International Journal of Environment and Pollution Research, 12(2),1-11, 2024
Print ISSN: 2056-7537(pri5nt)
Online ISSN: 2056-7545(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Plant Bioindicators in Assessing Air Quality: A Short Review

Putu Satya Narayanti [1], Astija[2], I Nengah Kundera[3]
[1]*Science Education Doctoral Program , University of Tadulako, Central Sulawesi*
[2] *Science Education Doctoral Program, University of Tadulako, Central Sulawesi*
[3] *Science Education Doctoral Program, University of Tadulako, Central Sulawesi*
Corresponding author: satya03nara@gmail.com

doi: https://doi.org/10.37745/ijepr.13/vol12n2111   Published January 14, 2023

Citation: Narayanti P.S., Astija, Kundera I.N. (2024) Plant Bioindicators in Assessing Air Quality: A Short Review, *International Journal of Environment and Pollution Research*, 12(2),1-11

ABSTRACT: *Air pollution, long recognized as having an adverse impact on health and comfort, is increasing in urban and industrial areas of society at a rate that makes it one of the most pressing environmental problems. Pollution refers to the introduction of harmful substances into the environment, negatively impacting humans and other organisms and contributing to the degradation of the quality of our environment. This paper aims to discuss the identification of certain plant species that can be used as biological indicators in assessing air quality. In this context, the aim of this paper is to analyze several theoretical aspects of biological monitoring and provide a report on the progress of using plants as biological indicators of air quality. This paper aims to describe the most significant aspects of current knowledge in this field, evaluate the applicability of the methodology, and detail its advantages and disadvantages when compared with traditional methods.*

KEYWORDS: bioindicators, plant, assessing, air quality, short review

INTRODUCTION

Air pollution is a major concern throughout the universe due to its impact on living and non-living things. Before an area can be said to be polluted, it is necessary to carry out a bottom-up or top-down environmental assessment (Abulude et al., 2021). Air pollution refers to substances in the atmosphere that have the potential to pose a risk to humans and the environment, and these substances can exist as solid particles, liquid droplets, or gases (Manisalidis et al., 2020). Air pollution can be natural or the result of human activities. Air pollution can be classified into two categories, namely primary pollutants and secondary pollutants. Primary air pollutants are substances that are directly emitted in certain processes and are present in the atmosphere in a composition similar to that when the emissions occurred. Examples are ash from volcanic eruptions, carbon monoxide from vehicle exhaust, or sulfur dioxide released by industry. Meanwhile, secondary air pollutants are not released directly into the atmosphere, but are formed or transformed into other compounds in the atmosphere through reactions or interactions between primary pollutants, such as the formation of ground-level ozone or the formation of photochemical fog (Bhargava, 2020). The dangerous impacts of air pollution on the environment include the emergence of various diseases, global warming, acid rain, thinning of the ozone layer and the influence of animals on plants. Air pollution has caused several respiratory problems and heart disease in humans (Chandrakar, 2020).

Living organisms are starting to be used as biological indicators to indicate the level of pollution in an environment. Cyclical and quantitative studies of pollutant concentrations in bioaccumulators have become the basis of modern biological monitoring (biomonitoring) of environmental pollution. Biomonitoring studies are carried out with passive methods (passive biomonitoring), where living organisms occurring naturally in the environment are analyzed, and with active methods (active biomonitoring), for example plants that live in environments with low pollution are moved and displayed in more polluted ecosystems, for example. heavy metal (Wacławek et al., 2022). Biological indicators are able to explore the life span of pollutants integrating past, current and future ecosystem status. They are supportive, objective, straightforward, applicable across multiple scales, and scalable. Biological indicators are also naturally occurring ones that are used to assess certain ecosystems and detect positive and negative changes within them (Zaghloul et al., 2020).

Each component in a biological system has the potential to act as a biological indicator that reflects the conditions of their environment. In many cases, the main role of biological indicators is as an early warning of contamination. Biological indicators are often used to detect the synergistic and antagonistic effects of various pollutants, as well as to analyze the possible impact of pollutants on organisms. An important criterion in determining biological indicators is a rapid and accurate response to pollution, fit for purpose and the capacity to detect changes caused by poor management, land use change, pollution and/or climate change in a particular ecosystem. Biological indicator responses are essentially rooted in physiological aspects, although in some situations they are also influenced by more complex characteristics. This review presents the use of biota, namely plants, microorganisms and animals, to see pollutants in the air or atmosphere. This study presents the most significant biological indicators.

Aim and Objectives of the Review

Based on the background presented , the aim of this study is to analyze what organisms are capable of being bioindicators in assessing the level of air pollution in certain areas. The results of this research study can be used as an additional reference for further research regarding organisms that function in determining the level of air pollution, especially in areas with high levels of pollutant contamination. So that people can take policies to reduce pollution.

This is a normal text paragraph; the style for it is "Normal". This is a complementary sentence.

MATERIALS AND METHODS

A literature review is a written summary of journal articles, books, and other documents that describe the past and current state of information regarding a research topic. This research was carried out using the literature review method, where the research produces output based on available data, as well as an explanation of findings so that they can be used as examples for research studies. The author searches for data or literature from journals, articles and book references to obtain a solid foundation in compiling the content or discussion of the research. The research process uses a literature review method which involves searching and collecting various journals, then drawing up several conclusions which are then analyzed in depth in a detailed manner, aiming to achieve optimal final results and in accordance with predetermined expectations (Andriani, 2022). By following predetermined procedures, a search for journal articles was carried out through the Google Scholar, DOAJ, Neliti, Research Gate, and Garuda databases using the keywords "bioindicator organisms" and "air pollution assessment". A total of 9 pieces of literature used in this research were articles that were published in the 2019-2023 time period.

The data used in this research comes from secondary data obtained indirectly through reviewing articles in national and international journals. The Systematic Literature Review process involves several steps, namely: (1) Planning, this stage involves formulating and determining research questions. (2) Review, this step focuses on searching literature from various articles contained in the database, then the literature is grouped based on type. (3) Documentation, at this stage, all findings from the selected literature are recorded and then explained further. Information obtained from the literature becomes the basis for responding to research questions (Suciati et al., 2021). Data analysis techniques refer to the process of qualitative analysis and research Miles (1992) which has 4 stages, namely : (1) Data collection , at this stage articles are collected based on the keywords bioindicator organisms and air pollution assessment (2) Data reduction , at this stage, data reduction is carried out by filtering articles that have been collected to suit the problems identified in the research. Next, the data was analyzed through summarizing, coding, theme tracing, and grouping. , (3) Presentation of data , where the data is arranged according to tabulated groups , and (4) Drawing conclusions, this stage is the process of drawing conclusions based on the results found .

RESULTS AND DISCUSSION

This session explains various types of organisms that are used as bioindicators of air pollution levels in certain regions or regions. The research results in this literature review are an analysis and summary of data from various articles obtained from national journals. Based on the search, nine (9) related articles were obtained, taken from 2019 to 2023 and presented in table 1 and table 2 .

Higher Plant Species In Assessing Air Pollution

In table 1, several related articles higher plant species used as bioindicators in assessing air pollution.

Table 1. Higher Plant Species that Serve as Bioindicators

Researcher and Year	Findings
(Berame et al., 2023)	Utilization of white teak tree leaves (*Gmelina arborea)* as a bioindicator to assess the Air Pollution Tolerance Index (APTI) as a simple and effective method for evaluating environmental health in three cities in the Caraga Region, Philippines.
(Polyakova et al., 2022)	The use of pine trees is also said to be able to act as a bioindicator for air pollution in Central Siberia, Russia.
(Rahman et al., 2022)	Research on the trembesi tree (*Samanea saman*) in its function as a bioindicator of air pollution in the central area of Sudirman district (SCBD), Jakarta.
(Terekhina & Ufimtseva, 2020)	Analysis of the accumulation of chemical elements by the leaves of trees and shrubs in the urban Central District of St. Petersburg which is the habitat of white elm (*Ulmus laevis*), small-leaved lime (*Tilia cordata)* , poplar trees (*Populus Sp.),* and beach rose (*Rosa rugosa)*
(Díaz et al., 2023)	Revealing the potential of lettuce plants as a marker of air quality because they experience the accumulation of several elements that are suitable for the environment where lettuce grows.

A commercial plant that can be a bioindicator for air pollution is the white teak plant (*Gmelina arborea)* which is deliberately planted as a wood-producing plant. Research conducted Berame et al., (2023)in the Philippines regarding the use of Gmelina arborea tree leaves as a bioindicator for assessing the Air Pollution Tolerance Index (APTI) as a simple and effective method for evaluating environmental health in three cities in the Caraga Region, Philippines. To calculate APTI, four biochemical parameters of tree leaves were evaluated, namely relative water content, total chlorophyll content, pH of leaf extract, and ascorbic acid content. The APTI category results show that all G. arborea samples from different locations tend to be sensitive to air pollution. Bayugan City showed the highest level of sensitivity with an APTI value of 7.66, while Butuan City and Cabadbaran showed a lower level of sensitivity with APTI values of 9.54 and 9.11, respectively. Analysis using the Kruskal-Wallis Test revealed significant differences between the APTI values of G. arborea trees in the three sampling locations in the Caraga Region. From APTI calculations at all locations, it can be concluded that the G. arborea species can be effectively used as a bioindicator for detecting air pollution with varying levels of sensitivity.

Pine trees are also said to be capable of being a bioindicator of air pollution located in Central Siberia, Russia.Polyakova et al., (2022) monitoring this pine tree area for one year from 2021-2022. Hundreds of pine trees are marked with numbers in pine forest area A and pine forest area B based on tree diameter, tree height and tree strength.

International Journal of Environment and Pollution Research, 12(2),1-11, 2024
Print ISSN: 2056-7537(pri5nt)
Online ISSN: 2056-7545(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Needle color changes have been recorded every year, starting from 2012 in pine forest B and 2019 in pine forest A. Through phytopathological analysis, the influence of pathogens or pests on the needles has been excluded; these changes are related to the impact of air toxins. The strength condition of pine forests A and B has experienced a sharp decline over the last 3-4 years, with more severe degradation occurring in pine forest B. This degradation is confirmed by an increase in the forest strength status category score, which is measured on a 6-point scale. Currently considering the possibility of stopping degradation and restoring forest ecosystems in metropolitan cities, provided that the industrial technology currently used undergoes changes.

The trembesi tree (*Samanea saman*) studied Rahman et al., (2022)here is often found in city centers, especially in the central area of Sudirman district (SCBD), Jakarta. They analyzed the structure of the bark of the trembesi tree, which has an average thickness of 6.13 mm, as well as the concentration of pollutant elements such as Pb (lead), Cd (cadmium), Cu (copper), Cr (chromium), Mn (manganese) and Zn (zinc).). Research findings show variations in bark thickness in the range of 3-9 mm, with an average of 6.13 mm. The cuticle has a blackish gray color, while the phloem shows a brownish color, and the cambium layer appears very thin. The results of elemental analysis showed the presence of Cu, Cr, Mn, and Zn in the wood, although Cd was not detected in all trees in the four lots studied. Furthermore, Mn shows dominance as the main pollutant in all trees, with a concentration of more than 40 ppm or more than 69% of the total pollutant, followed by Cu, Zn, and Cr. Based on the results of pollutant analysis and material accumulation in the bark, it can be concluded that the bark has the potential for biomonitoring of pollutants in urban environments.

Terekhina & Ufimtseva (2020)analyzed the accumulation of chemical elements by the leaves of trees and shrubs in the urban Central District of St. St. Petersburg. Tree species such as white elm (*Ulmus laevis*), small-leaved lime (*Tilia cordata)* , poplar tree (*Populus Sp.),* and coast rose (*Rosa rugosa)* accumulate more pollutants and are recommended for air-protective afforestation functions. The *Tilia cordata* species is the most common species found in urban green spaces, and can be used as an indicator of atmospheric pollution levels. Next, it (Díaz et al., 2023)was revealed that lettuce plants also have the potential to be a marker of air quality because they accumulate several elements that are suitable for the environment where the lettuce grows. This includes urban areas, locations close to traffic roads, as well as areas closest to forests and coastal areas. This effect was more significant when the lettuce was not washed before sampling. Therefore, the use of lettuce appears to provide an indication of locations that may be exposed to higher levels of air pollution. The results also show that it is not only local atmospheric activity that influences the accumulation of elements such as Pb (lead), but also the contribution of the environmental background in which lettuce is grown can be an important factor in exposure to pollutants. This system has the potential to be an affordable addition to air quality measurement, in addition to conventional chemical analysis methods and air monitoring networks.

Print ISSN: 2056-7537(pri5nt)

Online ISSN: 2056-7545(online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development -UK

Based on the five research results above, it shows that plants can be useful as bioindicators of contamination of surrounding abiotic compartments. The types of contaminants studied were detected in the samples, indicating that plants are able to absorb pollutants through deposition in the air. Concentrations of polycyclic aromatic hydrocarbons (PAHs) in wild and pioneer plants in urban areas with significant traffic and industrial impacts are generally higher compared to areas with less traffic and industry, and than in natural areas with less anthropogenic impacts . Additionally, the individual health risks caused by consuming agricultural crops such as lettuce grown in city parks appear to be negligible. However, this conclusion is only valid if it is assumed that the soil used in growing lettuce is clean and that the lettuce is washed well before consumption. Recommendations also include selecting farming locations in urban areas that are far from roads and have green cover. However, it is recommended to carry out further evaluations taking into account the possible additional contribution of contaminants from other agricultural products to ensure that safety thresholds are not exceeded. Further checks are also needed to ensure that food grown in cities with higher levels of atmospheric pollution is still safe for human consumption.

Lower Plant Species In Assessing Air Pollution

Meanwhile, table 2 presents articles related to several types of lower plants that are used as bioindicators in marking air pollution.

Table 2 . Lower Plant Species that Serve as Bioindicators

Researcher and Year	Findings
(Lopes et al., 2019)	Demonstrating the use of lichens can be a simple and economical way to detect and monitor air pollution.
(Contardo et al., 2021)	Evaluating the physiological response of a sensitive moss species (Evernia prunastri) exposed for three months in a complex urban area in Milan, Italy.
(Bukabayeva et al., 2023)	evaluated the potential of lichens as bioindicators of heavy metal content in the air in Burabay National Park
(Sampe et al., 2020)	Evaluating the potential of lichens as an alternative index in assessing air quality in Indonesia, functioning as a bioindicator. Lichen samples were collected from six locations, three in the Gelora Bung Karno City Forest, Jakarta, and three in the University of Indonesia City Forest, Depok.

An alternative method for evaluating the impact of air pollution on the environment is through the use of bioindicators on lower plants such as green mosses and lichens. Research conducted by Lopes et al., (2019) in Miguel Pereira District, State of Rio de Janeiro, wanted to show that the use of lichens can be a simple and economical way to detect and monitor air pollution. This research detected 21 moss taxa spread across 9 families and 13 genera. The locations at Javary Lake and São Roque Street show higher specific richness values and IAP (Atmospheric Purity Index Values) (21.66 and 31.45 respectively) which indicates that the air pollution at these locations is regular and low.

Print ISSN: 2056-7537(pri5nt)
Online ISSN: 2056-7545(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

On the other hand, in two other locations which are Jalan Aurea and Bus Terminal, specific wealth and IAP values were found – 7.91 and 11.23 respectively indicating high and high air pollution.

Contardo et al., (2021)evaluated the physiological response of a sensitive moss species (*Evernia prunastri*) exposed for three months in a complex urban area in Milan, Italy . The investigated parameters depend on the photosynthetic activity of mycobiont damage (membrane damage and antiradical activity), and the production of secondary metabolites involved in the protective function of the organism. The research results show that although air quality in Milan is still heavily polluted due to particulate matter and nitrogen oxide (NOx) pollution, the overall situation is not as severe as the one that caused the death of this sensitive biomonitor. Bukabayeva et al., (2023) evaluated the potential of lichens as bioindicators of heavy metal content in the air in Burabay National Park, northern Kazakhstan. A total of 56 moss species were identified belonging to 23 genera and 16 families on the roadside or in nearby forests. The results were that almost all samples, such as the lichen species *Evernia prunastri* (L) and *Cladonia alpestris* (L), showed concentrations of Pb, Cr, Cd, As, Ga, V, and Cs which were in the high category. Overall conditions have not reached a level that would cause death to these sensitive biomonitors, at least in the short term. However, the vitality of samples exposed in the study area showed a significant decrease compared to samples exposed in the control area. This indicates that urban air quality still negatively influences the survival of lichens at current levels.

Then obey Sampe et al., (2020) in the context of Indonesia's need for a more appropriate air quality index, considering that the index currently being used has not been specifically designed for the environment and genetic diversity of society in Indonesia. This research was conducted with the aim of evaluating the potential of lichens as an alternative index in assessing air quality in Indonesia, functioning as a bioindicator. Lichen samples were collected from six locations, three in the Gelora Bung Karno City Forest, Jakarta, and three in the University of Indonesia City Forest, Depok. Moss identification is based on chemical tests and identification keys. The amount of moss was counted and plotted on a National Air Quality Index (NAQI) graph to determine the air status at each location, whether it was clean, at risk, nitrogen polluted, or very nitrogen polluted. Two of the seven sampling locations showed nitrogen pollution, while the other five locations showed more serious levels of pollution. This data indicates that air quality throughout the region tends to be inadequate and polluted. However, these findings contradict the nitrogen pollutant data provided by the Meteorology, Climatology and Geophysics Agency (BMKG). Therefore, in the future a calibrator is needed to ensure accuracy in conducting air quality analysis using lichens.

Lichens have become a common choice as receptor-based biomonitors in air quality research. Historically, they were used qualitatively, with a decrease in moss populations indicating a problem in air quality or the presence of chemical contamination. However, in recent decades, the use of moss has evolved into a more quantitative approach, where their chemical composition provides an indication of poor air quality. Most studies exploring the chemical constituents of mosses aim to determine variations in specific chemical elements or compounds within moss populations over a particular time period or at a particular location. In the context of air quality studies, conceptually, it is recommended that analyzes include monitoring of air, airborne particulates, as well as rainfall to evaluate existing conditions and potential negative impacts on specific ecosystems. However, there are several challenges that may be faced in implementing this concept. One of the main obstacles is cost, which often limits the number of measurement locations, especially over large geographic areas. Collecting and measuring other air components can also be difficult, and in some cases, even impossible with existing technologies. Additionally, our understanding of the relationship between airborne chemical concentrations and adverse impacts on plant communities remains limited.

Chemical analysis of lichens provides a more affordable approach to air sampling, where airborne contaminants can be measured indirectly. Many moss species obtain nutrients directly from the air and rainfall, thereby acting as air quality integrators. Because mosses are widespread, have characteristics of steady growth, and long lifespan, they can function as passive collectors over time periods extending beyond a few years. However, obstacles in using lichens as a living chemical sampling tool require problem solving to provide interpretable and relevant results.(Stolte, 1993).

The findings above provide confidence that the more urban an area is, the higher the level of air pollution. Chiarini et al., (2021)explains that urban areas often act as major consumers of natural environmental resources, which in many cases places unsustainable pressure on natural resources. Because more than half of the global population, namely around 55%, lives in urban areas. Environmental degradation associated with urban production can threaten the health and quality of life of many people around the world. Therefore, there is a need to monitor and measure progress in achieving sustainable urban development through the use of appropriate indicators.

Plants have a significant role in monitoring and maintaining ecological balance by being actively involved in the cycle of nutrients and gases. In addition, plants provide a large leaf area which is useful for venting, absorbing and accumulating air pollutants, which aims to reduce the level of pollution in the air environment. The application of biomonitoring methods to plant species is a crucial approach in efforts to monitor and reduce air pollution. Air pollution is in the global spotlight because of its negative impact on plants, animals and humans. Therefore, joint action is needed to address and monitor air pollution. The use of plants as a biomonitoring tool offers a relevant method due to its sustainability, affordability and environmental sustainability aspects. Plants that are sensitive to certain pollutants can serve as an effective tool in addressing health and environmental problems associated with air pollution (Cen, 2015).

Plants have an important role in cleaning the atmosphere by absorbing pollutants through the surface of their leaves. As a consequence, the accumulation of pollutants has a negative impact on the condition of the leaves, affecting parameters such as the Air Pollution Tolerance Index (APTI), leaf extract pH (pH), Relative Water Content (RWC), Total Chlorophyll Content (TC), and Ascorbic Acid Content (A A). This negative impact is an indicator of the level of pollution in the area (Sahu et al., 2023).

CONCLUSION

Based on the results of the literature review above, the following conclusions were obtained: (1) Organisms that are capable of being bioindicators of air pollution come from higher plant species such as white teak trees, elm trees, poplar trees, small-leaved lime trees, trembesi trees and roses. beaches and lettuce plants. As well as lower plant species such as green mosses and lichens. (2) Urban areas with a high population, mobility and level of development, the higher the air pollution generated, thus affecting the survival of organisms, especially plants.

RECOMMENDATIONS

This research can be developed in the form of research that aims to investigate air pollution by measuring the biochemical properties of trees as indicators (bioindicators), which will later be used to estimate seasonal variations in air quality at that location. Various leaf biochemical parameters, such as pH, relative water content, total chlorophyll, and ascorbic acid, were measured on seven different plants placed near sources of pollution from brick burning during winter, summer, and post-monsoon.

REFERENCE

Adryanti Felicia Sampe, D., Maria-Deanne Awuy, J., Krista Mustikaning Sekar, T., Febrian Wijaya, S., Zahwa Ananda, A., Trisha Marella, D., Mahanaim Tampubolon, P., & Lestari, R. (2020). Pilot study of air quality index assessment of nitrogen pollutant using lichen as bioindicators in Jakarta and Depok, Indonesia. *E3S Web of Conferences*, *211*. https://doi.org/10.1051/e3sconf/202021102014

Andriani, W. (2022). Penggunaan Metode Sistematik Literatur Review dalam Penelitian Ilmu Sosiologi. *Jurnal PTK Dan Pendidikan*, *7*(2). https://doi.org/10.18592/ptk.v7i2.5632

Berame, J. S., Josue, J. E., Bulay, M. L., Delizo, J. J., Acantilado, M. L. A., Arradaza, J. B., & Dohinog, D. W. M. G. (2023). Efficacy of Tree Leaves as Bioindicator to Assess Air Pollution Based on Using Composite Proxy Measure. *Nature Environment and Pollution Technology*, *22*(3), 1331–1341. https://doi.org/10.46488/nept.2023.v22i03.020

Bhargava, A. (2020). Air Pollution - Sources and Classification. *Open Access Journal of Biogeneric Science and Research*, *1*(4). https://doi.org/10.46718/jbgsr.2020.01.000022

Bukabayeva, Z., Abiyev, S., Silybayeva, B., Assanova, U., Sharipkhanova, A., & Sagdatkyzy, B. (2023). Epiphytic and epigeal lichens as bioindicators of air pollution in the Burabay National Park, Kazakhstan. *Biodiversitas*, *24*(5), 2701–2709. https://doi.org/10.13057/biodiv/d240523

Cen, S. (2015). Biological Monitoring of Air Pollutants and Its Influence on Human Beings. *The Open Biomedical Engineering Journal*, *9*(1), 219–223. https://doi.org/10.2174/1874120701509010219

Chandrakar, K. (2020). Air pollution: Causes, effects and solution. *~ 251 ~ The Pharma Innovation Journal*, *9*(3), 251–253. http://www.thepharmajournal.com

Chiarini, B., D'Agostino, A., Marzano, E., & Regoli, A. (2021). Air quality in urban areas: Comparing objective and subjective indicators in European countries. *Ecological Indicators*, *121*. https://doi.org/10.1016/j.ecolind.2020.107144

Contardo, T., Gazzotti, S., Ortenzi, M. A., Vannini, A., & Loppi, S. (2021). Biological Effects of Air Pollution on Sensitive Bioindicators: A Case Study from Milan, Italy. *Urban Science*, *5*(3). https://doi.org/10.3390/urbansci5030064

GG, P., VA, S., NM, P., EM, P., & NS, K. (2022). Suburban Pine Forests as Bioindicators of Air Pollution. *Journal of Biomedical Research & Environmental Sciences*, *3*(12), 1389–1392. https://doi.org/10.37871/jbres1608

Izquierdo-Díaz, M., Hansen, V., Barrio-Parra, F., De Miguel, E., You, Y., & Magid, J. (2023). Assessment of lettuces grown in urban areas for human consumption and as bioindicators of atmospheric pollution. *Ecotoxicology and Environmental Safety*, *256*. https://doi.org/10.1016/j.ecoenv.2023.114883

Ken Stolte. (1993). *Lichen as Bioindicators of Air Quality*. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Lopes, R. da S., Martins, M. P., Oliveira, R. L., & Gurgel do Amaral, F. P. (2019). Monitoring air pollution with living organisms. Case Study Use of Lichens as Bioindicators in the Miguel Pereira city, Rio de Janeiro, Brazil. *Chemical Engineering Transactions*, *74*, 253–258. https://doi.org/10.3303/CET1974043

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. In *Frontiers in Public Health* (Vol. 8). Frontiers Media S.A. https://doi.org/10.3389/fpubh.2020.00014

Matthew B. Miles, A. M. H. (1992). *Qualitative Data Analysis: A Sourcebook of New Method. Terjemahan Tjetjep Rohendi Rohidi. Analisis Data Kualitatif: Buku Sumber tentang Metode-metode Baru*. Penerbit Universitas Indonesia (UI-PRESS).

Olawale Abulude, F., Alaba Adeoya, E., Adeleye Olubayode, S., Dare Oluwagbayide, S., & Usha, D. (2021). Trends in air Pollution: The Use of Mosses as Biomonitors. *Quality of Life (Banja Luka) - APEIRON*, *20*(1). https://doi.org/10.7251/qol2101031a

Rahman, M. M., Adzkia, U., Nandika, D., Siregar, I. Z., & Karlinasari, L. (2022). Urban tree bark analysis for monitoring of air pollution level in Jakarta business district. *IOP Conference Series: Earth and Environmental Science*, *1109*(1). https://doi.org/10.1088/1755-1315/1109/1/012052

Sahu, B., A. Mahapatra, P.K. Kar, D.K. Sahu, & Pradhan, B. (2023). Brick Kiln Induced Air Pollution: Assessment Through Apti Of Plant Species. *Pollution Research*, *42*(03), 373–378. https://doi.org/10.53550/pr.2023.v42i03.011

Suciati, I., Wahyuni, D. S., & Sartika, N. (2021). Mathematics Learning Innovation During the Covid-19 Pandemic in Indonesia: a Systematic Literature Review.

Print ISSN: 2056-7537(pri5nt)
Online ISSN: 2056-7545(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran, *7*(4), 886. https://doi.org/10.33394/jk.v7i4.3833

Terekhina, N. V., & Ufimtseva, M. D. (2020). Leaves of trees and shrubs as bioindicators of air pollution by particulate matter in Saint Petersburg. *Geography, Environment, Sustainability*, *13*(1), 224–232. https://doi.org/10.24057/2071-9388-2019-65

Wacławek, M., Świsłowski, P., & Rajfur, M. (2022). The Biological Monitoring as a Source of Information on Environmental Pollution with Heavy Metals. *Chemistry, Didactics, Ecology, Metrology*, *27*(1–2), 53–78. https://doi.org/10.2478/cdem-2022-0006

Zaghloul, A., Saber, M., Gadow, S., & Awad, F. (2020). Biological indicators for pollution detection in terrestrial and aquatic ecosystems. *Bulletin of the National Research Centre*, *44*(1). https://doi.org/10.1186/s42269-020-00385-x