Lichens: excellent bioindicators for air quality monitoring

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Abstract. Our paper is a short list of arguments based on knowledge gained in laboratory practice, showing why lichens are of great importance in air quality biomonitoring. Lichens have a number of key characteristics that make them very good air quality bioindicators and useful organisms for biomonitoring: sensitivity to air pollution, slow growth, long lifespan, no cuticle, no roots, sponge-like consistency, wrinkled and rough surface, sessile nature, ability to survive dry, good diversity, wide distribution, easy transplantation, capacity to show response to pollution, simple structure, easy identification, and have enough historical data collected in literature or databases.
Key Words: air pollution, biomonitoring, ecotoxicology, long lifespan, sensitivity, urban pollution.

Introduction. Environmental protection has become not just a health issue, but a legal one (Petrescu-Mag & Petrescu-Mag 2011). Ensuring a healthy environment for society and its descendants is an issue that must be seriously considered. Among environmental protection issues, air quality is an intensively investigated one.

Today, air quality monitoring is done by many specific means. Lichens have a number of key characteristics. Because of these characteristics, lichens have been widely used in research (Voicu et al 2019; Voicu 2021) or biomonitoring programs to assess air quality, especially in areas with industrial or urban pollution (Petrescu-Mag & Oroian 2015a,b). Their sensitivity and adaptability make them valuable tools for researchers and environmental agencies aiming to understand and mitigate the impacts of air pollution on ecosystems and human health (Petrescu-Mag et al 2010). Our paper is a short list of arguments based on knowledge gained in laboratory practice, showing why lichens are of great importance in air quality biomonitoring.

Sensitivity to air pollution. Lichens are highly sensitive to changes in air quality, particularly to pollutants like sulfur dioxide, nitrogen oxides, ozone, heavy metals, and particulate matter (Das et al 2020). They can accumulate these substances from the atmosphere, which can affect their growth, physiology, and overall health (Milow et al 2022).

Slow growth and long lifespan. Lichens grow slowly (Voicu 2022) and have relatively long lifespans compared to many other organisms. This allows them to integrate environmental signals over a longer period, providing a historical record of air quality (Todoran et al 2010).

No cuticle. Lichens do not have a cuticle on the outside of their bodies, which makes it possible to absorb airborne pollutants through their entire thalloid body and not just through their roots (as is the case with seed plants) (Mag 2003; Petrescu-Mag & Papuc 2019).

No roots. Lichens do not have roots, so everything they absorb is taken from the air, not from the soil. Thus, it will be a bioindicator of air quality in the strict sense (Mag 2003; Petrescu-Mag & Papuc 2019).

Sponge-like consistency. Due to the fungus in the composition of the lichen, it has a sponge-like consistency, being able to absorb water and pollutants from the air (Mag 2003).

Their surface is wrinkled and rough. The surface of lichens is rough and wrinkled, similar to intestinal villi in animals, which makes the contact surface with air large (Mag 2003; Petrescu-Mag & Papuc 2019).

Non-mobile organisms. Lichens are sessile (non-mobile) organisms, which means they remain in one place for their entire lifespan. This makes them particularly useful for monitoring localized air quality in specific areas.

Kept alive dry. Lichens are incredibly resilient organisms, and they can survive extended periods of desiccation (drying out). Some lichens are capable of entering a state of dormancy in response to dry conditions, effectively slowing down their metabolic processes until they receive moisture again (Mag 2003; Petrescu-Mag & Papuc 2019; Paoli et al 2023).

The exact duration a lichen can survive without water depends on several factors, including the species of lichen, environmental conditions, and the health of the lichen prior to desiccation. In favorable conditions, some lichens have been known to survive in a dried-out state for several months to even years.

However, it's important to note that while lichens can withstand desiccation, they are not immortal, and extended periods of dryness can still be detrimental to their overall health and viability. Once rehydrated, they can often resume their metabolic activities and continue their life cycle.

If you're working with lichens and need to preserve them for an extended period, it's recommended to store them in a dry environment, preferably with some airflow, to reduce the risk of mold or other harmful organisms taking hold. However, for long-term preservation or if you're trying to maintain their vitality for research or conservation purposes, it's generally best to store lichens in a state of regular hydration to ensure their continued health and viability.

Wide distribution. Lichens can be found in various habitats worldwide, from urban areas to remote wilderness. This makes them versatile indicators for assessing air quality in different environments (Petrescu-Mag & Papuc 2019). The presence of lichens in the urban environment makes them attractive for urban air quality studies (Mag 2003; Todoran et al 2010). In urban areas, certain lichen species are more common and better adapted to the specific conditions, such as air pollution and temperature fluctuations (Mag 2003).

Here are some of the most common lichen species found in urban environments: *Xanthoria parietina* - this lichen has bright orange or yellow coloration (see Figure 1). It is frequently found on hard surfaces like tree trunks, walls, pavements, or rocks, and is resilient to pollution; *Physcia stellaris* - this lichen has a grayish-green thallus and is common on tree trunks and other surfaces (see Figure 1). It is relatively tolerant to urban conditions; *Flavoparmelia caperata* - a lichen with an olive-green thallus, often found on trees, fences, and rocks. It can tolerate moderate pollution; *Parmelia sulcata* - this lichen has a grayish-green thallus and is frequently found on trees, fences, and buildings; *Hypogymnia physodes* - a light green lichen with a leafy thallus, often found on tree trunks, including in urban areas; *Lecanora chlarotera* - it is a lichen with a light gray to whitish thallus, found on hard substrates like building walls; *Usnea* spp. - these lichens have pendant growth, resembling a beard, and can be found on trees in urban areas.

Figure 1. *Xanthoria parietina* (yellow/orange) and *Phiscia stellaris* (grayish-green) collected from Cluj-Napoca.

Diversity of species. There are thousands of lichen species (Goodenough 2020), each with its own sensitivity to different pollutants. This diversity allows for monitoring a wide range of environmental conditions.

Very easy transplantation. Lichens can be transplanted very easily. Transplantation is useful for studies carried out in exact places and the drawing up of pollution maps (Todoran et al 2010).

Visible responses to pollution. Many lichens exhibit visible changes in color, morphology, or growth rate in response to air pollution. For example, some lichens may change from a healthy green to a bleached or discolored state when exposed to pollutants (Mag et al 2003).

Simple structure and easy identification. Lichens have a relatively simple structure compared to many other plants, which makes them easier to study and identify (Norkulov et al 2021). This simplicity aids in consistent monitoring efforts.

Availability of historical data. In some regions, historical data on lichen populations and their condition have been collected for decades, providing valuable long-term datasets for assessing trends in air quality (Man et al 2022).

Conclusions. Lichens have a number of key characteristics that make them very good bioindicators and useful models for biomonitoring: sensitivity to air pollution, slow growth, long lifespan, no cuticle, no roots, sponge-like consistency, wrinkled and rough surface, sessile nature, ability to survive dry, good diversity, wide distribution, easy transplantation, capacity to show response to pollution, simple structure, easy identification, and have enough historical data collected in literature or databases.

Conflict of interest. The authors declare that there is no conflict of interest.

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