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Shifting Smog Patterns in the Indo-Pak Region: Impressions of Climate Change

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Abstract

Climate change is intensifying smog, turning into seasonal hazard in India and Pakistan. Vehicle emissions, urban heat islands, crop residues burning and industrial discharges plays major role in this mixture, which mostly consists of $PM_{2.5}$, PM_{10}, nitrogen oxides and ground level ozone by raising temperature, changing wind patterns, prolonging dry spells. Rising temperature alters the wind patterns while prolonged dry spells caused by climate change can accelerate smog formation by accelerating chemical reactions and pollutant retention. The result of this phenomenon is worse with huge impact on human health, economy and agriculture. Cardiovascular, respiratory and mental health issues are prevalent on the other hand reduced agricultural production results in financial loss. Addressing these crises requires comprehensive approach, including sustainable agriculture, afforestation, use of cleaner energy sources, and international collaboraitons. Along with this, improving air quality monitoring system, raising public awareness, implementation of effective policies are component of solution. A mutual response of Indo-Pak is essential to mitigate effects of climate change and smog, ensuring better air quality and sustainability in region.

Keywords: Smog, Climate change, Indo-Pak, Ground level ozone, Air Pollution

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1. Introduction

Smog Pattern in India and Pakistan are being significantly impacted by climate change, which are affecting regions' ecological and environmental acpects.[1] Smog is actually a seasonal hazard particularly severe during winter, making Indo-Pak most polluted countries in Asia and world.[2] Human induced activities like industrial emissions, vehicle exhaust, coal-based energy production and burning of agriculture residues are the main contributors to smog, this toxic mixture is composed of particulate matter ($PM_{2.5}$ and PM_{10}), ground level ozone, Sulfur Oxides, Nitrogen Oxides and VOCs emissions poses threats to environment and humans.

Climate change aggravates smog by changing atmospheric conditions, increasing the severity, frequency and duration. Rising temperature enhances the chemical interactions between (NOx) and VOCs leading to high concentration of ground level ozone, main component of photochemical smog. Urban heat islands, like Lahore, Karachi, Delhi and Mumbai, amplify the problem. These areas characterized by less vegetation cover and dense buildings, trap heat and pollutants, intensifying smog[3] furthermore, altered wind pattern and weak air circulation due to high rise buildings allow pollutants to accumulate in these areas.[4] During winters, thermal inversions confine the smog close to the ground, creating dangerous pollution episodes.[5]

Irregular rainfall pattern also worsens smog conditions. As rainfall, aids to remove atmospheric pollutants but unexpected and irregular rainfall, allows pollutants to retain and degrade the air quality, Precipitation pattern, changes with increased frequency of wildfires and open burning of agricultural remains[6] contributes to the release of massive amount of PM and greenhouse gasses in atmosphere, creates feedback loop where smog and climate change reinforce each other[7].

Effects of smog on Pakistan and India are reflective, impacting agriculture, human health and economic activities. The prevalence of cardiovascular and respiratory diseases, surge during smog events.[8] vulnerable populations are children, elderly and those with pre-existing conditions, suffer most. As smog reduces sunlight, harm staple food crops like rice and wheat due to ground level ozone, obstruct photosynthesis. [9, 10]. Additionally, Smog impacts daily life by impairing transportation, reducing visibility and obstructing iconic landmarks like taj mahal, effects tourism. [11]

Even with attempts to combat smog, there's still many problems to address. India has adapted National Clean Air Program (NCAP) and Graded response Action Plan (GRAP),[12] On the other hand, Pakistan has

introduced measures like Punjab Green development program [13] and bans on agriculture burning. However, issues like budget constraints, enforcement concerns, and transboundary nature of smog complicates it the most.[14] The shared Airspace of Indo-Gangetic plain, underscores the need of regional cooperation to address cross border pollution effectively.[15]

This review highlights the critical importance of mitigating the interplay between smog, climate change in Indo-Pak region. Coordinated air quality monitoring, shift to clean energy, sustainable agriculture and public awareness are important and essential steps. By adopting strategic approach, with broader climate adaptation and mitigation measure, both the nations can safeguard public health, sustain their economies and build resilience against climate change. Although the stakes are high, cleaner and healthier future can be achievable through rapid, cooperative and sustained actions. [16,17]

Climate change impact on smog pattern

In Addition to the effects already discussed, climate change also affects smog pattern by changing the seasons and pollution events. For instance, longer and warmer autumn season hinders the arrival of natural mechanisms like snow and rainfall, that is in air purification [18]. Moreover, smog chemical composition become more intensifying because of climate change, primary pollutants, Secondary aerosols produced by chemical reaction are hazardous to human health and produced when temperature and solar radiations rise[19].

The another ignored factor is melting of glaciers in Himalayan region, indirectly effects smog pattern[20] Glacier retreat modifies local water cycle, available in rivers that are essential for farming operations. Because of this, farmers might depend more and more residue burning to clear their fields, increasing smog emissions. [21] Changing of soil and vegetation type also have an impact on natural dust emission, worsen smog development when mixed with manmade pollution. [22]

Lastly, changing in ocean current impacts circulation pattern over south Asia, like India Ocean Dipole (IOD), which is impacted by climate change. [23] Such changes trap haze from high populated areas. Interaction between regional climatic shifts and pollution sources are two complex ways by which composition and behavior of smog changes, this calls for creative and rapid solution, adapted to these changing patterns.

Regıonal Vulnerabilities

Cities like Lahore and Delhi are especially vulnerable to smog on regional level due to confluence of environmental, socioeconomic and demographic factors.[24] These sister cities exceed WHO standards for pollutants, like sulfur dioxide, Carbon monoxide Particulate matter and nitrogen dioxide, resulting in respiratory problems, chronic bronchitis and pulmonary illnesses. Childrens are also susceptible because of their developing organs and weak immune system, high population level in urban areas also exacerbates pollution level.

Lifestyle also plays a role, like spending lot of time outside increase population exposure to contaminants.[25] Furthermore, youngsters are also exposed to long term effects of smog due to industrial priorities, economic limitations and thermal inversions that obstruct pollution control efforts. These vulnerabilities are made worse by insufficient regulatory frameworks, poor policy implementations and insufficient air pollution monitoring.

Health Impacts

In Indo-Pak smog has negative impacts on people health, especially in crowded cities like Lahore and Delhi. These polluted conditions lead to formation of smog, effects on respiratory, cardiovascular and mental health. Chronic respiratory conditions, like bronchitis, asthma and COPD are common among citizens[26]. Particulate matters are famous for their deep penetration in lungs results in inflammation, asthma and decreased lung functions. According to research in Northern India, Delhi, Chandigarh, Uttar Pradesh Haryana and Rajhistan, shows prevalence rate of Asthma is 6-9% and made worse by extreme smog. [27]

Smog also raises the risk of heart diseases. Over 2.5 million deaths are recorded in India due to air pollution each year. There was study in 2024, indicates that the large percentages of deaths are caused by heart strokes, caused by the long exposure to the pollutants including $PM_{2.5}$ and Carbon monoxide (CO), increases 30-40% asthma in smog affected areas like Delhi, Dhaka, and Lahore. Premature deaths are recorded in India in 2019, cause 1.67 million deaths alone [28]

Lahore, Pakistan is also facing comparable health issues. According to research, hospitals in Lahore record more

rate of respiratory disorders during smog season. According to Pakistan Medical Association study, hospitalizations for bronchitis, asthma and pneumonia increased during the time of severe smog. Another study shows that the children in Lahore are at great risk, because of extended exposure to pollutants cause delayed lung development and reduced their lung's ability to function properly.[29]

Prolonged and severe smog conditions lead to the risk of cancer for both nations, due to presence of Benzene and polycyclic aromatic hydrocarbons. These chemicals increase the risk of especially lung cancer. According to case study in India, indicates that poor air quality is associated with an increase in cancer diagnose. [30]

Another worrying impact of smog is on mental health, like anxiety, depression and fatigue are caused by prolonged exposure with smog. A study carried out in Kolkata, India discovered a connection between rate of depression and higher air pollution level with people. Similarly in Pakistan, scientist have connected the levels of air pollution in Lahore and Karachi with increased level of stress, anxiety and cognitive memory loss in older people. Stronger Air quality standards improved monitoring system and all health care efforts are needed to sort these health problems as evidence by terrible effects of smog on public health in both nations.

Economic consequences

According to study, flight delays and road blockage due to smog can cause economical loss and cause damage to human health as well as in northeastern Pakistan and surrounding regions of India. Stubble crop burning in Haryana and Punjab mixed with fog that led to intense smog in this area and have adverse impact on public health. [31]

Allergic response, cardiovascular disease and exacerbating respiratory disease cause due to adverse smog condition. Different factor of smog affects the health of human being in different ways like NO_2 cause the lung irritation by increasing the inflammation of airways and may decrease immunity system against respiratory infection. So, the health expenditure of every person who is affected by smog are our economic loss. [32]According to the recent study of WHO (World Health Organization) there is about 7 million premature deaths in 2016. [33]

Drivers of climate change induced smog

According to a study, the world highest level of air pollution in Pakistan is due to sub-2.5 particulate emissions. A significant contributor to human made air pollution is road transport. With the population of 240 million Pakistan is the world fifth most populated country and the transport contribute around 23% of Pakistan GHG Emissions.[34]

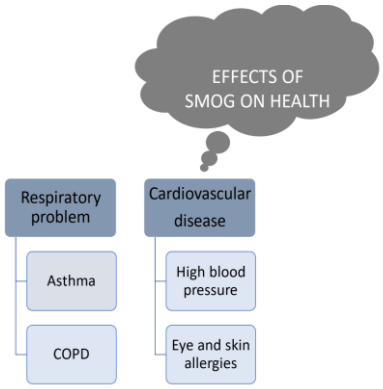

Figure 1: Effects of smog on human health

In power plant and vehicles burning of coal, oil and gas causes air pollution that is further converted to smog under stable conditions. Air pollution in caused by the combustion of coal and crops' stubble in Pakistan and India.

Mitigation and adaptation strategies

According to a study, the dust and small particles present in air that absorbs and scatters sunlight and reduce visibility is called smog. So, the transportation, industrialization and human activities like agriculture, deforestation and construction are the causes of smog formation.

The mitigation strategies are:

(a) Use of public transport

(b) Afforestation

(c) Construction should be far away from towns and societies. [35]

Climate change, pollution and resource scarcity are the environmental issues faced by Punjab and surrounding cities of India. Pakistan Bureau Statistics, Punjab Environmental Protection Agency and World Bank data indicates that many cities of Punjab fall in "unhealthy and sensitive group" with the range of 101-150. So, by enforcing traffic regulations across the district of Punjab the role of Punjab traffic police has truly made remarkable progress. [36] Most importantly the anti-smog campaign by Punjab environmental protection agency (EPS) has shown significant impacts.[37] Through expanding green plantation to reduce smog severity by initiatives like Billion Tree Tsunami. Reduction of

private vehicle reliance and inadequate policy enforcement, the need of public transport encouragement. Although the adaptation includes public awareness campaigns.[38]

Conclusion

Climate change and some anthropogenic activities like stubble burning, industrial discharges, and urban heat islands made smog in Indo-Pak region a serious environmental and public concern. A feedback loop with climate change is created when smog episodes are made worse by shifting atmospheric conditions, weak wind patterns, thermal inversions and erratic rainfall. Particularly in susceptible groups, the health effects are significant and include mental health problems as well as cardiovascular and respiratory disorders. The problem is made worse by financial losses from medical expenses, decreased agricultural output, and disruptions to daily living.

Although they are crucial mitigation techniques including afforestation, sustainable agriculture, cleaner energy sources are difficult to put into practice effectively addressing the transboundary character of smog requires regional cooperation. Important first measures in finding a solution include stepping up air quality monitoring, enforcing laws and increasing public awareness.

In conclusion, combating smog in Indo-Pak region necessitates a comprehensive strategy that combines climate mitigation and air pollution control. The catastrophic effects of smog can be lessened and more sustainable future can be guaranteed with a rigorous and persistent effort.

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