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Biomonitoring with Lichens: Evaluating Heavy Metal Concentrations, Environmental Factors, and Lichen Diversity in Bengaluru, Karnataka, India

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ABSTRACT

Lichens are commonly used in biomonitoring due to their unique characteristics that make them a cost-effective option. Unlike chemical analysis, sampling lichen diversity is less expensive, enabling a more extensive sampling coverage while reducing costs. This diverse group of organisms can be used to detect areas that are affected by pollution, land use changes, and ecological imbalances. In recent years, researchers have been working to establish a reliable protocol for lichen sampling in biomonitoring to enhance its utility and minimize any variations caused by extraneous environmental factors. In this article concentrations of heavy metals s (Cd, Cr, Cu, Fe, Ni, Pb and Zn), acidity and electrical conductance of few flowering trees bark (Albizialebbeck, Delonixregia, Pongamiaglabra, Callistemon Lanceolatus, Cassia Fistula, Cassia Javanica) were evaluated to determine the impact the lichen value diversity in six different places based on different environmental factors. It has been stated that the correlation between acidity level and lichen species exists in all investigated tree species. Six lichen species (Chrysothrixcandelaris (L.) Laundon, Graphisscripta (L.) Ach, G. scripta (L.) Ach., leucosorodes Nyl, D. consimilis (Stirton) Awasthi, D. aegialita (Afz. in Ach.) Moore and L.(perplexa Brodo) were registered, among them three were foliose and three were crutose. Lichen leucosorode Nyl was predominant in Albizialebbeck, Delonixregia, Pongamiaglabra trees. It was observed that the lichen diversity was less near heavy traffic location, industrial areas and also rougher bark of trees provided a better habitat of wider variety of lichen species.

Keywords Lichen value, Electrical conductance, Air quality, Biomonitoring, Environmental variables.

INTRODUCTION

Lichens are widely recognized for their sensitivity to various types of habitat alterations, many of which are caused by human activities. This ability to detect changes is due to the special physiological features of lichens, making them useful tools for monitoring and indicating shifts in habitats. By providing a comprehensive representation of all disturbances present in their surroundings, lichens serve as valuable indicators of environmental changes.

There are three methods by which biomonitoring

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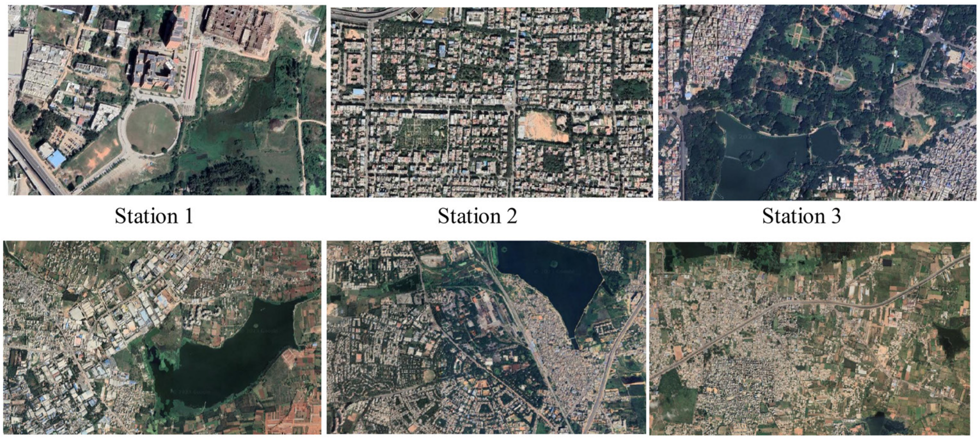
can be carried out using lichens: Analyzing changes in diversity and/or population, examining variations in physiological traits, and utilizing lichens as accumulators of contaminants (Branquinho 2001). A multitude of studies have been conducted worldwide that rely on lichen diversity, with the assumption that species that are sensitive to pollution will decrease in areas with high pollution levels, while more tolerant species will persist like Nimis *et al.* (1991), Mazzei *et al.* (2013), Sujetovienė (2014), Asif *et al*. (2018), Ding *et al.* (2020), Kiviat (2013), Matos *et al.* (2019), Dittrich *et al.* (2022), Loppi (2019), Çetin (2020).

The mapping of lichen biodiversity or richness can highlight areas with differing degrees of perturbation, but using only this data is insufficient in determining the underlying causes of such perturbations. In order to identify the stressors responsible for the declines in lichen biodiversity, further examination of the abiotic factors impacting lichen communities is imperative. Hence, in environmental pollution studies, a more comprehensive approach of chemical analysis is advisable to determine the specific pollutants (Matos *et al.* 2014). In addition to pollution, lichen biodiversity is also susceptible to changes in various environmental factors such as temperature, precipitation, landform, and soil composition. These abiotic variables, which encompass both macro- and micro-climatic variations, play a crucial role in determining lichen biodiversity. Thus, it is important to consider the effects of these macroclimatic variables when studying changes in lichen populations (Srivastava and Bhattacharya 2015).

The presence of industries, high population density, and heavy vehicular traffic are the major sources of pollutants such as dust, sulfur oxides, nitrogen oxides and heavy metals. These pollutants cause significant chemical and physical alterations to the tree bark, which serves as a natural habitat for epiphytic lichens. This study endeavors to explore the diversity of lichen values and its relationship with acidity, electrical conductivity and concentration of heavy metals in six distinct locations (Begum *et al.* 2009). Bengaluru, also known as the "Garden City," serves as the capital of the Karnataka state in India and is located at coordinates 12.9716^{0}N and 77.5946^{0}E, situated at an altitude of 1000 meters above sea level. As one of the rapidly expanding cities in India, Bengaluru has experienced significant growth in both population and economic activity in recent decades, boasting a metropolitan population of 8.52 million. A major contributor to the rise in air pollution is the exponential increase in vehicular traffic and industrial growth. Studies have revealed a distinct pattern in the response of lichen species to increasing levels of air pollution. The disappearance of fruticose lichens occurs first, followed by foliaceous lichens, while the crustose (cork-forming) forms of lichens are the last to vanish. Consequently, analyzing the composition of lichen flora in various areas within a city, such as residential zones, industrialized areas, parks, and marketplaces, provides a reliable method for assessing air pollution levels. PESIT South Campus (Station-1) is a private co-educational engineering college located on Hosur Road and is about one kilometer from Electronic City situated at 12.8615 ^{0}N and 77.6647^{0}E. The beautiful campus accommodates diverse variety of flora. The Hosur-Sarjapur Road (Station-2) serves as a major transportation hub, connecting numerous bustling areas such as Whitefield, Electronic City, the Outer Ring Road, Marathahalli, and Koramangala, with heavy traffic flow situated at 12.9121° N, 77.6446° E. It is a fast-developing part of south-east Bengaluru. This road always faces traffic jams especially during peak hours. Also, this road on either side provides green space. Lalbagh Botanical garden (Station-3) is a 240 acres (0.97 km^2) garden and is located in south Bengaluru at 12.9507^0 N and 77.5848^{0}E. The garden has over 1,000 species of flora. The garden also has trees that are over 100 years old. The Jigani Industrial Area (Station-4), situated at 12.7791° N, 77.6436° E, is predominantly occupied by chemical and pharmaceutical industries. However, the environmental plight of this region is starkly evident as the sprawling Hannegara Lake surrounding the area suffers from extreme pollution caused by industrial waste. Yelahanka (Station-5), located north of Bengaluru town, is a recently developed residential area at 13.1155° N, 77.6070° E. This region boasts the presence of Yelahanka Lake, which enhances its appeal as a habitat for diverse lichen species. The tranquil lake contributes to making Yelahanka an ideal environment for various lichen species to thrive. Located on the outskirts of Bengaluru at 13.0693° N, 77.7982° E, Hoskote (Station-6) is a rapidly de-



Station 1 Station 2 Station 3

Station 4 Station 5 Station 6

Fig. 1. Satellite view of the selected stations for collecting samples throughout Bengaluru.

veloping rural area Fig. 1. Primarily known for its residential character, it exhibits minimal industrial development in its surroundings. Hoskote offers a serene environment and holds immense potential for further growth and expansion.

The aim of this study was to gather the necessary information for conducting a comprehensive pollution assessment. A map was created to identify the areas where chemical analysis should be focused. The objectives of this research also included determining the efficacy of the sampling design chosen for evaluating lichen biodiversity in reflecting the impact of atmospheric pollution, rather than solely microclimatic variations.

MATERIALS AND METHODS

This study is to investigate the effect of environmental stress on lichen species. Lichen species were identified based on the species of the genera. Lichens that exhibit tolerance to pollution have the ability to accumulate substances from rainfall and capture airborne particles. Consequently, certain pollutants become concentrated within the lichen itself. Sampling trees common in all the three locations were selected for the conduct of acidity and electrical conductivity. Three samples of bark from each tree belonging to six different locations were taken grinded. Two grams of finely milled bark was mixed with 20 ml deionized water and left to stand for 24 hours. Electrical conductivity and acidity were measured using pre-calibrated digital pH meter and Conductivity meter at room temperature (Begum *et al.* 2009).

For measuring concentration of heavy metals Lichen samples were carefully collected from the bark of palm trees with diameters ranging from 50 to 70 cm, at a height of 0.5 to 0.7 meters. After collection, the lichens were delicately removed from the bark and dried in an oven at a constant temperature of 80°C. The dried lichen samples were then powdered (0.5g) for subsequent metal analysis. Extraction of the lichen samples involved using a mixture of concentrated HCl and HNO3 (in a 3:1 ratio) and digestion at 80°C, with the addition of a few drops of perchloric acid. The resulting mixture was filtered using Whatman filter paper No. 42, and the filtrate was diluted to the desired volume using de-ionized water. Finally, the total concentrations of Cd, Cr, Cu, Fe, Ni, Pb, and Zn in the filtrate were determined using an atomic absorption spectrometer. Buffer capacity ($\beta = dn/dpH$) was determined by soaking two grams of bark samples in 20 ml of deionized water for 2 hrs. The liquid was separated and pH was determined by using pre-calibrated pH meter at room temperature. Titration was done using 0.01 N HCl. The pH value was recorded after each acid addition. A magnetic stirrer was used to mix the solution (Begum and Hari Krishna 2010). The mill equivalents (N × mL) of acid needed to change the pH to 3.0 were calculated as the buffer capacity of tree bark.

RESULTS AND DISCUSSION

The Lichen Biodiversity Index (LBI) was created by Cioffi *et al.* (2009) and later improved by Abas and Awang to evaluate air pollution levels. It was specifically designed to account for the diversity of tropical lichens, particularly those found in urban environments. The LBI evaluates the number and occurrence rate of lichen species present in a given environment and translates this data into a corresponding condition rating. The objective of this project was to utilize data on lichen biodiversity to obtain the necessary information for an pollution evaluation in Bengaluru. Additionally, the aim was to reduce the amount of chemical analysis required by restricting it to specific sites. Figure 2 shows the result of pH value for different species of tree barks at three different locations. Analysis shows that there were significant differences in acidity between trees (1% level of probability) and also in different locations. The bark pH value was low in all the tree species of Station-2 and Station-4 in comparison with Station-1, Station-3, Station-5 and Station-6. The lowest mean pH value in all the location was of Pongamiaglabra (pH = 3.1) in Station-4. The highest mean pH value (pH= 5.9) was found in Cassia Javanica (Station-3). The difference in acidity level may be attributed to heavy traffic and increase in air pollution level.

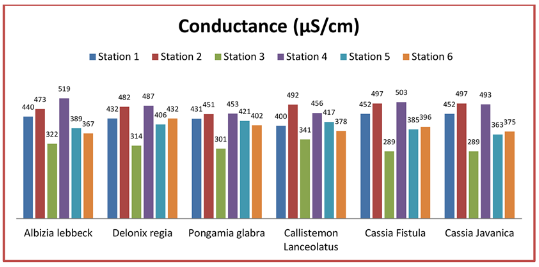


Fig. 3. Conductivity of barks of experimental trees in three different locations.

Via the deposition of contaminants, chemical processes that erode the bark, and biological effects on tree health, pollution can affect the conductivity of tree bark. Pollutants that have been deposited may leave a coating of contamination on the bark's surface, thus reducing its capacity to conduct electricity. Corrosion of the bark and disruption of its conductivity capabilities can result from chemical reactions with contaminants, such as acid generation. Moreover, the structure and conductivity of the bark may change as a result of stress and damage brought on by pollution.

Fig. 3 Shows the result of electrical conductance for 6 different species of tree bark at six different locations. Highest value of electrical conductance was recorded in locality with higher level of air pollution and vice versa. The bark conductance values in all the tree species were high in Station-2 and Station-4 in comparison with other stations. The electrical conductivity values were correlated acidity of the tree bark. The average lowest EC values (289 µS/cm) was found in *Cassia fistula* bark in Station-3 and highest EC values (519 µS/cm) Albizialebbeck in Station-1. Linear relationships existed between the pH and conductivity of the tree bark (Abas *et al.* 2022).

The ability of natural systems to act as a buffer against pollution can be significantly impacted.

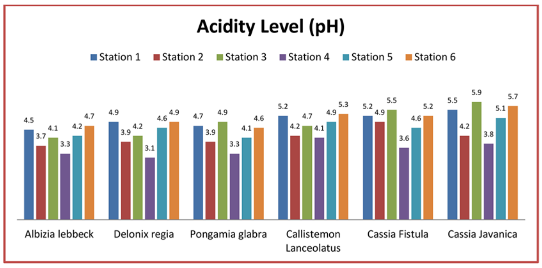


Fig. 2. pH values of barks of experimental trees in three different locations.

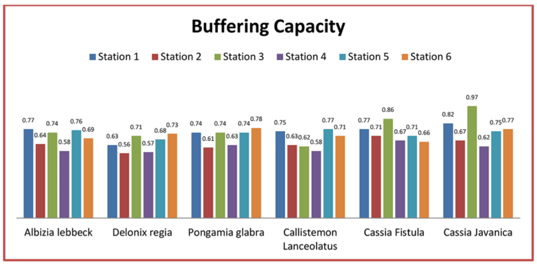


Fig. 4. Buffering capacity of barks of experimental trees in three different locations.

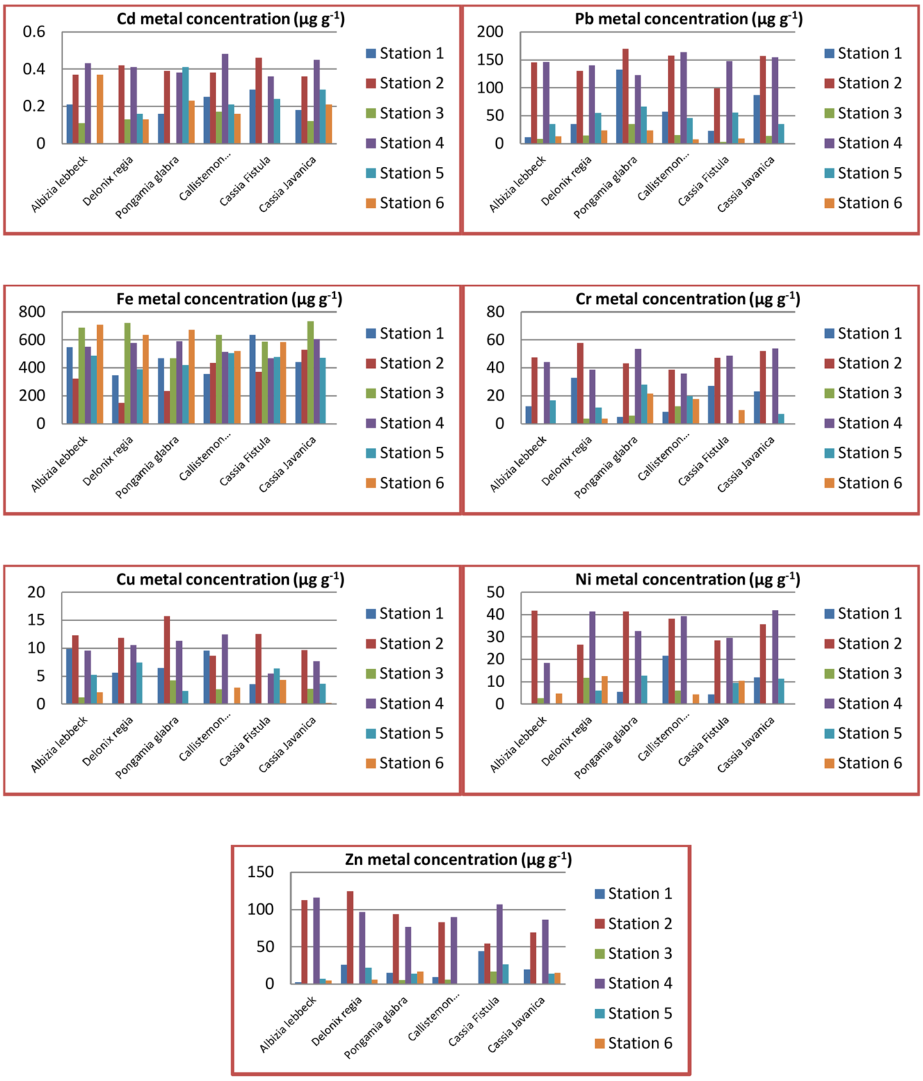


Fig. 5. Metal concentration (µg g^{-1}) in various lichen species from various stations throughout Bengaluru.

Pollutants' chemical interference can upset the equilibrium of buffer's constituent parts, lowering their capacity to withstand pH variations. By affecting the microbal populations in charge of maintaining pH stability, imbalances in key nutrients brought on by pollution can also have an impact on buffer capacity. Moreover, acidification can result from acid rain, a frequent side effect of pollution, which can directly lower pH levels in soils and water bodies. Also, as plants are crucial in maintaining pH balance through activities like ion uptake, release, and organic acid synthesis, pollution-induced vegetation loss might reduce buffer capacity.

Fig. 4 Shows the result of buffer capacity for different barks of tree species. The highest mean buffer capacity values of 0.97 was for *Cassia javanica* at Station-3 and least mean buffer capacity value of 0.56 for *Delonixregia* at Station-2. The buffering capacity values in all the tree species were highest in Station-3 followed by Station-6, Station-5 and Station-1 respectively. The buffering capacity was observed remarkably low at Station-2 and Staion-4 in comparison with other stations. Bark of the species with high pH value may have been acidified with time.

The amount of pollution in the environment is closely correlated with the prevalence of heavy metals in lichens. Lichens are useful bioindicators of pollution due to their extraordinary capacity to absorb and retain airborne contaminants, particularly heavy metals. Heavy metals are released into the environment as a result of industrial processes, car emissions, and other human activities. These heavy metals can subsequently be deposited on lichen surfaces and taken up by their tissues. Researchers can determine the amount and effects of pollution by evaluating the concentration of heavy metals in lichens, which reflects the pollution levels in the area. Scientists can learn more about air quality and pinpoint regions with varied pollution loads by examining the heavy metal level in lichens taken from various sites.

The heavy metal analysis of different lichen species was conducted from all the stations and their diversity was observed to vary significantly. Station-3 and Station-6 showed a greater variety and abundance of lichens, which can be attributed to the presence of a non-polluted atmosphere with moist and shady conditions, creating a suitable environment for lichens to thrive. In contrast, Station-2 and Station-4 had a lower number of lichen species (Fig. 5).

CONCLUSION

Lichen bio-monitoring studies are a useful method for focusing chemical sampling by identifying areas with significant or minimal disturbance. The impact of micro-climatic variations on lichen biodiversity data is minor, and any variations between sites are likely due to regional-scale disturbances, such as air pollution, rather than local factors such as tree characteristics or other sources of disturbance. Additional pollution measurements could help to clarify the effects of wind in spreading pollution from sines to the south, as more disturbed areas occur in that direction. By analyzing lichens from the same area, chemical analysis can significantly improve the interpretation of data and accurately associate each pollutant level with observed lichen bio-monitoring studies and individual species frequencies. This could greatly improve the accuracy of lichen diversity analysis as a starting point for future air quality evaluations.

This investigation also examines the concentrations of heavy metals in lichens and their correlation with atmospheric deposition. The findings provide valuable evidence of elevated levels of heavy metals in our environment, indicating air contamination in industrial and heavily trafficked areas. Lichens are highly sensitive to polluted air and possess the ability to accumulate and retain heavy metals within their structures for extended periods. Consequently, they serve as a valuable biomonitoring tool for detecting various aerial pollutants, including heavy metals.

Based on the information acquired, it can be concluded that Station 2 and Station-4 is likely the most polluted location of the various stations mentioned. The accumulation of industrial waste, heavy traffic flow, frequent traffic jams are significant contributors to the high levels of pollution and heavy metal concentration in the areas. In contrast, Station-3 and Station-6 are expected to have lower levels of pollution. This is primarily attributed to their favorable locations. Station-3 is situated within a vast garden that boasts a diverse range of flora, encompassing over 1,000 species, including numerous mature trees. The presence of such greenery can contribute to the purification of the air and mitigate the impact of pollutants. Station-6, on the other hand, benefits from being located in an area with less industrial development and fewer manufacturing facilities. As a result, the emissions of heavy metals and other pollutants in this vicinity are likely to be comparatively lower. These factors suggest that both Station-3 and Station-6 are less prone to heavy metal pollution compared to other areas being studied. This green space may help to absorb and filter pollutants from the surrounding air. Station-1, Station-4 and Station-5 may fall somewhere in between, given that it is located on a busy road but also features lakes and a diverse variety of flora in the areas.

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