Environmental Studies
FACT SHEET
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Number 123

Lichens as Biomonitors

This Factsheet:
- Describes the nature of lichens
- Explains how and why they can be used as biomonitors
- Reviews recent exam questions on this topic

Lichens are a mutually beneficial relationship between a fungus and an alga.

The fungal hyphae provide:
1. anchorage - for example, to a gravestone, tree, rock or wall
2. nutrients - the products of fungal digestion
3. protection against desiccation (drying out)

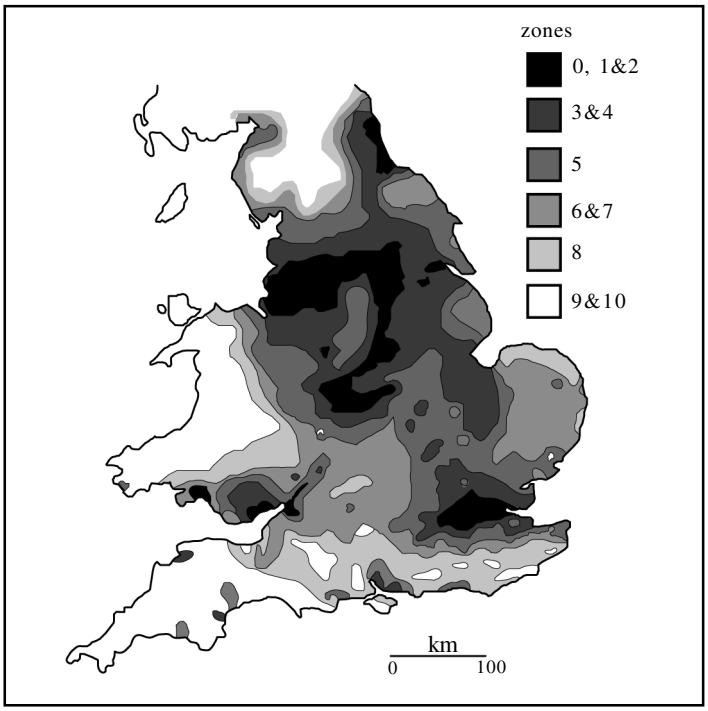
In turn, the alga provides the fungus with the products of photosynthesis (carbohydrates).

Lichens have traditionally been used as indicators of sulfur dioxide (SO_2) pollution. Since the alga lack an impermeable cuticle over their surface, they readily absorb sulfur dioxide and other pollutants.

Different lichen species have different sensitivities to sulfur dioxide and this means that we can get an indication of sulfur dioxide levels by recording which species of lichen are present in an area.

Hawksworth and Rose made a classification of eleven zones covering England and Wales based upon the presence or absence of lichen species which grew on tree trunks (Fig.1).

Fig. 1 Lichen assemblages as indicators of mean winter atmospheric concentrations of SO_2



Source: Hawksworth and Rose (1970)

Lichens can also be used as **bioaccumulators** – they absorb pollutants such as gases and heavy metals and store them in their tissues. Thus they can provide quantitative data on the concentrations of pollutants in different areas.

This ability to accumulate pollutants can have unexpected effects. Following the Chernobyl disaster in 1976, lichens in northern Scandinavia accumulated so much radioactivity that the reindeer which fed on them were considered dangerous for human consumption.

Lichens that are transplanted from a rural area to urban areas with heavy traffic show physiological and anatomical changes e.g. when exposed to high levels of either sulfur dioxide or nitrogen dioxide the lichens respond by producing more chlorophyll pigments. The increase in chlorophyll concentration is positively correlated with the levels of these pollutants so, by measuring the chlorophyll concentration of urban lichens, we can get an accurate indication of the level of these pollutants in the surrounding air.

Typical Exam Question

A student investigated the growth of lichens in woodland. Her hypothesis was that there was greater growth of lichens on beech trees than on oak trees.

She selected a sample of twelve beech trees and twelve oak trees and determined the percentage cover of lichen in a quadrat on each tree. She placed a single 50 x 25 cm quadrat frame on the south facing side of each tree trunk at 1.2m from the ground. Only trees with a minimum diameter of 50 cm were selected.

Identify two ways in which the student attempted to standardise the collection of her data and explain why each procedure was followed (4)

Markscheme
Equal number of each tree species;
To ensure equal sampling intensity/allow statistical analysis;

Position of quadrat consistent;
Eliminate height/closeness to ground as a variable;

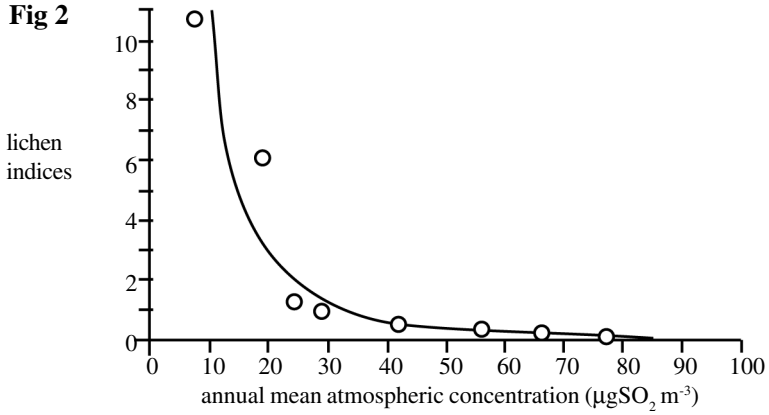
Chose similar sized trees;
Eliminate age/width as a variable;

Case Study: Sulfur emissions from a coal-fired power station

Scientists investigated the use of lichens as biomonitors of sulfur dioxide pollution downwind of a coal-fired power station in Pennsylvania.

The presence/absence and size of lichen colonies was incorporated into a lichen index. Lichen indices were calculated for 15 sites over a distance of 3km downwind of the power station. Fig. 2 shows their results.

Fig 2



- As mean sulfur dioxide concentrations increased i.e. as samples were taken closer to the power station, the lichen indices decreased.
- The scientists then used these results to predict levels of sulfur dioxide pollution at other sites at which similar lichen indices had been constructed.

Lichens have been used as indicators of atmospheric pollution for hundreds of years. For example, lichens have been monitored in the City of Edinburgh since 1760!

Over the 250 years a total 242 different species have been recorded from just about every type of habitat in the city but in the 1990s only 137 could be found (Table 1).

Table 1. Presence or absence in 1970's of lichens reliably recorded on tree trunks in Edinburgh since 1760

Lichen species	Approximate upper limit of SO_2 tolerance g m $^{-3}$	Pollutant zone of Hawksworth and Rose (1970)
Pleurococcus sp	. > 17 0	**1 (severely polluted)**
Lecanora conizaeoides	About 150	**2**
Lepraria incana, Buellia punctata	125	**3**
Parmelia saxatalis, P, suicata, Hypogymnia physodes, Chaenotheca ferruginea, Lecanora expallens, Lecidea scalaris, Physcia adscendens, Xanthoria parietina	70	**4**
Parmelia glabratula, Platismatia glauca, Ramalina farinacea, Evernia prunastri, Calicium viride, Physconia grisea, Opegrapha varia, 0. vulgata, Lecanora chlarotera, Lepraria candelaris	60 5	**5**
Pseudovernia furfuracea, Xanthoria polycarpa, Parmelia revoluta, P. exasperatula, Physconia 50 6 pulverulenta, Pertusaria pertusa		**6**
Arthopyrenia biformis, Physcia aipolia, Usnea sub- 40 7 floridana, Bavidia rubella, Parmelia caperata		**7**
N/a		**8**
Ramalina fraxinea, Lobaria amplissima, L. pulmonaria	30 9	**9**
Sticta limbata, Lobaria scrobiculata	< 30 10 (pure)	**10 (pure)**

Conclusion

Lichens are slow-growing pioneer species that colonise a wide variety of substrates including rocks, walls and trees. They are sensitive to a wide range of pollutants and can therefore be used to predict the presence or absence of atmospheric pollutants. They also accumulate pollutants and can therefore be used to provide ongoing quantitative data on pollutant levels in an area.

References:

Hawksworth, D.L. and Rose, F., 1970. Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens. Nature, London, 227 : 145—148.

Practice Questions

1. Lichens consist of a fungus and an alga living together. Both organisms benefit from the relationship.
   Suggest how the relationship between the fungus and the alga allows the lichen to survive on an exposed rock (3).

2. Students investigated whether aspect affected the abundance of the foliose lichen *Parmelia sulcata* on the bark of trees in a town.

The students recorded the number of colonies within a 50cm^2 quadrat, placed one metre above the ground on each of three trees. A chi-squared test was applied to the results.

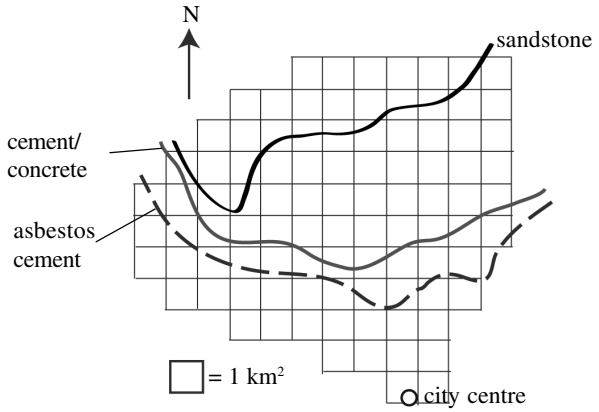
(a) What would the null hypothesis be for this investigation? (1).
(b) The table shows the students' results. Complete the table (1).

	No. of colonies on a tree facing		
	North	East	South
Observed	21	33	54
Expected			

(c) The students calculated a chi-squared value of 15.5 from these results. This chi-squared value has a probability of less than 0.001. Explain what this means in this investigation (2).

3. The lichen *Lecanora muralis* grows on walls and roofs in NW Europe.
   Ecologists surveyed the distribution of *L. muralis* in a part of the city of Prague. Wind direction in the area is variable and levels of air pollution, including sulfur dioxide, decrease from the centre of the city outwards. *L. muralis* does not tolerate sulfur or other acidic substances and was found growing on three different habitat types:
   - sandstone blocks, used to build the tops of walls
   - walls constructed using alkaline cement or concrete
   - roofs made of asbestos cement

   The diagram shows some of the results of the survey. *L. muralis* was found north of the lines shown on the map for each of the three types of habitat.



Which habitat type allows *L. muralis* to tolerate the highest level of sulfur dioxide pollution?. Explain your answer (3).

Markscheme

1. algae photosynthesise/ convert carbon dioxide into carbohydrates;
   carbohydrates available to the fungus;
   fungus protects alga from intense sunlight/desiccation;
   fungus anchors the lichen to the rock;
   Fungus absorbs water/mineral ions which are available to the alga;

2. (a) Aspect has no effect on the growth of Parmelia sulcata/ There is no difference in the number of lichens growing on different sides of the trees;

(b)

	No. of colonies on a tree facing		
	North	East	South
Observed	21	33	54
Expected	36	36	36

(c) Null hypothesis should be rejected;
   Aspect does influence growth of this lichen;
   Results not due to chance;

3. asbestos cement;
   the lichen is growing closest to the polluted city centre on this substrate;
   grows closest to city centre on asbestos cement roofs;
   acid rain is neutralized by alkaline building materials;

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