# CHANGES OF EPIPHYTIC LICHENS IN THE SURROUNDINGS OF MAGNESITE FACTORIES NEAR JELŠAVA (SE SLOVAKIA) IN THE PERIOD 1973–2004

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Abstract

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Influence of magnesium emissions on epiphytic lichens in the vicinity of magnesite works Lubeník and Teplá Voda in the valley Muránska dolina was studied in 1973–1974. In 2003–2004 the site was revisited to assess potential changes after the thirty years. Decreased load of harmful substances distinctly reduced the size of "lichen desert" (territory where epiphytic lichens were totally absent). Nonetheless, an increased accumulation of Mg in thalli of *Xanthoria parietina* even in more distant localities from pollution sources was determined. Recent measurements of bark pH showed an outlasting high bark alkalinity (pH 9.1) in neighbourhood of an alkaline waste dump and values from neutral to moderately alkaline (7.06–7.73) in wide vicinity of both magnesite works. Subsequently development of nitrophilous components from the association *Physcietum adscendentis* with dominating *Xanthoria parietina* has been stimulated.
Even so, the actual occurrence of more or less nitrophobous *Hypogymnia physodes, Usnea* sp. juv. or moderately nitrophilous *Evernia prunastri* and *Ramalina fastigiata* in a distance only 2 km from magnesite work Lubeník indicate future trend, although certainly a slow one, when nitrophobous species would return or even predominate.

*Key words*: epiphytic lichens, mosses, magnesium emissions, Slovakia

## Introduction

In 1950s and 1960s the production of magnesium oxide (MgO) in Slovakia rapidly grew. Roughly up till 1955 the magnesite was industrially processed in shaft furnaces, so the dispersion of emissions reached only some tens or hundreds metres from their source.

Later it was processed in rotatory furnaces. Insufficiently separated submicroscopic particles (0.01–250 μm) escaped from them together with gases into environment in dependency of terrain morphology and prevailing winds in distances as far as several tens kilometres.

Magnesium emissions contain mainly 65–80% MgO, 5–6.5% $Fe_2O_3$, 1.5–2.5 CaO and 12–22% of gases. They cause an increase in alkalinity (e.g. in a distance of 500 m from the plant Teplá Voda soil pH reached 9.54, cf. Kaleta, 1970, 1975), impoverish the vegetation and in the neighbourhood of factories totally destruct the environment.

Both magnesite factories – Lubeník and 3.5 km distant Teplá Voda – are situated in the central part of valley Muránska dolina between the towns Revúca and Jelšava. After reconstruction of the later magnesite plant in 1967 production and the outflow of injurants substantially increased. The measurement of dust pollutants fall still before the reconstruction confirmed values higher than 1000 t/ $km^2$. In one case the fall even reached 75.817 t/$km^2$ (Kaleta, 1970). Under certain metorological conditions (e.g. calm) the whole valley and adjacent mountain slopes were veiled in dusty clouds.

Since 1985 more efficient filters were installed (type AMERTHEM) which improved the situation (Bobro, Hančulák, 1997). As SLOVMAG issued in 1999, total quantity of solid particles decreased by 83.4%, comparing to the amount from 1989. Total quantity of emitted pollutants (in tons) from the both magnesite works in last years are shown in Table 1.

T a b l e 1. Total quantity of emitted pollutants (in tons)

SMZ, a. s. Jelšava – Teplá Voda*

| Harmful substances | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|
| Firm subst. | 148 | 130 | 113 | 117 |
| $SO_2$ | 101 | 164 | 291 | 300 |
| $NO_x$ | 698 | 833 | 1102 | 827 |
| CO | 94 | 185 | 787 | 913 |

SLOVMAG, a.s. Lubeník*

| Harmful substances | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|
| Firm subst. | 139 | 156 | 91 | 59 |
| $SO_2$ | 244 | 264 | 224 | 208 |
| $NO_x$ | 256 | 213 | 300 | 299 |
| CO | 3721 | 3847 | 2723 | 2600 |

*later described only as Lubeník and Teplá Voda

Despite new separators, immediate vicinity of the plants is still affected by the pollutants, obviously augmenting existing deponies, thus hindering formation of closed vegetation cover there and thicking the crusts (2-5 mm) on bark of trees (Bobro, Hančulák, 1997).

## Material and methods

In summer months of 1973 and 1974 the impact of pollutants on vegetation of epiphytic lichens from magnesite plants in Lubeník and Teplá Voda was studied (Pišút, 1974, 1978). After thirty years the investigation was repeated (in 2003 and 2004).

During the first investigation lichens on mostly isolated deciduos phorophytes with diameter larger than 20 cm in the nearer or more distant vicinity of the pollution sources on 136 sites were studied. Lichens were present on 83 of them.

On every studied tree pH value was determined colorimetrically. A small piece of tree bark was moistened with destilled water (using a small sprayer) and after a while an indicator paper was applied. The accuracy of measurement was ± 0.5 pH.

Condition of individual species on localities (f) was registrated using triple scale in which especially vitality and abundance (Pišút, Lisická-Jelínková, 1974) was taken into consideration. The resistance factor of individual species (Q) was expressed by the average number of epiphytic lichens occuring together with the examined species. Index of atmospheric purity (IAP) of individual sites was calculated using the formula of De Sloover and LeBlanc (1968).

In the years 2003–2004 investigation especially in the nearer vicinity of both factories was performed. Epiphytic lichens were studied on 34 sites. From 10 phorophytes bark for laboratory determination of pH was collected. Upper 3 mm thick layer of bark was cut off and crushed into approximately 10–15 mm large pieces. Altogether 4 grams of dried and processed bark were soaked for 24 hours in 30 ml of destilled water. PH values of decanted extract were measured by pH-meter (Beckman Φ 12pH ISE Meter). Each sample was measured 3 times, mean values are used. Thalli of *Xanthoria parietina* from 4 sites were collected for chemical analyses.

Nomenclature of lichens follows Bielczyk et al. (2004), that of mosses Kubinská, Janovicová (1996).

## Results

In 1973–1974 no lichens, neither epigeic nor epipetric occurred in the vicinity of the factories. The first thalli of epiphytic lichens grew in dependence of increased distance, climatic and especially orographic factors in the valley Muránska dolina SE in a distance of 7.5 km from the factory Teplá Voda, but on a site protected from dustfall N of this pollution source even in a distance of 2.3 km and behind the mountain ridge SW from the factory Lubeník in a distance of 3.2 km.

The area where the IAP values were lower than 1 was conditioned by the configuration of terrain and had an elliptic form (see Fig. 1). Towards the borders of this zone alkalinity of bark surface gradually decreased (see Figs 2–4). Crossing the border-line number of the species and their quantity increased significantly, so that the IAP values were quickly increasing. This transitional zone (B) in investigated area was usually 1–2 km wide. It passed into zone C (IAP >10) defined as being little or not influenced by immissions. On several sites, especially in broken mountain terrain it was impossible to determine the borders between zone B and C, because of mosaic influence of immissions. Whereas in protected slopes and in small lateral dales epiphytic species were relatively prospering, on mountain passes and on exposed mountain ridges it was again possible to observe damaged and extinct lichens. Lichenological research showed that the area very negatively influenced by dustfall (zone A) was substantially larger then it was assumed on the basis of higher plants investigation (Kaleta, 1975).

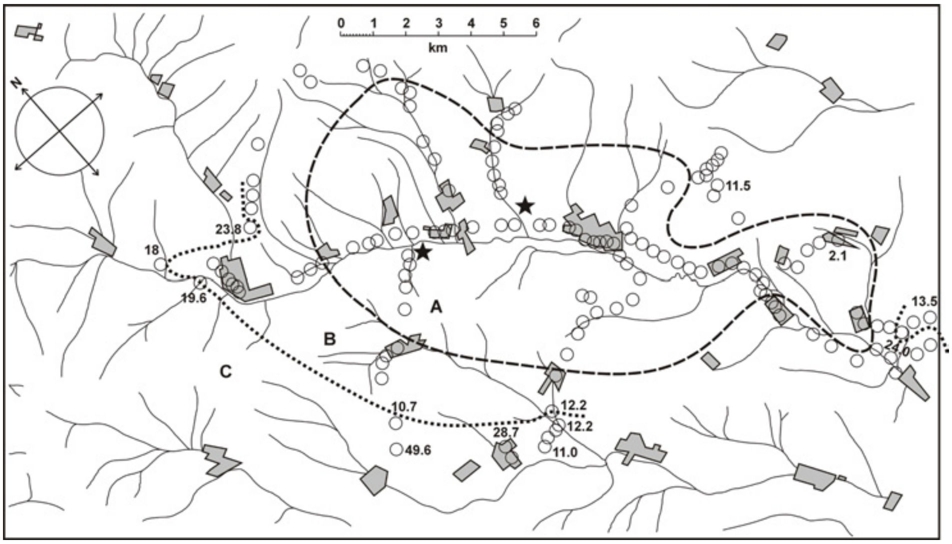


Fig. 1. Zones of air pollution in the vicinity of magnesite works in the valley Muránska dolina in 1973–1974: Zone A: IAP < 1, Zone B: IAP 1-10, Zone C: IAP > 10. Stars: locations of magnesite works. Empty circles: sampled sites.

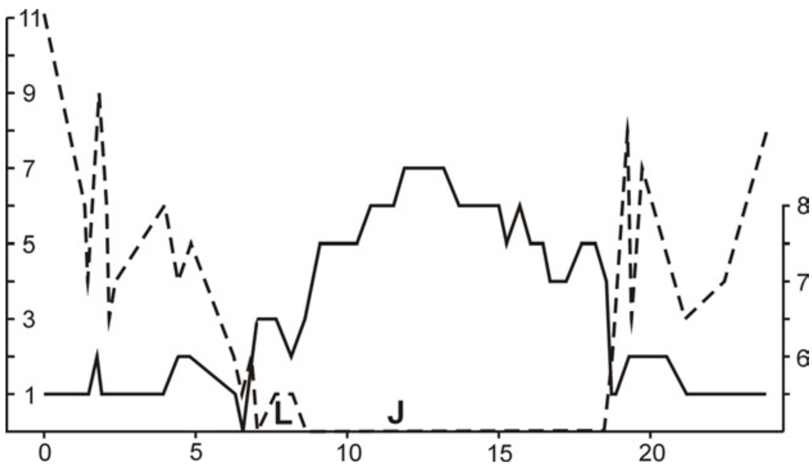


Fig. 2. Bark pH (full line) and the number of epiphytic lichen species (dotted line) along transect A in the valley Muránska dolina in 1973 (letters L and J – magnesite works Lubeník and Teplá Voda).

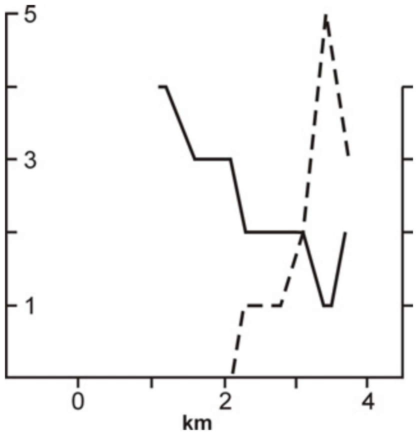


Fig. 3. Bark pH (full line) and the number of epiphytic lichen species (dotted line) along transect B ( magnesite work Teplá Voda – village Kopráš) in 1973.

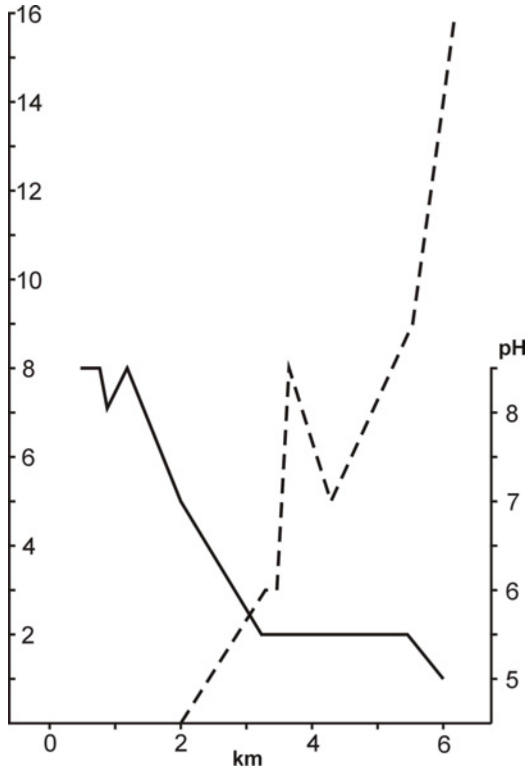


Fig. 4. Bark pH (full line) and the number of epiphytic lichen species (dotted line) along transect C (magnesite work Lubeník – village Železník) in 1973.

Totally 50 species were recorded, among them 8 not closely specified. The most frequent and the most tolerant to immissions was *Xanthoria parietina* (40 sites, see Fig. 5) and also other species from the association *Physcietum adscendentis* (*Phaeophyscia orbicularis* – 35 and *Physcia adscendens* 27 sites). Besides those following species were present: *Parmelia sulcata* (26), *Melanelia fuliginosa* (20), *Pertusaria amara* (19), *Phlyctis argena* (17), *Lepraria incana* (17), *Evernia prunastri* (17), *Lecanora chlarotera* (17), *Flavoparmelia caperata* (14), *Candelariella xanthostigma* (14), *Physconia grisea* (12), *Lecidella elaeochroma* (12) (incl. *Lecidea glomerulosa*), *Hypogymnia physodes* (11), *Physcia dubia* (11), *Physconia distorta* (11), *Lecanora hagenii* (10), *Parmelia* sp. morb. (9), *Melanelia subargentifera* (9), *Lecanora carpinea* (8), thallus crustaceus ster. (8), *Melanelia glabra* (8) *Lecanora argentata* (7), *Parmelina tiliacea* (7), *Caloplaca cerina* (6), *Xanthoria candelaria* (6), *Cladonia fimbriata* (5), thallus crust. sored. (5), *Parmelia saxatilis* (5), *Candelaria concolor* (4), *Anaptychia ciliaris* (4), *Pertusaria* sp. morb. (3), *Physcia aipolia* (3), *Lecanora saligna* (3), *Bacidia rubella* (3), *Ramalina farinacea* (2), *Physcia tenella* (2), *Lepraria* sp. (2), *Amandinea punctata* (2*), Physconia enteroxantha*

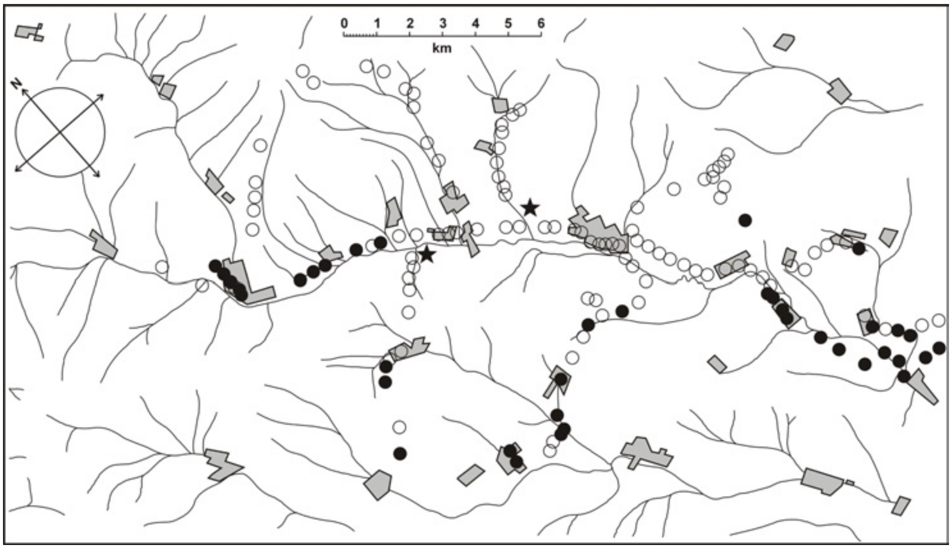


Fig. 5. Distribution of *Xanthoria parietina* in the vicinity of magnesite works in the valley Muránska dolina in 1973–1974 (black circles).

(2), *Pertusaria albescens* (2), *Lecanora* ex aff. *L. argentatae* morb. (1), *Physcia* sp. morb. (1), thallus ster. cf. *Phlyctis* (1), *Lecanora allophana* (1), *Melanelia exasperatula* (1), *M. subaurifera* (1), *Physcia stellaris* (1), *P. caesia* (1).

Recently from the surroundings of magnesite plants came news about an extreme increase of lichens on orchard trees. Therefore we concentrated on repeated research especially in vicinity of immission sources, further on sampling of *Xanthoria parietina* for chemical analyses and tree bark for measuring of pH.

On 34 localities in nearer vicinity of works (an exception is locality Paseky near townlet Muráň, 13.5 km NW of Lubeník and locality between villages Šivetice and Licince, 9 km SE of Teplá Voda) 27 epiphytic species were recorded. As thirty years ago, the most frequent were *Xanthoria parietina* (30 localities – see Fig. 6), *Phaeophyscia orbicularis* (18) and *Physcia adscendens* (15 localities). They were followed by *Lecanora hagenii* (8), *Parmelia sulcata* (6), *Physcia tenella* and *Ph. stellaris* (both species at 5 localities), *Phaeophyscia sciastra* (3), *Hypogymnia physodes*, *Evernia prunastri*, *Caloplaca holocarpa*, *Candelaria concolor* a *Lecania cyrtella* (all 2 localities), *Amandinea punctata*, *Buellia griseovirens*, *Phlyctis argena*, *Usnea* sp. juv., *Physconia grisea, Candelariella aurella, Candelariella reflexa, Lecanora chlarotera, Melanelia elegantula*, *Melanelia fuliginosa, Ramalina fastigiata* juv., *Scoliciosporum sarothamni, Lecidella elaeochroma* and *Collema flaccidum* (all at 1 locality).

Decreased load of immissions made colonisation of phorophytes by lichens (but also mosses) easier on the part of former lichen-desert. Its extent has been remarkably reduced

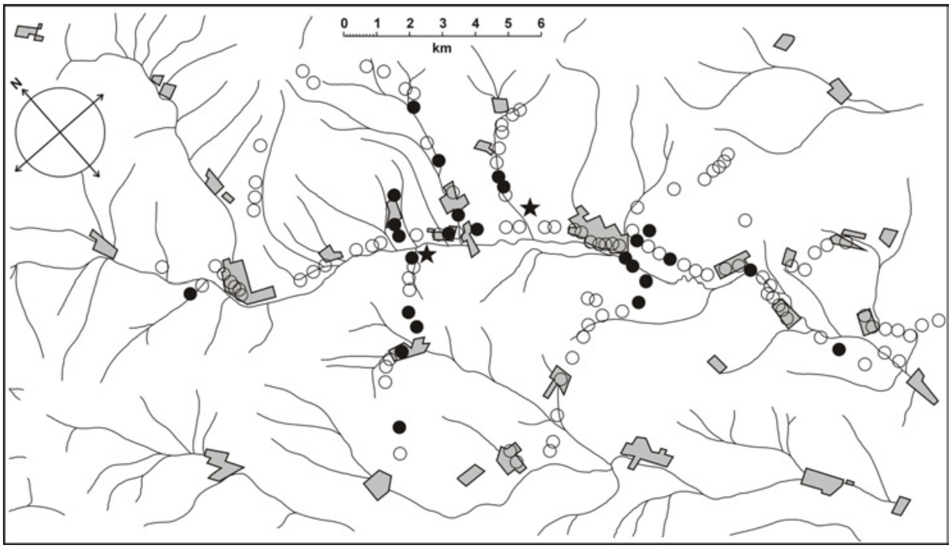


Fig. 6. Distribution of *Xanthoria parietina* in the vicinity of magnesite works in the valley Muránska dolina in 2003–2004.

in comparision to the past. First thalli of species from the association *Physcietum adscendentis* with the dominating *Xanthoria parietina* appeared just in distance of several dozen metres from the factory in Lubeník, 1.7 km NWW and 1 km N from the factory Teplá Voda.

The influence of prevailing winds in the valley Muránska dolina causes, that the thalli SE of this immisssion source occurred only in a distance of 3 km. Gradual improvement of the situation is documented e.g. by comparision of past and recent distribution of *Evernia prunastri* (Fig. 7) and *Hypogymnia physodes* (Fig. 8). In 1973–1974 first thalli of *Evernia prunastri* in the valley Muránska dolina appeared 4.5 km NW of emission source Lubeník and 11.3 km SSE from the factory Teplá Voda. Nowadays they were registered in a distance of 1.7 km N and 2 km SW from Lubeník. Whereas in 1973–1974 first thalli of *Hypogymnia physodes* were observed only in a distance 5.4 km NW and 5.5 km SW from Lubeník, in 2003 they were registered in a distance of 1.7 km N and 2 km SW from this factory. In 1973-1974 first thalli of this species appeared in a distance of 8.5 km NW, 5.7 km SEE and 7.5 km SWW from the factory Teplá Voda, but only 4 km NW away from there in 2003.

Note. Pollutants from magnesite works also adversely affect the epiphytic bryophytes. During investigations in 1973 and 1974 they were totally absent in vicinity of the factories. Improved conditions were recorded e. g. at:

Revúcka Lehota, 1.3 km NNW from Lubeník, *Juglans regia*: *Orthotrichum affine*, *Anomodon attenuatus*.

Chyžné, cooperative farm 3.0 km NE from Lubeník and 3.0 km NW from Teplá Voda, *Salix fragilis*: *Orthotrichum diaphanum, O. obtusifolium*.

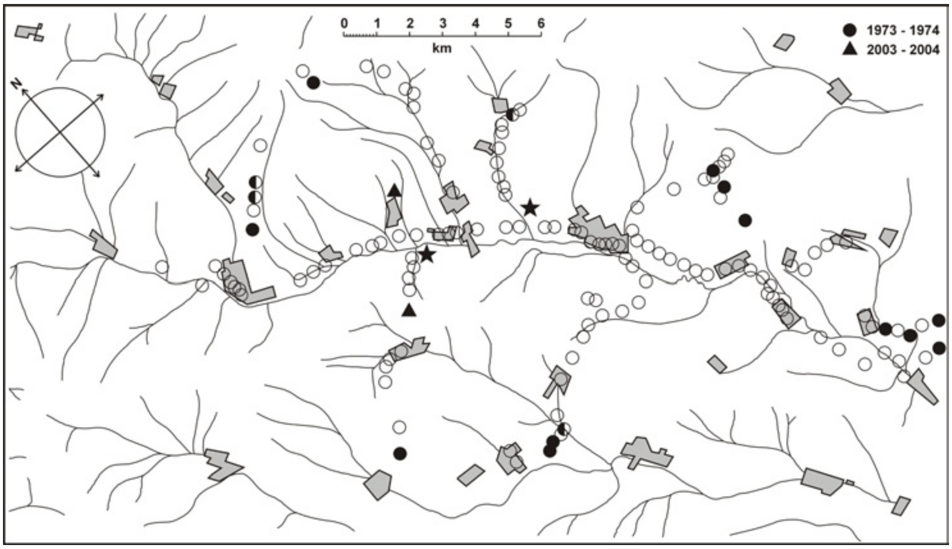


Fig. 7. Distribution of *Evernia prunastri* in the vicinity of magnesite works in the valley Muránska dolina. Black circles and black and white circles (dammaged thalli): 1973–1974. Black triangles: 2003–2004.

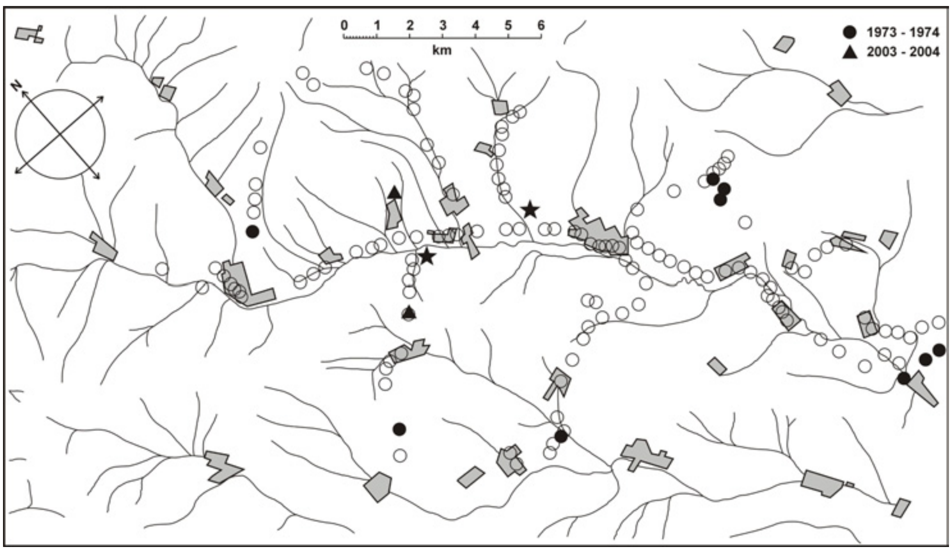


Fig. 8. Distribution of *Hypogymnia physodes* in the vicinity of magnesite works in the valley Muránska dolina. Dots: 1973–1974. Triangles: 2003–2004.

Side road Jelšava–Nandraž, 4 km SE from Teplá Voda, *Malus domestica*: *Orthotrichum affine*, *Pylaisia polyantha*.
Road Jelšavská Teplica–Šivetice, 500 m behind Jelšavská Teplica, *Salix alba*: *Orthotrichum speciosum*.

## Discussion

Epiphytic lichens are very sensitive to magnesite emissions (Pišút, 1974, 1978). The emissions especially increase substratum alkalinity and most likely also ability of lichens to accumulate MgO (Mićović, Stefanović, 1961). Spectrophotometric analyses carried on *Xanthoria parietina* confirmed high accumulation of emitted magnesia in the whole territory, even on sites relatively distant from emission sources. Measured values are shown in Table 2.

T a b l e 2. Accumulation of emitted magnesia [in $\mu g.g^{-1}$]

| Locality | Chyžné | Paseky | Jelšava-Nandraž | Šivetice – Licince |
|---|---|---|---|---|
| Distance from Teplá Voda | 4 km NNW | 18 km NW | 4 km SSE | 9 km SE |
| Mg | 1436 | 1577 | 3978 | 1911 |

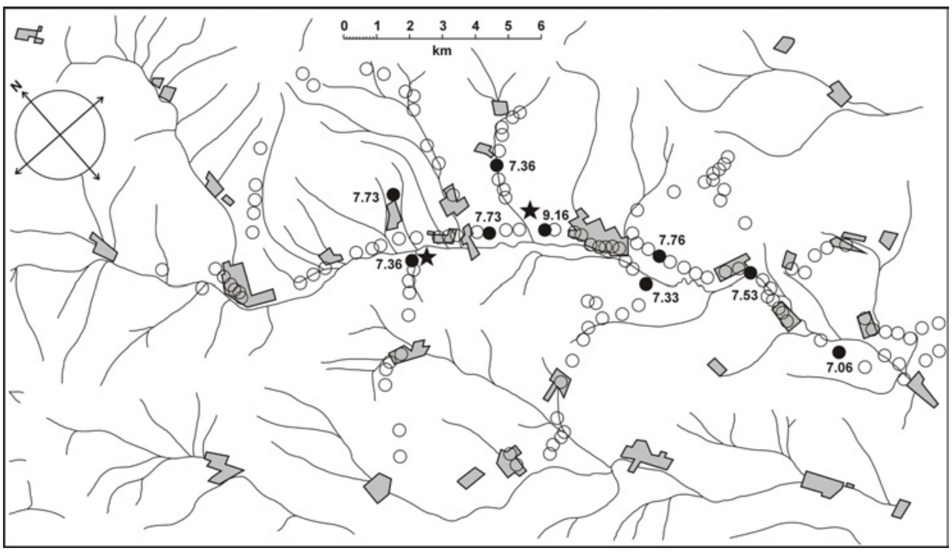


Fig. 9. Bark pH in the valley Muránska dolina (locality Paseky near village Muráň with bark pH 7.26 is out of the map).

Whereas in 1973–1974 the declining gradient of bark pH values was relatively sharp (see Figs 2–4), the actual measurements of pH (Fig. 9) show prevailing high bark alkalinity (pH 9.1) in the neighbourhood of Teplá Voda spoil heap, caused evidently by crust of basic dust, and values from neutral to moderate alkalinic pH (7.06–7.76) in the wide surroundings of factories. For comparision: According Barkmann (1969), the bark acidity of some trees ranges normally in lower values, e.g. *Salix* sp. 4.1–6.2, *Juglans regia* (4.3–7.3 – the last value probably caused by impregnation of dust), *Fraxinus excelsior* (5.2–5.8/–6.8/), *Pyrus communis* 4.8, *Padus avium* (4.9–5.1).

Similar trend was recorded by Wittman, Türk (1988) in the vicinity of Austrian magnesite factory near the town Hochfilzen, where in 1973–1975 the emission of $SO_2$ decreased about 99%, but the dust particles were still released into the environment. After 15 years in the neigbourhood of the work a nitrophilous association *Physcietum adscendentis* developed on coniferous trees (bark pH 5.5–6) with dominatig strikingly orange yellowish *Xanthoria parietina*. Out of this zone affected by emissions bark pH values of coniferes were 3.5–4.

Thirty years of negative influence of basic injurants in the valley Muránska dolina consequently weakened the vitality of phorophytes which is manifested through the loss of foliage and desiccation of some branches, but at the same time stimulated the development of photophilous, neutro- up to temperately alkaline and noticeable nitrophilous association *Physcietum adscendentis*, occuring on substrata with pH values 5–7 (Trumpener according Klement, 1955). Optically *Xanthoria parietina* prevailed. An increased emission of $NO_x$ also stimulates development of nitrophilous epiphytic lichen flora especially along the roads.

According to literary sources *X. parietina* is relatively toxitolerant. After Ferry et al. (1973) in England it occurs abundantly also under average winter concentrations of $SO_2$ about 60 $\mu g/m^3$, on tree bases 70 $\mu g/m^3$. It is interesting that in N Bohemia (Anders, 1935) this lichen was becoming rare in first decades of 20$^{th}$ Century ("Fand sich früher nicht selten an Allee- und Feldbäumen…Jetzt ist sie nur noch spärlich zu finden"). Lichenological research in wide vicinity of Liberec in the area of 350 $km^2$ mostly with average year concentrations of $SO_2$ higher then 70 $\mu g/m^3$ (Anděl, Černohorský, 1978) showed its practically total absence (it was recorded from a single locality!).

Completely different situation occured in the vicinity of Jelšava. Very interesting was not only the increased frequency of *X. parietina* (88.2% from 34 sites, against 29.4% from 136 in the years 1973–1974) but also its occurrence near the sources of emissions. In 1973–1974 the species was totally lacking there, its absence was distinct in the area N to NE from the works (see Figs 5, 6).

Frequency of other species from the association *Physcietum adscendentis* increased, too: *Phaeophyscia orbicularis* from 26.7% to 52.9%, *Physcia adscendens* from 19.8% to 44.1%, but also of rarely occurring taxa: *Physcia tenella* (5 sites against 2 in the past), *Physcia stellaris* (5 against 1).

However, the occurrence of more or less nitrophobous species *Hypogymnia physodes, Scoliciosporum sarothamni*, *Usnea* sp. juv. but also moderately nitrophilous *Evernia prunastri*, *Ramalina fastigiata* in a distance only 2 km from magnesite factory Lubeník outlined future development, although certainly slow, when species from nitrophobous associations would be established.

Especially remarkable is the epiphytic occurrence of *Collema flaccidum* in a distance of 7.5 km NW from Lubeník, on the range of area once loaded by alcalinic dustfall. Epiphytic occurrence of this threatened (EN see Pišút et al., 2001) indicatory species of natural mountain forests in a height of 340 m above see level is exceptional in Slovakia.

One may expect that actual expansive spreading of species from the association *Physcietum adscendentis* especially in more distant sites from both emission sources will successively decrease and several sensitive species would again recolonise the trees there.

*Translated by the authors*

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Pišút I., Pišút P.: **Zmeny epifytických lišajníkov v okolí magnezitových závodov pri Jelšave (JV Slovensko) v období rokov 1973–2004.**

V rokoch 1973–1974 sa uskutočnil výskum vplyvu magnezitových imisií na flóru epifytických lišajníkov v okolí magnezitiek Lubeník a Teplá Voda v Muránskej doline. V rokoch 2003–2004 sme výskum opakovali. Cieľom bolo porovnať zmeny, ktoré tu nastali v priebehu tridsiatich rokov. Zníženie množstva emitovaných škodlivín spôsobilo výrazné zmenšenie „lišajníkovej púšte“, oblasti v ktorej žiadne epifytické lišajníky nerástli.

Napriek tomu sme zistili zvýšenú akumuláciu horčíka v stielkach druhu *Xanthoria parietina* aj vo väčších vzdialenostiach od zdrojov imisií. Aktuálne merania pH borky stromov preukázali pretrvávajúcu vysokú alkalitu borky (pH 9.1) v susedstve deponia alkalických odpadov a hodnoty od neutrálnych po slabo alkalické v širokom okolí závodov, pôsobiace stimulačne na rozvoj nitrofilnej flóry zo spoločenstva *Physcietum adscendentis* s dominantným druhom *Xanthoria parietina*.

Výskyt viac či menej nitrofóbnych druhov *Hypogymnia physodes*, *Usnea* sp. juv. a iných, ale aj anitrofilných až mierne nitrofilných druhov *Evernia prunastri*, *Ramalina fastigiata* vo vzdialenosti iba 2 km od magnezitky Lubeník však naznačuje budúci, aj keď iste pomalý vývoj, v ktorom sa postupne budú navracať a presadzovať druhy anitrofilných spoločenstiev.