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Review

A Review of Air Pollution Mitigation Approach Using Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API)

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Abstract: Air pollution is a global environmental issue, and there is an urgent need for sustainable remediation techniques. Thus, phytoremediation has become a popular approach to air pollution remediation. This paper reviewed 28 eco-friendly indigenous plants based on both the air pollution tolerance index (APTI) and anticipated performance index (API), using tolerance level and performance indices to evaluate the potential of most indigenous plant species for air pollution control. The estimated APTI ranged from 4.79 (*Syzygium malaccense*) to 31.75 (*Psidium guajava*) among the studied indigenous plants. One of the selected plants is tolerant, and seven (7) are intermediate to air pollution with their APTI in the following order: *Psidium guajava* (31.75) > *Swietenia mahogany* (28.08) > *Mangifera indica* L. (27.97) > *Ficus infectoria* L. (23.93) > *Ficus religiosa* L. (21.62) > *Zizyphus Oenoplia Mill* (20.06) > *Azadirachta indica A. Juss.* (19.01) > *Ficus benghalensis* L. (18.65). Additionally, the API value indicated that *Mangifera indica L.* ranges from best to good performer; *Ficus religiosa* L. and *Azadirachta indica A. Juss*. from excellent to moderate performers; and *Cassia fistula* L. from poor to very poor performer for air pollution remediation. The Pearson correlation shows that there is a positive correlation between API and APTI (R2 = 0.63), and this implies that an increase in APTI increases the API and vice versa. This paper shows that *Mangifera indica* L., *Ficus religiosa* L., and *Azadirachta indica A. Juss.* have good potential for sustainable reduction in air pollution for long-term management and green ecomanagement development.

Keywords: air pollution; API; APTI; indigenous plant; environmental pollution; sustainable environmental–pollution nexus; green ecomanagement development

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1. Introduction

Globally, clean air is essential for the environmental–public health nexus; however, the deterioration of air quality due to the discharge of pollutants from numerous sources into the environment is becoming a global health issue for climate and human health [1–3]. Air is considered polluted when there is a high concentration of one or more contaminants in the atmosphere [4]. Anthropogenic or natural pollutants found in the atmosphere comprise gaseous pollutants, such as sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_X), ozone (O_3), lead (Pb), and particulate matter ($PM_{2.5}$ and PM_{10}); these are known as the criteria pollutants [5–7]. The pollutant concentrations in the atmosphere vary depending on the sources, distribution pattern, meteorological conditions, and the topographical features of an environment [8]. These pollutants are no doubt proven to be dangerous to the environment and human health, causing various diseases to humans, plants, and animals [1]. Air pollution has been reported to alter the ecosystem and has negative effects on plants by reducing photosynthetic pigment, stomata conductance, net photosynthetic rate, and grain protein contents [9]. The persistence of these pollutants in the environment could pose problems in distant areas, while in some cases posing an additional problem of transboundary pollution due to variation in meteorological factors, such as wind and speed, which disperse these pollutants far and wide [10].

Both ambient and indoor air are contributing to a wide range of potentially life-threatening health problems, and they have been reported to negatively affect the population in low-income countries. In addition, air pollution has been declared "the silent killer" with about 7 million deaths every year as estimated by the World Health Organisation [11,12]. Likewise, over 95% of the world's population was reported to be breathing unhealthy air in 2016 [13]. This led to the death of 6.1 million people due to long-term exposure to contaminated air for which India and China were found to be jointly responsible for over 50% of global deaths attributed to $PM_{2.5}$ [13]. Epidemiological studies have shown that air pollution could cause several human health diseases, such as pulmonary, cardiac, vascular, and neurological diseases [14,15], chronic respiratory symptoms, and diseases among elderly people worldwide [16]. Further, a consistent increase in cardiac, respiratory disease, lung cancer, and mortality in the world is attributed to exposure to air pollution from different sources [17,18].

Atmospheric particulate matter ($PM_{2.5}$) as one of the air pollutants is estimated to cause 3.3 million premature deaths yearly, particularly in Asia, and poses a range of negative effects on human health [19]. Thus, bio-monitoring studies in the field of air pollution science concerning urban ecosystem restoration are extremely relevant because, once the pollutants are released into the atmosphere, they disperse and affect the environment negatively. Therefore, the role of plants in air pollution abatement has been increasingly recognised and reported by several researchers [20–25]. The application of plants for reducing and absorbing pollutants from the atmosphere has been proposed as the only ecomanagement approach (approach to lessen the harmful impact of human activity on the environment) for air pollution [9,26,27]. This is an eco-friendly approach, as it is safe, preserves the environment through energy efficiency and reduction of the contaminant in a cheaper way, has no adverse effect on the environment, and uses a sustainable source of energy [23,28,29]. Based on the responses of plants towards air pollution, the analysis of some biological parameters of each species helps in determining tolerance levels. The appropriate plant species can be identified by evaluating certain biochemical and socio-economic characteristics, which could be obtained from the two indices commonly known as the air pollution tolerance index (APTI) and anticipated performance index (API), respectively.

Several studies have been conducted by researchers on either plant APTI or API for air pollution reduction [9,26,27,30–32]; hence, there is a need to integrate these two indices to ascertain the tolerance level for sustainable green ecomanagement development. This review combines both APTI and API of reoccurring indigenous plants across the world to explore and ascertain their tolerance level for sustainable eco-management. The study aim was to identify the most common plants that exhibit good tolerance levels and API values for air pollution reduction in any season, under any environmental condition, weather, and climatic variation. Sustainable ecomanagement could lead to the promotion of planting more indigenous plants that can enhance air quality through the uptake of pollutants [33].

2. Components and Impacts of Ambient Air Pollutants

Ambient air pollutants include gaseous pollutants and particulate matters that are present in the atmosphere at normal temperature and pressure. Various anthropogenic activities are responsible for releasing pollutants into the atmosphere; these include coal power generation [34–36], domestic fuel burning [37,38], brick industries [39,40], mining activities [41], and vehicular emission, among others [42]. Meanwhile, the impact of long-time exposure of humans to air pollutants can cause several respiratory diseases, such as chronic bronchitis and asthma, and cardiovascular, reproductive, and gastrointestinal problems [1,43]. The pollutant's concentrations are measured in micrograms per cubic meter ($\mu g/m^3$) or parts per million (ppm) [6].

2.1. Particulate Matter (PM_{10} and $PM_{2.5}$)

Particulate matter (PM) originates from primary emissions (e.g., soot from combustion sources (such as construction sites, unpaved roads, fields, and smokestacks), sea salt, and soil from wind-driven resuspension) and the formation of secondary particles in the atmosphere [13]. Particulate matter (PM) is a term used for physical and chemical substances that exist as discrete particles, either as liquid droplets or solids over a wide range of sizes [44]. In terms of the mass concentration, PM may be characterised as particles smaller than 2.5 µm in aerodynamic diameter ($PM_{2.5}$) or less than 10 µm in aerodynamic diameter (PM_{10}), shown in Figure 1. Particulate matters ($PM_{2.5}$) as air pollutants have both short-term and long-term effects. Particulate matters (PMs) may cause adverse health effects on humans, affect plant life and the ecosystem and become global environmental problems if exposed to high concentrations [27,45]. Exposure to ambient fine particles has been linked to an increase in adverse effects on human health because they can penetrate the respiratory system if inhaled, deposit into deep regions of the lungs, and cause respiratory infection, heart and lung diseases, lung cancer, premature death and mortality [16,46,47]. This is based on their quantity and physical and chemical properties; some of these chemical parameters include benzene, sulphates, chlorides, nitrate, and even some metals [1]. Continual contact with air pollution affects the lungs of growing children and may worsen or complicate medical conditions in the elderly [16].

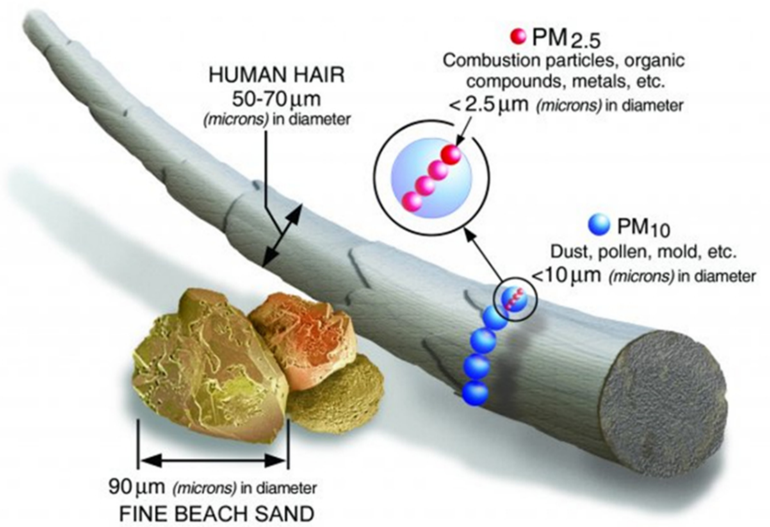

Figure 1. Comparisons of particulate matter size (PM) [44].

2.2. Ozone (O_3)

Ozone (O_3) is an important secondary pollutant that forms photochemically when organic compounds react with nitrogen oxides (NO_x) [48]. For instance, this occurs when pollutants emitted by cars, refineries, chemical plants, power plants, industrial boilers, and other sources chemically react in the presence of sunlight. Hence, the presence of heat and sunlight is highly important for its formation, shown in Figure 2. Children and older people with lung diseases, such as asthma, as well as people who exercise and work outside under the sun, are at high risk of O_3 exposure. Its effects include reduction in lung function, increased respiratory symptoms, and possibly premature deaths [5,48]. Additionally, it affects sensitive vegetation and ecosystems, including forests, parks, wildlife refuges, and wilderness areas, among others.

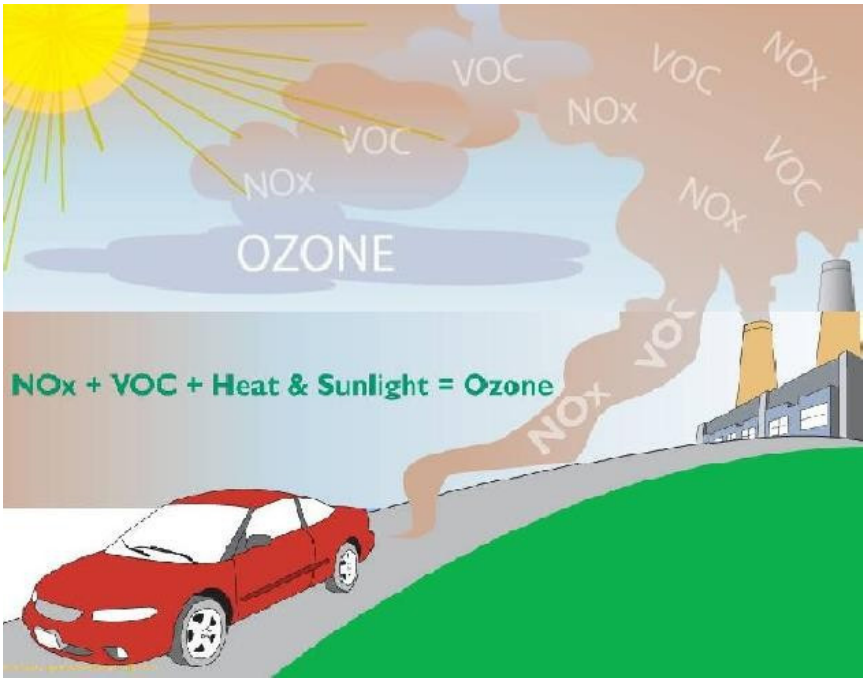

Figure 2. Formation of ozone.

2.3. Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless, and tasteless gas that is slightly lighter than air [49]. It is a by-product of combustion, present whenever fuel is burned in a limited supply of air (oxygen). CO is formed by the incomplete combustion of natural gas and any other material containing carbon, such as gasoline from vehicles, kerosene, oil, propane, coal, and wood, among others. The health risks associated with CO vary with its concentration and duration of exposure. Effects range from subtle cardiovascular and neurobehavioural effects at low concentrations to unconsciousness and death after prolonged exposure or after acute exposure to high concentrations of CO [50]. The United States Environmental Protection Agency has estimated that as much as 95% of CO comes from vehicle emissions. A high level of CO is harmful to human health because CO has a great effect on oxygen delivery to the body's organs (e.g., heart and brain) and tissues (e.g., skin) [5]. Normally, CO will cause headaches and even visual impairment. At comparatively high levels, CO can directly cause death, especially to people with heart diseases [51].

2.4. Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is an acidic, colourless, and poisonous gas that may remain in the atmosphere for periods of up to several weeks. It can be detected by taste and odour in a concentration that ranges between 0.38–1.15 ppm and above 3 ppm, with an irritating odour. It is estimated that 65 million tonnes of SO_2 per year enter the atmosphere because of human activities, primarily from the combustion of fossil fuels. Other possible sources include fuel-based industry, vehicle emissions, smelting of mineral ores, and refinery. Of these, energy-producing companies using coal are by far the greatest contributor. In the United States, it is estimated that almost 65% of SO_2 emissions are from coal-fired power stations [52]. The adverse effects on human health are coughing, asthma, and chronic bronchitis [53]. Effects of a high concentration of SO_2 in the environment include damage to plant foliage, harming trees and decreasing their growth. It also contributes to acid rain, which can harm sensitive ecosystems.

2.5. Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a suffocating, brownish gas: one of a family of highly reactive gases, the nitrogen oxides (NO_x). They are formed when fuel is burned at high temperatures. Nitrogen dioxide is also an irritant to humans and corrosive to metals. Scientists in the United States have observed the adverse effects of photochemical contaminants on human health, especially in urban areas [6]. However, the US EPA only regulates NO_2 because it is the most prevalent form of NO_x in the atmosphere that is generated by anthropogenic activities. Nitrogen oxides also play a significant role in the aesthetic impact, due to their ability to cause yellow-brown discolouration on buildings and vehicles. Nitric oxide is a gaseous air pollutant that is a precursor to nitrogen oxides, which react to form photochemical smog. For decades, it has been known for its adverse effects on humans and vegetation. Exposure to NO_x can affect the sensory perception function of humans, causing lung infection and respiratory problems.

3. Phytoremediation, an Eco-Friendly Management Method in Reducing Air Pollution

In the quest for an alternative eco-friendly approach, the impact of air pollutants on the biochemical, physiological, and morphological parameters of plants are being explored as a vital part of air pollution science [54]. Plants have been labelled as the lungs of cities, acting as natural biofilters in reducing air pollution through active absorption and accumulation mechanisms [55]. In urban environments, trees have been found to be suitable bio-monitors and bio-indicators of air pollution [56]. They play an important role in improving air quality by taking up gases and particles, depending on the plant's tolerance or sensitivity level [57–59]. Today, phytoremediation is now being considered as an alternative eco-friendly technology for removing pollutants from contaminated water, soils, and air, using plants [60,61].

Studies on the elemental composition and distribution of dust particles adsorbed on leaves and their tissues have been reported by some researchers [9,62,63]. Roadside deposition studies across the world have demonstrated that significant quantities of pollutants are deposited on plants in China [64] and India [63], which has drawn attention to gaseous pollutants, PM, and heavy metal accumulation in plants at high concentrations. Due to the ability of plants to absorb air pollutants without any adverse effect to them, several reports have proposed treating air pollutants by various plant parts as the new sustainable environmental health method [65–67], using various phytoremediation techniques [68].

However, the response and tolerance of plants to air pollutants vary with different behaviour patterns and tolerance. The air pollution tolerance index is employed in the world to develop appropriate environmental indicators and mitigation strategies to assess the sensitivity, response, and tolerance of plants to air pollutants, using only biochemical parameters [9,26]. Furthermore, for the reduction of air pollution using greenbelt development in an area, the anticipated performance index (API) needs to be considered with the help of many socio-economic characteristics of the plant [69]. The API is an improvement over the APTI, which has been used as an indicator to assess the capability of predominant species in the clean-up of atmospheric pollutants.

Phytoremediation Techniques

The following technique can be used for the removal of environmental pollutants. The phytoremediation techniques include rhizofiltration, phytodegradation, phytostimulation, phytovolatisation, phytoextraction, and phytostabilisation, shown in Figure 3 [59,68–71].

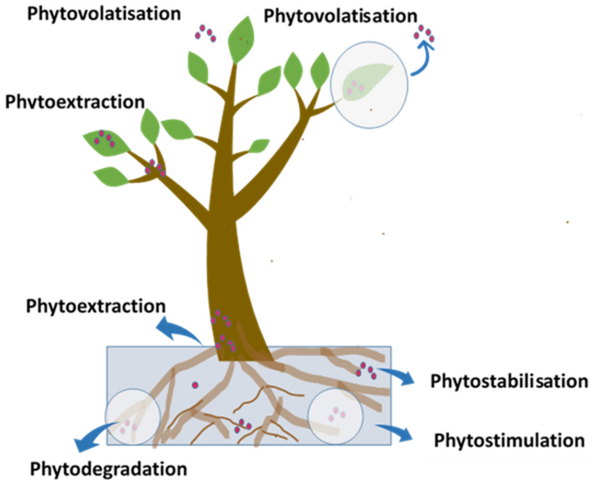

Figure 3. Schematic representation of phytoremediation techniques.

- Phytoextraction This is the accumulation or uptake of pollutants by the plant as they absorb water from soil and the environment, which are stored in the plant leaves, roots and shoots but are not broken down. This technology is most often applied to metal-contaminated soil and may be toxic to organisms, even at relatively low concentrations [72]. According to Kapourchal et al. [73], there was a high concentration of lead (Pb) in the soil due to continuous exposure to vehicle exhaust air pollution, and the lead was extracted from the contaminated soil using the phytoextraction method.
- Rhizofiltration Rhizofiltration is used basically in filtering contaminated groundwater. This is the process in which plant roots are used to take up and store contaminants (toxic substances or excess nutrients) from surface water or groundwater [72]. After the plants reach the contaminants' saturation limit, they are harvested similarly to the phytoextraction method [71]. The successive implementation of this remediation technique requires a better understanding of the plant–water interactions that control the extraction of a targeted metal from polluted water resources.
- Phytodegradation Phytodegradation (also called phytotransformation) is the process of breaking down harmful pollutants in plant tissues, using their enzymes after taking up and storing them for a period [72,74]. The remediation technique utilises plants and associated rhizosphere microorganisms to remove, contain or transform toxic substances or excess nutrients in soils, sediments, and groundwater, among others [74]. The transformation of organic contaminants into more water-soluble molecules enables plants to diminish the toxicity of air pollutants. This is assisted by endocytic bacteria that colonise the plant inner tissues without causing any side effects on their host (plant) [59,75]. Persistent organic pollutants (POPs) can be abated with phytoremediation techniques as reported by Erakhrumen and Agbontalor [76].
- Phytostimulation Phytostimulation (also known as rhizodegradation) is the technique where the plants release certain substances through their roots into the soil or groundwater. The released substances increase the microorganisms' ability to break down and destroy contaminants at a faster rate [77]. This process is critical for the applied technology of rhizoremediation that combines phytoremediation and bioaugmentation and is effective for the removal of organic contaminants in soils [59].
- Phytovolatisation This is the technique where pollutants are uptaken by the plants from the soil, and then converted into a volatile form and then released into the atmosphere [68,72]. This means that the contaminants present in the water taken up by the plant pass through the plant or are modified by the plant and are released to the atmosphere (evaporates or vaporises). In the case of air pollution, phytovolatilisation occurs when pollutants are diffused into the phyllosphere of plants, where the toxicity

of pollutants may be lowered before being transformed into a volatile component in the atmosphere [78].

- Phytostabilisation Phytostabilisation is defined as the immobilisation of contaminants in the soil through accumulation and absorption by roots, adsorption onto roots, or precipitation within the root zone of plants. This is used in the treatment of soil, sediments, and sludges [77]. Particulate matters as well as carbon dioxide (CO_2) are absorbed by plants through their foliage and shoots and accumulate in the phyllosphere, then phytostabilise and immobilise in the wax layers of the plants [59,71].

4. Air pollution Indices

4.1. Air Pollution Tolerance Index (APTI)

The air pollution tolerance index is an inherent quality of plants to encounter air pollution stress, which is presently of prime concern, particularly in industrial and non-industrial areas. The ability of a plant to maximally absorb pollutants from the air without a negative impact on the plant is determined using APTI. It is a function of biochemical parameters, which include the relative water content (RWC in %), the total chlorophyll of the leaf (TC in mg/g), the pH of the leaf extract (pH), and the ascorbic acid content of the plant (AA in mg/g). The effect of the pollutants only on the biochemical parameters is known by the APTI. This expresses the capacity of a plant to combat air contamination. APTI can be calculated using Equation (1) [79].

$$\mathrm{APTI} = \frac{[\mathrm{AA}(\mathrm{TC} + \mathrm{pH}) + \mathrm{RWC}]}{10} \tag{1}$$

Ascorbic acid can be estimated by 2,6-dichlorophenol (indophenol dye) using the method suggested by Agarwal [80], whereas the total chlorophyll concentration can be obtained using the spectrophotometric method [81]. The relative water content of leaf material can be estimated by taking the initial weight and dry weight of the leaf material. Four biochemical parameters (AA, TC, pH, and RWC) in plant leaves can be used to determine the sensitivity, response, and tolerance of a plant to air pollutants. The tolerant plant species can be used as an indicator of air quality and provides lasting solutions to the menace caused by air pollutants to humans [9]. The classification of APTI results of different plants into different tolerance levels is given in Table 1. Plants with higher index values are known to be tolerant to air pollution, while lower index plants are less tolerant [27]. Hence, species with low index values are more sensitive to air pollution and act as biological indicators of air pollution as well as tools for monitoring environmental pollution.

Table 1. The tolerance level of plants for APTI.

Range of APTI	Tolerance Level
30–100	Tolerance
17–29	Intermediate
1–16	Sensitive
<1	Very sensitive

Sources: [31].

4.2. Anticipated Performance Index (API)

The most suitable plant species for ecomanagement can also be determined by calculating API. API is particularly useful in the selection of plants species that can perform a dual purpose of improving the air quality by cleaning up atmospheric pollutants and supporting the recreational benefit [33,82]. Additionally, a study showed that an anticipated performance index (API) is significant for ecomanagement to fight against air pollution, which is reflected by some biological and socioeconomic characteristics of the plants; therefore, API is more effective for this purpose [69]. The API of different plant species were calculated by combining the APTI value, and some biological and socio-economic characters, which include plant habit, laminar structure, canopy structure, types of plant, and economic value, as shown in Table 2. Table 3 shows the classification of plant species according to their API score. Various plant parameters, such as leaf size and canopy structure, also help the plant's capacity for pollution reduction. Different plant species have different characteristics. The API score (%) is further calculated using Equation (2) [69].

$$\text{API} = \frac{\text{No of } (+)\text{obtained}}{16} \times 100 \qquad (2)$$

Table 2. Gradation of plant species based on APTI and other biological and socio-economic characters.

Grading	Characters		Pattern of Assessment	Grade Allotted
Tolerance	APTI		9.0–12.0	+
			12.1–15.0	++
			15.1–18.0	+++
			18.1–21.0	++++
			21.1–24.0	+++++
			24.1–27.0	++++++
			27.1–30.0	+++++++
			30.1–33.0	++++++++
			33.1–36.0	+++++++++
Biological and socio-economic	Plant habit		Small	–
			Medium	+
			Large	++
	Canopy structure		Sparse/Irregular/globular	–
			Spreading crown/open/semi dense	+
			Spreading dense	++
	Type of plant		Deciduous	–
			Evergreen	+
	Laminar structure	Size	Small	–
			Medium	+
			Large	++
		Texture	Smooth	–
			Coriaceous	+
		Hardiness	Delineate	–
			Hardy	+
	Economic value		Less than three uses	–
			Three or four uses	+
			Five or more uses	++

Maximum grades that can be scored by a plant = 16; Sources: [69,83].

Table 3. Plant species classification using anticipated performance index species.

Grade	Score (%)	Assessment Category
0	Up to 30	Not recommended
1	31–40	Very poor
2	41–50	Poor
3	51–60	Moderate
4	61–70	Good
5	71–80	Very good
6	81–90	Excellent
7	91–100	Best

5. Assessment of Air Pollution Using APTI and API

The assimilation or reduction capacities of 28 different plant species were reviewed from published articles, and their tolerance levels were estimated based on the four biochemical values, socio-economic parameters, APTI values and API values for air pollutants as found in the literature. Most of the selected articles (literature) were from Nigeria and India, with two major distinct seasons, which are wet (rainy) and dry seasons. They are both tropical regions that experience temperatures below 10 °C and temperatures that tend to exceed 40°C, which are varied depending on the season of the year [84]. The rainy season in Nigeria ranges between April and October, with generally lower temperatures, which is the same period of the rainy season (monsoon) in India. Like Nigeria, South India typically receives a lot of rainfall. The dry season starts from November to March. The dry season in Nigeria is accompanied by a dust-laden air mass from the Sahara Desert, locally known as harmattan. The harmattan, from the northeast, is hot and dry and carries reddish dust from the desert, causing high temperatures during the day and cool nights [84,85]. This similarly occurs in other places around the world with similar climatic conditions.

Table 4 refers to the results of the ascorbic acid content (AA), total chlorophyll content (TC), pH of the leaf extract (pH), and relative water content (RWC), which give collective information on the investigated samples' biochemical parameters for APTI. The mean concentration of ascorbic acid (AA) in plants ranged from 29.50 mg/g (*Swietenia mahogany*) to 0.38 mg/g (*Syzygium malaccense*), while RWC for the plants ranged from 98.1% for *Araucaria heterophylla* to a lower value of 45.8% for *Syzygium malaccense*. Plant survival under stress conditions depends on the RWC. Exposure to air pollution when the transpiration rates are higher may lead to desiccation; hence, the higher the water content within the plant body, the better it is equipped to combat and maintain its physiological balance under stress conditions as well as its drought tolerance capacity. Hence, maintenance of the plant RWC is an important parameter in air pollution management because this could affect the relative tolerance of plants towards air pollutants [27]. On the other hand, ascorbic acid is an antioxidant that influences the resistance of plants to adverse environmental conditions, including air pollution [86]. A high concentration of ascorbic acid favours the defence mechanism of a plant in an environment. A lower concentration may be attributed to the consumption of ascorbic acid during the removal of cytotoxic free radicals generated in chain reactions after the penetration of oxidative pollutants into foliar tissues [9,87].

Furthermore, the highest value of the total chlorophyll contents of the selected plants reviewed in this article was found in *Ficus infectoria* L. (TC = 12.20 mg/g), while the lowest value was reported for *Mangifera indica* L. (TC = 0.34 mg/g). For the pH value, also found to affect the plant tolerance level, *Ficus benghalensis* L. had the highest pH of 8.14, while *Syzygium malaccense* was reported to have a pH of 2.88, which is considered low among the plants reviewed. A higher pH is known to improve the tolerance level of plants against air pollution [27,30]. The chlorophyll content of plants varies from species to species, depending on biotic and abiotic conditions, the pollution level, and the age of the leaf. The chlorophyll content of a plant greatly signifies its photosynthetic activity as well as the growth and development of its biomass. The total chlorophyll concentration depends on the pollution status and levels of pollutants in an area. A lower chlorophyll content could be because certain pollutants reduce the total chlorophyll content in plants [88,89] as reported by [27]. Agrawal et al. [90] also reported a reduction in chlorophyll content of different crop plants due to exposure to O_3, SO_2, and NO_2. Pheophytin formation by the acidification of chlorophyll SO_2 has been reported. Other studies have also shown the impact of air pollution on the chlorophyll content [91], ascorbic acid content, relative water content, and leaf extract pH [92].

Table 4. Biochemical parameters along with APTI values of the plants from the literature.

S/No	Plants Species	TC (mg/g)	pH	RWC (%)	AA (mg/g)	APTI	References
1	*Psidium guajava*	2.19	6.36	77.69	28.90	31.75	Study A [93]
2	*Swietenia mahogany*	1.52	5.86	70.73	29.50	28.08	
3	*Mangifera indica* L.	2.13	6.33	84.66	24.50	27.97	
4	*Alstonia scholaris (L.) R.Br.*	1.49	5.94	79.76	13.20	16.72	
5	*Ficus religiosa* L.	2.17	6.30	73.64	9.06	15.11	

Table 4. *Cont.*

S/No	Plants Species	TC (mg/g)	pH	RWC (%)	AA (mg/g)	APTI	References
6	*Ficus hispida*	1.60	6.58	69.96	8.04	13.26	
7	*Ficus benghalensis* L.	6.54	5.93	55.65	6.65	18.65	Study B [94]
8	*Polyalthia longifolia Sonn.*	5.78	6.89	60.25	6.42	15.65	
9	*Ficus religiosa* L.	9.87	6.98	60.54	6.98	14.42	
10	*Cassia fistula* L.	4.44	5.43	54.24	6.07	13.65	
11	*Azadirachta indica A. Juss.*	3.87	6.2	54.21	6.79	12.98	
12	*Alstonia scholaris (L.) R.Br.*	3.81	6.05	50.42	5.26	9.01	
13	*Nerium odorum Sonnad.*	3.52	6.54	53.54	4.08	8.65	
14	*Mangifera indica* L.	1.73	5.54	96.04	12.98	19.03	Study C [69]
15	*Manikara zapota (L). P. Royen.*	2.25	5.69	85.62	6.54	13.76	
16	*Swietenia macrophylla King.*	3.33	6.27	86.07	2.17	10.67	
17	*Polyalthia longifolia Sonn.*	3.38	6.43	92.55	1.16	10.39	
18	*Ficus religiosa* L.	1.75	7.17	87.25	1.54	10.10	
19	*Azadirachta indica A. Juss.*	1.79	6.11	77.5	2.19	9.48	
20	*Tamarindus indica* L.	1.53	3.22	77.62	1.46	8.45	
21	*Ficus infectoria* L.	12.20	7.80	81.30	7.90	23.93	Study D [83]
22	*Ficus religiosa* L.	11.26	6.90	76.42	7.70	21.62	
23	*Zizyphus Oenoplia Mill.*	8.98	7.60	72.00	7.76	20.06	
24	*Mangifera indica* L.	9.78	5.76	91.18	6.78	19.65	
25	*Azadirachta indica A. Juss.*	6.80	6.20	76.00	8.78	19.01	
26	*Cassia fistula* L.	3.87	5.80	74.48	4.84	12.13	
27	*Nerium odorum Sonnad.*	1.86	6.70	71.00	1.76	8.60	
28	*Acacia auriculiformis*	0.47	7.01	92.8	1.87	10.7	Study E [95]
29	*Chrysophyllum albidum*	0.51	6.10	89.6	2.23	10.4	
30	*Araucaria heterophylla*	0.43	6.71	98.1	0.58	10.2	
31	*Mangifera indica* L.	0.34	6.14	68.8	1.77	8.03	
32	*Elaeis guineensis Jacq.*	0.61	7.32	70.6	1.06	7.90	
33	*Syzygium malaccense*	0.45	3.55	45.8	0.54	4.79	
34	*Saraca indica*	1.80	6.31	84.32	6.49	13.71	Study F [96]
35	*Azadirachta indica A. Juss.*	1.89	6.29	83.67	5.71	12.98	
36	*Shorea robusta*	2.58	6.57	72.31	5.65	12.64	
37	*Ficus religiosa*	2.17	6.45	75.35	5.99	12.61	
38	*Eucalyptus sp.*	1.85	6.22	79.00	5.83	12.61	
39	*Tectona grandis* L.f.	2.54	6.63	70.36	5.83	12.43	
40	*Mangifera indica* L.	4.16	5.28	92.18	3.24	12.27	Study G [30]
41	*Moringa pterygosperma*	2.36	5.42	84.70	4.76	12.17	
42	*Cassia fistula* L.	3.88	5.72	72.68	3.76	10.87	
43	*Acacia auriculiformis*	1.72	5.55	82.56	3.48	10.78	
44	*Ficus religiosa* L.	1.78	5.62	80.72	3.46	10.63	
45	*Ficus benghalensis* L.	1.68	8.14	82.26	2.32	10.50	
46	*Ficus infectoria* L.	1.61	7.82	86.16	1.45	9.98	

Table 4. *Cont.*

S/No	Plants Species	TC (mg/g)	pH	RWC (%)	AA (mg/g)	APTI	References
47	*Terminalia catappa*	1.09	4.51	88.90	5.16	12.0	Study H [97]
48	*Mangifera indica* L.	1.05	4.41	94.50	2.15	10.60	
49	*Carica papaya*	0.62	6.50	72.10	3.60	9.77	
50	*Syzygium malaccense*	1.09	2.88	90.80	0.38	9.23	

AA: ascorbic acid content, TC: total chlorophyll content, pH: pH of leaf extract, and RWC: relative water content.

The APTI mean value for the plants as found in the literature ranged from 31.75 (*Psidium guajava*) to 4.79 (*Syzygium malaccense*) as summarised in Table 4 and Figure 4. Out of 28 species reviewed for pollution assimilation, 8 species showed APTI values ranging from 31.75 to 18.65, which fall within the tolerance and intermediate ranges of 17 to 100 (Table 2), where some are found more than once. The plants showed in the order of tolerance (% difference in APTI) as *Psidium guajava* (31.75) > *Swietenia mahogany* (28.08) > *Mangifera indica* L. (27.97) > *Ficus infectoria* L. (23.93) > *Ficus religiosa* L. (21.62) > *Zizyphus Oenoplia Mill* (20.06) > *Azadirachta indica A. Juss.* (19.01) > *Ficus benghalensis* L. (18.65). Other 20 plant species have APTI values between 16.72 and 4.79, which are considered sensitive (Table 2). In addition, the ability of other plant species apart from the abovementioned was previously reviewed and reported by other researchers [32,97–100]. The APTI of the same plant or different plants varies from place to place based on different air pollution levels, seasons, climatic variation, and other environmental factors, such as temperature and humidity [25,101,102].

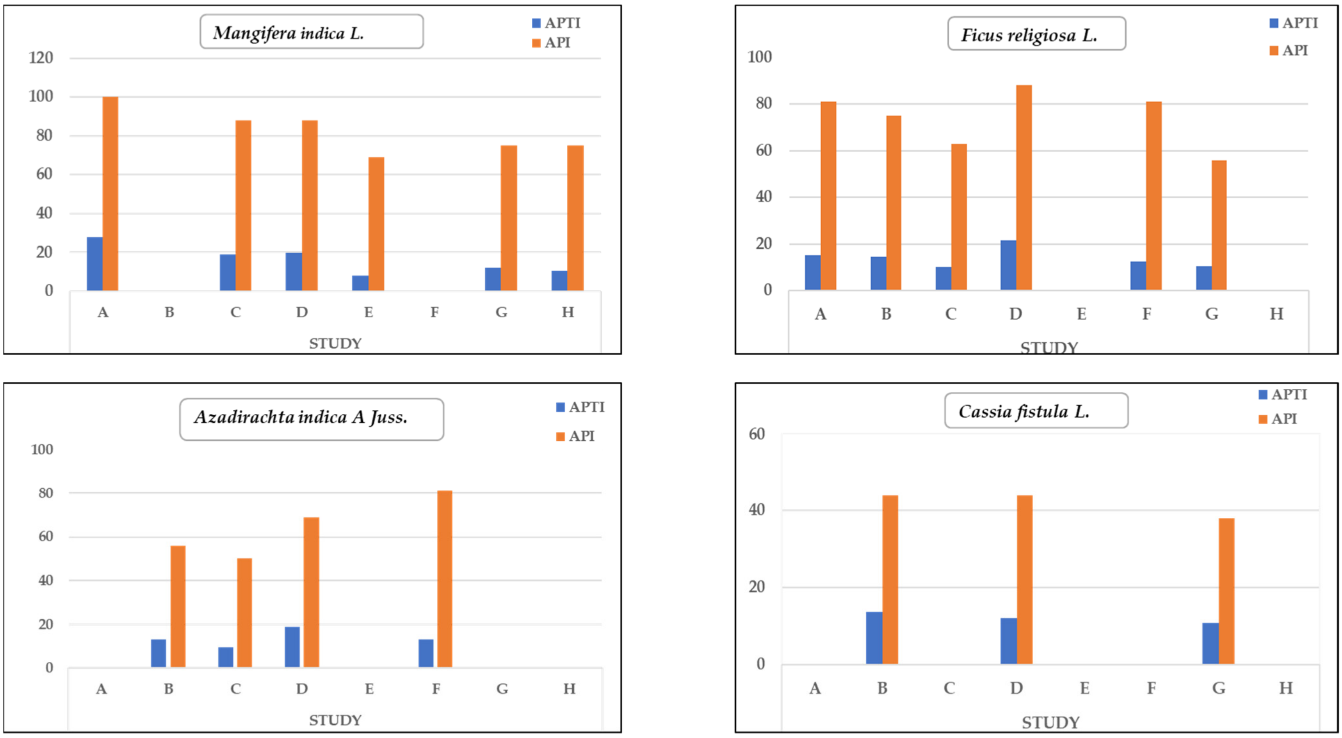

Figure 4. Variations of APTI and API in the four different plants from eight different studies.

The socio-economic parameter and APTI of the 28 plant species reviewed for pollution assimilation were subjected to a grading scale to determine the anticipated performance of plant species [60]. *Swietenia mahogany, Mangifera indica* L., *Ficus infectoria* L., *Psidium guajava, Ficus benghalensis* L., *Ficus religiosa* L., *Saraca indica, Azadirachta indica A. Juss.* and *Eucalyptus* sp. scored high, above 80%, which is the range from excellent to best (Table 5). Interestingly, a few of these species were studied by different researchers across the globe for having better API [24,25,32,103]. However, Figure 4 shows that *Mangifera indica* L., *Ficus religiosa* L., *Azadirachta indica A. Juss.* and *Cassia fistula* L. were the most common plant studied by at least three studies (studies A–H). This shows that they are the most common plants that have the capability of remediating air pollutants. *Mangifera indica* L., *Ficus religiosa* L., and *Azadirachta indica A. Juss.* are intermediate in tolerance level and have high API scores, which implies that they are good plants for the phytoremediation of polluted air. Out of these three plants, *Mangifera Indica* L. has the highest API value, and this is similar to the work carried out by [25]. In addition, there is a greater API value for the species with higher APTI [83]. Therefore, plant species that have high API values are recommended for green ecomanagement development, according to Tsega and Deviprasad [103].

Table 5. Evaluation of plant species based on APTI and some biological and socio-economic parameters.

S/No	Plant Species	APTI	TH	CS	TT	Laminar		EI	H	Grade Allotted		API Assessment	References
						LS	LT			Total Plus	% Score		
1	*Psidium guajava*	++++++++	+	-	-	+	+	++	+	14	88	Excellent	Study A [93]
2	*Swietenia mahogany*	+++++++	++	++	+	-	+	++	+	16	100	Best	
3	*Mangifera indica* L.	+++++++	++	+	+	+	+	++	+	16	100	Best	
4	*Alstonia scholaris (L.) R.Br.*	+++	+	++	+	+	+	+	-	10	63	Good	
5	*Ficus religiosa* L.	+++	++	++	+	+	+	++	+	13	81	Excellent	
6	*Ficus hispida*	++	+	-	-	+	+	+	-	6	38	Very poor	
7	*Ficus benghalensis* L.	++++	++	++	+	++	+	+	+	14	88	Excellent	Study B [94]
8	*Polyalthia longifolia Sonn.*	+++	+	+	+	++	-	+	+	10	63	Good	
9	*Ficus religiosa* L.	++	++	++	+	++	+	+	+	12	75	Very good	
10	*Cassia fistula* L.	++	+	+	-	+	-	+	+	7	44	Poor	
11	*Azadirachta indica A. Juss.*	++	++	++	-	-	-	++	+	9	56	Moderate	
12	*Alstonia scholaris (L.) R.Br.*	+	+	+	+	-	-	+	+	6	38	Very poor	
13	*Nerium odorum Sonnad.*	-	+	+	-	+	+	-	-	4	25	Not recommended	
14	*Mangifera indica* L.	++++	++	+	+	++	+	++	+	14	88	Excellent	Study C [69]
15	*Manikara zapota (L). P. Royen*	++	++	++	+	-	+	++	+	11	69	Good	
16	*Swietenia macrophylla King.*	+	++	+	-	+	+	++	+	9	56	Moderate	
17	*Polyalthia longifolia Sonn.*	+	+	+	+	+	-	+	+	7	44	Poor	
18	*Ficus religiosa* L.	+	++	+	+	++	+	+	+	10	63	Good	
19	*Azadirachta indica A. Juss.*	+	++	++	-	-	-	++	+	8	50	Poor	
20	*Tamarindus indica* L.	-	+	+	+	-	-	+	+	5	31	Very poor	

Table 5. *Cont.*

S/No	Plant Species	APTI	TH	CS	TT	Laminar		EI	H	Grade Allotted		API Assessment	References
						LS	LT			Total Plus	% Score		
21	*Ficus infectoria* L.	+++++	++	+	+	++	+	++	+	15	94	Best	Study D [83]
22	*Zizyphus Oenoplia Mill.*	+++++	+	+	-	-	+	+	-	9	56	Moderate	
23	*Ficus religiosa* L.	+++++	++	+	+	++	+	+	+	14	88	Excellent	
24	*Mangifera indica* L.	++++	++	++	+	+	+	++	+	14	88	Excellent	
25	*Azadirachta indica A. Juss*	++++	++	++	-	-	-	++	+	11	69	Good	
27	*Cassia fistula* L.	++	+	+	-	+	-	+	+	7	44	Poor	
26	*Nerium odorum Sonnad.*	-	+	+	-	+	+	-	-	4	25	Not recommended	
27	*Cassia fistula* L.	++	+	+	-	+	-	+	+	7	44	Poor	
28	*Acacia auriculiformis*	+	+	+	+	-	-	++	+	7	44	Poor	Study E [95]
29	*Chrysophyllum albidum*	+	++	+	+	+	-	++	+	9	56	Moderate	
30	*Araucaria heterophylla*	+	++	+	+	+	-	+	+	8	50	Poor	
31	*Mangifera indica* L.	-	++	++	+	+	++	++	+	11	69	Good	
32	*Elaeis guineensis Jacq.*	-	++	+	+	+	-	++	+	8	50	Poor	
33	*Syzygium malaccense*	-	++	++	+	+	++	++	+	11	69	Good	
34	*Saraca indica*	++	++	++	+	++	+	++	+	13	81	Excellent	Study F [96]
35	*Azadirachta indica A. Juss.*	++	++	++	+	++	+	++	+	13	81	Excellent	
36	*Shorea robusta*	++	++	++	-	++	+	++	+	12	75	Very good	
37	*Ficus religiosa* L.	++	++	++	+	++	+	++	+	13	81	Excellent	
38	*Eucalyptus sp.*	++	++	++	+	++	+	++	+	13	81	Excellent	
39	*Tectona grandis* L.f.	++	++	++	-	++	+	++	+	12	75	Very good	

Table 5. *Cont.*

S/No	Plant Species	APTI	TH	CS	TT	Laminar		EI	H	Grade Allotted		API Assessment	References
						LS	LT			Total Plus	% Score		
40	*Mangifera indica* L.	++	++	+	+	++	+	++	+	12	75	Very good	Study G [30]
41	*Moringa pterygosperma*	++	+	-	-	+	-	+	+	6	38	Very poor	
42	*Cassia fistula* L.	+	+	+	-	+	-	+	+	6	38	Very poor	
43	*Acacia auriculiformis*	+	++	-	+	+	+	-	+	7	44	Poor	
44	*Ficus religiosa* L.	+	++	+	-	++	+	+	+	9	56	Moderate	
45	*Ficus benghalensis* L.	+	++	+	+	++	+	++	+	11	69	Good	
46	*Ficus infectoria* L.	+	++	+	+	++	+	++	+	11	69	Good	
47	*Terminalia catappa*	+	++	++	+	-	-	++	+	9	56	Moderate	Study H [97]
48	*Mangifera indica* L.	+	++	++	+	++	+	++	+	12	75	Very good	
49	*Carica papaya*	+	++	+	+	+	-	++	+	9	56	Moderate	
50	*Syzygium malaccense*	+	++	++	+	++	+	++	+	12	75	Very good	

(APTI)—air pollution tolerance index, (TH)—plant habit, (CS)—canopy structure, (TT)—type of plant, (LS)—lamina size, (LT)—texture, (HI)—hardiness, and (EI)—economic importance.

6. Correlation Matrix Analysis

Table 6 shows the Pearson correlation among calculated parameters, such as APTI, API, TC, pH, RWC, and AA. Generally, according to the correlation matrix, there is either a weak or strong correlation among the calculated parameters, except for RWC, which shows a negative correlation. There is a positive correlation among API, APTI, and AA, and a positive correlation between TC and APTI. This implies that an increase in any of the above parameters will lead to an increase in the others (Table 6). Thus, each of the parameters played a crucial role in the computation of the tolerance and performance level. On the contrary, some plants in the study *(Saraca indica, Azadirachta indica A. Juss.*, *Ficus religiosa* L., and *Eucalyptus* sp.) have low APTI and show excellent API. This could be because of good socio-economic factors, which could enhance the phytoremediation capability of these plants.

Table 6. Pearson correlation matrix for the calculated parameters.

Variables	TC	pH	RWC	AA	APTI	API
TC	1.00					
pH	0.30 **	1.00				
RWC	−0.20	−0.03	1.00			
AA	0.11	0.09	−0.06	1.00		
APTI	0.46 **	0.22	0.07	0.89 *	1.00	
API	0.22	0.13	0.20	0.53 *	0.63 *	1.00

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed). AA—ascorbic acid content, TC—total chlorophyll content, pH—pH of leaf extract, RWC—relative water content, APTI—air pollution tolerance index, and API—anticipated performance index.

7. Conclusions

Air pollution control is more challenging, compared with water and soil remediation; however, with phytoremediation, which involves plants and their microbiomes, good air quality can be obtained. Phytoremediation is proven to abate the effects of various air pollutants and environmental disturbance towards achieving sustainable eco-management. This study provides APTI and API as useful insights for selecting tolerant and sensitive species for future planning and ecomanagement, where plants are continuously exposed to air pollutants. The correlation analysis confirms that there is a positive correlation between API and APTI (R^2 = 0.63), which implies that an increase in APTI will lead to an increase in API of the plant and vice versa. This review shows that *Mangifera indica* L., *Ficus religiosa* L., and *Azadirachta indica A. Juss.* plants exhibit good tolerance levels against air pollution in different areas with different seasons and environments. Therefore, plants with high APTI levels and API value have good potential for green ecomanagement development and the attainment of a sustainable population–pollution interaction for the long-term management of air pollution in tropical regions of the world.

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