for Economic Co-operation and Development (OECD) (3) projects that outdoor pollution especially particulate matter and ground-level ozone would be the prime cause of environment related deaths in 2060 resulting in 6 to 9 million premature deaths annually worldwide. Indoor or household air pollution due to burning of biomass and coal has caused 3.2 million deaths globally (4). According to WHO, approximately 6.7 million deaths occurred globally due to respiratory illness, cardiovascular diseases and cancer in 2019 and 8.1 million deaths in 2021 caused by air pollutants (5,6). India and China will face higher morbidity and mortality threat in 2050 ascribed by ground level ozone and particulate matter (PM)2.5 (7). The cause of superfluous death due to fine particulate matter and ozone pollution is reported to be 8.34 million with mortality burden of 52% cardiometabolic conditions; 32% ischemic heart disease, 19% COPD and 23% stroke, 21% lower respiratory infection, 6% lung cancer and an indeterminate 20% with arterial hypertension and neurodegenerative diseases (1,4,8).

Air Pollution impacts in LMICs

Almost 99% of the population especially in LMICs like India are exposed to ambient and indoor air pollution with reference to $PM_{2.5}$ µg/m3, the key pollutant for human health that exceeds WHO's recommended safe guideline levels. In LMICs, indoor pollutants consisting of dense smoke and fine particulate matters especially soot, black carbon and methane generated from burning wood, crop waste, charcoal and dung are 100 times higher than the acceptable level leading to noncommunicable diseases encompassing stroke, ischemic heart disease, lower respiratory infection and lung cancer, with women, children, people with chronic illness, and Persons with Disabilities (PwD) more vulnerable (4,5). The disease burden from substantial exposure to ambient and indoor air pollutants are COPD (Chronic Obstructive Pulmonary Disease), chronic asthma, pulmonary failure, cerebrovascular and cardiovascular mortality, induced diabetes, higher rate of infant mortality and fatal diseases in adults. Prolonged exposure to air pollution could ultimately result in asthma, lower respiratory infections, stroke, ischemic heart disease, mental health issues, gestational complications and negative birth outcomes (1,4,9).

Air pollutants increase the vulnerability of children by adversely affecting metabolic pathways, damage cell and tissue growth, immune functions, brain development, lessened academic achievement and behaviour patterns (5,9). Population ageing is also related with air quality impact where the aged population above 60 is increasing and younger generation below the age of 15 is decreasing due to exposure to particulate matter and ground level ozone elevating the mortality rate, as they are more likely to experience adverse effects to pollution exposure (3,10). Convincing evidences show that chronic exposure to air pollutants increase the risk of psychiatric morbidity especially xenobiotic heavy metals like lead and cadmium, increase the risk of mental health problems affecting neurocognitive pathways causing anxiety, depression, bipolar affective disorders and schizophrenia directly or indirectly (11,12). Air pollutant particles entering through transplacental, respiratory and transdermal pathways cause premature mortality, pregnancy issues, neonatal death, congenital anomalies, higher rates of psychosis during adolescence and early adulthood and adults experience higher psychotic burden (11).

Comparative Projection of Particulate Matter 2.5 in LMICs

The detrimental effect of $PM_{2.5}$ on lungs and cardiovascular system intensifies with substantial increase in its size and compositions. Tables 1 and 2 projects a comparative $PM_{2.5}$ data of LMICs in Asia (13,14). Table 1 confirms the higher pollution hazard of $PM_{2.5}$ which is constantly on the rise over 5 years in India and Pakistan, elevating higher disease burden of vulnerable population; whereas low-income countries like Tajikistan, Myanmar and Cambodia maintain PM2.5 levels not exceeding 3

times above WHO standard. Table 2 shows the very hazardous status of $PM_{2.5}$ turning the air unfit for breathing and existence in Lahore; Peshawar, Delhi and Islamabad, in spite of government policies and laws to contain air pollution. Even though the death rate due to household air pollution is reduced by 36% in China and South Asia, populations in LMICs are still exposed to higher levels of outdoor $PM_{2.5}$(6)

Table 1: $PM_{2.5}$ concentration in µg/m3 - Region and country wise Air Quality index of LMICs

Region	Country	2020	2021	2022	2023	2024
Central Asia	Tajikistan	30.9	59.4	46	49	11
	Kyrgyzstan	43.5	50.8	31.1	33.1	49
	Uzbekistan	29.9	42.8	33.5	28.6	36
	Kazakhstan	21.9	31.1	23	22.2	13
	Turkmenistan	-	20.4	21.6	-	23
Eastern Asia	Mongolia	-	33.1	29.5	22.5	4
	China	34.7	32.6	30.6	32.5	45
Southeast Asia	Indonesia	40.7	34.3	30.4	37.1	72
	Myanmar	29.4	25.9	24.3	28.2	22
	Vietnam	28	24.7	27.2	29.6	13
	Thailand	21.4	20.2	18.1	23.3	14
	Cambodia	21.1	19.8	8.3	22.8	14
	Malaysia	15.6	19.4	17.7	22.5	7
	Philippines	12.8	15.6	14.9	13.5	13
Southern Asia	Bangladesh	77.1	76.9	65.8	79.9	36.3
	Pakistan	59	66.8	70.9	73.7	72
	India	51.9	58.1	53.3	54.4	71
	Nepal	39.2	46	40.1	42.4	36
	Afghanistan	-	37.5	-	-	19
	Iran	-	30.3	32.5	-	20
	Sri Lanka	22.4	17.4	20.7	19.3	25.2
Western Asia	Iraq	39.6	49.7	80.1	43.8	16
	Armenia	24.9	33.9	31.4	26.4	52
	Lebanon	-	25.7	-	-	23
	Turkey	18.7	20	21.1	20.3	15.9
	Azerbaijan	-	17.6	18.9	18.8	8

0-5 µg/m3: Meets WHO guideline; 5.1-10 µg/m3: Exceeds by 1 to 2 times; 10.1-15 µg/m3: Exceeds by 2 to 3 times; 15.1-25 µg/m3: Exceeds by 3 to 5 times; 25.1-35 µg/m3: Exceeds by 5 to 7 times; 35.1-50 µg/m3: Exceeds by 7 to 10 times; >50.1 µg/m3: Exceeds by over 10 times

Table 2: $PM_{2.5}$ concentration in µg/m^3 - Air Quality index of major LMIC Cities

City	2020	2021	2022	2023	As on 12 November 2024
Lahore	79.2	86.5	97.4	99.5	448
Peshawar	-	89.6	91.8	76.5	249
Delhi	84.1	96.4	92.6	102.1	202
Islamabad	39	41.1	40.6	42.4	196
Hyderabad	34.7	39.4	42.4	39.9	79
Jakarta	39.6	39.2	36.2	43.8	69
Mumbai	41.3	46.4	46.7	43.8	60.4
Bengaluru	27.5	29	31.5	28.6	56.6
Beijing	37.5	34.4	29.8	34.1	50
Kolkata	46.6	59	50.2	47.8	49
Tehran	31.8	31.7	-	-	48.2
Hanoi	37.9	36.2	40.1	43.7	46
Bangkok	20.6	20	18	21.3	39
Colombo	-	17.6	-	-	33.1
Baghdad	-	49.7	-	45.8	31
Ankara	-	17.2	-	11.3	30
Kabul	-	37.5	-	-	25
Shanghai	31.5	27.7	25.4	28.7	23
Dhaka	-	78.1	65.8	80.2	20.6
Kathmandu	-	50.9	40.7	41	20.6
Kuala Lumpur	16.5	18.6	17.6	22.9	13
Kyiv	-	18.8	9.5	8.9	9.7

Occupational Hazards

The perilous effect of air pollution on construction, airport, cement and mining industry, thermal power plant, quarry and sandblasting workers has reflected on health to a larger extent. $PM_{2.5}$ and heavy metals including arsenic, chromium and nickel, asbestos and silica has increased the risk of pleural effusion and plaque, lung cancer, mesothelioma, work related asthma, pneumoconiosis, asbestosis and silicosis (15). Congested vehicle movement and high levels of traffic-related air pollutants (TRAP) especially in LMICs affect traffic officers and drivers triggering ischemic heart disease, hypertension, myocardial infarction and stroke consequently increasing mortality risk (16).

Indoor pollution is a major threat to health professionals, IT employees and beauty salon workers who are under air-conditioned enclosures and exposed to varied chemical air pollutants like dust, volatile organic compounds (VOCs) and irritants. This sick building syndrome (SBS) induced by airborne pollutants is reported to cause respiratory allergies, ocular irritation, itching, headache and related health problems (17). Beauty salons, a booming cosmetic industry is found to be polluted with VOCs like esters, phenols, hydrocarbons, toluene, ketones, xylene, benzene, terpenes, camphor, formaldehyde and acetaldehyde. Increased use of these chemical pollutants potentially increases the risk of cancer, interrupt foetal development while of prenatal exposure and adversely influences infant growth (18). Air-conditioned enclosures have high humidity and dense air which adsorbs and enhances concentration of total VOCs and airborne pollution intensifying health threat (17,18).

Geopolitical Conflicts

The current war scenario between Israel and Gaza has generated planet warming emissions with 281,315 metric tons of carbon dioxide and other toxic pollutants during the first two months of war, which is more than the annual footprint of 20 climate-vulnerable nations of the world. The report also states this massive carbon emission and wider toxic pollutants might remain longer in the atmosphere even if the war ends (19). The Russia-Ukraine war is also reported to contribute for a sharp rise in air pollutants comprising nitrogen oxide (NOx), nitric oxide, carbon mono and dioxide, hydrogen cyanide (HCN), undue levels of harmful substances like arsenic, mercury and cadmium and uncontrolled heat emissions due to explosion of missiles and artillery weapons (20). Conversely, advance technologies designed to minimize air pollution also poses immense atmospheric danger in long term use. Invention of Green technology like electric vehicles (EV) to curb transport emissions scaled some benefits; however, the potential risk associated is the higher release of gaseous pollutants from battery-powered EVs. EV fire involves higher hydrogen fluoride emissions metal emissions like nickel, cobalt, lithium, and manganese and EV fleets may not be an alternate option to augment air quality and human health (9).

DISCUSSION

The global environmental and human health stance is turning bleak and hence advocating laws and policies to diminish atmospheric and indoor air pollution to ensure public health impacts crucially requires evidence-based synthesis categorizing air pollution as a disaster. Studies on the association between depression and $PM_{2.5}$ is mostly neglected in assessment and treatment protocols. Etching a roadmap to curb the interrelated effects of air pollution on climate and health is predicted to get worsened by 2050, also is a key factor. Imposing "Carbon pricing", could alleviate the magnitude of Ultrafine particulate matters released from combustion in vehicles, industries and power plants and emission of Greenhouse gases keeping compatible air pollutant levels (9). The governments also could spur the development of green and clean energy thereby directing towards adapting to low-carbon economy. The projected vulnerability of population to occupational hazard in ambient and enclosed conditions need immediate attention as the intensity of disease occurrence is invisible yet potent threat to health. Adequate measures to check the point and non-point sources of air pollution, an elaborate emission inventory data and region wise periodical monitoring of implemented air quality policies through private or government authorities often, will enable stringent implementation of air quality standards.

RECOMMENDATION

Air pollution is upsurging as a frequent humanitarian crisis leading to disastrous conditions, henceforth promoting urgent comprehensive research on green and clean fuel access for populations in LMICs and implementing policies to curtail usage of solid fuels that elevates $PM_{2.5}$ pollution is inevitable at city and national level. Future studies on risk reduction strategies including snowballing the knowledge gaps in correlating indoor and ambient air pollutants exposure and

brain pathways, age, gender and ethnicity-based health studies, prioritising educational institutions as stakeholders for promoting holistic health among younger population, alternative approaches to create health awareness and coping strategies at individual and community levels would substantially reduce pollution in the long run. Framing multi-faceted intervention policies incorporating health, transport, agriculture and industrial sectors especially in LMICs to monitor and accurately address pollution issues at rural and urban areas is mandate to efficiently alleviate air pollution levels.

LIMITATION OF THE STUDY

Data on air pollution levels and global disease burden is volatile and hence accurate interpretation of its impacts on population is restricted. The complex interconnectivity between air pollution and wellbeing is presented in a comprehensive manner considering the type of article.

RELEVANCE OF THE STUDY

The present overview on health impacts and hazardous levels of air pollution on various domestic and working sectors, especially in major cities like Delhi in India and Lahore in Pakistan confirms immediate enhancement of community health, strategies and interventions to mitigate health impacts, alleviate particulate pollutants; hence provides nut-shell information for the policy makers to focus on air pollution as crucial health and environmental issue.

AUTHORS CONTRIBUTION

All authors have contributed equally.

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There are no conflicts of interest.

DECLARATION OF GENERATIVE AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

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