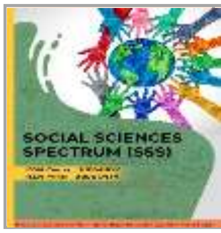

Social Sciences Spectrum

A Double-Blind, Peer-Reviewed, HEC recognized Y-category Research Journal

E-ISSN: 3006-0427 **P-ISSN:** 3006-0419
Volume 04, **Issue** 01, 2025
Web link:https://sss.org.pk/index.php/sss

Mitigating Smog, a new Challenge to Pakistan and the Applications of Bio-receptive Materials, Moss Concrete an Architect's Perspective

Aksam Qureshi
Assistant Professor, School of Architecture and Design, Comsats, Lahore, Punjab, Pakistan
Correspondence: **aksamqureshi@gmail.com**

Umer Mahboob Malik
Assistant Professor, SADU, Institute for Art and Culture, Lahore, Punjab, Pakistan
Email: **umer.mahboob@iac.edu.pk**

Kashif Riaz
Master's Scholar, SADU, Institute for Art and Culture, Lahore, Punjab, Pakistan
Email: **kashifriaz@kriaz.studio**

Zahid Ramzan
Assistant Professor, School of Art & Design, National Textile University, Faisalabad, Punjab, Pakistan
Email: **zahid_archi@hotmail.com**

Article Information [YY-MM-DD]

Received 2024-12-10 **Accepted** 2025-01-30

Citation (APA):

Qureshi, A., Malik, U, M., Riaz, K & Ramzan, Z. (2025). Mitigating Smog, a new Challenge to Pakistan and the Application of Bio-receptive Materials, Moss Concrete an Architect's Perspective. *Social Sciences Spectrum*, *4*(1), 145-170. https://doi.org/10.71085/sss.04.01.209

Abstract

Pakistan, a country with a rich cultural heritage and natural beauty, now faces a stark environmental challenge. Major cities like Lahore, Karachi, and Islamabad are often shrouded in smog. Every winter in Pakistan, the urban areas face the worse smog that comes with a greater intensity having serious impacts on the physical health and psychological issues among all age groups. The health of the ecosystems is also worsening, asking for the integration of more green spaces in our urban built fabric. This introduction delves into the multifaceted problem of air pollution in Pakistan, setting the stage for a detailed exploration of its causes, impacts, and potential solutions.

This research paper aims to highlight the use and application of new construction materials with case studies, to help combat and eradicate the smog issues to build healthy and eco-friendly environments for next generations to come. One solution stands out as bio-receptive concrete called **Moss Concrete**. The incorporation of moss with concrete will make it, a natural, eco-friendly bio-receptive construction material to create self-sustaining, living walls and having a potential of purifying the air by absorbing additional *Co_2 emissions* present in the atmosphere without requiring any additional systems or maintenance.

Keywords: Smog, Bio-receptive Materials, Moss Concrete, Living Wall Systems, Effects and Concerns, Geographical factors.

Introduction

Smog in Pakistan and in the neighboring regions, is becoming one of the greatest risks to economy, environment and health. The major cities of these countries are being declared the worst in the world for their Air Quality Index, AQI. The industrial revolution, rapid urbanization of the human settlements and current technological advancements are considered as the key factors for the spread of the smog globally. The people living in these cities face adverse environmental and health effects. People of all ages are affected due to these concerns. The worst affected are the children with developing lungs and geriatric patients with chronic respiratory diseases, impacting hospital and healthcare facilities with an increase in number of patients visiting emergency departments. The education sector is another due to students' absentees. The significant impact this smog has recently been seen in Lahore, where all economic activities were put to halt, hindering the normal functioning of a society.

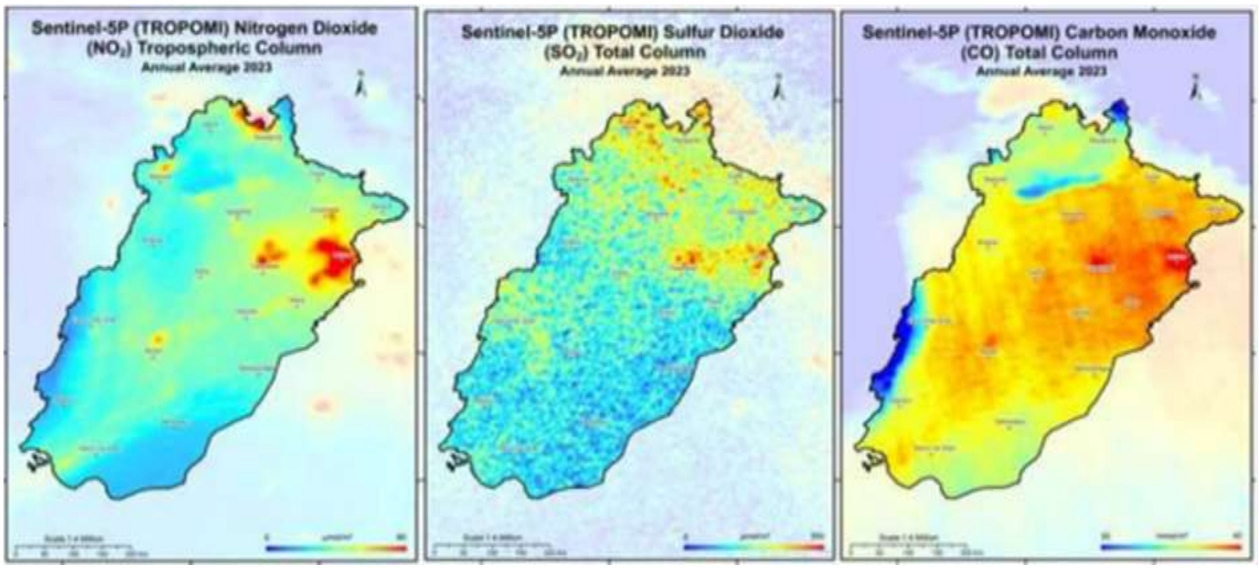

Figure 1: Air Pollution Hotspots of Punjab, 2023 showing Lahore, Multan, Gujranwala, Faisalabad, Rawalpindi, Sahiwal, and DG Khan as the most polluted cities in Punjab. *Image Source: The Urban Unit, 2023*.

Smog and what is it made of?

In early 1900s[1], the world became familiar with the word Smog, an air pollutant which is the mixture of smoke and fog. It is primarily formed through complex chemical reactions between various pollutants present at the base of ozone layer. The mixture of the gases with residues and water vapors that are executed daily frame Exhaust cloud. The increase of poisons in climate is another reason for this Exhaust Cloud, a phenomenon caused by the consumption of coal, commonly used in industries and fossil fuels for the running of our vehicles.

"The primary wellsprings of these forerunners are poisons which are discharged from gas, diesel motors, modern plant and other warming exercises. It is frequently caused by high temperatures, substantial traffic and other temperature sources or dampness, these are couple of fundamental factors behind the expanding of brown haze issues. Wind speed is low amid the winter season because of this reason smoke and haze are stagnating at one place which are primary drivers of making exhaust clouds and turn out to be extremely destructive for the general population on ground level. It irritates nature and our perceivability locale. Brown haze just relies upon

temperature because of the temperature reversal wind or air can't move upwards and remain on ground level which serves to from exhaust cloud." [2]

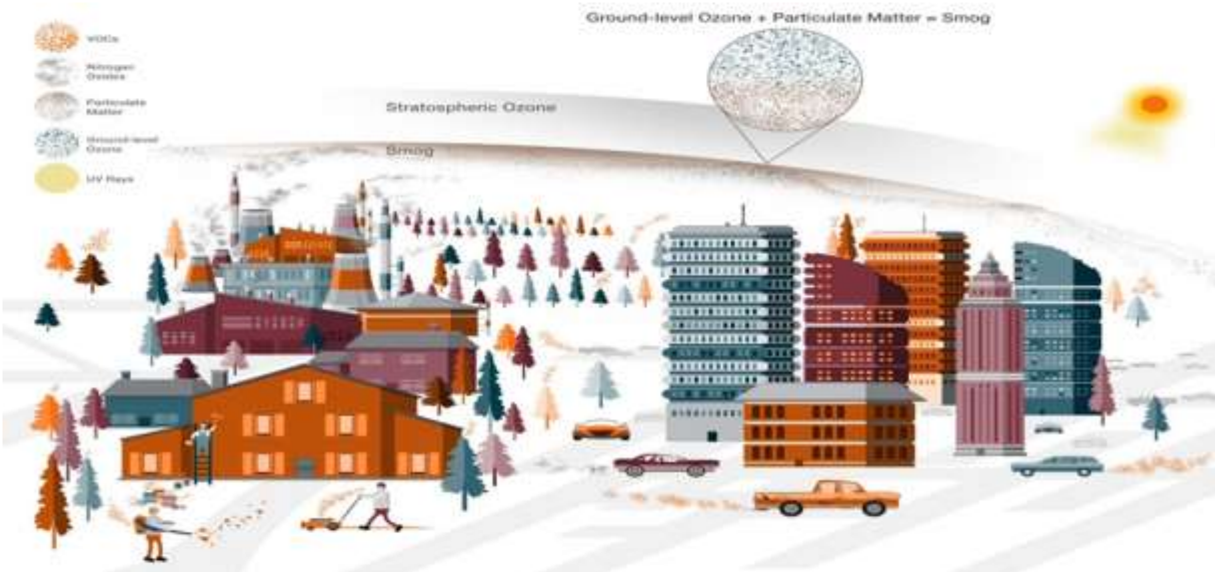

Figure 2: Accumulation of Smog and the Atmospheric Layer
Image Source: Caltech Science Exchange, Pasadena, California.

Depending on the origin and characteristics, smog is mainly of two types,

- Sulfurous Smog, and
- Photochemical Smog.

Sulfurous smog, alternatively known as London smog, is usually seen in the winter, caused by the use of sulfur-bearing fossil fuels, particularly coal. Smog primarily affects those regions that are away from the equator. Coal burning, accumulation of particulate matter from industrial activities and drop in temperature are sources of this type of air pollution. Sulfurous smog is characterized by a high concentration of sulfur dioxides, nitrogen dioxides, and dust.

Photochemical smog, also known as Los Angeles smog, is mostly formed when the atmospheric temperature reaches its extremes during summer months. Los Angeles smog consists mainly of carbon oxides, nitrogen oxides, and hydrocarbons. Unlike sulfurous smog, photochemical smog originates from exhaust fumes and industrial emissions.

Smog has harmful impacts on human health and the environment. It typically appears as a brownish or grayish haze, especially in urban areas usually close to water reservoirs and open lands. In cities like Lahore, Pakistan, smog becomes particularly noticeable when weather conditions trap the pollution near the ground, making it more harmful.

Smog and Lahore- Once a Garden City

Lahore, once renowned as the "City of Gardens" for its rich greenery and vivid landscapes, now faces a periodic environmental crisis, severe smog which is transforming its skies into a grey, suffocating blanket that's becoming a threat to resident's health, economy, and daily life. Unlike the natural fog, which comprises of water droplets, smog is a noxious mixture of smoke, fog, and other air-pollutants from vehicle emissions, industrial activities, and seasonal crops burning. During the winter months, this toxic haze blankets Lahore, which poses a serious health risk that demands immediate action from both local authorities and citizens.

Figure 3: Lahore crippled by hazy smog at the start of winter, November 2024

Image Source: The NEWS International.

Over the past 6 years, Lahore has consistently ranked among the top 15 most polluted cities in the world. In recent years, the Air Quality Index (AQI) has surpassed the hazardous limits and sometimes has even crossed 300-400 AQI far above the safe level, the Punjab Environmental Quality Standards and World Health Organization (WHO) has set due to this air pollution of Lahore.[3]

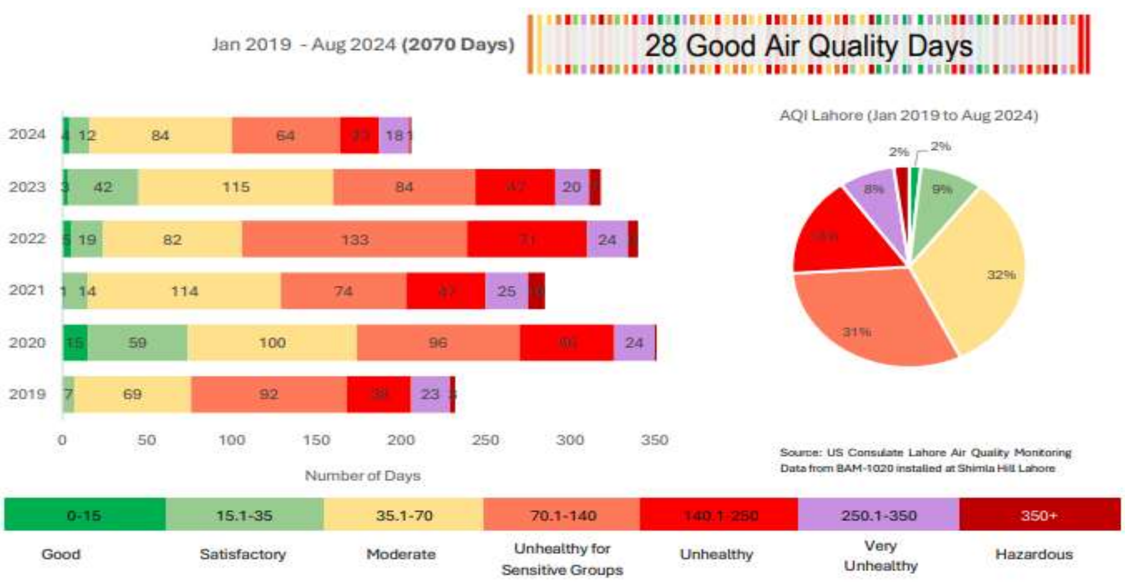

Figure 4: AQI data, Lahore from January 2019 to August 2024.
Image Source: US Consulate Lahore Air Quality Monitoring Data from BAM-1020 installed at Shimla Hill Lahore.

And this AQI is still deteriorating with the increase in Lahore's population. According to the 2023 census, Lahore's population has increased to over 13 million, with an annual growth rate of 3.41%, further damaging the city's infrastructure and resulting in an increase in vehicle and industrial emissions.

"The primary contributor to Lahore's smog is the city's location near the Ravi River, which creates a microclimate conducive to fog formation. This natural tendency combines with high levels of pollutants from industry, vehicle emissions, and seasonal crop burning, resulting in a thick, hazardous haze. This smog sharply reduces visibility, causing accidents, delays, and severe disruptions to daily life."[4]

Figure 5: Lahore and its Geographical Location.
Image Source: www.worldmap1.com.

Lahore sees its worst smog from October to February and reaches its peak in the months of November and December. During these months, cooler temperatures, along with temperature inversions, trap pollutants close to the lower levels of the earth surface. The crops burning in the surrounding agricultural regions, increase in vehicle and industrial emissions coupled with the lack of wind movements prevents dispersion of pollutions and worsening air quality.

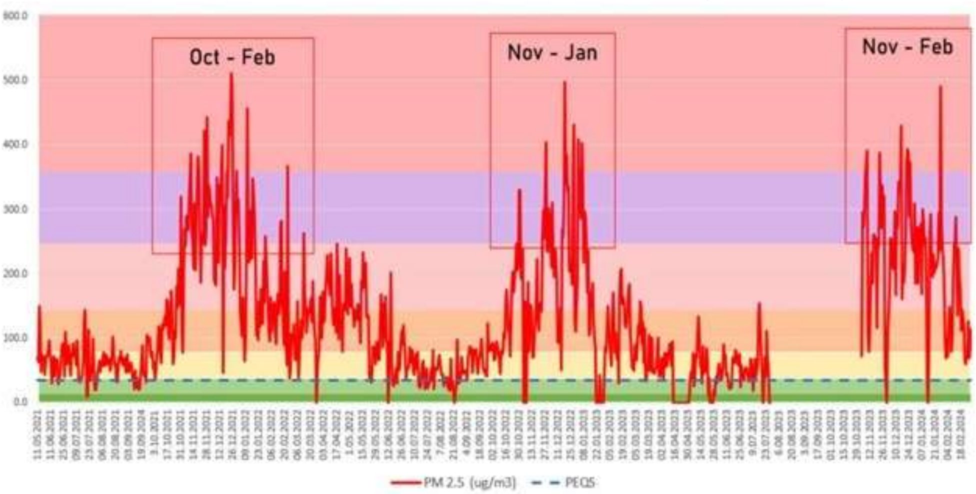

Figure 6: Smog in Lahore is typically at its worst from October to February, with the peak months being November and December. Image Source: The Urban Unit, Punjab.

Figure 7: Crop Residue Burning, A cause of increase in Air Pollution.
Image Source: www.eco-business.com.

Smog, its impact on environment, economy, and health- Lahore

Smog has far-reaching and alarming consequences for the people of Lahore. With every passing year, there is an increase in road accidents claiming numerous lives due to poor visibility caused by smog. It also disturbs air and rail travel, causing economic losses and significant inconvenience for passengers. Respiratory issues, asthma and bronchitis, are worsened due to prolonged exposure to smog in every age group, especially the elderly, and individuals with pre-existing health issues.

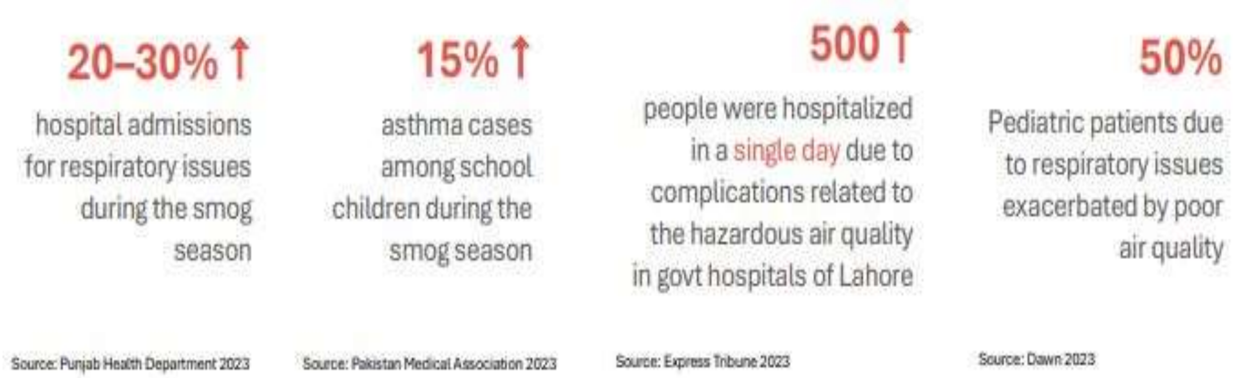

Figure 8: Incremental Increase in Patients due to Smog.
Image Source: Punjab Environment Protection Department 2024.

The environmental impact of Lahore's smog is equally troubling. The diminished sunlight impedes crop growth, threatening agricultural productivity and the livelihoods of farmers. Moreover, the increased moisture and pollution in the smog accelerate the deterioration of infrastructure, resulting in damage to buildings and roads.

Environmental lawyer Rafay Alam told DW that, *increased pressure from citizens on the government is due to growing awareness that pollution is "a human rights violation" because "people are dying from the air they breathe."*[5]

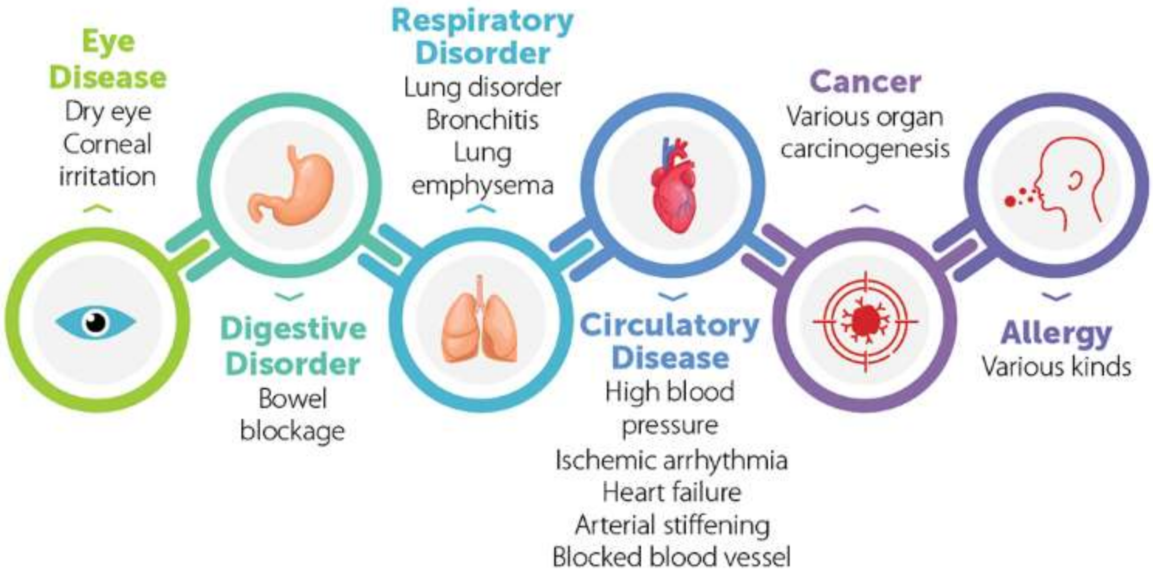

Figure 9: Effects of Smog on Public Health.
Image Source: The Energy and Resource Institute, India.

Smog also has a serious impact on the economics of Lahore. The city faces lockdowns during peak smog days, resulting in losses of billions of rupees. There's a reduced economic and declined tourism activity during these days. The hazardous weather also affects small businesses and daily-wage workers due to the slowdown of the economy.

"The economic impact is equally severe, with the World Bank estimating that air pollution costs Pakistan approximately 6% of its gross domestic product (GDP) or over $22 billion each year."[6.]

Is Smog a Seasonal Issue?

Considering smog, a seasonal issue is an interesting misconception. Not only does Lahore generate the same number of emissions throughout the year, also it's increasing with every passing year. With less air speed, smog becomes visible in the winters as the pollutants don't rise due to increase in moisture and gather in the lower layers of the airspace. Its formation gets facilitated by the winter weather and lack of rainfall.

Figure 10: Smog choking lives in Pakistan.
Image Source: www.pakistantoday.com

While the winter season in cities like Lahore experiences severe air pollution, the dynamics in Southern Pakistan, particularly in cities like Karachi, exhibit a different pattern. This variation is due to the region's distinct climatic, geographical, and socio-economic factors.

In contrast to Lahore, Karachi's air pollution levels tend to escalate during the summer months. The following are the key factors that contribute to this:

- Karachi, being located on the coastal region results in high humidity, which, when combined with the summer heat, leads to the formation of ground-level ozone, a harmful pollutant.
- The urban heat island effect is worsened by dense development and a lack of green spaces, which increases temperatures and intensifies air pollution.
- As a major industrial hub, Karachi experiences significant emissions from industrial activities, particularly during the summer.
- Additionally, the high demand for energy for cooling in the hot months results in increased emissions from power plants. The monsoon season further complicates air quality, bringing dust and particulate matter while worsening traffic congestion, which increases vehicular emissions.
- The ongoing urban expansion and associated activities contribute to air pollution throughout the year.

Reasons and Sources of $PM_{2.5}$ Air-Pollution in Pakistan

Air pollution which becomes **SMOG** in winters in Pakistan, is driven by several interconnected factors. One major contributor is the continuous rise in pollution levels, as various sources consistently release harmful emissions into the atmosphere. Globalization has exacerbated the problem with increased industrial activity and transportation contributing significantly to air pollution. Rapid urbanization also plays a key role, as the expansion of cities brings higher levels of emissions from both residential and industrial areas. The widespread use of heavy transport, such as trucks and buses, further intensifies the pollution. A significant portion of air pollution is released into the environment through the burning of fuels such as coal, petroleum, wood, and others. Vehicles, including cars, trucks, and trains, that run on gasoline and diesel are major contributors to air pollution by emitting harmful gases like carbon monoxide and nitrogen oxides. Industries and factories also play a key role, releasing various pollutants from manufacturing processes into the atmosphere. The power sector, particularly power plants that burn fossil fuels like coal and natural gas to generate electricity, is another significant source of air pollution. Finally, engines that experience incomplete combustion, such as those found in older vehicles or poorly maintained machinery, release higher levels of harmful pollutants. Collectively, these activities degrade air quality and contribute to the growing environmental and health challenges related to air pollution.

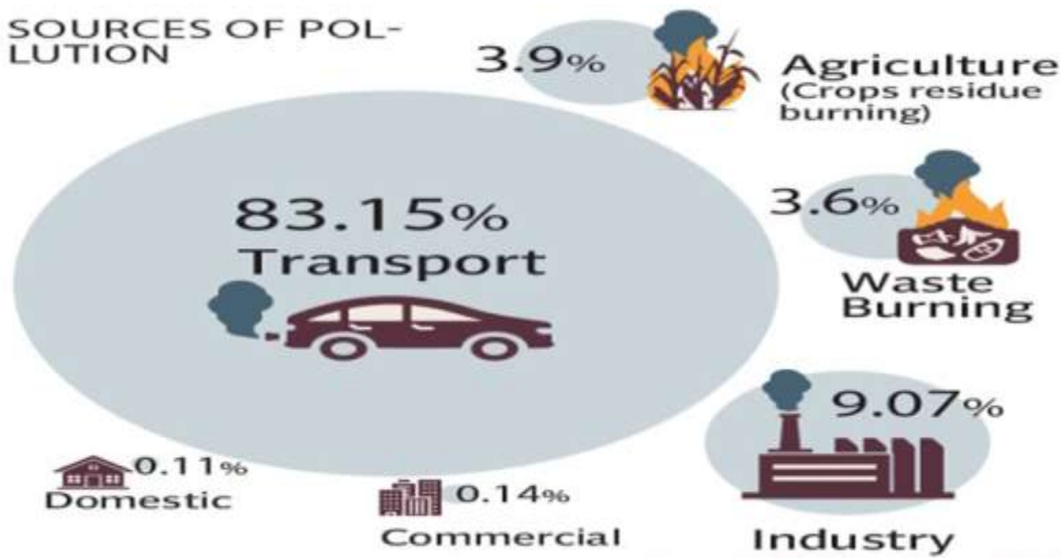

Figure 11: Sources of $PM_{2.5}$ Air Pollution.
Image Source: The Urban Unit, Punjab 2023.

Additionally, the country's hot climate and abundant sunshine promote the formation of ground-level ozone, which worsens air quality. The use of inefficient and polluting brick kilns adds another layer to the pollution issue. Moreover, the lack of sufficient green spaces in urban areas means fewer plants are available to absorb and filter out harmful pollutants. As Pakistan's population continues to grow, so do the demands for resources, leading to increased consumption and further environmental strain. Additionally, the use of fireplaces, especially in residential areas, contributes to both indoor and outdoor air pollution by emitting particulate matter and carbon dioxide.

Figure 12: Sources of PM $_{2.5}$ Air-Pollution in Pakistan
Image Source: IQAIR.

Geographical Factors that Impact Smog

Geographical factors have a significant role in the formation, spread, and severity of smog in various regions. Cities located in valleys or basins, such as Los Angeles[7] and Mexico City[8], are particularly vulnerable to smog due to surrounding mountains that trap pollutants, preventing them from dispersing. In contrast, areas with flat terrain are less prone to smog, as pollutants can disperse more freely without physical barriers. Climate also affects smog levels, with temperature inversions[9] being a key factor. When a layer of warm air traps cooler air, these inversions occur at the surface, leading to higher concentrations of pollutants, and are common in cities like Los Angeles [10], Mexico City[11], and Beijing[12]. Additionally, cities with more sunny days, particularly in warmer climates, are more likely to experience photochemical smog[13], as sunlight is necessary for the formation of ground-level ozone. Wind patterns[14] also influence smog accumulation; cities with low or calm winds, such as Lahore[15], are prone to smog buildup because pollutants are not dispersed. In contrast, prevailing winds can carry pollutants from industrial or urban areas, spreading them over wider regions and worsening air quality. Coastal cities or those having close proximity to water bodies[16] experience variations in smog levels due to sea breezes, which can either bring clean air or carry pollutants from nearby industrial zones. Lastly, altitude[17] can also affect smog levels, with higher-altitude cities experiencing less smog because pollutants tend to stay closer to the ground. Cities situated at altitudes above 1500 meters have lower atmospheric pressures, which can contribute to reduced visibility near industrial areas. Understanding these geographical factors is essential for developing effective strategies to combat smog in different regions.

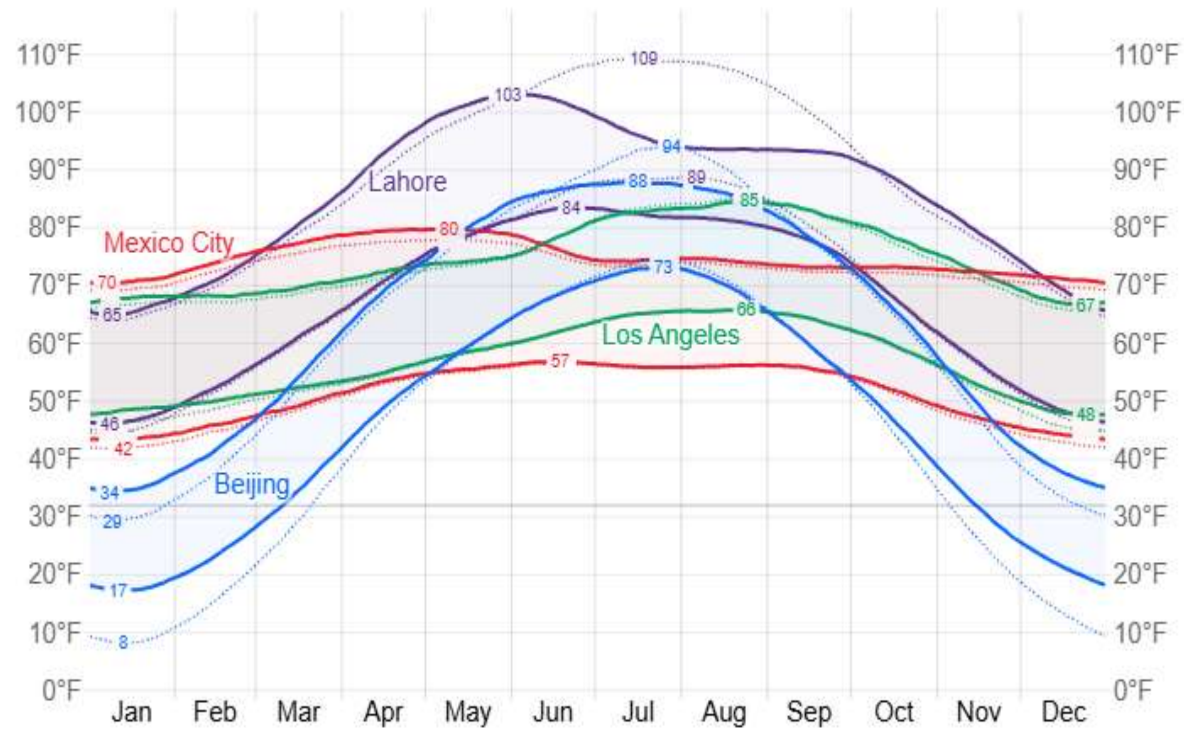

Figure 13: Comparison of average temperatures of Beijing, Lahore, Los Angeles and Mexico City *Data Source: www.weatherspark.com*.

This temperature graph compares the yearly climate patterns of Beijing, Lahore, Los Angeles, and Mexico City. Los Angeles stands out with the most stable temperatures, staying between 55-70°F year-round. In contrast, Lahore and Beijing experience extreme variations, Lahore reaches above 100°F in summer and Beijing drops below 20°F in winter. Mexico City maintains moderate temperatures between 55-75°F throughout the year. All cities follow typical seasonal patterns with summer peaks around July-August and winter lows in January.

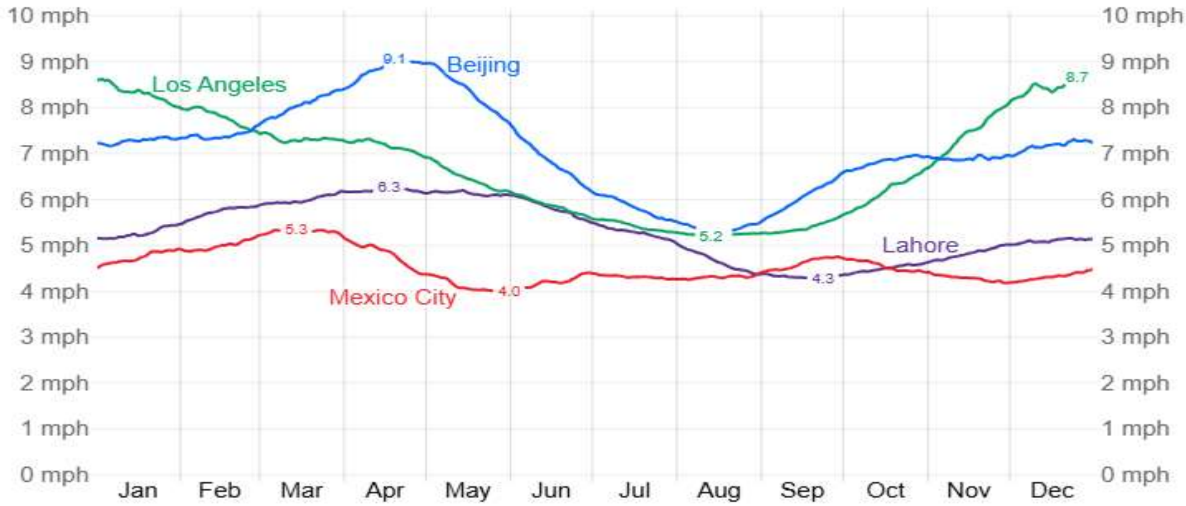

Figure 14: Comparison of average wind speed of Beijing, Lahore, Los Angeles and Mexico City *Data Source: www.weatherspark.com.*

This wind speed graph compares annual patterns across Beijing, Lahore, Los Angeles, and Mexico City. Los Angeles and Beijing show the most variation, with Los Angeles reaching peak winds of nearly 9 mph in winter and Beijing peaking in spring. Mexico City maintains the lowest average wind speeds around 4-5 mph, while Lahore stays steady at 5-6 mph throughout the year. Unlike temperature patterns, which show dramatic seasonal changes, wind speeds remain relatively moderate across all cities, generally staying within a range of 4-9 mph.

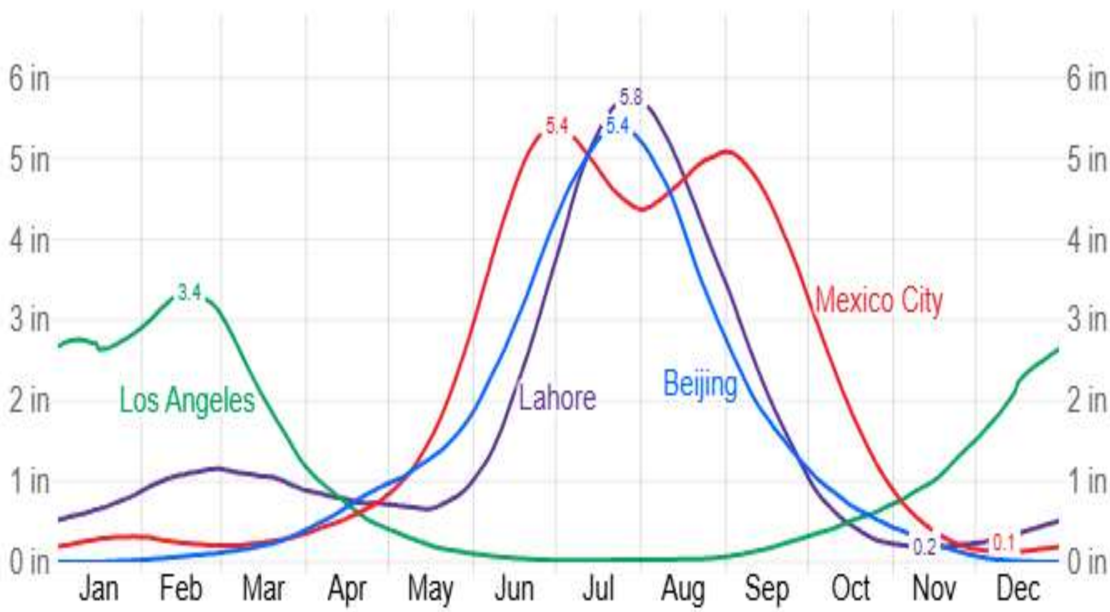

Figure 15: Comparison of average monthly rainfall of Beijing, Lahore, Los Angeles and Mexico City *Data Source: www.weatherspark.com.*

This precipitation graph shows distinct rainfall patterns. Mexico City experiences the longest rainy season from June to September, with rainfall reaching 5.4 inches. Lahore and Beijing share similar monsoon patterns, both peaking in July at about 5.5 inches. Los Angeles displays a completely different pattern with winter rains (December-February) peaking at 3.4 inches, while remaining extremely dry during summer months.

Findings on Geographical Factors Impacting Smog

These climatic data and geographical factors help explain these cities' vulnerability to smog; Los Angeles, USA, has a basin-like topography, which, when combined with temperature inversions, limited rainfall and emissions from vehicles, create its persistent smog problems. Beijing, China, is surrounded by mountains on three sides experiences winter temperature inversions that trap pollutants, though its spring winds and summer monsoons provide periodic reliefs, leading to severe smog events. Mexico City's consistent but low winds combined with its high-altitude basin faces year-round smog challenges due to industrial emissions and vehicle exhausts despite summer rains. Lahore, Pakistan, is situated in the Indo-Gangetic Plain, bordered by the Himalayas to the north and the Thar Desert to the south. This valley-like setting, steady winds and dry winters contribute to severe smog accumulation and become a cause for pollutants to become trapped, preventing their effective dispersion.[18]

These cities illustrate how geographical features, such as topography and natural climate factors, can exacerbate smog challenges and negatively affect air quality.

SMOG Around the World

Smog is not a new issue and the cities like London, Beijing, and Mexico City have long struggled with it. London's historic smog events, Beijing's pollution from industrialization, and Mexico City's trapped pollutants due to its geography all demonstrate the global challenge of air quality. Similarly, Lahore faces its own smog crisis, driven by industrial emissions, vehicular pollution, and crop burning. Here are the examples of these cities how they have tried to mitigate the curse of Smog.

The Great Smog of London

In 1952 from December 05th-09th, the city of London was covered by the deadly smog for 5 days produced by the combination of industrial pollution and worst weather conditions. The smoke and fog brought London to a near halt and resulted in thousands of deaths. The prompt reaction was, Parliament passed the Clean Air Act, four years later that marked as a turning point in the history of eco-sustainability.[19]

The local municipality of London has implemented several key measures to improve air quality. These include identifying pollution sources, reducing emissions from road traffic and air travel, promoting sustainable building practices, and minimizing pollution from industry and construction. The city also emphasizes leading by example, with active involvement from boroughs, businesses, and individual Londoners in supporting air quality initiatives.[20]

Figure 16: London during Smog days.
Image Source: Leaf by Greenly https://greenly.earth/en-us/leaf-media.

Beijing Smog, 2013

Beijing has struggled with severe smog and air pollution for many years, but **2013** was particularly notorious. In that year, Beijing's air quality reached alarming levels, with an average $PM_{2.5}$ concentrations of **101.56 micrograms per cubic meter** [21], which is significantly higher than the World Health Organization's recommended safe limit.

Figure 17: Smog in Beijing
Image Source: https://sustainablemobility.iclei.org/air-pollution-beijing/

Smog in Beijing is caused by several factors, including coal burning whose emissions have harmful pollutants like particulate matter, nitrogen oxides and sulfur dioxide. Vehicle emissions significantly contribute to the pollution, as the number of vehicles on the road continues to rise. Industrial activities, such as those from cement factories and steel mills, also release large amounts of pollutants. Additionally, the city's rapid urbanization and construction generates considerable dust, further worsening air quality. These combined sources of pollution make smog a persistent issue in Beijing. Smog in Beijing has serious health, economic, and environmental impacts. It contributes to respiratory issues like asthma and lung cancer, while also reducing visibility, which disrupts transportation. Economically, smog harms tourism, commerce, and industry, leading to financial losses. Environmentally, it damages crops, forests, and water bodies, threatening both biodiversity and agricultural productivity. These effects underscore the urgent need for effective pollution control measures in the city.

Several measures to combat air pollution were taken by Beijing city government that include the Clean Air Action Plan[22] to reduce coal use and promote clean energy, stricter emission standards for vehicles and industries, and increased reliance on renewable energy. Public awareness campaigns also aim to educate citizens about smog and encourage support for these efforts.

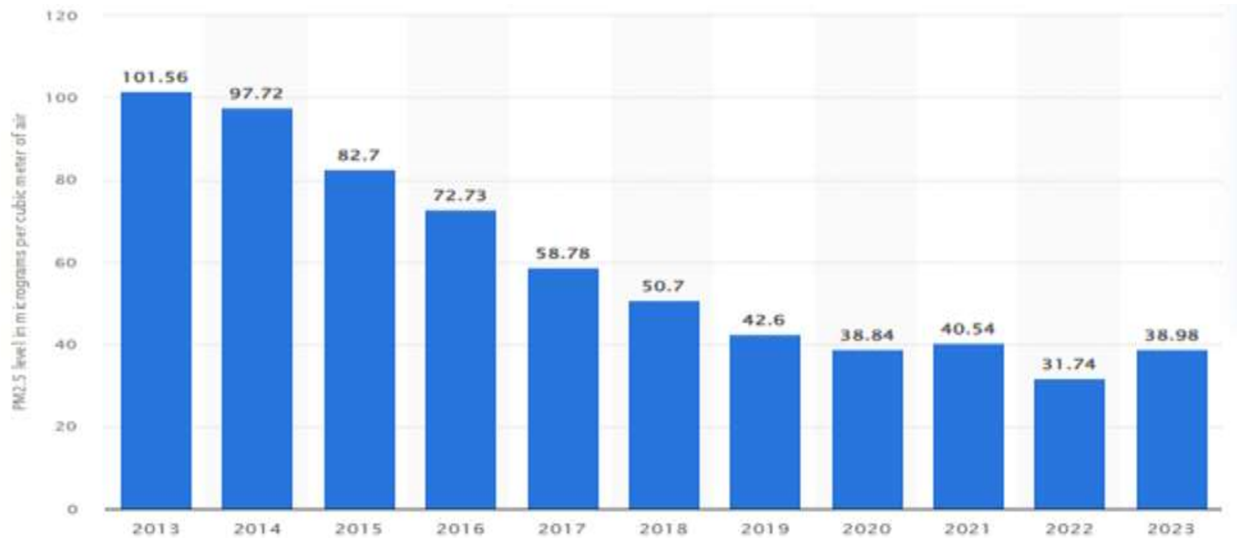

Figure 18: Average annual $PM_{2.5}$ air pollution levels in Beijing, China between 2013 and 2023
Image Source: https://www.statista.com/statistics/report-content/statistic/690823.

Mexico City, Mexico

The Mexico City metropolitan area, a home to over 21 million people, faces air pollution that can have negative long-term impacts for its residents. Severe smog problems in Mexico City emerged in the 1980s and became particularly acute during the early 1990s. The situation became so severe that by 1992, the United Nations declared Mexico City the world's most polluted city[23]. The city gained notoriety for its "black birds" days when pollution was so thick that birds would fall from the sky. Smog in Mexico City is caused by several factors, including emissions from many vehicles, industrial activities, and waste burning, which release harmful pollutants into the air. The city is located in a valley surrounded by mountains and exacerbates the situation by trapping these pollutants and preventing them from dispersing, making air quality a persistent challenge.

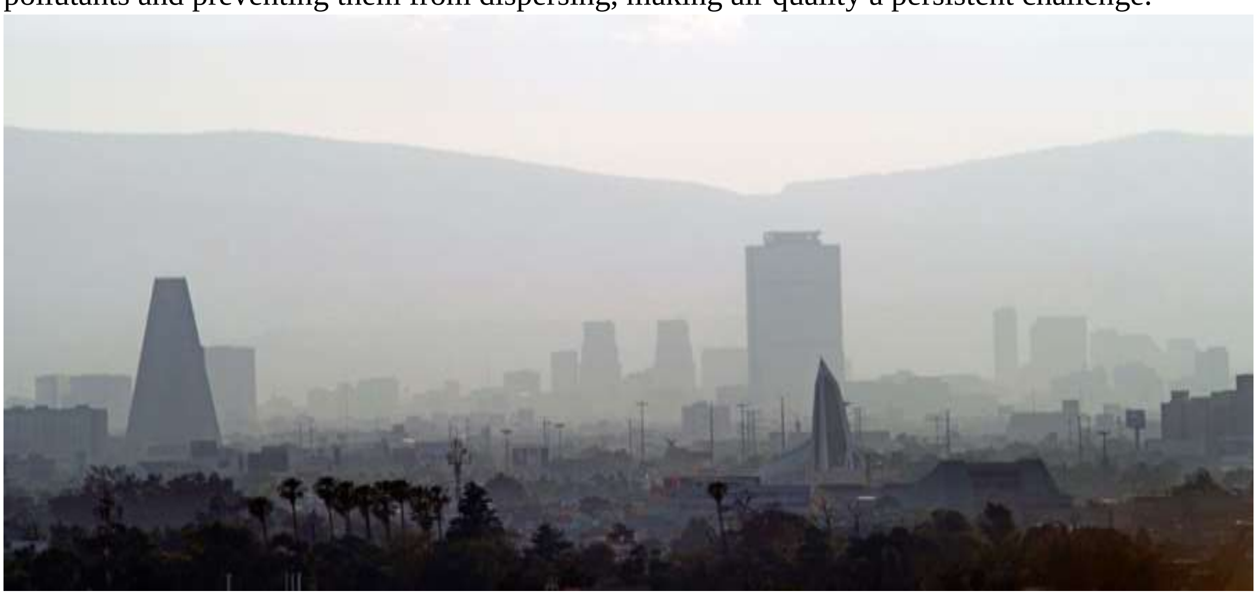

Figure 19: Mexico under SMOG cover.
Image Source: https://dialogue.earth/en/pollution/8786-how-mexico-city-slashed-air-pollution-levels-by-half/

Smog in Mexico City causes serious health issues, including respiratory problems like asthma and lung cancer. It also reduces visibility, disrupts transportation and daily life. Economically, smog leads to losses in tourism, commerce, and industry, while environmentally; it harms crops, forests, and water bodies, affecting biodiversity and agriculture.

The Mexican government has taken several steps to address air pollution in Mexico City, including the "Hoy No Circula"(No-Drive Days) [24] programs first introduced in 1989, which limits vehicle emissions, and stricter emission standards for vehicles and industries. Investments in public transportation, such as expanding the metro system in 2005, and efforts to increase green spaces have also been prioritized to help reduce pollution and improve air quality. These measures aim to create a healthier environment for residents.

Figure 20: Promoting bicycles to reduce Smog, Mexico.
Image Source: https://borgenproject.org/innovations-improving-air-quality-in-mexico-city/

While Mexico City has made progress in reducing smog, challenges persist. The city still experiences frequent smog episodes, particularly during the winter months.

Smog Mitigation and the Architects' Responses

By 2050, more than 68% of the global population will reside in urban areas, increasing the urban population by 2.5 billion.[25] Without intervention; this urban growth will reduce green spaces, leading to issues like biodiversity loss, heat stress, and worsening air quality, impacting both ecology and public's mental and physical health. To reduce these problems, the addition of green spaces becomes essential which is not always possible at ground levels due to spatial constraints, industrialization and urban sprawl around the globe.

Architects and urban planners are playing their role by addressing air pollution through innovative design strategies. This includes integrating green infrastructure, developing pollution-absorbing materials, creating sustainable urban spaces, and implementing advanced filtration technologies. The goal is to mitigate global environmental challenges by reimagining-built environments to reduce emissions and improve air quality.

To address the need for green spaces, *urban designers, planners and the inhabitants of cities are increasingly incorporating green roofs*[26] and façades into buildings. While these solutions offer various benefits, they require separate systems for attachment, leading to higher construction and maintenance costs, as well as increased structural demands on the buildings.

The world is advancing with innovative bio-receptive materials that transform architectural surfaces into active environmental filtration systems to mitigate urban air pollution. Bio-receptivity is defined as: “the aptitude of a material to be colonized by one or several groups of living organisms without necessarily undergoing any bio-deterioration.”[27] These technologies integrate photocatalytic surfaces like titanium dioxide coatings, green infrastructure such as living walls, and advanced material technologies including bio-receptive concrete and algae-integrated building envelopes. By using biological processes and nano-engineered materials, these approaches actively break down pollutants, absorb carbon dioxide, and filter particulate matter, offering a sophisticated architectural response without the need for an extra technical system to urban environmental challenges.

In recent days, a new type of green building material is gaining popularity as bio-receptive material. **Moss concrete** is an innovative bio-receptive material that transforms traditional concrete into a living surface. By creating specialized microstructures that support moss growth, it enables biological colonization while maintaining structural integrity, offering environmental benefits like carbon absorption and urban biodiversity enhancement.

Moss Concrete and how it is made

Concrete is a promising bio-receptive material due to its widespread use[28] and similarity to natural stone, but standard concrete does not support biological growth effectively. Therefore, a specialized mix must be developed for broader application in construction.

Moss concrete, an innovative and environmentally sustainable solution, also known as “living concrete” is a type of concrete that includes moss into its mixture to create a natural, eco-friendly building material that results in the aesthetic appeal of buildings. Moss Concrete combines the beauty of nature with the durability of concrete. The concept originated from the idea of using natural materials in construction to help improve sustainability and reduce environmental impact.

This idea of biological concrete is developed by Structural Technology Group of the Universitat Politècnica de Catalunya BarcelonaTech (UPC) [29], University in Spain[30] and Delft University of Technology, Netherland [31] by growing moss and other organisms such as lichen and fungi on the surface of structures to purify the air by absorbing excess carbon dioxide from the atmosphere. The construction process involves a base layer of conventional concrete followed by a water proofing layer which acts as a barrier against the surface on which moss will grow. The outer layer allows rainwater to penetrate that boosts the growth of the biological organisms. The growth and survival of moss is dependent on the retained water and salts. The waterproofing layer ensures that the moss and other organisms do not damage the concrete structure and structural integrity of the building remains maintained.

Figure 21: Image showing growth of Moss in Concrete.
Image Source: https://theplaidzebra.com/moss-growing-concrete-absorbs-co2-insulates-and-is-also-a-vertical-garden/

The choice of moss is strategic due to its rhizoids, which are nondestructive and function as adhesives. Unlike roots, rhizoids[32] don't damage the substrate they grow on, making moss an ideal plant for growing on concrete surfaces. Moreover, moss has several environmental benefits. Excellent at retaining moisture and by absorbing significant quantities of fine particulates, Moss can help improve air quality. It also encourages biodiversity by providing a habitat for small insects.

Figure 22: Moss and how it looks like.
Image Source: https://mossandstonegardens.com/blog/what-is-moss/

Moss naturally retains water, helping to reduce runoff during heavy rains. This can prevent urban flooding while also cooling surfaces through evaporation during hot weather, further mitigating climate extremes. *"Any surface covered in moss becomes a natural respiratory system for the city;*

holding up to 5 litres of water per square meter to keep buildings cool, and sequestering Co_2 from the air."[33]

Figure 23: Water Retention ability of Moss.
ImageSource:https://nl.linkedin.com/posts/respyrecompany_greensolutions-mossmagic-urbansustainability-activity-7272611111894450176-NfUI

Figure 24: Simulation of a vegetated facade at the Aeronautical Cultural Centre in El Prat de Llobregat, *Image Source: www.dezeen.com.*

Factors Affecting growth of Moss Concrete

A humid and moist environment with a porous surface that can absorb and retain water for a longer period is required to flourish the moss. A rough pored surface of concrete can provide a suitable substrate for the attachment and growth of moss spores.

"A study was conducted in 2018 in which different walling materials were compared for the growth of moss, and it was found that the more the porosity of a material, more will be the growth of moss".[34.]

It is interesting to note that Mosses can grow in any environment, from freezing snowy mountains to scorching hot deserts, and can survive in extreme conditions. "*Studies have shown that the lowest temperature they can photosynthesize (turn energy from sunlight into food) is around -15ºC and the highest is around 40ºC. Some mosses have even been known to survive temperature highs of 100ºC when dried out, and lows of -272ºC. That's a resilient little plant right there".*[35.]

Figure 25: Experimentation of Moss Growth in Concrete by Respyre, Netherland.
Image Source:https://www.linkedin.com/posts/respyrecompany_mossconcrete-urbanjungle-mosswall-activity-7112798362415820801-D_s8

Practical Applications of Moss Concrete

A living green wall in the interior or external facade can be created by using Moss concrete, where the growth of moss is supported by concrete. The water retention quality of this dense leaf system of mosses also helps in temperature regulation through evapotranspiration and the absorption quality can reduce the urban heat island effects and noise pollution and can be applied along highways, railways, and other noisy and highly air polluted urban areas.

Figure 26: Application of Moss Concrete. TU Delft Campus Building by Respyre.
ImageSource: https://www.brightvibes.com/the-power-of-moss-bio-receptive-concrete-can-help-cities-breathe-again/

Application of Moss Concrete around the World

Figure 27: Application of Moss Concrete at The Green Citer, Purmerend, Wheermolen-East
A renovation project that houses 144 units, BY Architects, 2023
Image Source: https://www.intermaris.nl/projecten/d-groene-citer/

Figure 28: Before the application of Moss Concrete. An Office cum Warehouse Building, Hoex Bouw and Schelfhout Belgium Carrelages - Tegels.
Image Source: Respyre's Post www.linkedin.com

Figure 29: After the application of Moss Concrete. An Office cum Warehouse Building, Hoex Bouw and Schelfhout Belgium Carrelages - Tegels.
Image Source: Respyre's Post www.linkedin.com

Figure 30: Application of Moss Concrete by Respyre, Netherlands.
Image Source: Respyre's Post www.linkedin.com

Figure 31: A living Wall using in the Interior of an Office Building.
Image Source: www.decon.in

Figure 32: A City Tree in Paris, France by Green City solutions
Image Source: www.cnn.com

Figure 33: A mossy "living wall", London's Piccadilly Circus. Green City Solutions
Image Source: www.dezeen.com

Conclusions

This research paper explores the potential of a relatively new construction material, **Moss Concrete,** as an innovative, sustainable solution, through its application globally, to help mitigate smog and air pollutants in buildings and infrastructure, especially in smog-prone areas. It is an economically viable solution which can turn gray concrete jungles into lush green landscapes to create healthier, eco-friendly urban environments for the generations to come.

In tropical climates like Karachi and Islamabad, where humidity and moisture levels are conducive to moss growth, this material can help provide both thermal regulation and environmental purification. Additionally, its natural insulation properties can make it an effective solution for maintaining ideal building temperatures by reducing energy costs for heating and cooling annually.

While the government is making efforts to address smog, more significant measures and public cooperation are needed. Architect's regulatory bodies like PCATP and IAP can arrange seminars and exhibitions to introduce this bio-receptive material among the fellow community and public. The building regulatory authorities like LDA, CDA, MDA, GDA, DHA and others can amend their byelaws for the integration of this material in the facades of high-rise public buildings, the way Singapore has incorporated the provisions of vertical gardens in their buildings. With its aesthetic appeal and eco-friendly qualities, Moss Concrete can become a popular and sustainable design choice as the world is shifting towards greener and eco-friendly more resilient urban habitats to increase diminishing local biodiversity, *a service nature is offering to society.*

Along with this, changes in other areas are also needed. To mitigate Smog, constructing anti-smog buildings is just not enough. It is also necessary to phase out vehicles and industries to hybrid sources of energy to reduce their emissions. Renewable energy is another resource. Wastes should be reduced, reused, recycled and filters should be installed at emission sources the way Zig Zag systems are adopted at brick kilns.

References

Britannica, T. Editors of Encyclopedia (2025, January 14). smog. Encyclopedia Britannica.

Usman, Muhammad. (2019). New Techniques for the Prevention Control of Smog and Air Pollution in Pakistan. Environment Pollution and Climate Change. 02. 10.4172/2573-458X.1000166.

Punjab Environment Protection Department. (2024). *CM Punjab smog mitigation plan 2024*. Punjab Environment Protection Department.

Hamza, A. (2024, November 08), The chilling smog of Lahore: a growing concern. The NEWS International.

Mari, B. (2021, December 07), Pakistan: How Lahore's smog is harming residents. Deutsche Welle.

Manzoor A. Dr., (2024, November 18). Smog's economic toll: why actions remain elusive? The Tribune Express.

Pitt, L. M. (2025, January 8). Los Angeles. Encyclopedia Britannica.

Mautner, C. Rincón (2025, January 4). Mexico City. Encyclopedia Britannica.

Britannica, T. Editors of Encyclopedia (2020, May 21). temperature inversion. Encyclopedia Britannica.

Duginski P. (2021, November 11) How a marine inversion over the L.A. Basin acted like a lid on a pot, trapping pollutants. Los Angeles Times.

Burgos-Cuevas, A., Adams, D.K., García-Franco, J.L. et al. A Seasonal Climatology of the Mexico City Atmospheric Boundary Layer. Boundary-Layer Meteorol **180**, 131–154 (2021).

Hua, S. (2022). The Correlation Between Temperature Inversion and Atmosphere Pollution in Beijing. Highlights in Science, Engineering and Technology, 25, 87-93.

Sher, E. (Ed.) (1998) Handbook of Air Pollution from Internal Combustion Engines: Pollutant Formation and Control. Academic Press, London

Jankowska M., Luta D., Koczwara M., Fraś-Zdeb A., (n.d.) Air pollution and weather – how do the weather condition causes smog? Airly.

WeatherSpark. (2025, January 25). Average weather at Lahore City, Pakistan year-round. WeatherSpark.

Zhu, D., & Zhou, X. (2019). Effect of urban water bodies on distribution characteristics of particulate matters and NO_2. Sustainable Cities and Society, 50, 101679.

U.S. Environmental Protection Agency. (1978). Altitude as a factor in air pollution (EPA/600/9-78/015)

Irshad M. (2024, November 16), Accessing Air Quality Trends and Impacts in Lahore, Pakistan,

Martinez, J. (2024, November 28). Great Smog of London. Encyclopedia Britannica.

Greater London Authority (2002, December) 50 years on The struggle for air quality in London since the great smog of December 1952, Greater London Authority.

Alam N. (2023, September 01), Clearing the skies: how Beijing tackled air pollution & what lies ahead.

(2023, August 28) China: National Air Quality Action Plan (2013), Airly

Wu T.L (2022, April 01), Air Pollution in Mexico City.

Kruger A. (2020, August 28), Let's Clear the Air: 5 Green Innovations Improving Air Quality in Mexico City.

Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G., Dewar, D., Huang, L., Inaba, A., Kansal, A., Lwasa, S., McMahon, J., Müller, D., Murakami, J., Nagendra, H., & Ramaswami, A. (2014). Human settlements, infrastructure and spatial planning. Cambridge University Press

Ksiazek, K. (2014). The potential of green roofs to support urban biodiversity. Green cities in the world, 101-124.

Guillitte, O. (1995). Bioreceptivity: a new concept for building ecology studies. Science of the total environment, 167(1-3), 215-220.

Cruz, M., & Beckett, R. (2016). Bioreceptive design: a novel approach to biodigital materiality. Architectural Research Quarterly, 20(1), 51–64.

Chalcraft E., (2013, January 3). Researchers Develop "Biological Concrete" for moss-covered walls. Dezeen Magazine.

Dharshini B., Vennila A., (2023), A Review on Moss Concrete, International Journal of Recent Advances in Multidisciplinary Topics, Volume 4, Issue 3

AMS Institute (n.d.) Bioreceptive concrete for liveable cities.

Asher H. (2023, July 22) The Marvels of Mosses: Their Ecological and Health Benefits, An Darach Forest Therapy,

https://www.linkedin.com/posts/hellotom_the-power-of-moss-bio-receptive-concrete-activity-7084219675936477184-6ypk

Awais, M., & Khattak, S. U. Exploring the Potential of Moss Concrete as an Eco-Friendly Solution to Mitigate Urban Heat Island Effect. 5th Conference on Sustainability in Civil Engineering (CSCE'23) Department of Civil Engineering Capital University of Science and Technology, Islamabad Pakistan

McHale E., (2020, May 03), 7 interesting things about moss.