Architecture Amidst Smog: In India

A dissertation

Submitted in partial fulfilment of the requirements of

the Ninth Semester Curriculum for the

Degree of Bachelor of Architecture of the

APJ Abdul Kalam Technological University

DISSERTATION

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Ar.Karthika Roshan ***Ar.Reena Mathew***
Guide ***Head of the department***

Valued by

External Examiner ***Internal Examiner***

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DECLARATION

I hereby declare that the Dissertation entitled "ARCHITECTURE AMIDST SMOG: IN INDIA" was carried out by me during the year 2021-2022 in partial fulfillment of the requirement for the award of the degree of Bachelor of Architecture of the APJ Abdul Kalam Technological University of Kerala. The dissertation is my effort and has not been submitted to any other University.

Kollam

January 2022 Daya Sara Daniel

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ABSTRACT

The study and analysis of ARCHITECTURE AMIDST SMOG: IN INDIA. In this study, We can see how smog impacts human life and activities, as well as the significance of design in smog reduction. This study mainly uses the Qualitative method. Different smog solutions like algal bioreactors, facade, dynamic responsive systems, etc are investigated and compared using various parameters. For this dissertation, types of smog and characters of PM 2.5 and PM 10 particles are studied. The role of architecture as spatialization and visualization were studied which gave a broader idea on the connection between architecture and human beings. The Indian scenario of smog was given priority and smog towers function and effectiveness were studied and analyzed. Each solution's effectiveness was examined through case studies, and suggestions for improvements were made. Varied solutions have different features and qualities that allow them to operate at various levels. The study's findings reveal the various strategic options available to India, as well as where these options can be implemented. Smog towers alone will not be sufficient to eliminate smog. The government should enact more laws and take more initiatives. Other solutions can be integrated into smog towers, or solutions can be modified to improve their performance. In India, more climate-based solutions are required.

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Chapter -1

SYNOPSIS

1.1 Introduction

Smog is a major health risk worldwide—outdoor Particulate Matter 2.5 and ozone pollution accounted for about 3 million and 0.5 million premature deaths. Corresponding numbers for India are 680,000 for outdoor pm2.5, 145,000 for outdoor ozone, and 480,000 for household pollution.

The Indian Supreme Court issued a notification in November 2019 requiring all states in the national capital region of Delhi (NCR) to erect pollution towers. These giant filtering systems are pursued as a control mechanism only in the absence of real action to control the emissions at different sources and control the continuous occurrence of high air pollution levels in Delhi and other major cities of India.

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1.2 Aim

To research, study and analyze different solutions and innovative technologies opted in different cities around the world and find the most effective one.

1.3 Objective

Study different sources of smog and types and their characteristic properties.

Study and analyze different architectural solutions to smog.

Comparison of different architectural solutions.

To investigate the various methods and policies implemented in various cities across the world.

Find an effective solution to India's smog.

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1.4 Methodology

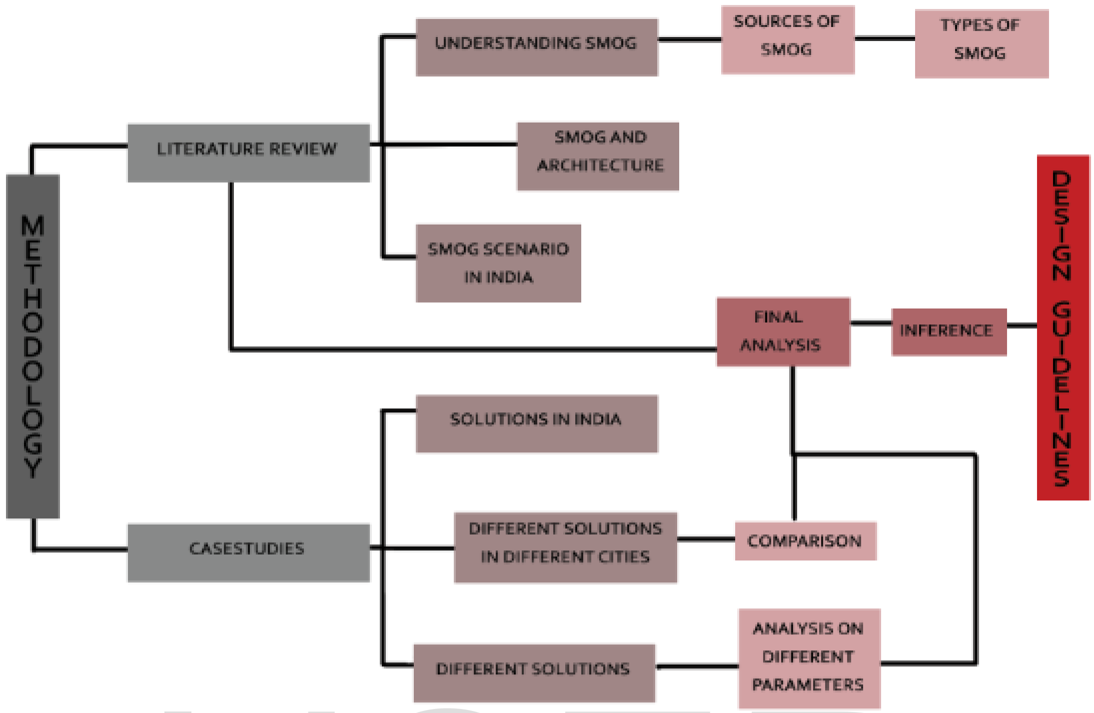

Chart 1 : Methodology

Source: Author

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1.5 Research Questions

1. Are smog towers effective?
2. What function does architecture have in reducing smog?
3. Is it possible to modify different present solutions to smog to create a better solution to India's smog?
4. How are indoor and outdoor smog solutions different?

1.6 Scope

Different strategies adopted by the government in other countries and their effectiveness.

Sources of smoke and solutions at the source. Based on the type of smog.

Solutions that have a direct impact on human social life and activities.

The impact of smog pollution on the region's flora and fauna.

1.7 Limitations

- Limitation in live case studies.
- The study focuses only on India.
- Lack of buildings in India that can be set as an example.
- Lack of data on new technological innovations.
- Number of laws, policies and strategies enforced in India is less.

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Chapter - 2

LITERATURE REVIEW

2.1 Smog

Smog, or smoke fog, is a type of intense air pollution. It is a yellowish or blackish fog formed mainly by a mixture of pollutants in the atmosphere which consists of fine particles and ground-level ozone.

Fig.1: Smog, Shanghai

Source: smog | National Geographic Society

2.2 Types Of Smog

Smog is classified into 2 types primarily - Photochemical smog and Sulfurous smog

2.2.1 Photochemical Smog

Photochemical smog is formed when UV radiation from the sun combines with nitrogen oxides in the atmosphere, resulting in smog. It is visible as a brown haze and occurs mainly in hot, densely populated cities in the morning and evening. It consists of gases like carbon oxides, nitrogen oxides, and hydrocarbons. It also forms a very noxious brown haze.

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Fig 2: Photochemical smog

Source: How Photochemical Smog is Formed - Prior Scientific

2.2.2 Sulfurous Smog

Industrial smog often exists in urban areas, where factories burn fossil fuels like coal, creating smoke and sulfur dioxide that mix with fog droplets to form a thick layer of haze near the ground. It's made up of a variety of dust that is high in sulfur, nitrogen, and carbon oxides, as well as soot.

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Fig 3: Sulfurous or Industrial Smog

Source: Energy Education

2.3 Particles In Smog

The particles of smog are classified into two: Coarse particles PM10 and Fine particles PM2.5.

Smog is made up of a variety of substances, including nitrogen oxides (NOx), sulfur dioxide (SOx), carbon monoxide (CO), and volatile organic compounds (VOCs), although particulate matter (PM) and ground-level ozone are the two main components (O3).

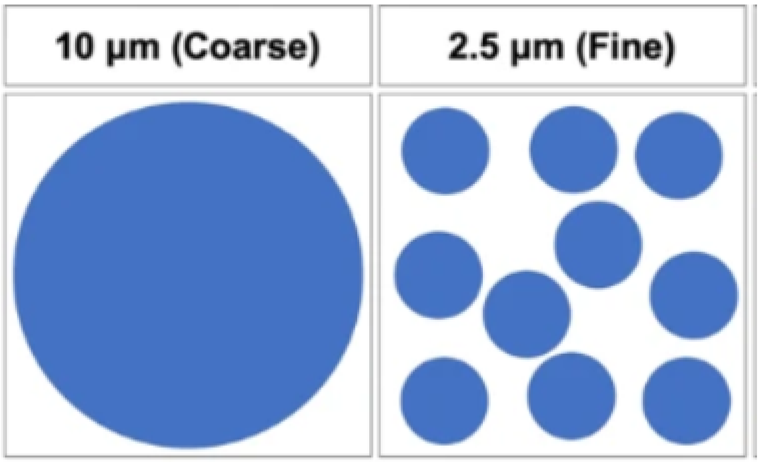

Fig 4: Coarse and Fine particle

Source: Ultrafine particles: unique physicochemical properties relevant to health and disease | Experimental & Molecular Medicine

2.3.1 Coarse Particles PM 10

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Coarse particles are the relatively large particles in the air that are mainly created by the mechanical breakdown of even larger solid particles. Dust, pollen, spores, fly ash, and plant and insect components are examples of coarse particles. Crushing and grinding rocks and soil produce these particles, which are then blown by the wind.

PM10 refers to any particle in the air with a diameter of 10 microns or smaller, such as smoke, dust, soot, salts, acids, and metals. Particulate matter can also arise indirectly when gases from vehicles and industries enter into chemical reactions. in the atmosphere.

2.3.2 Fine Particles PM 2.5

Fine dust (PM2.5) is an air pollutant that is harmful to human health at high air values. PM2.5 are tiny particles in the air that impair vision and make the air look cloudy at high concentrations. These contain toxic organic compounds, heavy metals from driving a car, burning plants (bush and forest fires or garden waste), melting (cleaning), and processing metals.

2.4 Sources Of Smog

Oxides of nitrogen, particularly nitrogen oxides and nitric oxides, are major pollutants that contribute to air pollution. They are released into the atmosphere by the combustion of fossil fuels from coal power plants, manufacturing emissions, and automobile exhaust. Halogen-containing chemicals such as chlorofluorocarbons are examples of less visible contaminants (CFCs). These are synthetic gases that are non-biodegradable and insoluble in water, therefore they cannot be washed away by rain.

Sources of smog are classified as Primary sources and Secondary sources:

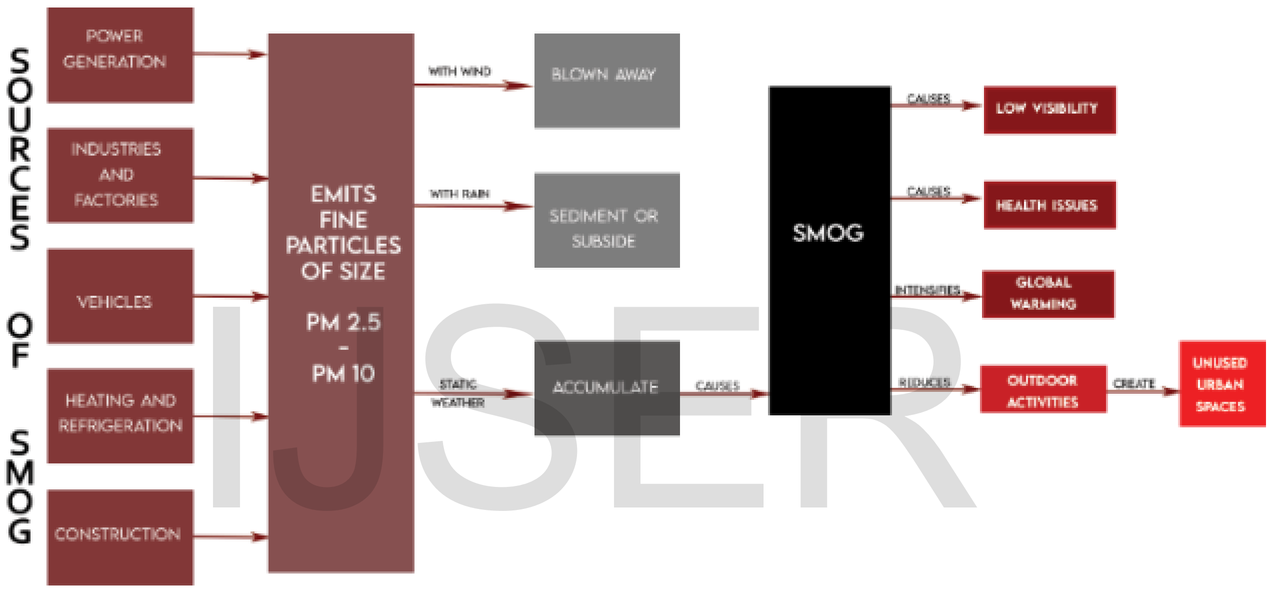

Chart 2: Sources of Smog

Source: Author

Reference: Sheng, Hui, "Architecture Amidst Smog" (2017). Architecture Thesis Prep. 35

2.4.1 Primary Source

Primary pollutants are the ones that contribute to smog formation and are emitted directly from the source.

2.4.1 Secondary Source

Secondary pollutants are formed in the atmosphere when main pollutants interact chemically with normal environmental circumstances.

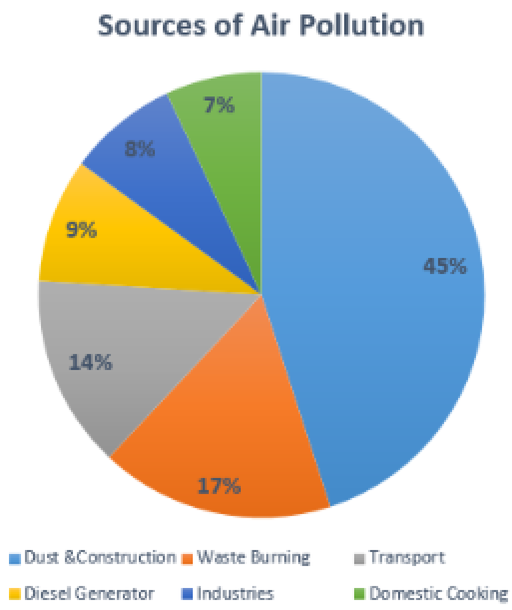

Chart 3: Sources of Smog

Source: Air Pollution - Stellar IAS Academy

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Chapter - 3

ARCHITECTURE AND SMOG

3.1 Architectural Relation With Public Spaces And Micro Climate

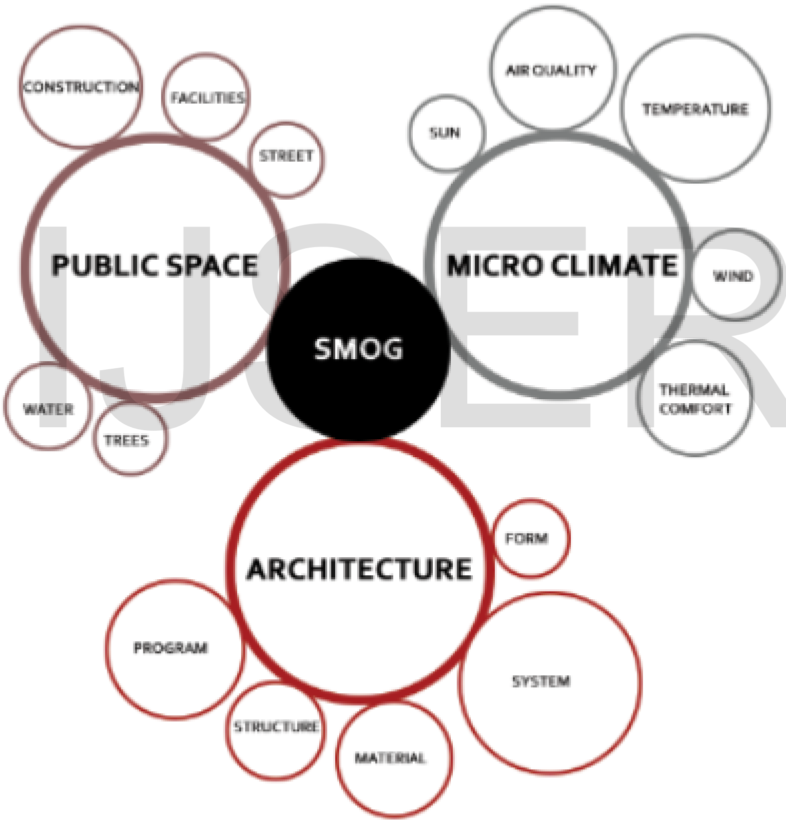

Fig 5 : Architecture and Smog

Source: Author

Reference: Sheng, Hui, "Architecture Amidst Smog" (2017). Architecture Thesis Prep. 35

3.2 Role Of Architecture

Architecture can contribute a lot to smog reduction 2 ways in which that is possible are:

1. Visualization
2. Spatialization

3.2.1 Visualisation

Visualization is a tool used by architects to interact with the public and explain projects, as well as a way to enhance awareness by reintroducing the concept into everyday life. Photo-realistic animation, live recordings, drone flights, schematic animations, hand drawings, and video interviews with other people are all examples of visualization.

3.2.1.1 R&Sie(n) B_mu Tower EXHIBIT

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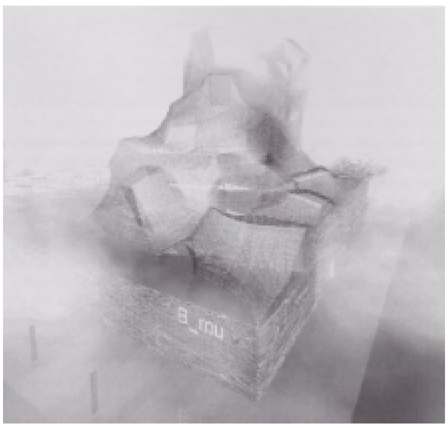
The goal of the project was to propose new ways of thinking about the relationship between architecture and the polluted air of city streets. It allows us to look at the city's pollution from a programmatic and formal standpoint.

Dirt and dust are attracted to the electrostatic skin. To keep the residents healthy, the exhaust filters the air, partially on the outside and more thoroughly on the inside.



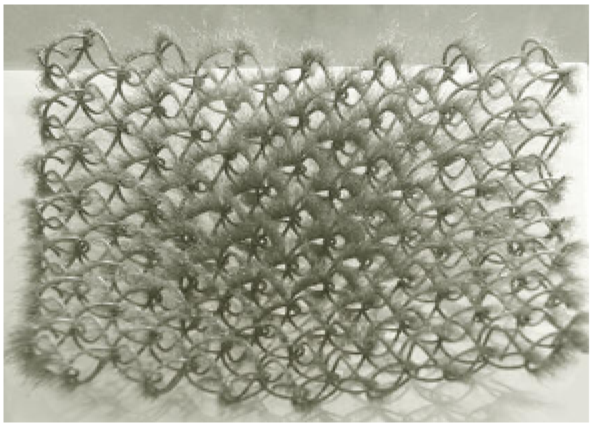


Fig 6,7: Electrostatic skin of BMU Tower Exhibit

Source: B_mu Tower | pzarch14

3.2.2 Spatialization

Information can be represented as a complicated design element thanks to spatialization. Give and create the meaning of scale, structure, and system in three dimensions to activate the room.

The use of visualization to bring a concept to life and add depth through spatialization gives architects the perspective they need to enter a completely new field.

3.2.2.1 Glass Smoking Rooms at the Airports

The spatial separation of rooms where smoking is allowed does not reduce fine pollutants being produced. Glass-enclosed rooms near the gathering spaces reduce the number of users.

"Smoking rooms in large urban airports, where smokers are collected into glass rooms and their enjoyment of tobacco becomes a suspect form of pleasure, a strange pause in spaces that emphasize movement."

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Fig 8: Glass Smoking room in USA Terminal

Source: [Should airports snuff out smoking rooms?]

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Chapter - 4

SOLUTIONS TO SMOG

4.1 Types Of Architectural Solution

Here, the architectural solutions to smog are classified into 6 categories :

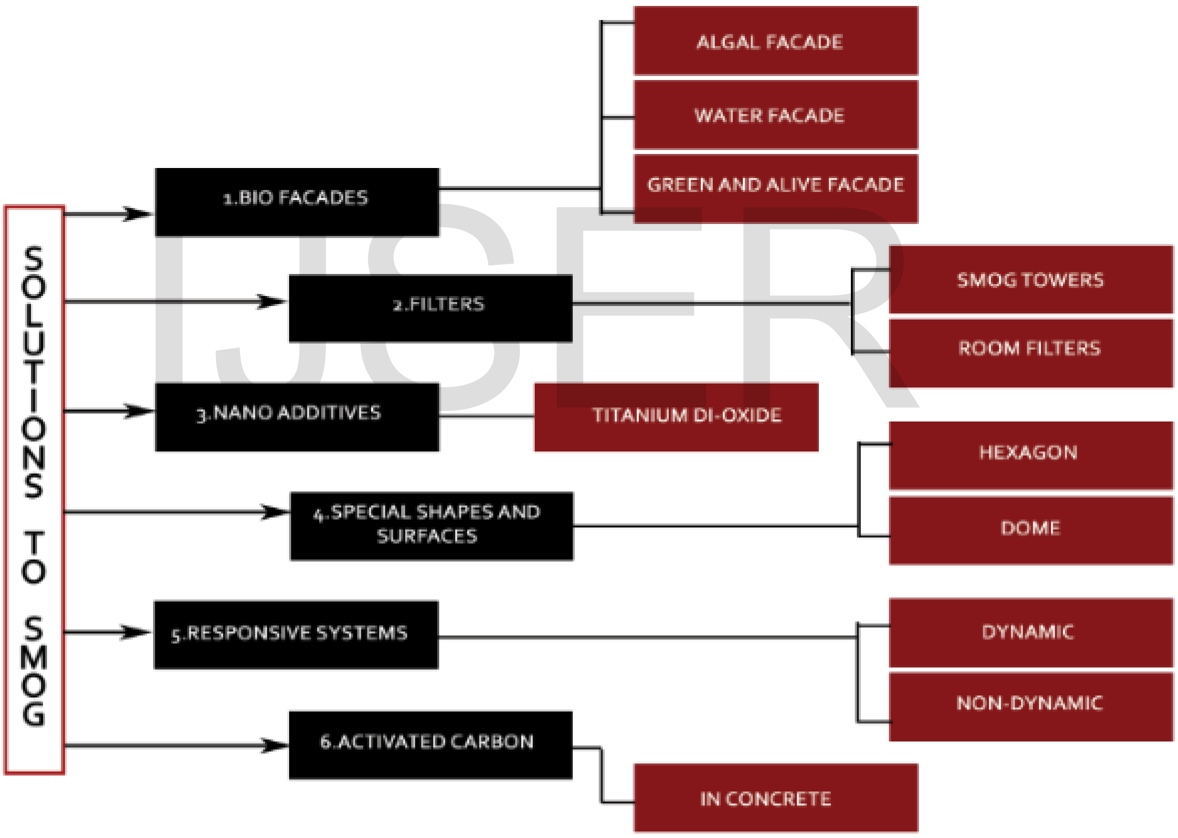

Chart 4: Architecture Solution to Smog

Source: Author

4.1.1 Bio Facades

Bio-facades are architectural features such as green walls, hanging gardens, green roofs, and pergolas that are used to create new or existing commercial, residential, and public buildings with tremendous imagination.

4.1.1.1 Algal Facades

As a result of algae photosynthesis, an algae facade is meant to improve interior air quality by producing O2 and absorbing CO2. Bio-facade-grown algae have the potential to be transformed into renewable fuel stocks like biomass or biofuel.

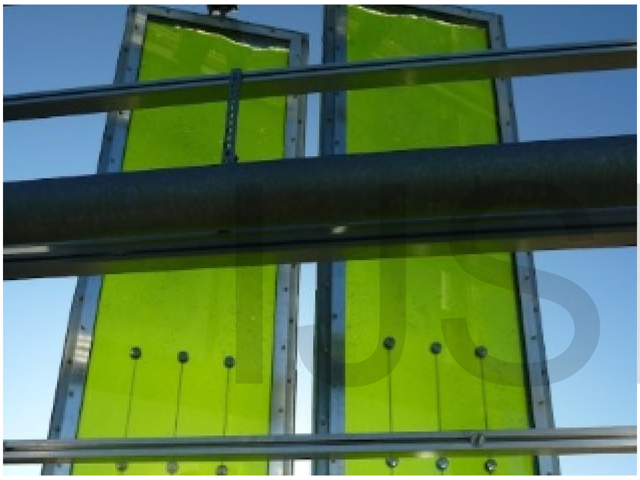

Fig 9: Algal facade

Source: Building Design + Construction

Fig 10: Algal facade

Source: ALGAE WORLD NEWS

4.1.1.1.1 Air Bubble, Poland By Ecologic Studio

It is located in Warsaw, Poland, one of the highest polluted cities in Europe. It is a children's play pavilion with 52 algal bioreactors that is 468 liters of living green chlorella sp. algae cultures. Throughout the day, the round design allows for optimal light collection from all angles. In addition, the inverted conical roof membrane encourages air recirculation. In 24 hours, the algae bioreactors can cover a 283-cubic-meter internal area. It has shown a weekly reduction in fine particles of 78.6 to 85.7 percent.

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Fig 11,12: AirBubble children pavilion

Source: Algae-filled AirBubble by EcoLogicStudio purifies the air as children play

4.1.1.2 Water Facades

Water increases the density of dust and fine particles thus forcing it to settle down. This mechanism is used in water facades to reduce smog. Water is sprayed, evaporated, made to pass through surfaces to collect particles along with it.

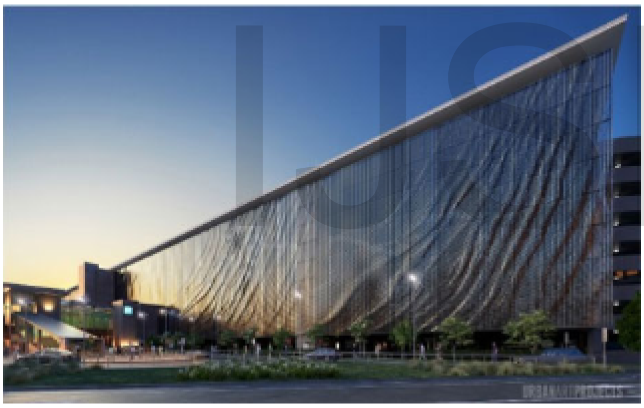

Fig 13: Water facade

Source: Web Urbanist

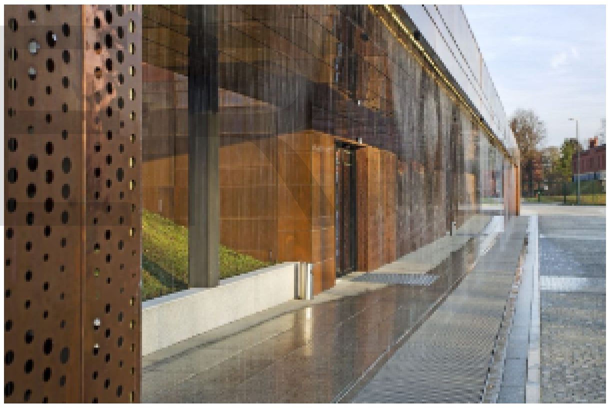

Fig 14:Water Facade

Source: Armadil Group

4.1.1.3 Green And Alive Facade.

Green roofs are a common nature-based solution that significantly reduces harmful substances in the air. Plants are effective in controlling the particles entering the building. Vertical forests or green facades absorb harmful gases and release them into simpler harmless components. It has shown about 20–40% lower pollution.

Fig 15,16: Green facade

Source: ArchDaily

4.1.1.4 Comparison

ALGAL FACADE	WATER FACADE	GREEN AND ALIVE FACDE
• NON –IDEAL IN HUMID AREAS AS IT INCREASES HUMIDITY	• COOLS OFF AIR	• HELPS IN IMPROVING MICRO CLIMATE
• INCREASING DEMAND IN THE MARKET AS INNOVATIVE TECHNOLOGIES ARE INCORPORATED	• IDEAL IN HOT AND DRY CLIMATE	• INCONSISTENCY
• NEED EXPERTS IN MAINTAINANCE AND REPAIR	• REQUIRES INSULATION	• EASY DAMAGE
	• NON COMPATIBLE WITH CLIMATE CHANGE	• PURIFY AIR
	• RAIN WATER MANAGEMENT POSSIBLE	• ATTRACTS INSECTS
	• IMPROVES INDOOR AIR QUALITY	• CAN CAUSE ALLERGIES IN SOME PEOPLE

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Table 1: Comparison of Bio facades

source: author

4.1.1.5 Analysis

Algal facades are ideal for dry and hot climates which helps in increasing the atmospheric humidity as well as reducing smog. Water facades are seen very less in the architectural buildings to reduce smog as it needs to come in direct contact with air to dissolve or settle down particles.Green facades are comparatively widely used in India as it is easier comparatively and the algal and water facade systems are unknown to many. Bio facades can be used as a combination of all three to create an ideal zone free from smog.

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4.1.2 Filters

These are mechanical equipment used to filter out fine particles, dust, etc from the air. These can reduce the smog in the air by filtering harmful substances from the air.

4.1.2.1 Smog Towers

Ionization is the most common method used by anti-smog towers. They take in dirty air from above and purify it before releasing it at the bottom.

4.1.2.1.1 Smog Free Tower By Daan Roosegaarde

It works by catching hazardous particles using ionization technology. It's a 7-meter-long, two-story aluminum structure. It is capable of filtering 30,000 m3 of air per hour. At a distance of 10 meters from the plant, the concentration of suspended dust was reduced by 12%. However, no improvement was observed within a 50-meter radius.

Fig 17: Smog free tower

Source:daan roosegaarde's smog-free tower brings clean air to Beijing

4.1.2.1.2 China Pollution Tower

It is a 100 m high structure that cleans 10 million m3 of air per day and covers an area of 10 km2. It draws air into greenhouses of about 3.5 thousand sq.m on its surface. It is filtered several times and, after being cleaned, is released.

Fig 18: Smog tower China

Source: [Beware China's 'anti-smog tower' and other plans to pull pollution from the air]

4.1.2.2 Room Filters

They are effective in removing particles from the air. To work efficiently to remove particles smaller than PM 2.5, two or more layers of different filters need to be set up. This is more effective indoors.

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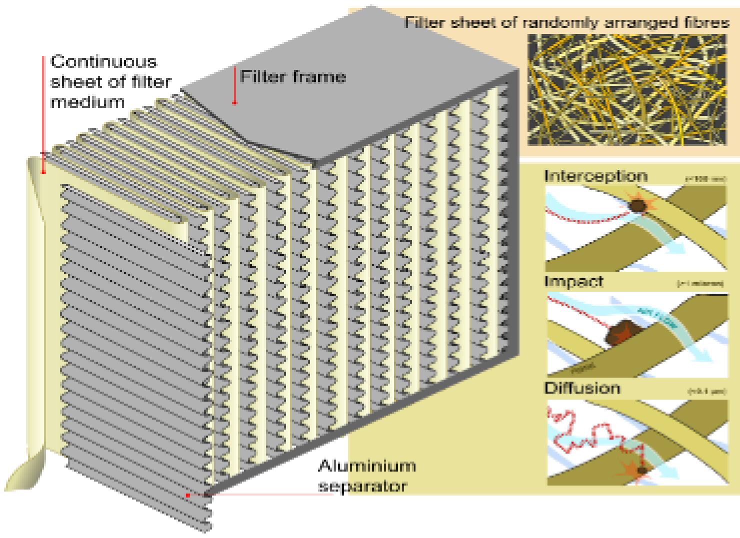

Fig 19: HEPA Room filter

Source: [HEPA - Wikipedia]

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4.1.2.3 Analysis

Smog towers are effective if used regarding the prevailing smog and other related factors.Room filters are very efficient when it comes to cleaning the indoor air (in the presence of HEPA filters)

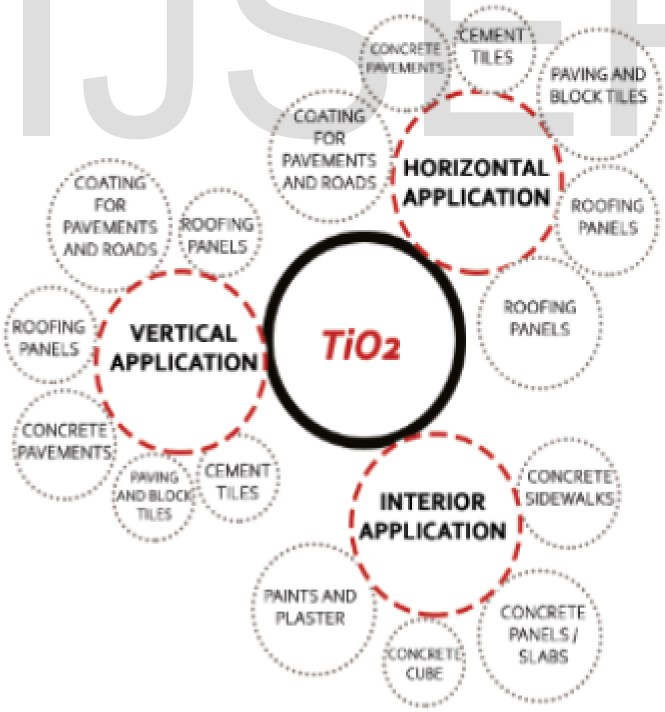
4.1.3 Nano Additives

Nanoparticles are substances with at least one dimension smaller than 100 nanometers. Nanoparticles can be utilized to modify the properties of a variety of materials. Nano-TiO2 is one of the most widely utilized nano additives.

4.1.3.1 Titanium Dioxide

Photocatalytic activity, hydrophilicity, and high UV absorption are all features of TiO2. TiO2's photocatalytic activity necessitates exposure to sunlight. To obtain the desired qualities, thin layers (coatings) of a few mm are adequate. VOCs (volatile organic compounds), microbes, and NO pollution can all be successfully decomposed by them.

Chart 5: Titanium Dioxide Applications



Source: author

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4.1.3.1.1 Solar Drop By Architect Vincent Callebaut

It's an elliptical construction atop abandoned railroad rails. It is made up of 250 square meters of solar photovoltaic panels that are coated in titanium dioxide (TiO2). It generates on-site electrical energy while also breaking down fine particles and reducing smog.

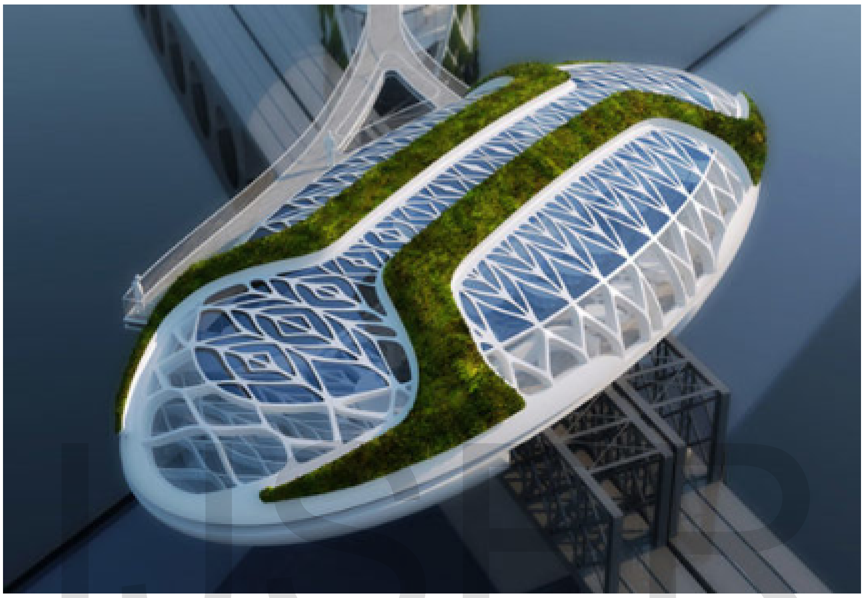

Fig 20: Solar drop

INHABITAT - Vincent Callebaut Architectures

4.1.3.1.2 Torre De Especialidades , Mexico City

Façade made of titanium oxide sucks up pollution with the titanium dioxide in the tiles.Photocatalytic concrete has titanium dioxide mixed in it . It is known as the tiocem in the market.

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Fig 21: Torre de Especialidades

Source : Torre de Especialidades | elegant embellishments | Archello

4.1.3.2 Analysis

Titanium dioxides are very effective in absorbing pollutants and converting them into non-harmful substances that come in contact with it.They are ideal to be used in paints and surface finishes

4.1.4 Special Shapes And Surfaces

Different shapes and surfaces have different surfaces and characteristics. Adding particular shapes and surfaces into a facade can increase area and more particles from the air can be absorbed

4.1.4.1 Hexagon

Hexagonal shapes have a larger surface area so while constructing a facade, hexagonal shapes can be adapted to create a honeycomb structure to treat more air.

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4.1.4.1.1 Honey Com Structures By Suzana Nunes

Porous materials are stable with a large surface area and can selectively extract materials. A flexible film with a complex structure that has Consistent patterns- interconnected, regularly shaped pores. This is a simple and fast method of developing selective filters . Materials used are from aerospace industry-valued strength to weight ratio

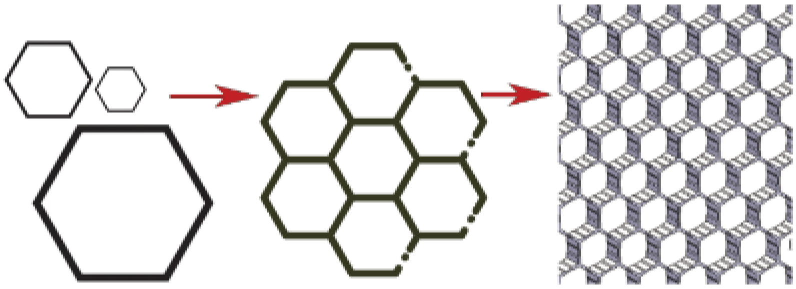

Fig 22: Honeycomb structure

Source: Author

Reference: Flexible, honey-comb like 3D material could clear air pollution: The Indian Express

4.1.4.2 Dome

4.1.4.2.1 Dome Over Manhattan By Buckminster Fuller

A proposal was made to enclose Manhattan in a glass bubble. Wire-reinforced, one-way vision, shatterproof glass, mist-plated with aluminum to prevent sun glare while admitting light, would make up its skin. It would have a large sparkling hemispheric mirror on the exterior and a translucent film on the interior that would show the sky, clouds, and stars. The temperature of the dome as a whole would be controlled at a comfortable level.

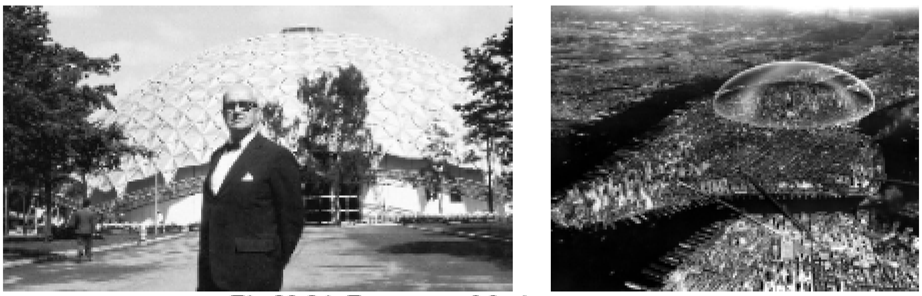

Fig 23,24: Dome over Manhattan

Source: How Buckminster Fuller Made A Dome Over Manhattan Sound Sensible

4.1.4.3 Analysis

They are efficient while considering form but as a smog solution, they are not very applicable Efficient use with new technologies can create something new and innovative

4.1.5 Responsive Systems

Buildings with responsive systems can modify their form, shape, color, or character in response to changing environmental conditions.

4.1.5.1 Dynamic Responsive Systems

Atmospheric and electrical phenomena-saturated architectural systems.

4.1.5.1.1 Super Galaxy By Jason Johnson And Nataly Gallero

It shifts between states of varied coherence (solidity, fluidity, and gaseousness), and its inner structure follows a discernible pattern. On many levels, a responsive system that actively interacts with its surroundings. It is in a condition of constant mobility.

It calibrates and recalibrates both global and local information in real-time (weather, pollution, conflict, etc). (desired micro-climates, heat exchange, light, and sound).

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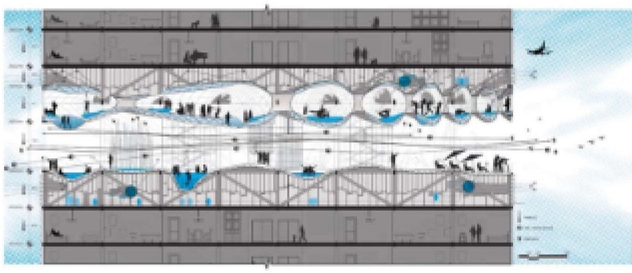

Fig 25,26: Super Galaxy

Source:Super Galaxy — Future Cities Lab

4.1.5.2 Non-Dynamic Responsive Systems

Architectural systems are static but respond to the surrounding database using static functions and materials.

4.1.5.3 Analysis

They are not so easily applicable in small-scale buildings and structures.They are sophisticated and need robotics and other technologies to function

4.1.6 Activated Carbon

4.1.6.1 In Concrete

Research is being conducted in Poland and worldwide on the effectiveness of concrete with activated carbon in absorbing and cleaning the air of NOx oxides. Activated charcoal is an adsorbent of NOx compounds. It shows significant chemical affinity to nitrogen oxides in terms of adsorption and reactivity. The material's large specific surface area per unit mass accounts for its high absorbent capacity.

4.1.6.2 Analysis

Activated carbon is an economical and efficient material in reacting with pollutants and making it simpler. The addition of this into concrete is beneficial in reducing smog and reducing lead from vehicles

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Chapter - 5

CITIES AND SMOG

5.1 Introduction

Around the world, more than 90 percent of people breathe in air that the World Health Organization (WHO) considers potentially harmful. Many urban areas are beginning to implement ultra-low emissions zones to ban cars

5.2 Cities Strategies And Policies

The Cities studied here are :

1. New York United States Of America
2. Bogota, Colombia
3. Accra, Ghana
4. Paris, France
5. Seoul, Republic Of Korea

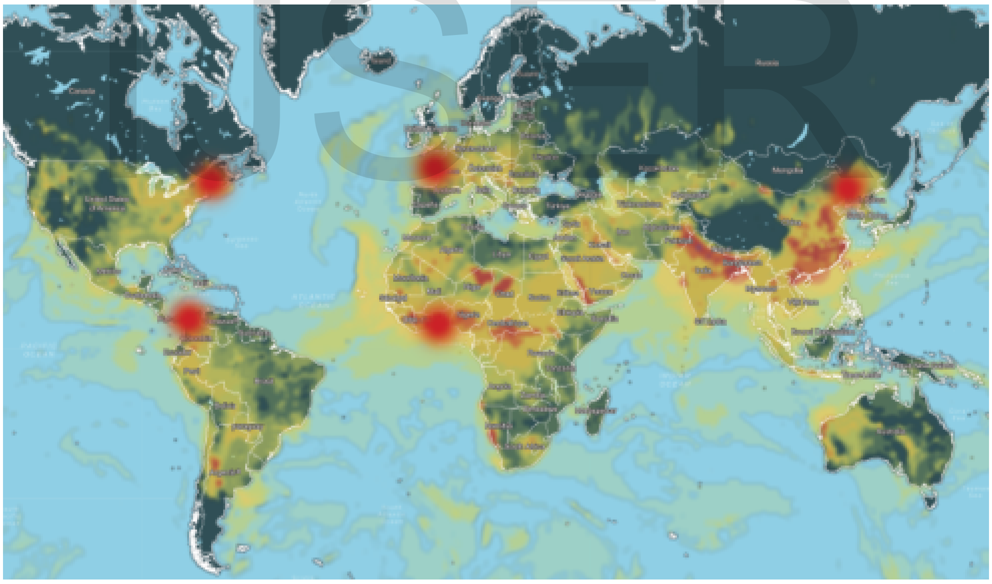

Fig 27: Cities Studied

Source: Author

Reference: Super Galaxy — Future Cities Lab

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	NEWYORK, UNITED STATES OF AMERICA	BOGOTA, COLOMBIA	ACCRA, GHANA	PARIS, FRANCE	SEOUL, REPUBLIC OF KOREA
TRANSPORTATION	• ADDED MORE PUBLIC TRANSPORTATION FACILITIES • BANNED CARS THAT TESTED HIGH ON POLLUTION STANDARDS • PRICE FOR CONGESION	• SWITCHED MORE TO BICYCLES • CAR-POOLING WAS PROMOTED • ADDED MORE PUBLIC TRANSPORTATION FACILITIES • IMPOSE STRICT EMISSIONS STANDARDS ON TRUCKS AND OTHER HEAVY- POLLUTING VEHICLES • FULLY ELECTRIC METRO RAIL SYSTEM	• ADDED MORE PUBLIC TRANSPORTATION AND INTRODUCED TO MORE AREAS • RESTRICTIONS ON THE MOST POLLUTING CARS ENTERING CITY CENTERS REMOVES VEHICLES WHICH DO NOT MEET EMISSIONS STANDARDS	• FREE PUBLIC TRANSPORT IN MANY PARTS OF THE CITY • RESTRICTIONS ON THE MOST POLLUTING CARS ENTERING CITY CENTERS • FORCE MOTORISTS TO DISPLAY COLOR-CODED AIR-QUALITY CERTIFICATES TIED TO EMISSIONS LEVELS ON THEIR VEHICLES	• MAKE SUSTAINABLE MODES OF TRANSPORT, SUCH AS WALKING, BIKING, AND PUBLIC TRANSPORTATION, ACCOUNT FOR 80 PER CENT OF TRIPS. • RECLAIMED ROADS FOR TREES AND NATURE
FUEL	• FUEL EMISION STANDARDS ON 1970 • LEAD REMOVED FROM GASOLINE • DIESAL REDUCTION STANDARDS AT PORT	• PROVISION FOR LEAD FREE FUEL • SWITCHED PUBLIC TRANSPORT TO ELECTRIC	• PROVISION FOR LEAD FREE FUEL	• REPLACE GASOLINE WITH DIESAL IN TAXIS AND PRIVATE VEHICLES • SWITCHED TO ELECTRIC PUBLIC TRANSPORT	• MORE ELECTRIC VEHICLES INTRODUCED
COOKING GAS	• NEW MIXED FUEL FOR HOME USE IS BEING PROVIDED TO ENSURE LOW NITROXIDE EMISSIONS	• A REASONABLE INTERIM TARGET IS TO CONVERT HALF OF THE HOUSEHOLDS BURNING SOLID FUEL TO IMPROVED STOVES WITH A CHIMNEY	• TURNING WASTE TO COOKING GAS • INIATIVE TO STOP LPG USAGE COMPLETELY	• REDUCE USAGE OF LPG AND LNG SHIFT TO ALTERNATIVE RENEWABLE SOLUTIONS	• SHUTTING DOWN COAL POWERED STATIONS • SHIFTING TO ELECTRIC HEATING AMECHANISMS

Table 2 : Cities and Strategies

Source: Author

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	NEWYORK ,UNITED STATES OF AMERICA	BOGOTA , COLOMBIA	ACCRA , GHANA	PARIS, FRANCE	SEOUL , REPUBLIC OF KOREA
URBAN SCENARIO	• Turning the city to urban forest	• Adding cycling infrastructure along with urban green land	------------------	• Banished cars from the Seine River quayside and reclaimed road space for trees and pedestrians	• Wind path forest" in Seoul, planting trees close together along rivers and roads to channel air into the city centre.
DOMESTIC WASTE BURNING	• Backyard waste burning prohibited in most areas • Campfire more than 3 ft not allowed	• Waste incineration facilities are provided	• Simple enforcement of existing laws, should be able to stop burning waste openly inside their own premises	• Limit indoor heating and avoid lighting wood fires and burning green waste in the open air.	• Domestic Municipal Solid Wastes in a Metropolitan Area of Korea is collected and treated
AIR QUALITY MONITORING	• New York State's ambient air toxics monitoring program was first established in 1985	• Air quality inex is shown on road side and in other areas to bring awareness to people .	• Ghana regularly issue air quality alerts to inform the public and sensitive populations about pollution levels in Ghana.	• Special air quality monitoring sensors are provided	• 5G enabled autonomous robots scan industrial complexes to monitor air quality, while a satellite monitoring system offers real-time air quality data to the public.
OTHER	• Fireworks and crackers are not allowed	• Spraying water on roads	• Mud roads are being paved to reduce dust in air	• Implementing low emission zones	• Factories being shut down which emit more pollutants into the air

Table 3 : Cities and Strategies (continuation)

Source: Author

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Chapter-6

SCENARIO IN INDIA

6.1 Introduction

In 2019, India had 21 of the world's 30 most polluted cities. According to a study based on 2016 statistics, at least 140 million people in India breathe air that is 10 times or more polluted than the WHO acceptable limit, and India is home to 13 of the world's 20 cities with the highest annual air pollution levels.

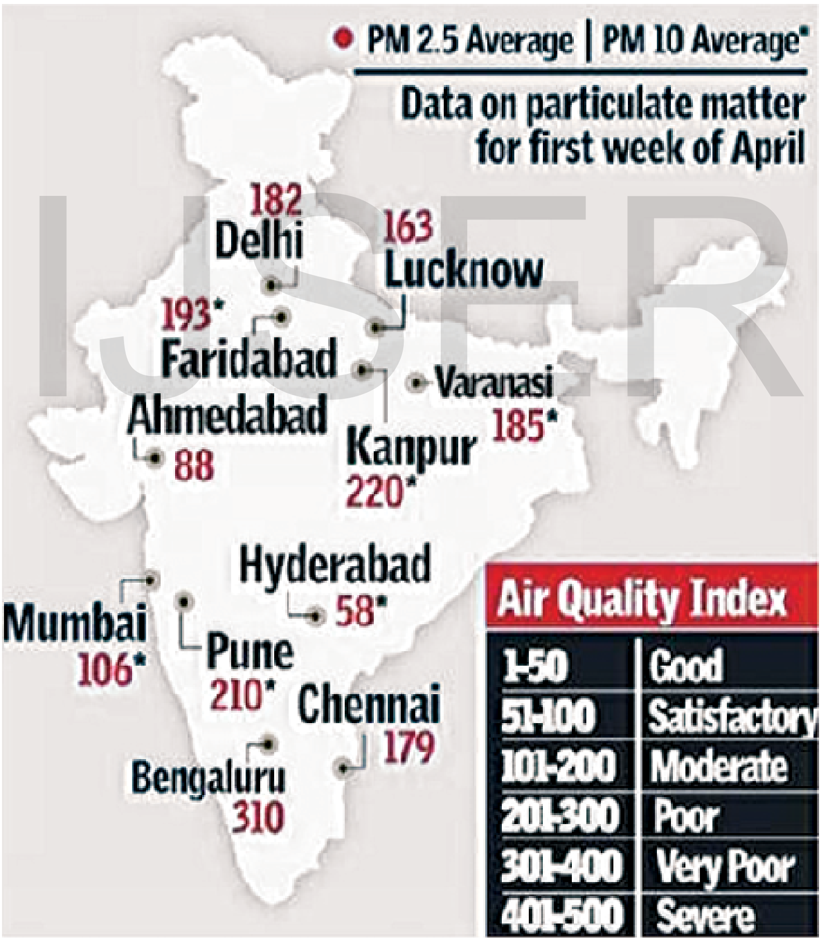

Fig 28: India's polluted cities (2019)

Source: Map Showing Air Quality Index of The Important Cities in India as of Nov 03, 2019 – Live Blog | Maps of India

6.2 Smog Over The Years

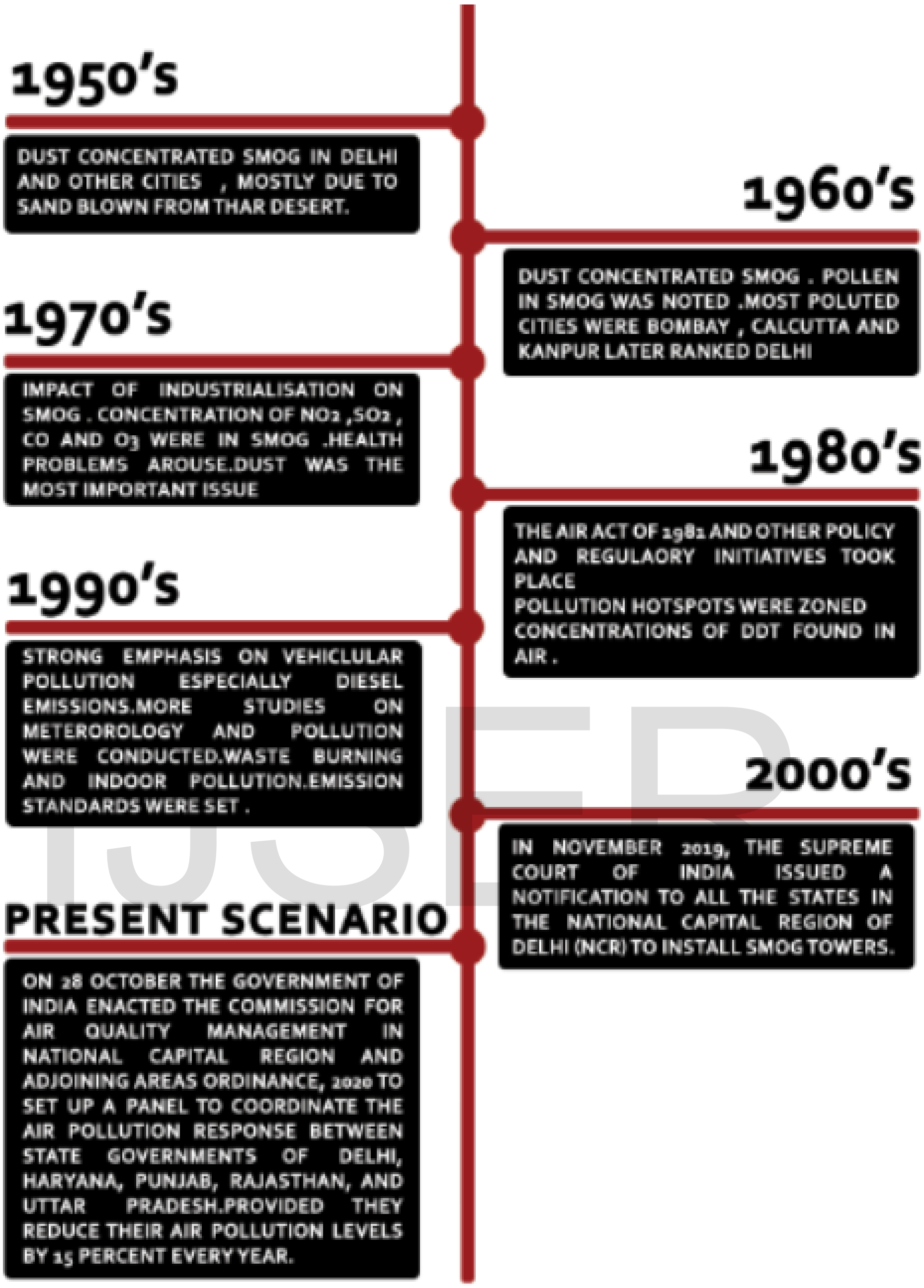

Chart 6 : India's pollution history

Source: Author

Reference: [How Delhi's fight against air pollution could get a boost if science was decolonized]

6.3 Present Scenario

India is ranked No.1 as the most smog polluted country in the world.

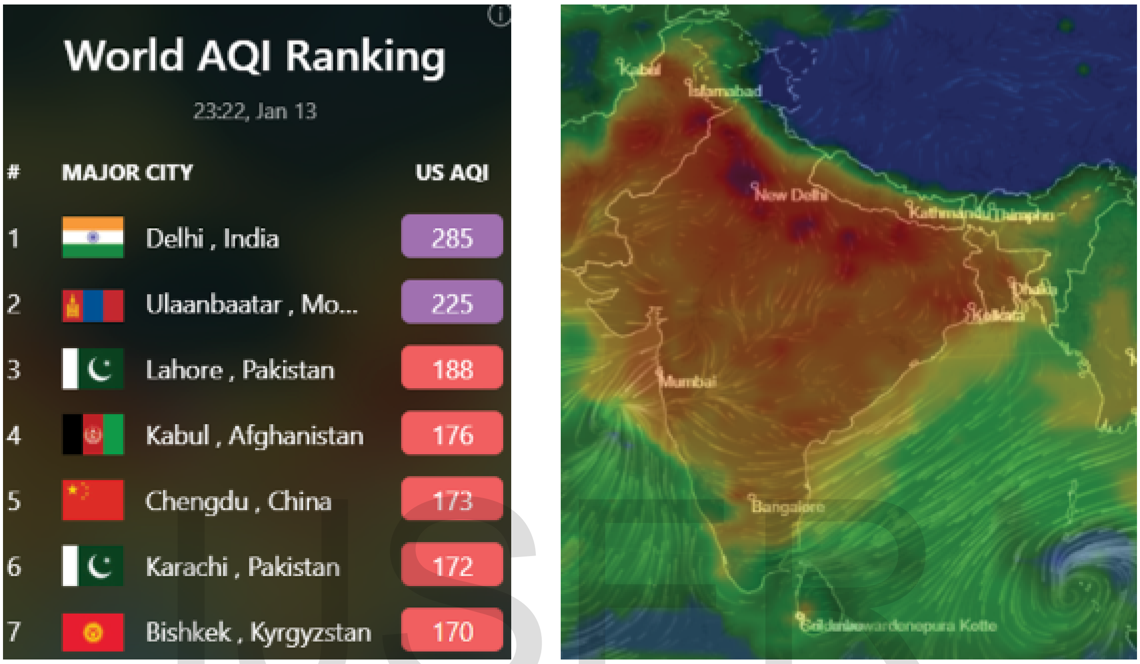

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Fig 29,30: India's pollution (Present)

Source: [World Live Air Quality Map | AirVisual]

6.3.1 Pollutants

Most pollutants seen in India's air are Nitrogen oxide, Sulfur dioxide, PM2.5 Particles, PM10 particles, dust, ozone, Carbon Monoxide, Ammonia, and Lead.

6.4 Solutions In India

6.4.1 The Smog Project By Znera Space

The project was created with a hexagonal grid that follows the urban grid of Lutyens Delhi . It has a 100-meter tower placed at the main city nodes. Semi-clean air is provided within two kilometers.Connected by sky bridges built with Hydrogen Generating Cells to power the towers. Specifically designed to remove smog and pollutants from the air, the project uses a filter capsule at the base and air propellers at the top. To catch airborne particles, inlet streams at the foot of a tower take in air and filter it through five stages of filtration, including carbon-activated charcoal, negative ion generators, and electrostatically charged plasma. Before being discharged into the atmosphere, the air is propelled upwards and passed through a photocatalytic filter to eliminate bacteria and viruses. Each day, the towers would produce 3.2 million cubic meters of clean air.

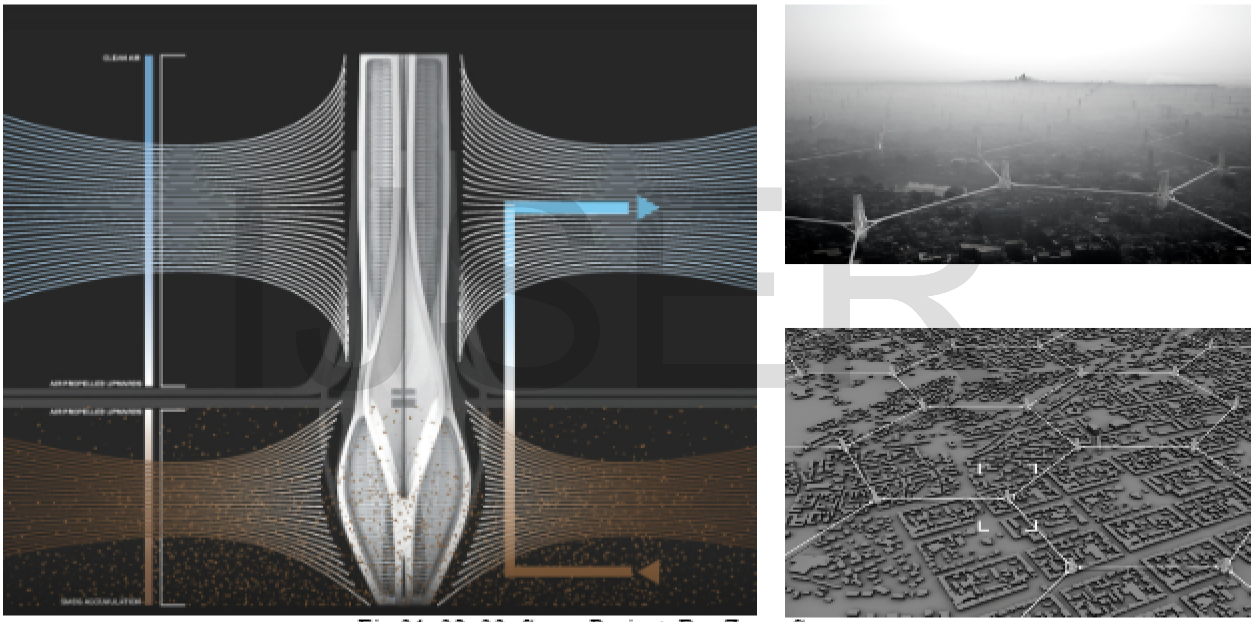

Fig 31, 32, 33: Smog Project By Znera Space

Source: [ZNERA Proposes a Network of Smog Filtering Towers To Pollution | ArchDaily]

6.4.2 M: Ofa Air-Filtering Green Office

"Urban sponge" – soaking up pollution and spitting back out clean air and water. The building shell, which is made of foam concrete, has hollow walls lined with bentonite clay to filter pollutants from the microclimate. The air quality will be improved and shade will be provided by vertical green walls and terrace gardens. The air will be cleaned even further by mechanical filters on the roof.

Fig 34, 35 :M: OFA Air-Filtering Green Office

Source: M: OFA Unveils Air-Filtering Green Office for the Delhi Pollution Control Committee

6.4.3 Pollution-Absorbing Towers By Symbiosis Studio

60 m high towers

Clean a 2.5-square-kilometer region and operate inside a 900-meter radius. They must be erected along the city's perimeter.

Fig 36: 60 m high pollution absorbing tower

Source: Studio Symbiosis proposes green, air-purifying towers for polluted Delhi

18 m high towers

30 million cubic meters of clean air. Each tower will have flora covering 60–70% of its surface area, reducing hazardous compounds even more. These will need to be deployed across New Delhi.

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Fig 37: 18 m high pollution absorbing tower

Source: [Studio Symbiosis proposes green, air-purifying towers for polluted Delhi]

6.4.4 Smog Free Towers In India

It's a 24-meter-tall tower with fans and air filters that pull filthy air in from the top and release cleaned air towards the ground via fans on the sides. It includes 40 large fans as well as 5,000 filters. There has been a 90% reduction in PM particles. It has a range of 1 kilometre and a release rate of 1000 square meters per second. During the monsoon, the biggest drawback is fungus development in the filters.

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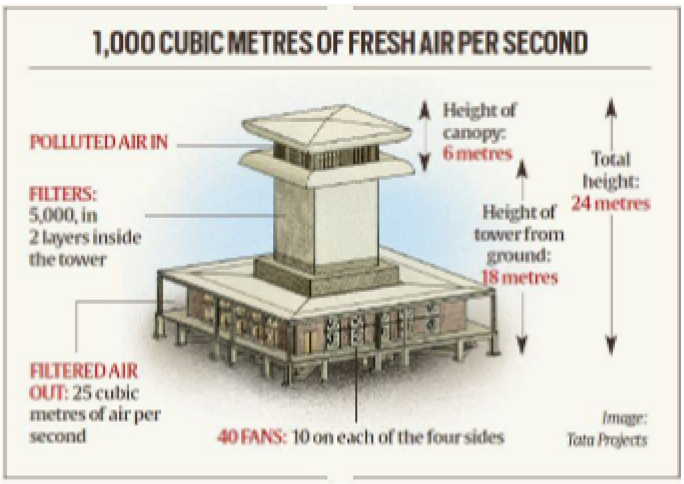

Fig 38, 39: Smog free towers India

Source: [Delhi's new smog tower: The technology, the impact, the evidence | The Indian Express]

Chapter - 7

INFERENCE

7.1 Area Covered And Effectiveness

Different solutions to smog were studied and a chart was drawn based on the area each solution covered. Some of the solutions are suitable for indoors while others are suited for outdoor likewise, the capacity to clean surrounding air is different. This is usually based on the volume of air it can take in and its effectiveness. some can clean air completely while Others semi clean the air.

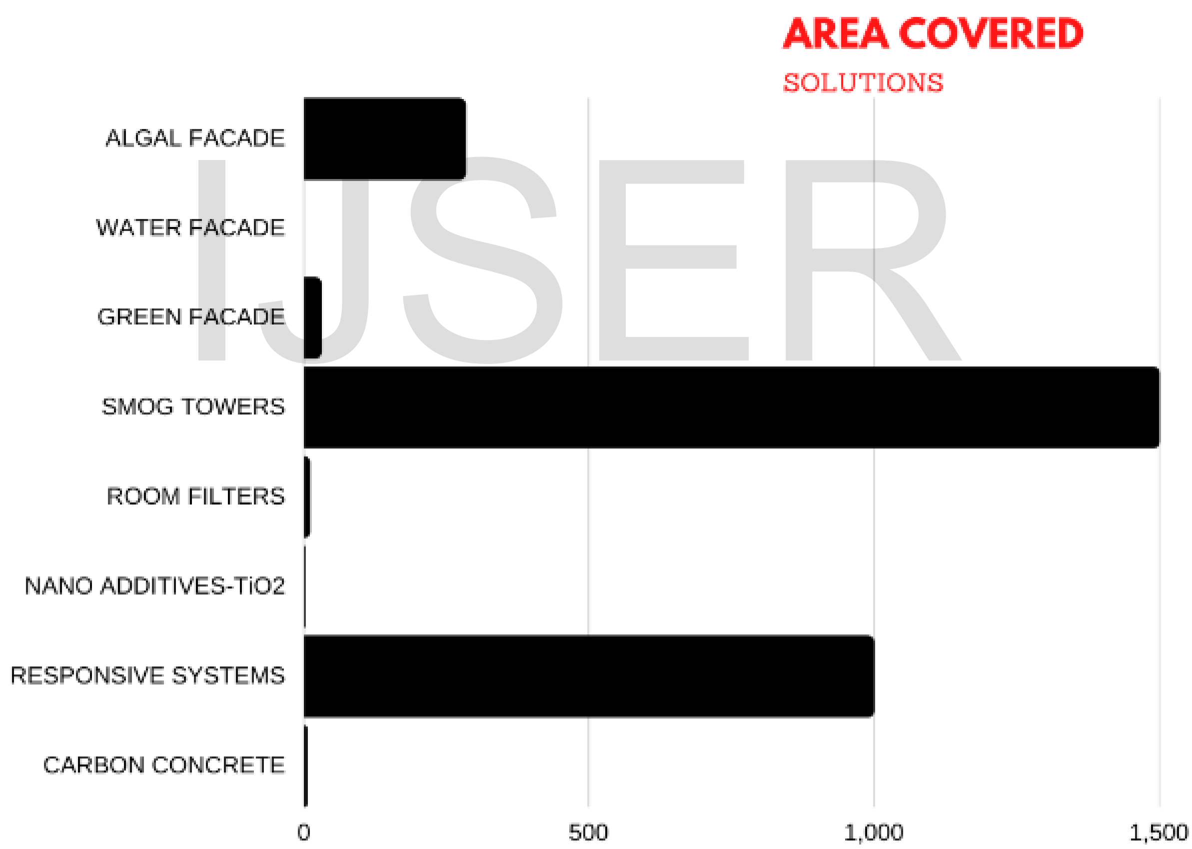

Chart 7: Solution and the area it covers
Source: Author

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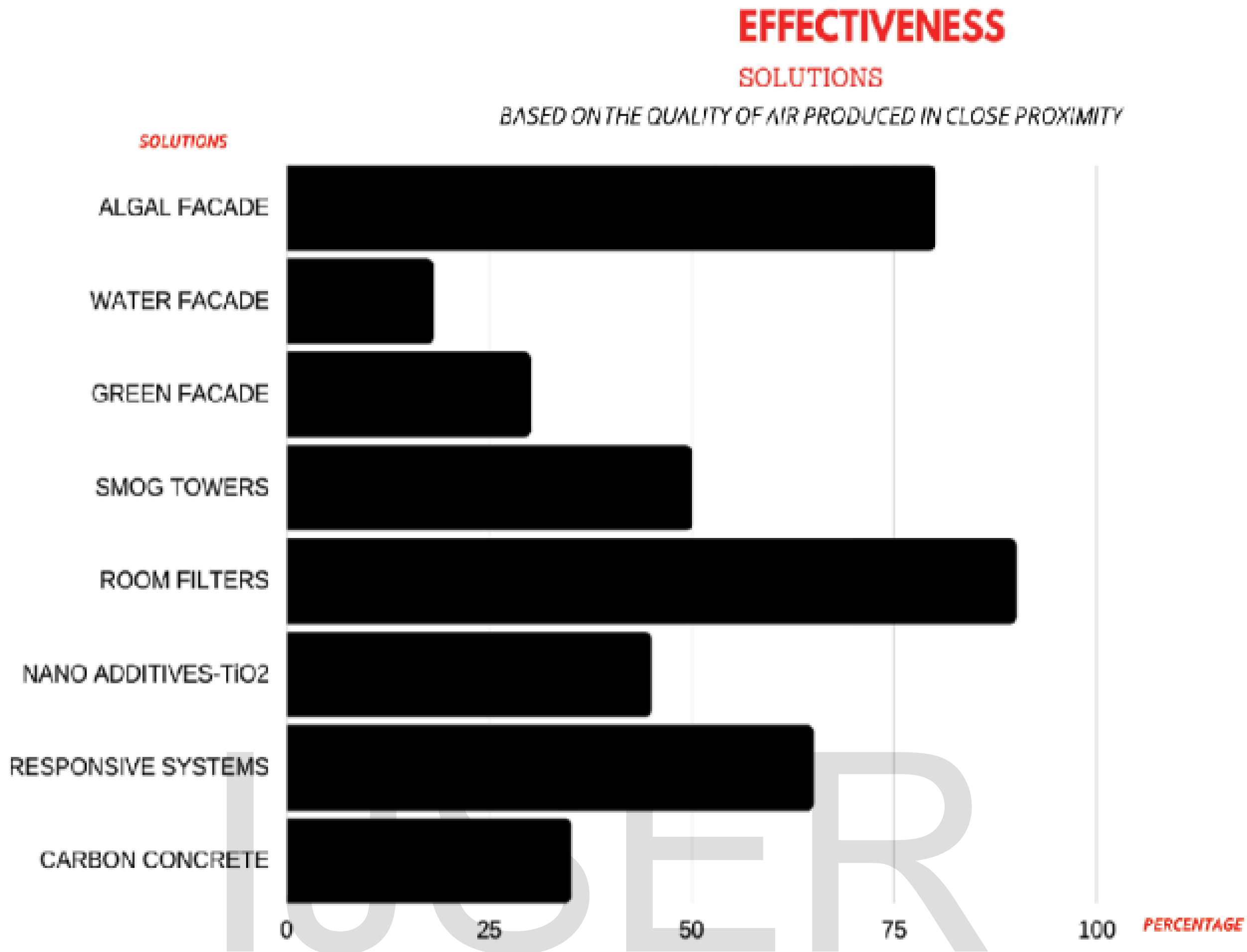

Chart 8: Solution and its effectiveness by the quality of air purifying
Source: Author

Smog tower covers the most area

Smog tower covers the most area.

Smog towers are effective up to 55% and are effective if additional features and mechanisms are incorporated.

Room filters and algal filters are the most effective

Room filters and algal filters clean air more efficiently. Room filters are best if HEPA filters are incorporated but can only be used indoors.

Algal filters in facade systems are economical and sustainable at the same time and can be used indoors and outdoors.

In a country like India, the most opted solution is smog towers.

This is because of the efficiency it has in cleaning the outdoor air partially or completely. The smog towers in India focus on cleaning the air above 7 meters.

In India, the harvest wastes are burned raw in Haryana and Punjab resulting in huge amounts of smoke rushing through the winds and settling in the provinces of Delhi's atmosphere.

Therefore, most smog tends to stay at a height above 7 meters. In India's smog dust and denser particles are also found resulting from the sand from the Thar desert and harmful particles like lead and other particles. So, to treat this, smog towers need to be placed in a way that cleans air below 7 meters. Most of the activity occurs below 7 meters - where people breathe and walk around, this is also important. So, in order to reduce this more low-rise solutions need to be adapted.

7.2 Indoor Outdoor And Simultaneous Solutions

SOLUTIONS	INDOOR	OUTDOOR	SIMULTANEOUSLY INDOOR AND OUTDOOR
ALGAL FACADE	✓	✗	✗
WATER FACADE	✓	✓	✓
GREEN FACADE	✓	✓	✓
SMOG TOWERS	✗	✓	✗
ROOM FILTERS	✓	✗	✗
TITANIUM DIOXIDE	✓	✓	✗
DYNAMIC SYSTEM	✓	✓	✓
NON-DYNAMIC SYSTEM	✓	✓	✓
ACTIVATED CARBON CONCRETE	✓	✓	✗

INFERENCE : THERE IS A LOT OF POSSIBILITIES IN MODIFYING THE PRESENT SOLUTIONS TO SMOG .MANY OF THESE SOLUTIONS CAN BE USED SIMULTANEOUSLY TO TREAT INDOOR AND OUTDOOR AIR

Table 4: Solution - INDOOR , OUTDOOR AND SIMULTANEOUS USAGE
Source: Author

Inference: There are a lot of possibilities in modifying the present solutions to smog. Many of these solutions can be used simultaneously to treat indoor and outdoor air.

7.3 Best Suited Solutions

	INDUSTRIES	COMMUNITY SPACES	PUBLIC OPEN SPACES	INDIVIDUAL BUILDINGS	MEGA STRUCTURES	ROADWAYS	INDOOR SPACES
ALGAL FACADE		✓		✓			✓
WATER FACADE		✓	✓			✓	
GREEN FACADE			✓	✓		✓	
SMOG TOWERS	✓	✓	✓				
ROOM FILTERS							✓
TITANIUM DIOXIDE		✓		✓			✓
HEXAGONAL SHAPE	✓			✓	✓		
DOME SURFACE		✓	✓		✓		✓
DYNAMIC RESPONSIVE SYSTEM	✓	✓			✓		✓
NON-DYNAMIC RESPONSIVE SYSTEM		✓			✓		✓
ACTIVATED CARBON CONCRETE				✓		✓	

Table 5 : Suitable solutions

Source: Author

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7.4 Ideal Solutions

In the flowchart below the ideal solution to clean outdoor and indoor spaces are shown :

Chart 9 : Ideal Solutions
Source : Author

Chapter - 8

DESIGN GUIDELINES AND RECOMMENDATIONS

Heavier Particles in the air tend to stay near the ground level as they are denser. They can be treated easily compared to fine particles which are less dense. Most of these heavier particles settle down by the wind, rain, or any other factors. SMog is a result when the particle is static and combines with smog. This can be treated with simpler techniques. In India, emphasis on particles below 7m is not treated properly. The guidelines and recommendations below suggest a few solutions to smog.

8.1 Design Guidelines 1: **Smog Towers With Algal Bioreactors**

Smog towers should be able to eliminate both fiber and denser particles. If this cannot be effectively implemented simultaneously, new modifications in the system can be used. Above 7 meters regular smog towers based on ionization or vacuum can be used while below 7 meters, bioreactors like the algal bioreactors can be incorporated which allows more clean air near the ground level where most activities occur.

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This bioreactor tower in the lower levels can be further modified into an activity area like an indoor play area, parks, or gathering space. They can minimize space wastage at the same time add more interaction into the entire structure and surroundings. This modification can help in cleaning both fine and coarse particles. This can be considered as an area providing clean air as well as bringing more social connectivity which was once lost due to smog.

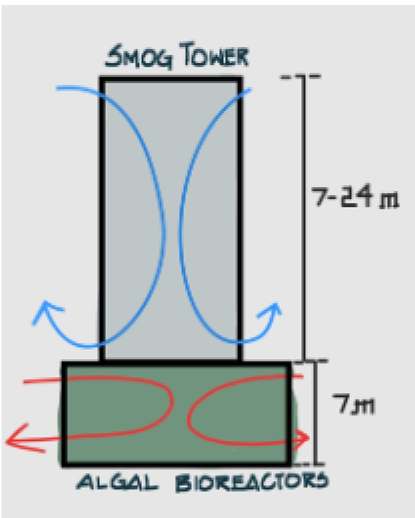

Fig 40: Incorporating bioreactor to smog tower

Source: Author

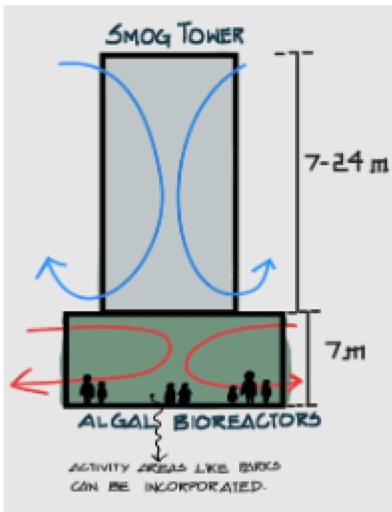

Fig 41: Incorporating activity spaces

Source: Author

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8.2 Design Guidelines 2: **Indoor - Outdoor Green Facade**

A green facade can be used to reduce pollutants from the air. This can be done more effectively by having them on both walls i.e. indoor and outdoor which allows more blockage of coarse particles while plants absorb finer pollutants and release some into less complex compounds which do not pollute the air.

Specific plant species absorb contaminants at a higher rate than others. This should be taken into account while developing and planning such structures. Hyperaccumulators are the name given to these plants. Endophytes are bacteria that live in the leaves of plants and can absorb, digest, and change toxins. *"New Caledonian tree Sebertia acuminata, which accumulates more than 20% nickel, Kabata-Pendias accumulate greater than 10% zinc accumulation by pennycress (Thlaspi calaminare), 10% nickel accumulation by alyssum (Alyssum bertolonii), up to 3% chromium concentration in Pamela suteri and broom tea tree (Leptospermum scoparium), and up to 3% uranium by Uncinia leptostachya and Coprosma arborea. An accumulation of up to 1% mercury also was reported in paper birch (Betula papyrifera).endophytes in the leaf surface have the ability to biodegrade and transform pollutants. " [**Plants That Remove Contaminants From The Environment By M. Cristina Negri, Ray R. Hinchman.**]*

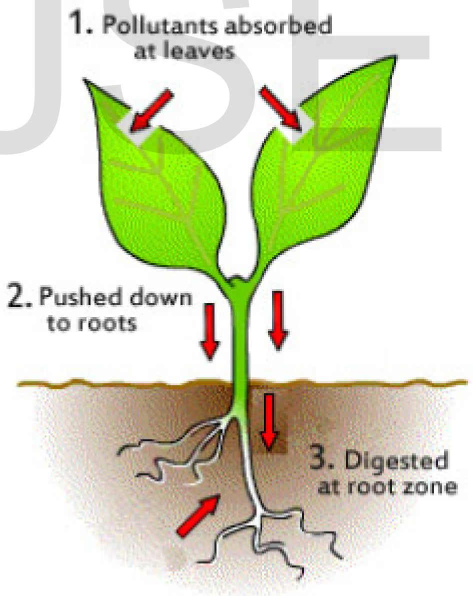

Fig 42 : Absorption Of Pollutants By Plant

Source : How Plants Clean Air

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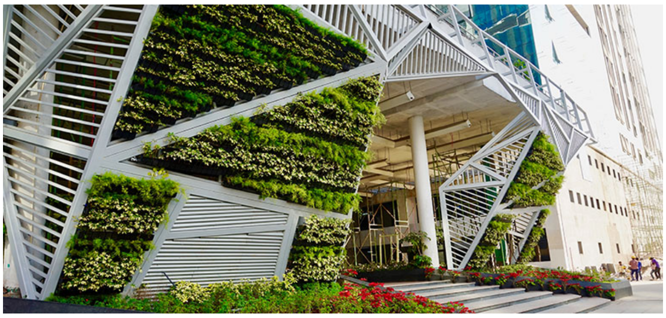

Fig 43 : Indoor Green Facade

Source: Ever Heard Of Green Walls? – Ups Battery Center

Fig 44 : Outdoor Green Facade

Source: Living Wall : Green Facade | Wfm Media

8.3 Design Guidelines 3: **Trees Near the Road**

Trees and plants absorb pollutants and they can block the passage of particles through the air allowing them to settle down, thus eliminating the formation of smog. Vehicular transportation on the roads results in pollutants accumulating around the area. Most pollution consists of heavy particles containing lead, dust, etc.

The provision of trees on the roadsides and on lanes can prevent the formation of smog at its source itself. Prevention of smog is better than its solution. Every road should have trees planted nearby or on its lane. Streets are the main stagnant point of air circulation which results in more accumulation of smog. Trees thus act as a barrier against pollutants.

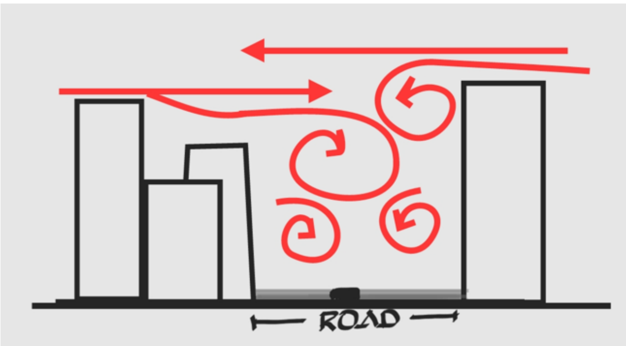

Fig 45 : Stagnant Air Above Streets

Source: Author

Fig 46 : Absorption Of Pollution By Trees

Source: Author

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8.4 Design Guidelines 4: **Mist Fountains in Public Spaces**

Water has the ability to combine with dust in the air and settles down the particles . While pollutants combine with water it becomes heavier allowing it to settle easily . Water must come into touch with particles in the air for this use. Inorder for this to happen fountains can be used in outdoor spaces.Mist fountains can spray or mist water to a larger cubic area thus allowing more pollutants to settle down.

Mist fountains can be incorporated into public outdoor spaces where more people gather . This helps in prevention of formation of smog .This is only applicable to heavier particles like dust in the air .

Fig 47 : Mist Fountains

Source :[How to Build a mist fountain | Decorationable]

8.5 Design Guidelines 5: **Activated Carbon - Road Construction**

Activated carbon has a porous structure which allows it to act as a sponge and collect particles like the pollutants in the air into its pores .Vehicles contribute to smog a lot . Mixing the paving material with activated carbon allows it to capture pollutants released from the vehicles right at the source .

Activated carbon should be used in road construction, thus reducing the smog accumulation and the amount of pollutants in the air.

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Fig 48 : Activated Carbon Concrete Road

Source :Author ,Pinterest

8.6 Design Guidelines 6: **TiO2 Infused Paints and Cement**

Titanium dioxide is a powerful weapon against smog . In the presence of sunlight / uv radiation , this releases active oxygen into its outer shell allowing complex particles to react and break down into simpler substances. Using it with paint and cement allows maximum surface area for reaction. tio2 combined with cement is available in the market as Tiocem and titanium infused paints are also available.

Smog hotspots should be made compulsory to use only tio2 infused paint which allows surface level absorption.

Fig 49: Titanium Dioxide Paint

Source :Titanium Dioxide Market Size & Share

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8.7 Design Guidelines 7: **Cavity Walls Using Foam Concrete**

In projects like M: Ofa Air-Filtering Green Office ,construction with foam concrete cavity walls are proposed . Foam concrete is porous in nature that allows dust and other particles in air to be captured and the cavity allows it to settle down which can be later removed .

Materials standards should be provided for smog polluted areas and this should include the usage of foam concrete and as cavity walls .

Fig 50 : Foam Concrete Cavity Wall

Source : HD1056: Block Acoustic Cavity Wall System -

8.8 Design Guidelines 8: **Dome Shaped Roofs for Activity Areas**

The dome shape allows more surface area , with proper material , this can absorb smog from a large volume of air .

Every indoor play courts ,sport centres and stadium and such closed activity spaces should have dome shaped roofs.

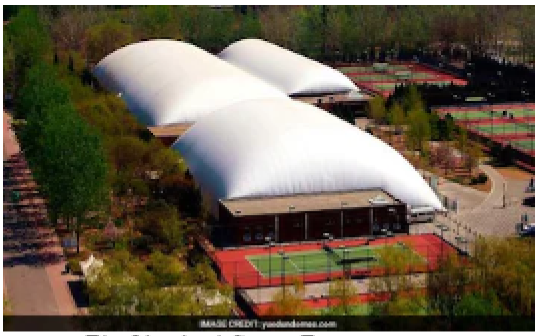

Fig 51 : Anti-Smog Domes

Source : Schools In China Begin Installing Anti-Smog Domes

8.9 Recommendations 1: **Placing Smog Towers Near The Source**

Smog towers are more efficient if placed at the source and also near the prominent nodes of the smog polluted area. The main sources that can be treated with smog towers are the factories and industries .

It must be made compulsory to have at least 1 smog tower near the factory outlets based on the average emissions from such sources.

Fig 52 :Smoke from Factories , Noida

Source : Noida all set to get its first air pollution control tower - Cities News

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Fig 53 :Smog ,Delhi

Source : Delhi's Anti-Smog Towers: Solution to Pollution Or Mere Waste of Money?

8.10 Recommendations 1: **Prevention At Construction Site**

Construction sites contribute a lot to dust and other denser particles in the smog. This can be prevented or reduced to a level by using sheets around the site which can act as a barrier to the pollution it contributes.

Fig 54 : Ongoing Construction Buildings Covered In Green Cloths

Source : Civil Engineering: Why are newly constructed or ongoing construction buildings covered in green cloths? - Quora

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Chapter - 9

POLICIES AND STRATEGIES RECOMMENDATIONS

9.1 Road And Transportation

- Enforcing of law that bans vehicles over 15 years, this should be enforced with proper awareness and inspection
- More bicycle paths and facilities around the cities
- Introducing more electric vehicles into the transport system of smog polluted zones .
- Mud roads should be constructed into paved road or concrete road to reduce the dust produced

9.2 Household And Domestic

- Using biogas instead of LPG should be promoted and subsidies should be provided.
- Burning wastes in open area should be prohibited .incineration facilities should be provided to burn harvest waste and domestic waste

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9.3 Factories And Industries

- New laws enforcing emission standards to the factories and other infrastructure .Air monitoring systems should also be installed

9.4 Air Quality Monitoring

- Hourly air quality data should be updated to the public .This helps in bringing awareness to the public . Graphical presentations and illustrations can be used to bring public attention to the issue .
- Special air quality monitoring systems can be used to identify and locate live pollutant emission data of the cities .

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9.5 Other

- Fireworks and crackers usage should be regulated and reduced during festivals and celebrations
- Color coded emission rate identifications should be provided to vehicles . Elimination of high emission vehicles from the smog hot-spots .
- Campfires and burning of wood and organic matter should be regulated .
- Every building constructed in the smog polluted zones should have the capacity to clean outdoor and indoor air to a minimum limit

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Chapter - 10

SOLUTION BRIEF

Findings of the solutions are shown in the following table :

	AIR CLEANED PERANNUM BY 1 SQ.M (IN CUBIC M.)	QUALITY OF AIR PURIFIED (IN %)	DURABILITY (≤5 YEARS OR ≥5 YEARS)	COST OF INSTALLATION (LOW, MEDIUM, HIGH)	COST OF MAINTAINACE (LOW, MEDIUM, HIGH)	INTERVALS BETWEEN MAINTAINACE (EVERY MONTH, EVERY 6 MONTHS, EVERY YEAR)	COST OF OPERATION (LOW, MEDIUM, HIGH)	OPERATING METHOD (MECHANICAL, CHEMICAL, BIOLOGICAL, ROBOTICS)	AVAILABILITY IN THE MARKET (LOW, MEDIUM, HIGH)	HIGH LABOUR SKILLS NEEDED (YES, NO)	SUITABILITY (INDOOR, OUTDOOR, BOTH)	ENHANCE AESTHETICS (YES, NO)	DRAWBACKS
ALGAL FACADE	283	70-80%	≥5 YEARS	HIGH	MEDIUM	EVERY MONTH	LOW	BIOLOGICAL	MEDIUM	YES	INDOOR	YES	- HEALTH CONCERNS - NEED SUNLIGHT
WATER FACADE	—	20-25%	≥5 YEARS	HIGH	MEDIUM	EVERY 6 MONTHS	MEDIUM	MECHANICAL	MEDIUM	NO	BOTH	YES	- HIGH ENERGY CONSUMPTION
GREEN AND ALIVE FACADE	900	25-30%	≥5 YEARS	MEDIUM	LOW	EVERY 6 MONTHS	LOW	BIOLOGICAL	HIGH	NO	BOTH	YES	- ALLERGIC TO SOME -NEED SUNLIGHT
SMOG TOWERS	18,000	50-60%	≥5 YEARS	HIGH	HIGH	EVERY YEAR	HIGH	MECHANICAL CHEMICAL	HIGH	YES	OUTDOOR	NO	- THE FILTERS ARE NOT RECYCLABLE
ROOM FILTERS	240	80-90%	<5 YEARS	LOW	LOW	EVERY MONTH	LOW	MECHANICAL	HIGH	NO	INDOOR	NO	- NEED HEPA FILTERS TO FUNCTION EFFICIENTLY
TITANIUM DIOXIDE	180	50-60%	<5 YEARS	LOW	LOW	EVERY YEAR	LOW	CHEMICAL	HIGH	NO	BOTH	YES	- NEED SUNLIGHT TO REACT WITH POLLUTANTS
DYNAMIC RESPONSIVE SYSTEM	12,000	60-70%	≥5 YEARS	HIGH	HIGH	EVERY YEAR	HIGH	MECHANICAL ROBOTICS	LOW	YES	BOTH	YES	- EFFICIENT BUT UNAVAILABLE
ACTIVATED CARBON CONCRETE	1000	30-35%	≥5 YEARS	LOW	LOW	—	LOW	CHEMICAL	HIGH	NO	BOTH	NO	- DIFFICULT TO APPLY IN MOST SURFACES

THE ABOVE DATA IS BASED ON THE STANDARD COMPARISON BETWEEN DIFFERENT SOLUTIONS OF SAME PARAMETERS.

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Table 6 : Solution Brief

Source : Author

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Chapter - 11

CONCLUSION

Smog and Air pollution are inevitable parts of India's current situation where this results in different health issues and also affecting day to day activities of people of that affected area

Even if enormous progress has been made in infrastructure and research, the plight of the people in India is far from over. While several of the latter case studies suggest an ecological relationship and at best can be used to draw causal inferences, these are the best.

Low emission vehicles and the implementation of various strict measures have resulted in some improvements and air pollution relief in India. However, the government and other authorities must take action to ensure the well-being and health of its citizens.

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Health is an integral and omnipresent aspect. While clean air is a citizen's right, the government cannot control all factors. Citizens must also take responsibility. Clean India is not possible without social commitment. Without community participation, the Clean Delhi vision would not be realized.

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