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Research Article

Smog Pollution in Lahore, Pakistan: A Review of the Causes, Effects and Mitigation Strategies

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ABSTRACT

Air, necessary for human survival, is mainly impacted by pollution, with smog being one of the most dangerous forms. The word smog is originating from two words smoke and fog, which is formed by the primarily due to human activities such as vehicular emissions, industrial pollution, crop burning, and construction activities, alongside environmental conditions. In Pakistan, particularly in Lahore, the smog crisis has intensified due to rapid urbanization, population growth, and unregulated industrial and agricultural practices. The smog is primarily composed pollutants such as (PM2.5, PM10), ozone, nitrogen oxides, and sulfur oxides, leading to severe respiratory, cardiovascular, and ocular health risks, including premature deaths. This review highlights the socioeconomic implications of smog, such as its adverse effects on tourism, education, and economic activities. Lahore, which is the 2nd largest city in Pakistan, experiences hazardous Air Quality Index (AQI) levels, exacerbated by heavy traffic, outdated vehicles, and high-sulfur fuels. Smog is responsible for low visibility, causing accidents and also degradation of infrastructure. The compounded effects of smog and the COVID-19 pandemic reveal a correlation between particulate matter exposure and respiratory health vulnerabilities. To mitigate the smog include short-term measures like traffic regulations, use of masks, and limiting outdoor activities, alongside long-term strategies like transitioning to electric vehicles, promoting public transportation, public awareness and afforestation. The public awareness campaigns and advanced monitoring system are essential for effective smog control. Internationally aligned policies, such as improved fuel standards and cleaner industrial practices, are also crucial. The collaborative efforts of governmental agencies, industries, and communities are pivotal to addressing Lahore's smog crisis. This study underscores the urgency of implementing sustainable energy solutions and comprehensive policies to safeguard public health, economic stability, and environmental integrity.

Keywords: Smog; Particulate matters; Health issues; Mitigation strategies

INTRODUCTION

Air is a basic need for our survival. Our survival without breathing is impossible. Human require 2200 times respires per a day. So, importance of respiration is determined by quality of air. When air is polluted such as smog or air pollution it is very dangerous for human survival. Air pollution is most serious problem facing by all over the world. Smog is basic type of air pollution. It is composed of both smoke and fog. It is also sometimes called photochemical smog. In London the term smog is firstly used. It results due to both human activities and environmental condition. The conference smog was organized in twentieth century, smoke and fog he combined the both two word to demonstrate the smoky fog, its drabness and odor [1].

The primary source of air pollution in Pakistan are human activities such as crops burning, vehicles emission, construction activities, burning of coal, fireworks, and smoke from brick kilns. Mainly fog contains clouds like formation at ground level so when these particles which originate from primary source are mix with that vapors of fog, results in photochemical smog. The photochemical smog is also resulted by the reaction of Nitrogen

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Dioxide (NO_2), Nitrogen Mono-Oxide (NO), Sulfur Dioxide (SO_2) and other volatile organic compound. These pollutants after the reaction form secondary pollutants such as Ozone (O_3) and fine Particulate Matter (PM2.5) and (PM10), which have major role in smog formation [2].

Pakistan is populated country in South Asia and its 2nd largest city and capital of Punjab Lahore growing rate of 4% annually. It regarded as most polluted city of Pakistan due to its high population of 11.1 million people in a Lahore smog results due to rapid urbanization, industrial pollution, heavy traffic, construction activities and coal burning industries.

Smog effect the human life such as impacting on respiratory and cardiovascular system and premature deaths. Smog amplifies health issues such as asthma, allergies, eye infections, respiratory infections, and then finely premature deaths. There are a wide length of studies that examine the pecuniary disease by using the data getting from hospitals and relation of air pollution directly to lungs capacity. The World Health Organization (WHO) reported that the air pollution "smog" has a great short-term and long-term impact on human health. According to statistics data finding as it responsible for around 3.7 million premature deaths in all over the world in 2012. According to Landrigan et al., almost 9M people died due to air pollution because it badly effects the human life [3].

The present study aims to evaluate the major public's perception and awareness of smog pollution, and also using the Contingent Valuation Method (CVM) for its control in the Lahore city, Punjab, Pakistan. This study also offer the methods used to prevent the effects of smog including public awareness, by social media and by different organization etc. The government of Punjab and federal government of Pakistan make rules and efforts to tackle smog, further action needed to completely resolve that problem. The public of Pakistan must urgently support governmental rules regulation to minimize and reduce smog because only state cannot overcome on that problem. Instant interventions, including the implementation of strict emission regulations and proportion of viable farming practices, coupled with permanent strategies such as the uptake of sustainable energy sources and educational campaigns, judged imperative. Cooperative efforts involving governmental bodies, industries, farming communities, and public involvement are the crucial in effectively reducing Lahore's smog disaster and enhancing a healthier, more sustainable future [4].

MATERIALS AND METHODS

Framework of smog formation in Pakistan

The phenomenon of smog occur in Lahore usually start from November. In atmosphere many polluted particles are suspended so because of low temperature in winter these particles are mix with water vapors and down to ground level. This condition cause low visibility. Smog is also formed when pollutants such as nitrogen dioxide, sulfur dioxide, carbon monoxide and volatile compounds emitted by sources like vehicles, industries, and burning of fossils fuels interact with sunlight. The schematic analysis of formation of smog is shown in Figure 1 [5].

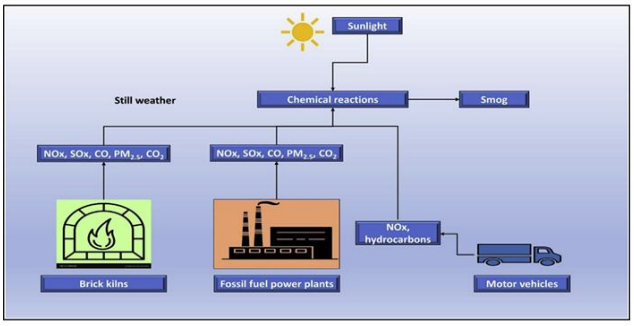


Figure 1: The diagrammatic illustration of formation of smog.

Previous researches showed that the Lahore city have very high level of PM10, PM2.5 and PM10s, Air Quality Index (AQI) stayed in the good to hazardous range. These particles have primary role in the formation of smog.

Factors responsible for causing smog

Air pollution is most dangerous problem facing by all over the world including Pakistan. The rate of pollution increases with the passage of time, it will also increase a hazardous level for our lives. Lahore is 2nd largest and most polluted city of Pakistan. Due to increase the population growth in developing countries like Pakistan resulted in more use of energy resources that decline air quality. Human activities play crucial in smog formation. As we know that when human population increase, cites are over loaded with traffics, usage of more energy resources and increases different types of industries which may have crucial role in increasing the polluted particles that result smog. The percentage of primary sources of air pollution in Lahore shown in Figure 2. Owing to rapid surge in population, Pakistan especially Lahore has witnessed a significant escalation in transportation usage, which play vital role in smog formation. According to Xie et al., about half of the global emission of smog pollutants stem from vehicles. The proliferation of private vehicles, notably in Punjab, which boasts around 19.6 million vehicles, including 6.2 million vehicles in only Lahore, which has great threat to air quality. The another main reason for spreading the winter smog in Lahore is burning of the agriculture residue in neighboring country India. When large amount of smoke is coming from Indian Punjab to Pakistan Punjab also influence the climatic condition in Pakistan. According to researches about 90% of the smog formation is due to smoke which are made by burning of agricultural wastes. Lahore is also an urban city of and industrial hub of the Pakistan, so construction activities are also at higher level in these areas which are also take part in the formation of smog indirectly and indirectly [6].

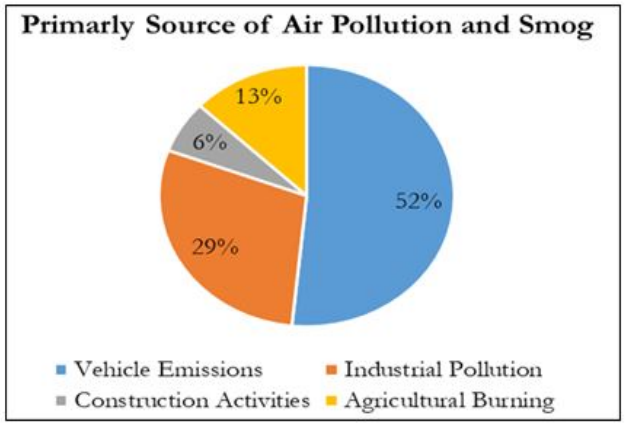


Figure 2: Primary source of smog on human health.

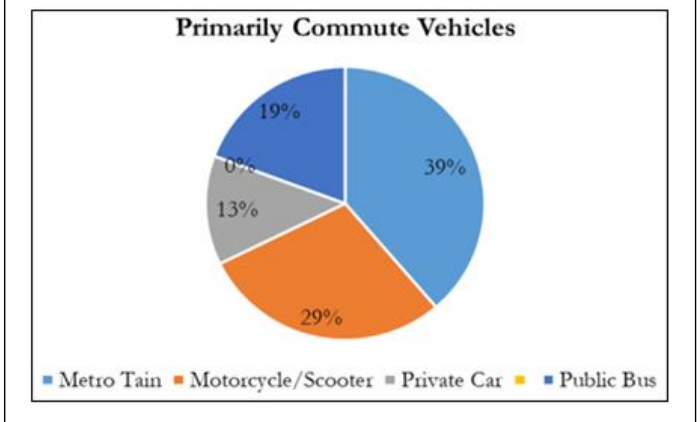


Figure 3: The graphical representation of transportation in the formation of smog.

Unraveling the complexity of smog

The urban air of Lahore contain many harmful compound such as sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen monoxide, volatile compounds, heavy metals, dust particles and (PM2.5), (PM10) and (O_3) particles which may by product of power plants, fossils fuel burning, vehicles emission, coal burning and different industries. The increasing in PM2.5 particulate matter cause the smog pollution and have high health risks since they can enter the respiratory system. Lahore is cultural and commercial hub of Pakistan may contains high number of private vehicles such as motor cycles, trucks, buses and other goods transportation which have significant role in smog formation. The percentage of their contribution in smog formation is illustrated in Figure 3. The quality of fuel also influences vehicle emission like Pakistan have diesel with high sulfur content and petrol with lower octane ratings, resulting in high emission as compared to other regions. The different school's buses and vehicles which produce more smokes through their engine are also have significant role in production of smog. According to study about 70% pollution in city is due to traffic, out of which 40% is from poorly maintained auto rickshaws, pickups and diesel buses. The heavy machinery which can be used for road making and traffic in mall road of Lahore, large no of cars and motorbikes in city also has contribution in smog formation. The current study help out in determining the factors involved in increase air pollution "smog" and analyzing the advanced methods for their controlling. Like industries operating without sufficient pollution control measures release considerable pollutants [7].

The other major reasonable factors for the occurrence of smog are burning of crops in Indian Punjab and smoke is entered in Lahore through Wagha border, so that is the reason that the level of air pollution in Wagha is double than the Lahore city. That smoke contains high proportion of particulate matters which involved in smog formation in winter season.

RESULTS AND DISCUSSION

Assessing the health impacts of winter smog

Lahore is important hub of Pakistan for commerce, industry, and finance, which has a huge impact on air quality control. The problem of smog pollution in this region has remarkable reflection of Pakistan. The World Health Organization (WHO) reported that surrounding air pollution like smog has a major short term and long impacts on human health, causing a congregation respiratory health risks. According to researches, 3.7 Million people were premature died globally in 2012 due to air pollution. Smog has primarily impacts on human health, by causing respiratory, cardiovascular, and ocular problems, also affecting allergic responses. It also responsible for visibility degradation in affecting mortality and allied travel issues through the formation of fog and smog. The smog is resulted by interaction of polluted materials from e.g.; burning, recirculated dust, and industrial activity under humid condition. The gaseous components such as (SO_2), (NO_2), (NO) and (O_3) are the main constituents of winter smog have great contribution in increasing the respiratory and cardiovascular diseases. The permissible limits according to WHO of these particles and their major impacts on human health are shown in Table 1. Smog have dangerous impacts on human as well as on animals and plants. It also effect the plant growth and responsible for their elimination. The results of smog on workplace health and livelihood loss is getting focus and data continue to demonstrate the importance of additional researches in this scope. Dust between 10 and 2.5 m are mainly captured in the upper respiratory tract this is called respirable dust fraction, because of small size they easily penetrate through vessels and effect the internal parts of the body. According to researches the and data of 2005 the PM2.5 reduce the life expectancy of EU people by 8 months average, results in loss of 3.6 million people per year.

Smog have catastrophic results on people of Lahore, it also considered as the biggest global challenge faced by modern world. Smog causes problem in body such as exacerbation of asthma, allergies, eye infection, respiratory tract infection and cardiac pathologies leading to pre mature death, the blood pressure issues such as systolic and diastolic blood pressure in the school children of Lahore city. In December 2018, Lahore, Islamabad, and Karachi which are most urban cities of the Pakistan country had Air Quality Index (AQI) levels of 336 (Hazardous), 159 (Unhealthy), and 141 (Unhealthy), its prove that the Lahore is most urban and also most polluted city of the country [8].

Table 1: Adverse effects of smog components on human health.

Order	Smog components	Limits (WHO)	Main source	Impacts on health
1	Ozone	8 h Mean=100 umg^{-3}	Brick kilns, power plants, VOCs	Harmful to the respiratory, and central nervous systems. Chronic obstructive pulmonary disease
2	PM 2.5	24 h Mean=25 umg^{-3}	Forest fibres, air planes, motor vehicles, dust	Cause of cardiovascular and respiratory diseases, asthma, arrhythmia, and damage to the central nervous system
3	NOx	1 h Mean=200 umg^{-3}	Cement kilns, industrial boilers, power plants	NOx can penetrate deep into the respiratory system, aggravating emphysema or bronchitis, also cause DNA mutations
4	SOx	24 h Mean=20 umg^{-3}	Fossils fuel burning, volcanic eruption	Responsible for lung cancer, digestive system and severely damage the respiratory system, even leading to death
5	CO	8 h Mean=10 umg^{-3}	Bushfires, volcanoes	Cause anemia, cardiovascular diseases, or respiratory problems. Headache, vomiting, dizziness, and may result in death

Dense clouds formed on the sky when smog are at an all-time high. It greatly effects the breathings system and also badly impacts on our immune system. The smoggy particles penetrate into the blood stream and cause serious diseases especially lungs cancer. There are two type of lung cancer is made due to smog pollutants one is consisting primarily of Small Cell Lung Cancer (SCLC) and the second one is Non-Small Cell Lung Cancer (NSCLC). Mostly people who live near the industrial areas and live in urban areas are more affected. The ozone which involved in the formation of smog also cause the 2.5 adenocarcinoma and (SCLC) adenocarcinoma. Lung cancer killed 1.3 million people every year worldwide [9].

The urban air quality is deteriorating day by day, due to this ever increasing pollution the health of 1.6 million people in a Lahore under threat. The damaging effects of smog are also notice foe animals and plants, including both organ and cellular level. Smog also contains major secondary pollutants which have badly impacts on human life and environment. The diseases like allergies, eye-watching bronchial infection, heart problem, including asthma and lung cancer are spread by these secondary pollutants. Smog also greatly affected the children and people which are exposed in road side and suffered with emphysema, bronchitis and asthma. The severity of the effects on human health due to smog relation is shown in Figure 4. Smog also enhance the degradation of rubber, plastics, paints, and dyes, dame to metals, stone, concrete, and clothing.

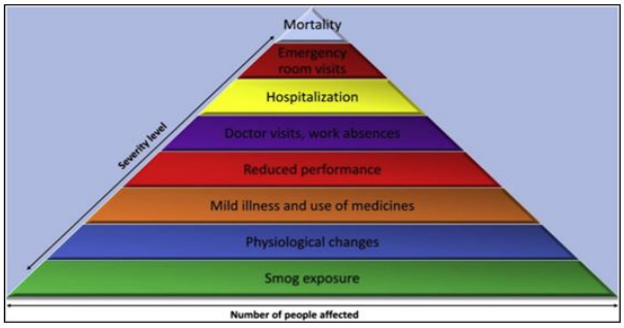


Figure 4: Hierarchy of the effects of smog on human health.

Smog effect tourism in a Lahore

The Lahore is tourism city of Pakistan, smog causing damages to visitor attractions includes as historical building sands places such as Badshahi Mosque, Minar e Pakistan etc. The foreign visitors and tourists due to health reason will avoid visiting a country disreputable for air pollution. Smog is responsible for negative experience of tourists and visitors by causing lower visibility and decreasing the aesthetic beauty of scenery, so, that low visibility cause the risk of accident. For example 10 people were died in one road accident due to low visibility in 2017. The Lahore is not just economic and industrial hub for Pakistan but it also have some historical and religious places not only for Muslims but also for non-Muslims. Smog not only effect the public visitors but also international just like members of the Sikh community who visit their holy shrine in Kartarpur. Poudyal et al., exposed through econometric models that a basic 10% enhance in visibility could probably attract an extra one millions tourists to a park. National economic progress and air quality have very strong relationship. A strong economy depends on healthy peoples, active businesses, thriving tourism, and enhanced employment opportunities. However, smog badly disturbs these aspects and thus obstructs economic growth. Due to smog from morning to afternoon affect the whole day work. Recent researches showed that smog led to prolonged closures of public and private schools, colleges, universities and offices in Lahore in 2023. The CPAK one of the largest economic project about 62 million USD investment, faces considerable issues due to smog disrupting transportation routes with in its vicinity.

Effecting relation of smog and coronavirus

The particles in smog and coronavirus have almost same impacts on human health. Particulate Matter present (PM) cause significant health risks, primary effect the respiratory and cardiovascular system. Coronavirus also effected human population in last 3 to 4 years of the world including Pakistan. The disease which is primarily caused by coronavirus is lungs cancer, chest infection, asthma, flue, and badly effect respiratory system, which are very common to that of smog causing diseases. The correlation between coronavirus and particulate matters and hospital admissions for respiratory issues are shown in Figure 5. The (PM2.5), that penetrate longer into lung tissue than larger particles, which increase the risk of chronic disease, like COPD (Chronic Obstructive Pulmonary Disease) and lung cancer, heart disease and finally stroke.

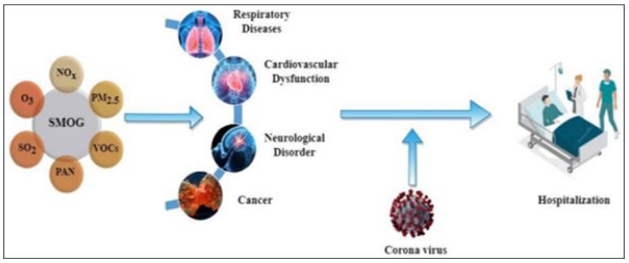


Figure 5: The relationship between coronavirus and smog.

According to recent research, among affected individuals, 27% die due to pneumonia, 8% due to lung cancer, 20% from COPD, and 45% from cardiovascular diseases. The PM2.5 in Western countries, estimated to reduce the life expectancy by an average of 8.3 months.

Smog reducing strategies in (Lahore) Pakistan

Air pollution (smog) is one of the major problems in the world including Pakistan. Many sources involved in this crisis, including automobile exhaust gases, industrial emissions improper waste disposal, agricultural practices, construction, and cigarette waste. For controlling smog spread first we controlling on these sources. Efficient method are present for detecting the smog pollutants such as smog monitoring like the AQS-1 measure smog severity and constituents, aiding in monitoring efforts. But the Pakistan current monitoring system is imperfect. Intervention me assures customized to Pakistan's statistics are presented to clash this issue. The country monitoring authorities same as Pakistan Environmental Protection Agency (Pak-EPA), play an important role, despite trial endure in orienting national air quality standards with international rule regulation. Lahore for example, records levels of pollutants substantially exceeding WHO guidelines, emitting a deteriorating air pollution crises. Harmful pollutants released when burning the trash, so it is necessary to properly dispose of waste through recycling or compositing. We need to follow 3R strategy such as reduce, recycle, and reuse. It helpful in minimizing the waste to reduce pollutants and pollution at the source and limits the need for burning or landfill dumping. Supporting the urban greening or tree planting program and contributing to urban greenery which help to absorb the carbon containing pollutants and produce oxygen which help in breathing, and lower the temperature which reduce the risk of formation of smog. Rules and regulations also help out in controlling it such as enforce a ban on crops burning this detrimental behavior will reduce and completely stopped by giving farmer alternatives like incentives and equipment for managing crop residue, results in reducing the airborne pollution.

Public awareness campaigns also helping in controlling that issue and widespread behavioral changes that informs the public about cutting back on car use, avoiding waste burning, also adopting and following eco-friendly habits. The sources such as community centers, colleges, and schools can all be quite helpful in spreading these messages. Large no of traffics in Lahore has primarily role in contributing in smog formation. We should use electric vehicles instead off diesel engine, and suggest the development of mass transit railways systems, such as high speed electric trains, could significantly increase air quality. To counter rising air pollution Pakistan has begun to slowly adapting electric vehicles, especially in populated cities such as Lahore, Karachi and Islamabad. The government need to offer tax benefits for EV manufacturing and consumers. Increasing the use of public transport instead of cars, motorbikes and rickshaws are the some policies which help out in controlling the air quality. In industries we should requires to upgrading technology with mechanical feeders and cleaner methods like vertical shafts kilns can ensure more efficient coal combustion,

thereby decreasing emissions government need to launch new policies including afforestation projects around the industrial areas of city, forming green barriers between industrial and urban regions.

The Provincial Disaster Management Authority (PDMA) in Pakistan also has issued guidelines advising against outdoor activities during smog events, promoting the use of masks. To addressing these problems some factors that can't be neglected such as public education and awareness of smog and its effects on human health. The public awareness *via* social media, seminars, conferences, and community campaigns) play an important role in controlling the air pollution (smog). The educated population can easily understand the effects of smog on human health as compared to non-educated. Along with public awareness some social and behavioral changes are needed to overcome on this issue. For example, in 2014, a nationwide program was launched by China to controlling the smog like household behavioral changes, increased online searches about smog effects, adjustment day by day consumption that reduce exposure to pollution. Some short term and long term policies to address that problem in Pakistan are shown in Figure 6.

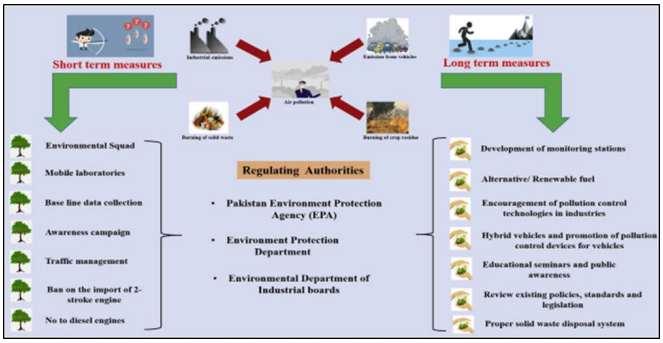


Figure 6: Proposed short- and long-term policies to mitigate smog pollution in Pakistan.

CONCLUSION

Smog, a critical form of air pollution, poses a severe threat to human health, the environment and socio-economic development, particularly in densely populated cities like Lahore, Pakistan. Its formation is resulted by human activities such as vehicular emissions, industrial processes, crop burning, and poor urban planning. Smog contributes to respiratory and cardiovascular diseases, premature deaths, and reduced visibility, impacting daily life, tourism, and economic productivity. The situation is exacerbated by inadequate pollution control measures and a lack of public awareness. Mitigation strategies must focus on enforcing stricter emission regulations, promoting electric and public transport, upgrading industrial processes, and implementing afforestation programs. Public awareness through education and campaigns is vital to drive behavioral changes. Collaborative efforts between the government, industries, and communities are crucial to achieving sustainable air quality improvements. Immediate and long-term interventions, guided by global best practices and localized policies, are essential to combat smog and protect public health and the environment in Lahore and beyond.

AUTHOR CONTRIBUTION

Hussain A write and give idea of the review article, Abbas M organize the article and Dr. Kabir make editing of the review article.

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