Why lichens are excellent bioindicators of trace metal pollution in urban areas

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Abstract. This paper aims to summarize the main characteristics of lichens that make them excellent bioindicators of air pollution with heavy metals. Also, the paper shows other possible uses of lichen species in the future.
Key words: *Cladonia*, *Evernia*, *Physcia, Pseudevernia,* trace metal pollution, *Xanthoria*.

Lichens are symbiotic species, consisting of a species of algae and a fungus, which have together a greater chance of survival than they would have if they lived separately (Singh et al 2017; Calcott et al 2018). The fungus provides the necessary water, while the algae produces food through photosynthesis (Honegger 2006).

Lichens, in contrast to the higher plant species, are excellent bioindicators of air pollution. What makes them special are the following characteristics:

1. They have no roots; thus, not all the water and minerals come from the soil, rock or wood where they grow.

2. They have no cuticle on the outside (they are not physically isolated), so they absorb the water and minerals from the exterior through their entire thallus surface (Mag-Mureșan 2003).

3. The most abundant source of moisture and minerals is the air surrounding them.

4. The surface of their thallus is very irregular, rough and creased, very suitable for capturing atmospheric dust.

5. They are perennial plants, resistant to cold and drought.

6. There are many species of urban lichens, so transplantation is not always required for research activities (study of native species is an easy and efficient variant of investigation).

7. Lichens can be kept for experimental purposes in a dry state for months or years, after which they can be brought to a vegetative state.

8. Different species of lichens can be found in almost all types of terrestrial ecosystems. Such examples for Romania and neighboring countries are presented below.

Xanthoria parietina and *Physcia stellaris* are the predominant species used in the monitoring of the air quality in Cluj-Napoca. They live in similar conditions and they are competing with each other for the woody surfaces of plants in urban areas (Figures 1 and 2). These two species are particularly resistant to pollution (Backor et al 2003; Silberstein et al 2007).

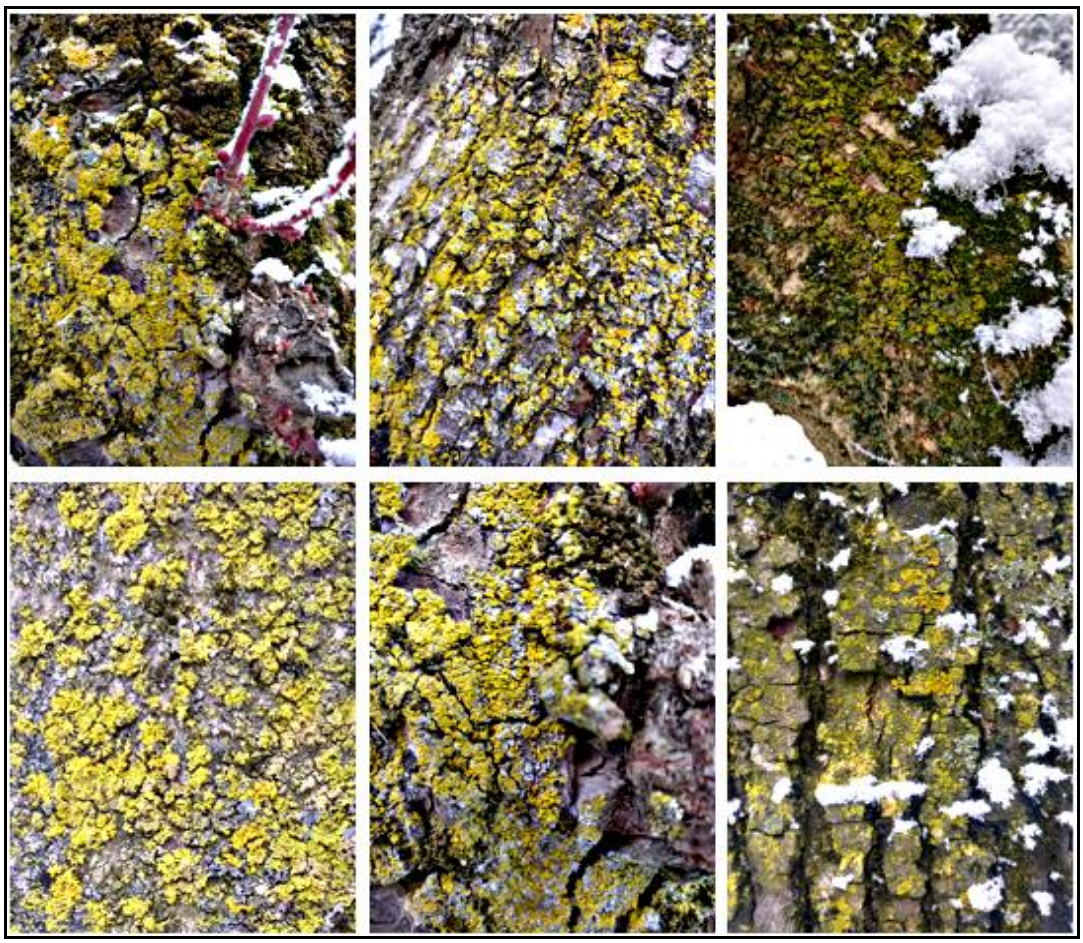

Figure 1. *Xanthoria parietina*.

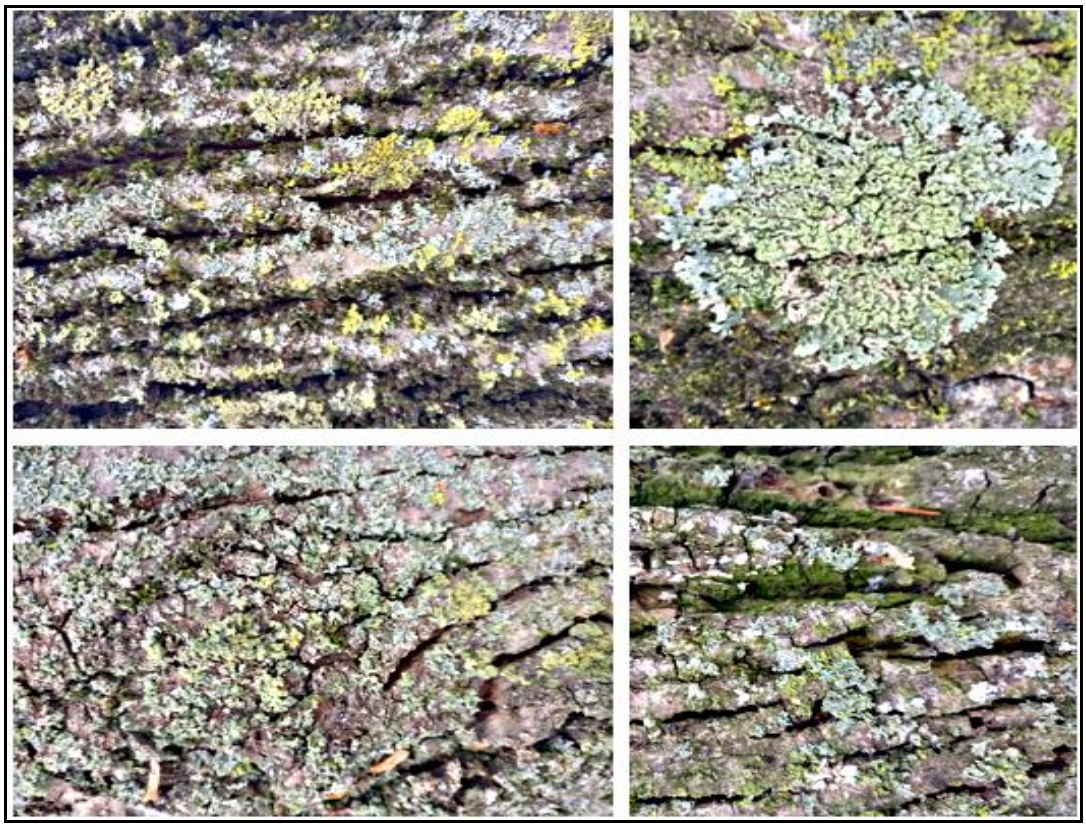

Figure 2. *Physcia stellaris*.

Cladonia spp. (Figure 3) and *Pseudevernia furfuracea* (*Parmelia furfuracea*) (Figure 4) grow especially in mountainous regions covered with coniferous forests. Ecotoxicologists mainly use them for studies that require lichen transplantation. *Pseudevernia furfuracea* is a lichen with a very large thallus and is therefore best suited for transplantation (Table 1). The lichen is rather sensitive to air pollution, its presence usually indicating good air conditions in the growing place.

Table 1

Results from 2003 monitoring of the concentration (ppm) of trace metals (Zn, Cu, Pb) in lichens from Cluj-Napoca (Todoran et al 2010; Mag-Mureșan 2003)

Station in Cluj-Napoca (Romania)	*Native lichens*						*Transplanted lichens Pseudevernia furfuracea*			*Control (P. furfuracea collected from unpolluted region)*		
	Xanthoria parietina			*Physcia stellaris*								
	Zn	Cu	Pb	Zn	Cu	Pb	Zn	Cu	Pb	Zn	Cu	Pb
Aurel Vlaicu Street	338	177	65	-	-	-	181	68	49	64	15	31
Calea Turzii Street	209	100	73	190	27	80	187	95	49	64	15	31
Parcul Feroviarilor (park)	255	130	53	271	59	101	197	53	41	64	15	31
Piata Unirii (square)	416	257	121	314	94	155	153	29	45	64	15	31
Botanic Garden	125	22	16	116	21	15	157	76	43	64	15	31
Clinicilor Street	310	135	119	-	-	-	136	152	43	64	15	31
Taietura Turcului Street	258	124	62	169	47	72	137	23	38	64	15	31

Note: Table 1 serves as an example of heavy metal pollution monitoring approach with native and transplanted lichens.

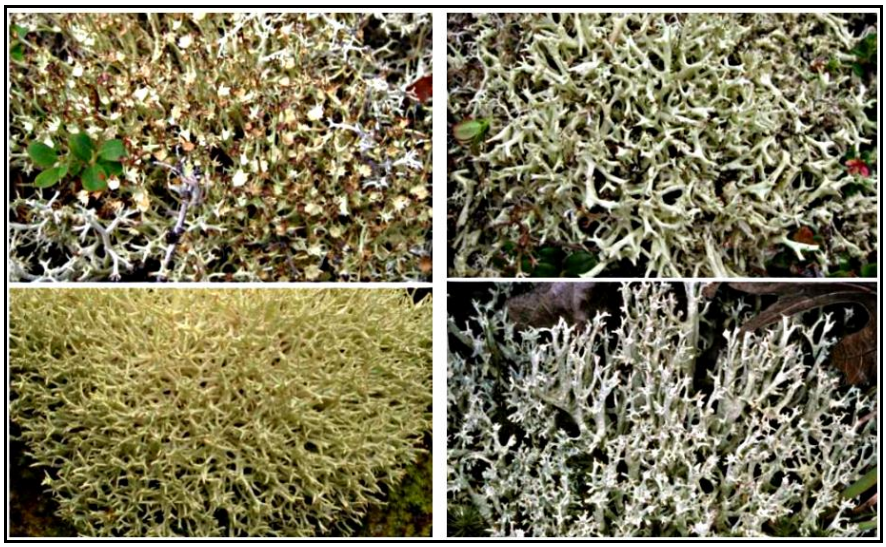

Figure 3. *Cladonia* spp. (Ahti & McCarthy 2013; photo credits: John McCarthy, Einar Tindal, Stephen Sharnoff).

Figure 4. *Pseudevernia furfuracea* (source: Saxifraga, Willem van Kruijsbergen; available at: http://freenatureimages.eu/).

Evernia prunastri (the plum lichen) is a species that can be found in many temperate forests throughout the northern hemisphere, including Romania and neighboring countries. The plum lichen grows primarily on the trunks and branches of oaks, but can also be found on the bark of other deciduous and coniferous trees, such as fir or pine. The body of the species is short (3-4 cm long) and bushy, growing compactly on the bark of the tree and forming large tufts. The shape of the lichen is branched, resembling the horns of a deer. The color varies from green to white-green, when it is dry and dark-olive to yellow-green when moistened (Figure 5).

Figure 5. *Evernia prunastri* (the plum lichen) (source: Saxifraga, Willem van Kruijsbergen; available at: http://freenatureimages.eu/).

With taxa specific to each biotope, lichens are very useful for air quality screening studies, mainly for trace metal pollution, especially because they absorb water mainly from the atmosphere, and heavy metals are abundant in the atmosphere due to anthropogenic emissions (Petrescu-Mag et al 2010).

Another scientific and practical utility of lichens is their potential to colonize humus-free, rocky biotopes from Earth (tailings dumps), or from other planets that will be terraformed and colonized in the distant future (Armstrong 2019). Lichens could become, along with algae, microorganisms and some invertebrates (e.g. tardigrades, Gagyi-Palffy & Stoian 2011; Petrescu-Mag 2016) the first colonizers of such planets and suppliers of organic matter and humus for future extraterrestrial ecosystems.

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