

Selecting Plants Species to Mitigate Pollution

Ayla Khan

Assistant Professor, Department of Architecture, Jamia Millia Islamia, New Delhi, India

Abstract: Many governments have an air pollution index and have set targets for 'safe' levels of air pollution, but almost every country is currently exceeding dangerous levels. In India, Delhi woke up to a smog enveloped day in November 2017. Which almost brought many normal activities to a stand still as per health advisory children and the elderly were to avoid outdoor activities. Air pollution is a continuing and ever growing hazard. Emissions from vehicles also contribute to poor air quality. In developing countries, deforestation and burning charcoal and wood for fuel is a driving factor. Cutting down trees not only releases CO₂, but also prevents forests from purifying our air. The environment is also affected by these phenomena because of rampant forest clearances, cutting of trees for urban expansion. Deforestation and urbanization have left us with lesser number of plants to combat the air pollution around us. Reducing green cover has also resulted in a global climate change. We should hence take measures to mitigate unabated development, construction and industrialisation by adapting plantation of species that help in maintaining environments. Plants as we have commonly known aid in reducing the amount of carbon dioxide in the air and increase oxygen. Not only do they provide nutrients for the entire food chain as well as the earth itself, but they are a safe and effective solution to some of our biggest environmental problems. They help to remove toxins from the air and contribute towards enhancing both the outdoor and indoor environments. Toxins such as nitrogen oxides, ammonia and sulfur dioxide are absorbed by plants through their leaves, bark and roots. This paper researches all such plants that can grow in India and especially in the climate of Delhi and help in reducing air pollution,

Keywords: Air Pollution, Environmental Health, House plants, Pollution Mitigation.

I. INTRODUCTION

Mainly there are three major types of pollution which are air pollution, water pollution, and land pollution of which air pollution is visible only sometimes although it is present. Air pollution is not natural, it results from burning fossil fuels—coal, oil, and natural gas. When petrol combustions to power vehicles, it produces carbon monoxide, a colourless, odourless gas. The gas is harmful in high concentrations and large amounts. City traffic produces highly concentrated carbon monoxide. Cars and factories produce other common pollutants, including nitrogen oxide, sulfur dioxide, and hydrocarbons. These chemicals react with sunlight to produce smog, a thick fog or haze of air pollution. The smog sometimes becomes so thick that it also blocks the sun. Smog can be brown or grayish blue, depending on which pollutants are in it and with no wind movement it can hang close to the ground.

In November 2017, Delhi woke up to a cloud enveloped grey sky an event that came to be known as the Great Smog of Delhi, the air pollution spiked far beyond acceptable levels. Levels of PM_{2.5} and PM₁₀ particulate matter hit 999 micrograms per cubic meter, while the safe limits for those pollutants are 60 and 100 respectively [1]. Schools were shut and health advisory to the elderly was to stay home. A phenomena that urged people to wear N95 masks to protect themselves and purify the indoor air by using air purifiers and it brought outdoor activities to a stand still.

Subsequently the anti-pollution economic segment saw a phenomenal rise through rapid sale of air purifiers. According to estimates from the London-based market research firm Euromonitor, the segment recorded sales of roughly Rs 116 crore in 2017. That's more than twice the 2014 sales of Rs 50 crore [2]. But air purifiers do not fair well in two cases one it can only be used in closed environments and secondly, it is something that masses at large cannot afford in India. Therefore it is imperative to think about measures that can be sustainable and viable and can be adopted to mitigate this phenomena that re-occurs in November and December in Delhi and across the country.

Air pollution is a continuing and ever growing hazard. Emissions from vehicles also contribute to poor air quality. In developing countries, deforestation and burning charcoal and wood for fuel is a driving factor. Cutting down trees not only releases CO₂, but also prevents forests from purifying our air. The environment is also affected by these phenomena because of rampant forest clearances, cutting of trees for urban expansion. Deforestation and urbanization have left us with lesser number of plants to combat the air pollution around us. Reducing green cover has also resulted in a global climate change. We should hence take measures to mitigate unabated development, construction and industrialisation by adapting plantation of species that help in maintaining environments.

Industrial human activities, such as the burning of greenhouse gases, release toxic chemicals and particles into the air. Concentrations are worse in crowded urban areas, and countries with huge manufacturing industries – such as China, India and Bangladesh – have the highest recorded levels globally. So we have to think globally how to reduce air pollution [3].

II. HOW PLANTS ADAPT TO AIR POLLUTION

Plants as we have commonly known aid in reducing the amount of carbon dioxide in the air and increase oxygen. Not only do they provide nutrients for the entire food chain as well as the earth itself, but they are a safe and effective solution to some of our biggest environmental problems. They help to remove toxins from the air and contribute towards enhancing both the outdoor and indoor environments. Toxins such as nitrogen oxides, ammonia and sulfur dioxide are absorbed by plants through their leaves, bark and roots.

Polluted air contains particles, odours and harmful gasses like nitrogen oxides, sulfur dioxide and ammonia. These pollutants settle on the leaves of trees and plants. The leaves and plant surface absorb these pollutants and through their stomata (pores) and filter these harmful substances from the air. Trees absorb odours and pollutant gases (nitrogen oxides, ammonia, sulfur dioxide and ozone) and filter particulates out of the air by trapping them on their leaves and bark. This improves the air quality in the micro-climate around the trees and contributes to a healthier and cleaner environment overall. Trees also soak up the harmful carbon dioxide in our atmosphere. In one year, an acre of mature trees absorbs the same volume of carbon monoxide as produced from a 26,000 mile car journey [4] Aside from cleaning the air for us, trees supply us with fresh oxygen to breathe. Delhi needs to wake up to the situation and improve its urban areas it is the time when we have to take action to reduce air pollution and not get too late.

It is also to be noted that several toxic gases are released from large-scale industrial processes and along with heat from the sun's rays gets trapped in the Earth's atmosphere – this is known as 'the greenhouse effect' and this is contributing to the overall rise of Earth's temperature. Which is resulting in an average global warming of 1.5 degrees accelerating icecap melting, severe drought and sea-level rise and the loss of many animal species. Trees planted in an urban environment can not only counteract the warming effects that concrete and buildings have on the environment (known as the urban heat island effect), they have also been observed to clean the air from pollutants and particulates created by vehicles etc. Through the process of photosynthesis, trees are able to absorb carbon dioxide from our atmosphere and reduce the 'greenhouse effect', creating a less polluted, a more sustainable world for our future generations. Particulate matter suspended in polluted air tends to settle onto leaves, and certain gases including nitrous dioxide (NO₂) are absorbed by leaves' stomata, filtering the air and reducing pollution levels slightly. But trees and other vegetation can also restrict airflow in their immediate vicinity, preventing pollution from being diluted by currents of cleaner air. In particular, tall trees with thick canopies planted alongside busy roads can act like a roof, trapping pockets of polluted air at ground level. Therefore judicious selection of plant species and appropriate planting design needs to be done.

It is not that only outdoor air is polluted, air inside the built environment can also be polluted. Many reasons are responsible for example the method of cooking (Indian cooking), cleaning products, deodorant, detergents, hair sprays, air fresheners, furniture polish and everyday dust are some of the factors responsible for surge in levels of indoor air pollution. Fine particulate matter can easily penetrate into human respiratory system, causing lung and cardiovascular diseases or exacerbating respiratory illness. It has also been linked to inflammation and heart disease. By one estimate, 8.9 million deaths a year globally could be attributable to exposure to outdoor fine particulate matter. According to a report by the World Health Organisation, 4.3 million people worldwide die due to poor air quality inside the house [5]. Air pollution is responsible for respiratory diseases, cancer, stroke, lung diseases such as asthma and heart disease. Around 3.8 million premature deaths occur annually from non-communicable diseases including ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer are all attributed to exposure to household air pollution. "WHO air quality guidelines" estimate that reducing annual average fine particulate matter (PM_{2.5}) concentrations from levels of 35 µg/m³, common in many developing cities, to the WHO guideline level of 10 µg/m³, could reduce air pollution-related deaths by around 15% [6].

III. PLANTS THAT CAN IMPROVE AIR QUALITY AROUND US

Plants is a generic term and may be classified as trees, shrubs, ground covers, palms, creepers and climbers. Of all of these trees, house plants and some climbers are very useful in mitigating air pollution. Different plant species respond differently to pollution. While some plants can tolerate fairly high levels of pollution (suspended particulate matter, dust and gases), others are sensitive. The response of plants to air pollution depends upon the type of pollutant present, its concentration, and the length of exposure to it. A comprehensive list of plants of Indian variety suitable for the climate of Delhi has been prepared in this paper. Brief detail has also been given about all the plants.

TABLE I LIST OF PLANTS THAT CAN IMPROVE AIR QUALITY

S.No.	Botanical name	Common name
	TREES	
	<i>Albizia lebbek</i>	Shirish
	<i>Azadirachta indica</i>	Neem
	<i>Alstonia scholaris</i>	Chitwan
	<i>Caesalpinia sappan</i>	Indian redwood
	<i>Celtis australis</i>	Mediterranean Hackberry
	<i>Delonix regia</i>	Gulmohar
	<i>Ficus benghalensis</i>	Banyan
	<i>Ficus carica</i>	Fig
	<i>Ficus religiosa</i>	Peepal
	<i>Grevillea robusta</i>	Silver oak
	<i>Ginkgo biloba</i>	Maidenhair Tree
	<i>Murraya koenigii</i>	Kari Patta
	<i>Mangifera indica</i>	mango
	<i>Polyalthia longifolia</i>	Ashoka
	<i>Psidium guajava</i>	Guava
	<i>Saraca indica</i>	Sita Ashok
	<i>Syzygium cumini</i>	Jamun
	<i>Terminalia arjuna</i>	Arjun
	<i>Tilia cordata</i>	Littleleaf Linden
	SHRUBS	
	<i>Chrysalidocarpus lutescens</i>	Areca Palm
	<i>Osmanthus fragrans</i>	Fragrant Olive
	<i>Rhapis excelsa</i>	Broadleaf Lady Palm
	HOUSE PLANTS	
	<i>Alchemilla vulgaris</i>	Lady's mantle
	<i>Anthurium scherzerianum</i>	Flamingo Lily
	<i>Aloe barbadensis</i>	Aloe Vera
	<i>Chamaedorea erumpens</i>	Bamboo Palm
	<i>Chlorophytum comosum</i>	Spider Plant
	<i>Chrysanthemum morifolium</i>	Chrysanthemum
	<i>Dracaena fragrans</i>	Corn Plant
	<i>Epipremnum aureum</i>	Golden Pothos
	<i>Erysimum cheiri</i>	Common Wallflower
	<i>Guzmania lingulata</i>	Scarlet Star Bromeliad
	<i>Hedera Helix</i>	Common Ivy
	<i>Hevea brasiliensis</i>	Rubber Plant
	<i>Nephrolepis exaltata</i>	Boston Fern
	<i>Philodendron selloum</i>	Philodendron
	<i>Sansevieria trifasciata</i>	Snake Plant
	<i>Spathiphyllum</i>	Peace Lily

IV. URBAN TREES CAN HELP CUT AIR POLLUTION

Cities usually come at the price of greenery and vegetation. Since prehistoric times, humans have busily cleared forests to make way for settlements. But increasingly, greenery has been edging its way back into modern urban landscapes, and for good reason. Vegetation helps cities become better habitats for wildlife and for people, and it helps to make city air safer.

While trees are generally effective at reducing air pollution, it isn't as simple as that more trees you have in an urban space, the better the air will be. Some trees are markedly more effective at filtering pollutants from the air than others. To make the most difference in air quality in a street or city, it has to be the right tree for the job. Trees can improve air quality in direct and indirect ways. Indirectly, they can help by shading surfaces and reducing temperatures.

If buildings are shaded by trees, it reduces the need for conventional air conditioning, and the emissions of greenhouse gases that come with it. Plus, lower temperatures decrease risk of harmful pollutants like ground level ozone that commonly spike on hot days in urban areas.

From an urban planning perspective, trees act as a readily available set of PM purifiers. The first aspect in this respect is dispersion – by crashing into trees and plants, concentrated clouds of minuscule particles get dispersed and so diluted by the air, decreasing the risk of inhalation by humans. The second one is deposition. PM can easily get trapped in the waxy, hairy leaves of trees and shrubs. When it rains, most of these particles are washed away by water into drains.

The extent to which each species performs such filtering activity depends mostly on canopy size, leaf size and leaf structure. Bigger canopies can trap more particles than smaller ones, and larger leaves can trap more pollutants than small ones. When it comes to leaf type, it is those with rough, rugged and hairy surfaces that act as the “best filters” for PM. Recent research suggests that tiny hairs on plant leaves in particular may play a big role in trapping the solid and liquid particles that make up PM [7].

Some popular Indian trees that do fairly well in Delhi Climate can be planted in residential green open spaces and around the neighbourhood to help reduce pollution. Trees like Karri Patta, fruit trees of Mango and Gauva are very beneficial and usually formed a part of traditional Indian residential gardens. Beautiful flowering tree like Gulmohar can be planted along with Neem, Siris, Chitwan and Ashok tree.

V. PLANTS THAT CAN IMPROVE AIR QUALITY INSIDE OUR HOUSES

From reducing stress levels to improving your focus, houseplants have many benefits. Volatile organic compounds, or VOCs, are used to make most home products—furniture, paint, carpets, and even the construction materials used to make the home itself. Over time, VOCs like formaldehyde, benzene, ammonia, and toluene are off-gassed into the air and can cause serious health issues. Something as natural as plants, nature’s own air purifiers, can help in keeping the house clear of air pollution by tackling the following pollutants-

- Formaldehyde, which comes from carpets and particle boards.
- Tetrachloroethylene is a synthetic chemical that is widely used for dry cleaning of fabrics and for metal-degreasing operations
- Benzene which comes from detergents, paints, furniture wax, thinner and other things.
- Xylene and Toluene which are used in some coloring pens, markers, spray paints, shoe polishes and adhesives.
- Carbon monoxide and nitrogen dioxides.
- Volatile Organic Compounds (VOCs) which come in solvents and chemicals in perfumes, hair sprays, air fresheners and furniture polish
- Biological pollutants which constitute of dust, fungi, allergens.

Plants that can help get clean indoor air are explained here in a simple manner so that they can be grown as potted plants in house holds.

1. Lady’s mantle (*Alchemilla vulgaris*)

This plant reduces the levels of nitrogen dioxide in the air and also traps harmful particles and hence this is yet another ideal choice for cleansing the air around us.

Lady’s mantle is an attractive and a hardy perennial plant. Its soft gray-green foliage is semi-round with scalloped-shaped leaves. It has hairy leaves. In late spring and early summer, the plant produces nearly inconspicuous chartreuse (yellow-green) blooms. It is a low-growing ground cover, about 6 to 12 inches (15-30 cm.) tall, and in addition to its attractive looks, has an interesting background. it can tolerate full sun, lady’s mantle performs better in shade when grown in warmer regions. Hence can be planted in pots and placed in the patio or in the lounge. There’s not much involved in caring for lady’s mantle. It’s a very carefree plant and doesn’t require any special attention or fertilizing.

2. Flamingo Lily (*Anthurium scherzerianum*)

Flamingo Flower is well-known by its red, oval spathes, each with a twisted, orange spadix covered densely with its tiny, true flowers. Spathes last for up to 8 weeks. Large pointed, dark-green leaves grow up to 7 in (18 cm) long and surround the upright flower stems. Anthurium leaves are poisonous. They contain calcium oxalate crystals that can cause severe burning in the mouth. Plant promotes wellness.



Fig. 1 Flamingo Lily (*Anthurium scherzerianum*)



Fig. 2 Aloe Vera (*Aloe barbadensis*)



Fig. 3 Spider Plant (*Chlorophytum comosum*)



Fig. 4 Areca Palm (*Chrysalidocarpus lutescens*)



Fig. 5 Corn Plant (*Dracaena fragrans*)



Fig. 6 Snake Plant (*Sansevieria trifasciata*)

3. Aloe Vera (*Aloe barbadensis*)

The plant acts as a natural air purifier and reduces toxic chemicals including formaldehyde and benzene – two chemicals that are present in cleaning products. Aloe Vera is an easy to grow succulent plant and it comes with a bag full of benefits. While with its presence, it helps in filtering benzene and formaldehyde that comes from carpets and particle boards, its extract aids in healing cuts, burns and skin problems. The gel inside Aloe Vera leaves are a natural anti-bacterial and are packed with a lot of vitamins. The sun-loving plant requires a lot of sunlight and little water. Also, you don't need big space or big pot to plant it. A small pot filled with soil and a leaf will work. Just keep it in your drawing room, near a window, and reap its benefits.

4. Bamboo Palm (*Chamaedorea erumpens*)

Bamboo Palm is one of the best plants to filter out benzene, formaldehyde, trichloroethylene, xylene, and toluene. Along with this, the plant makes for a pretty indoor plant, to be kept near a bedside table. The best thing about this plant is, it does not need water regularly, and in fact it does well only when it is underwatered, as compared to other plants.

It is a relatively small graceful palm with densely clumping, bamboo-like stems and feathery fronds. Canes can be up to 1cm (0.4 inch) in diameter. The delicate-looking, lacy leaves 60-90cm (24-35 inch) long with leaflets up to 38cm (15 inch) long at the top of slender, cane-like stems that cluster together. Leaf colour is a deep bluish green. The flowers are produced in inflorescences.

5. Spider Plant (*Chlorophytum comosum*)

Spider plant, also known as air plant, grows and spreads quickly. The plant fights against carbon monoxide, formaldehyde, benzene which comes from detergents, paints, furniture wax, thinner and other things. It can be propagated just like Aloe Vera, cut off one of the spider's leaves and place it in a pot and watch it grow. Spider plants neither require direct sunlight nor do they need to be put under cold weather. Keeping it in a room or in an office corridor will serve the purpose. The Spider Plant is an antioxidant as it effectively removes ammonia, benzene, formaldehyde and xylene – harsh chemicals that occur from cleaning products and furniture. The plant is extremely easy to grow and quickly improves air quality. A study found that within just two days, the plant removed up to 90% of the toxins found in indoor air [8].

One of the most popular houseplants, spider plant is a grass like, clump forming, evergreen perennial in the lily family. The leaves are linear, 20.3-40.6 cm long and less than 2.5 cm wide. Small white flowers are borne along outward arching wiry stalks. After blooming and fruiting, little tufts of leaves 'baby spider plants', develop on the stalks. These little "spiders" take root wherever they touch the ground.

6. Areca Palm (*Chrysalidocarpus lutescens*)

Areca palms not only filter indoor toxins from the air, but they also act as a natural humidifier, adding moisture to the air around them. Areca palms filter out harsh chemicals including acetone, xylene and toluene, which accumulate from products such as nail varnish, detergents, wooden furniture, poor ventilation, gasoline, cosmetics etc.

Golden Cane Palm is clump-growing with ringed, bamboo-like stems and yellow leaf-ribs. The foliage is evergreen, of fine texture and yellow-green in color. Pinnate, 6 to 8 pale green leaves per stem, 80 to 100 leaflets. Yellow male and female flowers on the same inflorescence. Flower stalk coming from below the leaves. Fruit is yellow to purple, 2 cm, oval in shape.

7. Chrysanthemum (*Chrysanthemum morifolium*)

Florist's chrysanthemums or "mums" are ranked the highest for air purification. They're shown to eliminate common toxins as well as ammonia.

This perennial is known for its reliable flowering from late summer to peak winter and for its ease of growth. Colors range from pure white to red, bright yellow, shades of orange, rust, and bronze, many pinks and lavenders. All types grow well in containers. Garden Mums grow in height 1 to 4 feet. Chrysanthemums have dark green, deeply lobed and aromatic leaves with soft grey undersides.

8. Corn Plant (*Dracaena fragrans*)

Corn plants' thick canes make them visually appealing, but they're also one of the most effective air-purifying plants, removing VOCs like formaldehyde, benzene, trichloroethylene, and carbon dioxide.

Corn Plant has rosettes of glossy, green leaves, broadly striped and banded with light green and yellow down the center. It is a slow growing pole shrub and the leaves can reach up to 3 feet long by 4 inches wide. When plants are grown in the ground, they can reach about 20 foot tall but their growth is limited when they are potted. Corn Plant has white flowers that are highly fragrant, hence the species name *fragrans*.

9. Golden Pothos (*Epipremnum aureum*)



Epipremnum aureum commonly called golden pothos, or clearly, is a climbing vine that produces abundant yellow-marbled foliage. It can be grown in pots and curtailed by trimming. Wallflower is a kind of ornamental plant highly suitable for outdoors. This plant can fight air pollution by filtering air. It can effectively filter pollutants of different sizes from the air like soot and dust and thus clean the air.

10. Scarlet Star Bromeliad (*Guzmania lingulata*)

Bromeliads, like the Scarlet Star, to remove 80% of VOCs from the air in only 12 hours. These flowering plants love humid environments, so consider placing them in the bathroom where they can soak up the steam from your showers.

Characteristic of the plant are smooth green leaves 45 cm long and 2 cm wide, with a flower stalk up to 30 cm long bearing small yellow flowers in the centre of a cup-shaped or funnel-shaped flower head of 4 cm long crimson bracts. The leaves come together to form a star shape in the middle. Scarlet Star is most popular for its brilliant pink or red flower bracts, but also can be found in shades of yellow and orange depending on the variety. What appears to be the flower on the plant is actually a grouping of modified leaves, called bracts. They are green at the beginning and little by little they start to color in bright colours depending on their variety.

11. English Ivy (*Hedera helix*)

English Ivy plant has leaves with large surface. This fact makes this plant the ideal choice for air purification. This plant pumps a good amount of oxygen into the atmosphere thereby freshening the air. The leaves of English Ivy come in many different styles, but all are mesmerizing when trailing down bookcases or out of hanging planters. Pot your ivy in soil or water and give it nutrients, and it becomes a low-maintenance, air-filtering piece of natural art. English Ivy can stimulate mucus glands and contains expectorant properties, which can help people with breathing difficulties. The leaves are actually used as medicine to reduce blockage and swelling of airway passages. The plant is also used medicinally to improve lung health, liver disorders, spleen disorders and others.

12. Snake Plant (*Sansevieria trifasciata*)

Low-maintenance snake plant, also known as mother-in-law's tongue, because of the shape and texture, is known for filtering formaldehyde, trichloroethylene, xylene, toluene, and benzene from the air. The catch is, unlike regular plants, snake plant absorbs carbon dioxide and releases oxygen at night. Keeping it in your house, can help you get direct oxygen. It is a low maintenance plant. The Snake Plant is extremely effective in its ability to absorb harsh chemicals like carbon monoxide, benzene, formaldehyde and other harsh chemicals found in indoor air. The plant also produces oxygen, absorbs CO₂ in the night and has proven to be beneficial for airborne allergies.

Sansevieria trifasciata is one of the most popular and hardy species of houseplants. It features stiff leaves that range from 6 inches to 8 feet tall, depending on the variety. Snake plants vary in color but usually have green banded leaves and commonly feature a yellow border. These plants are easy to grow and nearly indestructible; they will thrive in either very bright light or almost dark corners of the house. They generally grow slowly in indoor light but a few hours of direct morning sun will boost their growth.

13. Warneck Dracaena

Combat pollutants associated with varnishes and oils. The plant can grow indoors easily, even without direct sunlight. With striped leaves forming clusters atop a thin stem. It combats pollutants that come with paints, detergents, varnishes and oils. Dracaena plants have shown to be one of the most effective air filters. The plant removes formaldehyde, benzene, trichloroethylene and carbon dioxide – all of which are linked to health problems. Dracaena plants also tend to increase the humidity of a room which in turn helps to control respiratory distresses.

14. Peace Lily (*Spathiphyllum*)

the peace lily is unmatched in its ability to filter a range of chemicals from your air. Pair that with its low maintenance and unique look, and there's no doubt it tops our list of best air-filtering plants. Peace lilies have shown to improve indoor air quality by up to 60%. The plant absorbs mold spores which commonly occur from dust inside. The plant reduces levels of mold spores through absorbing them as food. The plant can be useful in areas of high humidity – like bathrooms for example, as it will keep the mold at bay.

Peace Lily, is a very popular indoor houseplant. It is a clump-growing herbaceous perennial which produces white flowers which look like the hood of a cobra. Leaves are shiny and glossy, attractive even with no spathes. Peace lilies are sturdy plants with glossy, dark green oval leaves that narrow to a point. The leaves rise directly from the soil.

15. Boston Fern (*Nephrolepis exaltata*)

Nephrolepis exaltata has broad fronds with alternate leaflets (pinnae) on either side of the midrib. The pale- to medium-green fronds can grow up to 4 feet long and 6 inches wide. There are two rows of round sori (clusters of spore-bearing organs; ferns are seedless vascular plants that produce spores instead of seeds) near the margins on the underside of the pinnae. Each leaflet is generally deltoid in shape, with slightly serrate, undulating edges.

Boston fern is a common ornamental plant frequently grown as a houseplant. Alongside being a natural air filter, the Boston Fern also restores natural moisture to the air. In fact, the plant has shown to be effective for people with dry skin or irritable noses or throats due to their moisturising properties.

16. Broadleaf Lady Palm (*Rhapis excelsa*)

The ornate broadleaf lady palm can help remove toxic ammonia that may be trapped in the air in your home or apartment. This plant has amazing air purifying properties. In fact, it ranked in the second position in NASA's Clean Air Study. It can filter benzene, formaldehyde, xylene, ammonia, and several other volatile organic compounds.

The Lady Palm is a delicate plant from the Palm family. It is the most popular species of *Rhapis* used in tropical landscaping. The name *rhapis* means 'needle' in Greek while *excelsa* is Latin for 'tall', referring to the needle-like segments of the leaves and the plant's tall stature. It has delicate foliage. The leaves are fan-shaped, glossy, and deep green in color. Each leaf can grow up to 20 inches long, divided into five ribbed oblong segments with toothed edges.

17. Philodendron

The philodendron plant purifies air by removing formaldehyde, which tends to occur from building materials and home furnishings. Formaldehyde occurs naturally and becomes threatening only through long-term exposure by inhalation.

Tree philodendron is a tropical plant with large, showy leaves that is grown as a houseplant in temperate climates. It can tolerate deep shade but prefers bright, indirect light and moist soil. It does not tolerate salt build up so flush soil regularly or use distilled water for irrigation. It can produce aerial roots that absorb water and nutrients.

18. Rubber Plant (*Hevea brasiliensis*)

Rubber plants improve indoor air as their large surface leaves act as a sponge and absorb harsh chemicals then break them down. The plant has shown to absorb carbon dioxide and convert it into breathable oxygen.

The rubber tree is a fast growing, medium to tall tree, with deep tap-roots. The trunk is smooth and straight with a grayish bark. It is known for its laticiferous system from which latex is extracted by tapping the trunk. It can also be grown in pots where its growth will be stunted and it can be placed indoors.

VI. QUALITIES OF PLANTS AND PLANTING DESIGN FOR REDUCING AIR POLLUTION

Qualities and characteristics of various plant species that help in reduction of air pollution have been discussed in this paper. It is simply not about planting in numbers but planting as per need and planting in organised way that will enhance landscaping of the area. Some flowering trees mentioned earlier like Gulmohar and Sita Ashok can be used as backdrop to courtyard spaces or large green areas or open areas near parking. Foliage trees can be planted as avenue trees and in clusters in large open spaces. This will help in a long way in reducing vehicular pollution. Trees that may not be popular species for landscape design can be used for plantation in areas of varied use. For example Neem is ecologically very special. It can tolerate very high levels of pollution and has the capacity to recover even if most of its foliage is dropped. Plants with a large leaf area such as neem, accumulate relatively higher quantities of lead. Trees vary widely in their capacity to absorb pollutants like particulate dust, CO₂, oxides of sulphur and nitrogen. A study of locations in New Delhi, done by National Environmental Engineering Research Institute, India in 1996 indicated that Neem tree is one of the most suitable species for checking urban pollution in industrial locations and it has potential in green belt development in hot spots with known history of high air pollution.

Neem trees can be planted in:

- Housing Societies – to repel mosquitoes and to enhance the availability of oxygen
- Road sides – to provide cooling shade and to reduce CO₂, SO₂ levels
- Parks – to provide a CO₂ sink, to purify the air and provide refuge for birds
- Highways – to absorb the pollutants and provide shade
- Around farm lands – to act as wind breaks, to bind soil against erosion and to provide natural home grown pest control material

They can be planted practically any location that receives plenty of sunlight and does not get water logged during rains.

Plants species like *Duranta* that can be grown as hedges can be maintained at slightly more than two meters (approximately 6.6 feet). These hedges can be co-ordinated with other shrubs of colourful foliage. *Lady's mantle* is an interesting plant to add to the garden, especially in shady borders. It is also commonly used as a ground cover and makes a nice edging when kept in bounds. It can be grown in borders along with *Aster*. *Aster* is a bioindicator plant that can change its appearance when the air around is polluted beyond a particular level. Thus we can get to know that the air quality is deteriorating and take the necessary steps for protection.

Palms are again excellent choices in planting for designed landscapes. Bamboo palm is a useful indoor palm because its adaptability to the environment, exotic look and anti-pollutant abilities. It is very common in malls, offices, homes and courtyards. Areca palm or Golden Cane Palm is tropical-looking plant, it serves as a super, bamboo-like screening plant and is relatively pest-free.

Peace lilies are indisputably terrific as houseplants. Small varieties look attractive on a tabletop and bigger ones can occupy a nice-sized spot on the floor. They filter more indoor pollutants than most other plants, so are great for bedrooms or other frequented rooms. Inside the tropical plant's pores, toxic gases like carbon monoxide and formaldehyde are broken down and neutralized. They can also be planted in medium sized flower beds along with flamingo lily to add colour and white flowers of peace lily look resplendent.

VII. CONCLUSION

After an extensive research of plants that help to reduce air pollution it is observed that plants in all categories such as trees, shrubs, palms, ground covers, climbers etc are available to reduce air pollution. As landscape architects we can make judicious choices in the best interest of the environment.

From a big-picture perspective, it makes the most sense to cut down on pollution at the source. More efficient solutions Delhi could put in place include:

- Putting emissions control technology on factories and power plants
- Removing old, polluting cars and requiring functioning catalytic converters
- Improving garbage collection and banning garbage fires

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BIOGRAPHY

Ayla Khan has a Bachelor's in Architecture and Master's in Landscape Architecture from the School of Planning and Architecture, New Delhi. As a landscape architect she has a keen interest in environment and ecology.