Biomonitoring of Air Pollution Using Plants

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Abstract- **Air pollution has become a major environmental problem facing the world today due rapid increase in industrialization and anthropogenic activities. As such, there is need for reliable and sustainable air pollution monitoring and control methods. Biomonitoring of air pollution using plants is the method of interest in recent time as it is cost effective, sustainable and environmentally friendly compared to traditional physico-chemical methods. Some plant species are highly sensitive to particular air pollutants and show specific responses to pollutants effects by showing specific damage symptoms. These species can be used to detect and monitor the presence or absence of air pollutants. Several methods such as index of atmospheric purity, air pollution tolerance index, and mathematical models had been proposed to study the role of plants in monitoring of air pollution. This paper therefore presents a shot review on biomonitoring of air pollution using plants.**

Keywords: Air pollution, Anthropogenic, Biomonitoring, Plants.

1. INTRODUCTION

Air is an important and vital component of this planet and any slight change in its composition may have negative effects on the growth, development and survival of different organisms on this planet. Air pollution refers to the number of harmful substances in the atmosphere of concentration and residence time more than the allowed range, which is beyond the capability of diffusion and dilution resulting in air quality deterioration, brought bad influence directly or indirectly to human health and ecological environment [1]. It is categorized into gaseous (mainly SO_2, NOx and O_3) and dust particles which include some heavy metals. It is one of the severe problems facing the world today due to the continual change in concentration levels of some gaseous and trace metals in the environment resulting from man's activities such as road transportation, vehicular traffic and industries [2, 3]. Air pollution has become a major environmental risk as far as public health is concerned. Reducing levels of air pollution may also reduce the global burden of disease. W.H.O has estimated that approximately 2 million and 1.3 million deaths worldwide mostly in developing countries have occurred due to indoor and outdoor air pollution [4, 5]. Several plants are known to be susceptible to very low concentrations of air pollution and exhibit a characteristic foliar injury following exposure to a specific air pollutant. They can therefore be used to determine the presence of air pollution in a given area. Monitoring for injurious levels of air pollutants by plants is a standard technique used in the diagnosis of air pollution injury on plants [4]. In recent years, increasing efforts are being made to use plants for detection of air quality. Biomonitoring is generally defined as the systematic use of living organisms or their responses to determine the condition or changes of the environment [5]. Biological monitoring of air pollutants can be passive or active. Passive methods observe plants growing naturally within the area of interest. Active methods detect the presence of air pollutants by placing test plants of known response and genotype into the study area [7]. Biomonitoring includes four concepts; the use of biomamarkers, bioindication, biointegration and bioaccumulation. Monitoring of air pollution using plants is cost-effective and environmentally friendly technique that substitute physical and chemical analytical methods of air pollution monitoring systems which is costly and unfriendly to the environment. Physical and chemical methods do not provide sufficient information on the risk associated with an exposure. Biological methods on the other hand, allow direct assessment of risk from an exposure. Another important of using plants in air pollution monitoring is that effects-related information which cannot be assessed by means of physical and chemical analytical methods of air pollution monitoring systems can be evaluated [7]. The aim of this paper is there to discuss the biomonitoring of air pollution using plants and the objectives are;

i. Discuss the background of information of air pollution and its effects of human being
ii. Examine the impacts of air pollution on physiological and biochemical features of plants and apply them to evaluate and monitor air pollution
iii. Discuss the various methods of monitoring air pollution using plants

2. IMPACTS OF AIR POLLUTION ON HUMAN HEALTH

Air pollution has been ranked in the top 10 causes of deaths in world, in global burden of diseases [8]. The distribution of air pollution diseases resulting in premature deaths is depicted as stroke (25.48%), chronic obstructive pulmonary disease (17.32%), ischemic heart disease (48.6%), lower respiratory infections (6.4%), and trachea, bronchus and lung cancer (2.02%) [8]. Industrial activities and anthropogenic activities have resulted in the release of toxic substances into the atmosphere that cause adverse health effects in human or animals; affect plant life and impact the global environment by changing the atmosphere of the earth. Under low concentration and long-term air pollution, body's immune and lung function will decline, and respiratory and circulatory system will change, inducing and promoting human allergic diseases, respiratory diseases and other diseases [8]. Inhalable particulate matter PM_{10} and fine particulate matter $PM_{2.5}$ is most harmful for health. They can come into bronchial causing bronchial inflammation [9]. SO_2 is oxidized to acid mist in the air, which can produce acute stimulation on the human eye conjunctiva, nose and respiratory tract mucosa [10]. NOx has low water solubility, and can invade the deep respiratory bronchioles and alveoli. After long-term inhalation, NOx will be oxidized by active substance oxidation surfactant, which produces nitrite and nitrate, and induces lung tissue corrosion and stimulation, causing bronchiolitis obliterans and pulmonary edema [11].

3. PLANT AS BIOASSAY SYSTEMS FOR MONITORING AIR POLLUTION

Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment [12]. Green plants have been used as air pollution indicators for many years. An indicator plant is one which exhibits symptomatology when exposed to phytotoxic concentrations of a pollutant or pollutant mixture. Green plants can also act as indicators of air pollution by accumulating the pollutant or some detectable metabolic product of the pollutant in their tissues [13]. It has been well established that vegetation canopies can act as sink for the air pollutants on not only gaseous pollutants but also the particulate pollutants [14]. Sensitivity and response of plants to air pollutants is variable. The plant species which are more sensitive act as biological indicators of air pollution whereas tolerant plants can be used for urban greening with an aim of improving the air quality The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the factors that determine resistance and susceptibility [15]. Effects of atmosphere pollution in Acacia (*Robinia psudo acacia L.*) leaves were studied in the city of Isfahan, Iran [16]. The tree has been found to be indispensable bioindicator of air pollution**.** Betula pendula (*Betulaceae*) was successfully used as a biomonitor in many studies for assessment of the pollution level in different countries like Russia. Olive tree leaves were used by Turan *et al*. [17] as a bioindicator for environmental pollution in the province of Aydin, Turkey.

A. Advantages of using plants as biomonitors [7, 18, 19];

i. Biological monitoring is generally less expensive than other methods and is thus particularly suitable for long-term monitoring over large areas without deploying sophisticated and high maintenance equipment.
ii. Indicator plants provide a direct method of studying the effects of the prevailing air pollution on living organisms
iii. They provide a measure of integrated effects of all environmental factors, including air pollutants and weather conditions
iv. Biological data can be used to estimate the environmental impact and potential impact on other organisms including humans.
v. There is an ease of sampling, and the absence of any necessary expensive technical equipment.
vi. It is possible to study the relationships between concentrations of air pollutants and its effects on plants when both are measured at the same site.
vii. It provides possibilities of determining spatial and temporal trends in the occurrence and intensity of effects of several air pollutants on natural and cultivated plants
viii. It is also possible to analyse the pollutants which is accumulated substantially within plants.

4. SELECTION OF BIOINDICATORS

The selection of biomonitor plants should consider the following factors [7, 19];

i. be easily identifiable in the field
ii. have a distinct response which is capable of predicting how the species or ecosystem will respond to the stress;
iii. widely distributed within the geographical range of pollution
iv. easy to sample repeatedly throughout the year in order to address temporal variability
v. They should be affordable

A. Using Lichens to Monitor Air Pollution

Lichens are epiphyte. They live on tree bark, rock, soil and several substrates. Lichens absorb water and minerals from rainwater and directly from the atmosphere, over their entire surface area. Lichen communities growing on tree bark (corticolous species) and walls and rocks (saxicolous species) show changes in response to air pollutants, particularly sulphur dioxide (SO_2), fluoro-compounds (F), deposition of nitrogen compounds and ozone (O_3). Lichens are particularly useful in indicating pollution loads over long periods. This makes them extremely sensitive to atmospheric pollution. As a result, there are usually very few lichens around industrial centers and towns [20]. Different lichen species vary in their tolerance to pollution and therefore make very good biological indicators of levels of atmospheric pollution. They are sensitive to gaseous pollutants, especially SO_2, fluorides and strongly oxidizing compounds, such as ozone. The sensitivity of lichens to air quality has facilitated their utilisation as important tools in air quality monitoring. The physiological and morphological features of lichens, which make them more sensitive to air pollutants than higher plants are absence of a cuticle, low chlorophyll content and lack of excretion [21].

B. Using Mosses to Monitor Air Pollution

Mosses like Lichens are also epiphyte. The moss is capable of surviving with ambient rainfall and thus act as a living collector and monitor of sulfur dioxide and heavy metals in the ambient air. Mosses undoubtedly are also capable of fluoride uptake and they may also be susceptible to other gaseous pollutants like ozone. When exposed to air pollution, mosses will appear black or brown and most communities will continue to decrease until disappear in long-term pollution [22].

C. Using Trees/Shrubs to Monitor Air Pollution

Urban trees and shrubs offer the ability to remove significant amounts of air pollutants and consequently improve environmental quality and human health [20]. Trees are capable of removing a significant amount of air pollutants from the atmosphere and hence should be considered an integral part of any sustainable plan intended at improving air quality. A large number of trees and shrubs have been identified as dust filters to check the rising urban dust pollution level [23].The assumption that plants are important absorbers of airborne particulate matters is supported by the confirmation obtained from studies dealing with trace elements, pollen, spore, salt, dust and unspecified particles . Trees remove gaseous air pollution primarily by uptake via leaf stomata. Inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces [24]. The use of higher plants especially different parts of trees, for air monitoring purpose is becoming more and more widespread. Roadside plant leaves are in direct contact with air pollutants, and may act as stressors for these pollutants [25]. Some selected plants suitable for biomonitoring of air pollution are listed in Table 1[26]

TABLE 1: Selected Plants Suitable for Biomonitoring of Air Pollution

Plant	Air pollutant
Tobacco, Tomato, Pea, Spinach, Oat, Crab Grass, Peanut	O_2
White Pine, Alfafa, Sesame, Cotton, Cucumber, Soybean, Pepper	SO_2
Moss, Bean, Chickweed, Mustard, Tobacco	PAN
Tomato, Lettuce, Citrus, Onion, Carrot, Tomato, Wheat, Corn	NO_2
Orchids, Cucumber & Marigold	C_2H_2
Apicot, Peach & Gladiolas	HF
Moss & Liches	SO_2, Particulates & Heavy Metals
Mango, Arjun, Jamun, Neem,	SO_2

5. EFFECTS AIR POLLUTION ON PLANTS PHYSIOLOGY

Air pollution is considered as a multi-stress agent, different kinds of pollutants like gaseous (SO_x, NO_x, VOCs) and particulates (trace elements and heavy metals, PAHs) are released in air as pollutants. Plants are left with no choice than to act as bystander and facing the air pollution exposure. Plants can also indicate pollution load in a particular area via alterations in physiological parameters such as pigment degradation, membrane damage, production of antioxidant metabolites and change in anti-oxidant enzyme activities [4]. The resistance and susceptibility of plants to air pollutants can be determined by its physiological and bio-chemical levels [24]. Damaging effects of air pollutants on plant growth and primary productivity has been reported by Ulrich [27]. Effects of air pollution on plants are reflected in terms of reduction in photosynthetic pigments, inhibition of certain physiological processes, alteration in metabolic functions and enzymes activities [26]. Ulrich [27] has reported suppression of growth and reduction in yield of crops in response to elevated concentrations of air pollutants. It has been established by several research groups that in response to abiotic stress, various biochemical changes occur in plants which include decreased chlorophyll and carotenoid content, and increased malondialdehyde (MDA) content [28, 29]. Pandey *et al.,* [30] observed relation of decrease in chlorophyll content with chloroplast damage while [31] has attributed decrease in chlorophyll content to inhibition of chlorophyll biosynthesis. Degradation of chlorophyll and de-coloration of leaves are the visible injuries caused by air pollutants. Chlorophyll content indicates photosynthetic activity in plants [31]. It is known that carotenoids have photoprotective function and protect chlorophyll from photoxidative damage [32]. Under stress, the protective function of carotenoids may be hampered as it has been reported that carotenoids too are affected by air pollutants [33]. Sharma and Tripathi [34] have observed reduction in chlorophyll *a*, chlorophyll *b* and carotenoids in *Ficus benghalensis* L. and *Dalbergia sisso* near sites with higher air pollution level. Similarly Nayek *et al.,* [35] have also reported substantial decline in total chlorophyll that ranged between 35 to 60% in *Shorea robusta*, *Alstonia scholaris*, *Peltophorum pterocarpum*, *Albizia lebbeck*, *Tectona grandis*, *Lagerstroemia speciosa* and *Delonix regia* exposed to industrial pollution. Air pollutants generate reactive oxygen species (ROS) that leads to damage at cellular and molecular levels [36]. Damaging effects induced by oxidative stress may get minimized by various enzymatic and non-enzymatic anti-oxidant defense mechanisms as has been suggested by [37]. Some symptoms of injury exhibited plants when expose to air pollutants are presented in Table 2 [38];

TABLE 2: Symptoms of exposure of selected Air Pollutants on Plants

S/N	Pollutants	Plant Injury/Symptoms
1	Sulphur dioxide (SO_2)	Interveinal necrotic blotches. Banding in pines
2	Nitrogen dioxide (NO_2)	Interveinal necrotic blotches
3	Ozone (O_3)	Upper surface flecks. Distal necrosis and stunted needles in pines.
4	Flouride (F)	Red brown distal necrosis in pines
5	Hydrogen Sulphide (H_2S)	Interveinal necrotic blotches
6	Ethylene	Chlorosis, necrosis. Dwarfing premature defoliation.
7	Trace Metals	Interveinal chlorosis, Tip and margin necrosis and Distal necrosis.
8	Chlorine (Cl)	Interveinal necrosis botches

6. METHODS OF BIOMONITORING OF AIR POLLUTION USING PLANTS

A. *Methods of Monitoring Air Pollution using Lichen and Moses*

Lichens and mosses may be considered as the most commonly applied biomonitor organisms. This is mainly because of their lack of any roots comparable to higher plants [39]. Various methods of monitoring lichens and moses are explained below;

i. Index of Atmospheric Purity (IAP)

Indices of Atmospheric Purity (IAP) examines the effects of a pollutant source on lichen communities. It is a quantitative phytosociological approach that requires the collection of data such as frequency and or percentage cover and a factor of tolerance to toxicity. IAP values generally increase as communities become more complex further from the pollution source. These values can also be plotted on a map (inventory plot), which in turn can be used to determine IAP zones. For example, in a group of six marked trees on each of the inventory plots, the abundance (a) and coverage (c) of three of the most important epiphytic lichen thallus types, crustose (C), foliose (F) and fructicose (R), are mapped at three heights, h (m): (i) from 0 to 0.5 m (ii) from 0.5 to 2.5 and (iii) above 3 m. From the data above, an IAP is calculated for each inventory plot (IAPt) for each stratum of observation separately (IAP_1 = observations on the tree trunks up to 0.5 m, IAP_2 = 0.5–2.5 m; IAP3 = above 3 m), using the following formulae:

$$IAP_{1,2,3} = C(a + c) + F(a + c) + R(a + c) \quad (1)$$

$$IAPt = IAP_1 + IAP_2 + IAP_3 \quad (2)$$

Where, the symbols represent the above mentioned observed lichen parameters. The IAP index has a span between 0–54 where the value 0 means a plot without lichens and much polluted air, and the value 54 means very rich lichen vegetation and very clean air [40].

ii. Dynamic Models

Dynamic models are usually considered for describing the dynamics of the accumulation of trace substances by lichens by taking into account knowledge on mineral cycling in lichens [39]. The model is presented as;
Time-dependent activity concentrations on a dry weight basis; c(t), are given as;

$$C\ (t) = Ip\,\frac{A}{M}\,e^{-(k01+\lambda)t} \quad (3)$$

for a pulse-linke input Ip (B(I-rn-2) and as;

$$C\ (t) = \frac{Ic}{k01+\lambda}\frac{A}{M}\ (1 - e^{-(k01+\lambda)t} \quad (4)$$

for a constant input rate Ic (Bq m-2 s-1). The ratio A/m can be interpreted as the effective surface area of fallout, trapped per lichen mass [41].

iii. Response methods

Information in lichen monitoring studies can be gained from observing morphological and physiological changes and the health status of lichens such as changes in chlorophyll content, proline, ascorbic acid and other biochemical parameters [42]. Quantifiable physiological changes can be examined as a measure of pollution stress. The advancement of laboratory techniques has aided the development of such procedures.

B. Methods of Monitoring Air Pollution using higher Plants

i. Air Pollution Tolerance Index (APTI) of Plants

The plant response to air pollution varies from species to species and also in terms of type of pollutant, its reacting mechanism, concentration and duration of exposure. The pollutants enter into the plants and react in a variety of ways before being removed or absorbed that may include accumulation, chemical transformation and incorporation into the metabolic system. In this process, some plants are injured while others show minimal effects. The use of a single parameter in ecophysiological research may not provide a clear picture of the pollution induced changes that may occur in plants. Therefore, an air pollution tolerance index based on combined values of ascorbic acid, relative water content, total chlorophyll and pH of leaf extract has been used for plant tolerance evaluation. The four biochemical parameters considered for APTI calculations are shown to be affected by air pollution by several researchers [43, 44, 45]. By calculating these parameters, the APTI can be computed as [43];

$$\text{APTI} = \frac{[A(T+P)+R]}{10} \tag{5}$$

Where, A = Ascorbic acid (mg/g), T = Total Chlorophyll content (mg/g), P = pH of leaf extract and R = Relative Water Content (%). The APTI index range is shown in Table 3 [43];

TABLE 3: Air pollution Tolerance Index (APTI) Range for Plants

APTI value	Response
<1	Very sensitive
1 to 16	Sensitive
17 to 29	Intermediate
30 to 100	Tolerant

Escobedo *et al.,* [15] reported that high pH may increase the efficiency of conversion from hexose sugar ascorbic acid. Role of ascorbic acid in photosynthetic carbon fixation has been observed by Pasqualini *et al* [46]. Assessment of APTI of plants exposed to air pollution have been carried out by several researchers [43, 45, 46, 47, 48, 49, 50]. Nayek *et al* [35] have estimated the APTI of *Shorea robusta*, *Alstonia scholaris*, *Peltophorum pterocarpum*, *Albizia lebbeck*, *Tectona grandis*, *Lagerstroemia speciosa* and *Delonix regia* near industrial sites and reported the former four plants as tolerant in those industrial zones. Thus, sensitive plants can be used as bio indicator of air pollution and on the other hand the tolerant plants can be used for urban greening as suggested by Miria and Khan [51]. Randhi and Reddy [52] studied air pollution tolerance Index (APTI value) of sixteen different plant species grown in different areas like residential areas, traffic areas, industrial areas and peri-urban areas of Hyderabad, Andhra. On the basis of tolerance index value, the plant species were characterized into sensitive, intermediately tolerant, moderately tolerant and tolerant plant species. *Delonix regia Hook. Peltophorum pterocarpum DC. Alestonia scholaris L., Ficus religiosa L., Samania saman Jacq and Azardirachta indica A. Juss* expressed high APTI values and these are suitable sinks to mitigate the air pollution. *Millingtonia hortensis L.f., Clerodendrum paniculatum L., Terminalia arjuna Roxb. Pongamia pinnata L., Polyalthia longifonia Sonn. And Emblica officinalis Gaertner showed* intermediate tolerance capacity and the other four plant species *Syzygium cumin L.i, Terminalia catappa L., Swietenia mahagoni L. and Saraca indica L.* acts as bio-indicators of air pollution stress as these are sensitive to the air pollution. Jissy Jyothi and Jaya [25] have worked on six different species- *Polyalthia longifolia, Alstonia scholaris, Mangifera indica, Clerodendron infortunatum, Eupatorium odoratum* and *Hytis suaveolens* growing adjacent to the National Highway-47 passing through Thiruvananthapuram district. *Polyalthia longifolia* expressed highest APTI values and proved to be a tolerant variety and the others are sensitive to air pollutants. Bakiyaraj and Ayyappan [13] have worked on ten physiological and biochemical parameters namely; leaf extract pH, Relative Water Content, Ascorbic acid, Chlorophyll, protein, amino acid, reducing sugar, starch and phenol to evaluate the susceptibility levels of eleven commonly grown plant species around Neyveli Lignite Corporation Limited (NLC) area of Tamilandu, India to air pollution. These parameters were determined and computed together in a formulation the Air Pollution Tolerance Index (APTI). Their results showed that *Eucalyptus sp* (6.52%) have the higher APTI value reflects the higher tolerance level in air pollution. Similarly *Murrya koenigii* (0.81) showed lower APTI value reflects sensitive nature against air pollution. A study recently undertaken by Nadgo´rska-Socha *et al* [53] to evaluate air pollution tolerance index and to determine the contents of selected metabolites revealed that *R. pseudoacacia* had decreased ascorbic acid and chlorophyll levels in the contaminated site. Whereas opposite tendency was recorded in *M. album leaves*. *M. album and R. pseudoacacia* proved to be sensitive species with the air pollution tolerance index lower than 11 and can be recommended as bioindicators. Tanee, and Albert [54] evaluated the APTI of 10 plants growing around the vicinity of Umuebulu Gas flare Station in Oyigbo Local Government Area of Rivers State, Nigeria. Their results showed order of tolerance as *Psidium guajava* (0.10%) > *Puerenia phaseoloides* (0.36%) > *Mallotus oppositifolus* (3.23%) > *Musa paradisiaca* (6.80%) > *Telfairia occidentalis* (7.01%) > *Cymbopogon* citratus (9.18%) > *Talinum triangulare* (9.36%) > *Vernonia amygdalina* (12.34%) > *Manihot esculenta* (14.61%) > *Ocimum gratissimum* (36.53%); showing *Psidium guajava* as the most tolerant species while *Ocimum gratissimum* as the most sensitive species to air pollution stress. Otuu *et al* [55] evaluated six species of ornamental plants commonly marketed (Ficus, Hibiscus, Ixora, Phitis, Toja and Red rose) in Enugu State, Nigeria for their (APTI). The APTI of each plant was computed from four physiological and bio-chemical parameters namely: PH of the leaf extract, Relative water content, Ascorbic acid and chlorophyll content. The APTI values ranged between 9.04-15.26 on Hibiscus and Toja respectively. The ornamental plants with high APTI (Tolerant) are recommended for use in domestic, industrial and urban land scapping both for their aesthetic values and phytoremediation potential of air polluted environment, while the plants with low APTI (Sensitive) are to be used as bio-indicators of environmental air quality. Another study carriedout by Agbaire and Esiefarienrhe [56] in Delta State, Nigeria examined the (APTI) of six plant species around Otorogun gas plant in Ughelli-South Local Government Area and found theorder of tolerance of the plant species as *Emilia Samtifolia* (1.49%)>

Manihot esculenta (2.19%)> *Elaesis guineensis* (2.41%)> *Impereta cylindrical* (25.56%)> *Eupatorium Odoratum* (35.17%)> *Psidium guayava* (45.11%).

i. Photosynthesis and Stomatal Conductance

Measurement of photosynthesis and stomatal conduction are common measures of gaseous air pollution damage in that they respond quickly to air pollutants and can be measured by non-destructive techniques. The stomatal conductance, photosynthetic rate and pigment content in Ruellia tuberose leaves as affected by coal-smoke pollution [57].

ii. Tree Ring Analysis

The analysis of tree ring usually gives the long term history of pollution in an area. Tree ring patterns offer a long-term, baseline dataset whereby changes in growth in response to pollution stresses can be detected. This method is complicated by the fact that air pollution effects on ring increments are not necessarily distinct and may be prone to misinterpretation. The potential of tree-ring analysis as a bioindication method in air pollution diagnosis is obvious. However, further research in this field is necessary to determine the credibility and future of the technique [38].

7. SUMMARY

Air pollution is considered as a multi-stress agent, different kinds of pollutants like gaseous (SOx, NOx, VOCs) and particulates (trace elements and heavy metals, PAHs) are released in air as pollutants. Plants are left with no choice than to act as bystander and facing the air pollution exposure. The pollutants enter into the plants and react in a variety of ways before being removed or absorbed that may include accumulation, chemical transformation and incorporation into the metabolic system. In this process, some plants are injured while others show minimal effects. Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment. Using biomonitoring methods to the plant species is an important approach towards air pollution monitoring and abatement.

8. CONCLUSION

Air pollution is one of the major environmental problems that is receiving global attention because of it adverse effects on both plants and animals. Hence, there is need of integral efforts toward remediation and monitoring of air pollution. Biomonitoring using plants remains the method of choice because of its sustainability, affordability and eco-friendliness. The plants that are sensitive to a particular pollutant or mixture of pollutants can be used as veritable tools towards mitigating environmental and health problems associated with air pollution.

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