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Lichens as Integrating Monitors for Air Pollution: A Review

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Abstract – The study of air pollution is very important throughout the world. Among the biological methods the use of lichens as a bio-indicator has been very popular. Lichens are used as effective monitors to detect low-level air pollution which may affect different flora and fauna communities. Lichens have been widely recognized as effective eco-friendly bio-monitors for detection of metal deposition on trees, rocks and bare ground. This article is concerned with the use of lichens in bio-monitoring of air pollution, how the lichens do recognize air pollution, the mechanisms of accumulation and trapping of particulate matters, understanding the mechanisms of alterations and the methods of study and factors affecting the process. Species of various lichen like Lecanora, Candelariella, Dirinaria, Buelia, Laurera, Lecanora, can act as air pollution indicator.

Key Words: Air Pollution, Bio-Indicator, Environmental Factor, Lichen, Epiphytic.

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1. INTRODUCTION

Lichens look like single plants, but they are associations of two different organisms, an alga and a fungus, living in close relationship. It is symbiotic association between an alga and a fungus, and forms composite organisms with an ability to colonize on a variety of substrates including surface of soils, rocks, bark of trees, decaying lags and man–made structures in different environmental conditions. The important parameters required for the growth and abundance of lichens are adequate amount of moisture, light and altitude, unpolluted air and undisturbed, perennial substratum.(1) They are cosmopolitan in nature, but are diverse in tropical region and luxuriant in temperate-alpine areas. Lichens along with mosses form dominant organism in earth ecosystem covering over 10 % of the earth's terrestrial habitat.(2-3) The lichens form a major component of Indian biodiversity; the eastern Himalaya contains the maximum number of 1141 species and is followed by Western Ghats and western Himalaya with 1136 and 781 species respectively.(4) Since lichens have no roots, they absorb much of their raw materials directly from the air and moisture around them. This makes them very sensitive to air pollution, climate change and air pollution are two very important fields to study as they impact not only human beings but also affect flora and fauna throughout the world. (5-6)

2. Lichens as bio-indicators of air pollution

As per World Health Organization - Air pollution is contamination of the indoor and outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Indicators are required to monitor ecological conditions and used for early warning. Lichens were recognized as potential indicators of air pollution as early as the 1860's in Britain and Europe. The lichen species best suited as bio-monitors are foliose (having a lobed, leaf-like shape) and fruticose (having upright or pendulous branches) epiphytic lichens. The properties that make them suitable for monitoring purposes are the weakly developed cuticle and vascular bundles, absence of real roots, their slow-growing nature and long life cycle and their broad distribution.(7-10)

Advantages of lichens that make them suitable bio-monitors

Lichens are very important for nutrient cycling. They don't have any vascular system and thus absorb water and humidity passively from their surrounding environment and adsorb metal ions through ion exchange process and trap fine particles of rock, soil or any other heavy metal pollutants within their body. Lichens external morphology does not very with change in environmental condition, and accumulation of pollutants can occur throughout the year. All the lichens are not equally sensitive to air pollutants but show different sensitivity to specific atmospheric pollutants.(11) The sensitivity usually follows a series; *crustose (flat, tightly adhered, crust-like lichens) < foliose (leafy lichens) < fruticose (shrubby lichens),* though there are exceptions to this gradation. Due to this specific response to atmospheric pollutants, lichens can be denoted as excellent markers of for early warning system to

monitor and detect climate change and air pollution.[12-18] Bio-monitoring surveys by lichens have also been carried out to estimate the pollutant load in forest ecosystems reported the sensitivity of lichen species to arrange of concentrations of air pollutants.[19-20] Loss of lichen diversity and change in their community due to air pollution, urbanization and changed climate has beenwitnessed in Bangalore and Kolkata cities.[21-23]

Mechanisms of accumulation and particulate trapping

Lichens have a large surface area-to-volume ratio due to their thin thallus and branching habit. Lichens accumulate nutrients from their environment by a variety of mechanisms, including intracellular uptake, hydrolysis, particulate trapping, ion exchange and extracellular electrolyte absorption. Due to the surface characteristics, various particles gets embedded in the lichen thallus under moist or dry conditions. The cell wall is mostly involved in the process of mass and charge balance. So, lichens now a day's used as accumulative monitors of persistent pollutants by determining the content of trace elements within them.[24-25]

3. Methods used to measure the responses of lichens to air pollution

The most widely used methods to measure these responses are fumigation and gradient studies.[26] The basis of undertaking gradient analysis method lies on the fact that characteristic of affected species varies according to the environmental gradients. Such studies are usually done around existing or projected sources of contaminants, with pollutant loadings expected to vary with distance from a source. Some difficulties may be faced when gradient studies are undertaken such as identification of species, determination of suitable indicator species and proper interpretation of data showing that the observed patterns reflect pollution stress and not other biotic and abiotic factors. Gradient studies can further be classified into stages;

1. By mapping all lichen species present in an area.

2. By transplanting lichens from uncontaminated sites to contaminated ones and measuring the bio-accumulation of pollutants within their body.

Mapping species present in a specific area

Lichens depend on atmospheric moisture: rain, fog and dew for growth. There are slow in growth and very sensitive towards the changing environmental conditions. Since, they absorb water and essential nutrients from atmosphere instead of from soil, hence they respond in altered manner to increased concentrations of pollutants in air. Mapping of air quality in an area can be made by following IAP (Index of Atmospheric Purity) method, based on number (n), frequency (F) and tolerance of the lichen present in the area under study.[27] IAP can be determined by using the following formula: IAP= $\sum$ Fi

Where F is the frequency (max 10) of the every i^{th} species that is calculated as number of rectangles in the grid. The rectangle is of the dimensions 30 X 50 cm each in which a given species appears. The IAP values are grouped into five quality levels which are given in Table 1.

Table 1: Quality levels of IAP values

IAP Levels	Degree of pollution
0 ≤ IAP ≤ 12	Very high level of air pollution
12 < IAP ≤ 25	High level of air pollution
25 < IAP ≤ 37	Moderate level of air pollution
37 < IAP ≤ 50	Low level of air pollution
IAP > 50	Very low level of air pollution

A combined study of air pollution with lichen and analysis of quantities levels of trace elements was done by Jeran et al. [28]

Use of transplanting methods

Lichen thalli are transplanted on a suitable substrate and exposed to polluted areas. Samples are taken periodically and observed for any damage. This method is used in bioaccumulation studies in order to study absorption, retention, localization and release, tolerance and toxicity of pollutants. A comparative study of atmospheric quality in five zones of Cordoba city (Argentina) was done using transplanted *Usnea* species.[29]

Sizing-up lichens

The size of lichens is a good indicator of air quality which depends on age and amount of sunlight. Assuming standard conditions for growth the data can be used to determine air quality. The relation between size and air quality is given in Table 2.

Table 2: Lichen size and air quality

Size in cm^2	Air quality
0 - 3	Poor air quality
4 - 6	Fair air quality
7 - 9	Good air quality
10 - 12	Excellent air quality

Responses of lichens to air pollution

Lichens are very sensitive to pollutants and therefore by measuring changes in community or population of lichens, we can estimate the biological effects of pollutants. Lichens have been used often as receptor-based bio-monitors in air quality studies.

Several experimental studies have been published on the effects of sulfur dioxide, nitrogen compounds, ozone, heavy metals and other atmospheric pollutants on the morphology and physiology of lichens.[30] Characters of lichens which are used to measure the magnitude of air pollution include morphological, physiological and population characteristics. Studies have emphasized the significance of lichen morphology and physiology in the accumulation of elements.[31] Microscopic studies reveal that long term air pollution not only changes the thallus structure but also altered the pigment structure of lichen. Different types of lichens have been studied for monitoring and quantification of diverse atmospheric pollutants. High amount of Mercury accumulation was observed in lichens near a thermometer factory in Kodaikanal.[8] Studies of Lucknow city showed that crustose lichen *Arthopyrenia nidulans* and foliose lichen *Phaeophyscia orbicularis* had high capacity to accumulate heavy metals.[9] Shukla et al. observed that accumulation of Polycyclic Aromatic hydrocarbon in the lichens of Garhwal Himalaya.[32] The crustose lichens can tolerate much more in polluted area than the other two types.

4. DISCUSSION

Air pollution in the recent years has become a serious problem not only in developed countries, but currently it raised as a major global environmental issue mainly due to the increased fossil fuel consumption in uncontrolled and non planning manner. Moreover, the lack of proper planning to implement mitigation control measures is also a hurdle in management of air pollution. Although, the various methods used to control air pollution provide accurate and reliable data, the instruments required for such assays are expensive and cannot provide monitoring at high intensity levels across large areas at different locations. Therefore, the forecast of air pollution is one of the safe and timely measures. Numbers of physical/chemical monitoring tools, available for motoring air quality are apart not only expensive but too time consuming. Bio-indicators, in this context are one of the best, inexpensive and natural agents, forecasting the presence of pollutants in air. Their response to any change in climate or pollution is much faster than any other biota. Comparison of lichens growth in polluted and healthy environment, a clear cut change in growth as well as addition or reduced growth can be observed. There are very much sensitive to air pollutants like SO_2, CO_2, CO etc.; thereby the number of lichen thalli in the polluted area is gradually reduced and ultimately it comes down to nil. For this reasons, the lichens are markedly absent in cities and industrial areas.

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