

THE POSSIBILITY AND EFFICIENCY OF BIOINDICATION METHOD IN FOREST AIR QUALITY MONITORING

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Abstract. The investigation concluded upon the existence of a sufficient number of indicator species of lichens which can be applied in monitoring the environment quality in the Republic of Moldova. The investigation also contributed to the establishment of legitimate facts that under the action of gaseous pollutants (i.e. SO₂ etc.) and depending on the source of pollution, geographic location, species sensitivity, duration of exposure induce the modification or total degradation of lichen thallus. Additionally, the Air Quality Gradation Scale (AQGS) and Lichens Tolerant Scale (LTS) towards different concentration of SO₂ in atmosphere air were developed. The efficiency of AQGS with some additional modifications was tested through assessing the quality of air in 62 forest ecosystems. Thus, in order to meet the country obligations under the Geneva Convention (1979), *Parmelia sulcata* species was proposed as a referent species (standard) in performing the monitoring of air quality at national and international level.

Keywords: lichens, indication, pollution, monitoring.

Rezumat. Posibilitatea și eficacitatea metodei bioindicației în monitoringul calității aerului din păduri. Lucrarea include rezultatele studiului premizelor implementării ecobioindicației în evaluarea calității mediului ecosistemelor forestiere din Republica Moldova, stabilindu-se existența unui număr suficient de specii indicatoare de licheni, care pot sta la baza realizării monitoringului calității mediului. Sunt stabilite legături privind modificarea sau degradarea totală a talului lichenilor sub acțiunea poluanților gazoși (SO₂ ș. a.), în funcție de sursa de poluare, condițiile geografice, sensibilitatea speciei, durata expunerii etc. Sunt elaborate Gradații de Evaluare a Calității Aerului (GECA) și Scala Toleranței Lichenilor (STL) față de SO₂. A fost demonstrată eficiența aplicării GECA, cu unele modificări, în testarea calității aerului din 62 ecosisteme forestiere. Astfel, în scopul îndeplinirii obligațiilor țărilor impuse de Convenția de la Geneva (1979), specia *Parmelia sulcata* este propusă ca obiect de referință (standard) în realizarea monitoringului calității aerului la nivel național și internațional.

Cuvinte cheie: licheni, indicație, poluare, monitoring.

INTRODUCTION

The presence of lichens as such is not necessarily an indication criterion, as previously stated by VICTOROV *et al.* (1962) for higher plants. To have an indicative value the lichens must have a certain abundance. In our view, a coverage of 10% of the substrate surface could be a clear indicator. This threshold is very important, especially for toxitoleration grades I and II since we cannot state that the air is clean upon identifying a few plants of lichens very sensitive to pollution. For certain species which could be used as indicators for the Republic of Moldova there were no information or the available information was controversial. Based on our research, which included results from laboratory and field observation on lichens from natural habitats, transplanted lichens and trials in laboratory, there were established new toxitoleration gradations or their initial toxitoleration was modified.

MATERIAL AND METHODS

Proceeding from the indicators abundance and toxitoleration we elaborated a scale with gradations for the evaluation of the air quality (Table 1). The evaluation of air quality by applying the lichens indication method to 62 forest ecosystems throughout the Republic of Moldova, allowed us to identify 90 lichens species out of which 50 species are bioindicators.

Table 1. Scales in air quality assessment based on abundance of lichens with different toxitoleration (BEGU, 2011).
Tabel 1. Gradații de evaluare a calității aerului în baza abundenței lichenilor de diversă toxitoleranță (BEGU, 2011).

Air quality	SO ₂ content in the air, mg/m ³	Abundance of species with different toxitoleration degree, % of substrate surface	Conventional colour
1. Clean	<0,05	I > 10 or I < 10 and II > 75	blue
2. Slightly polluted	0,05-0,1	I - 0-10 or II - 50-75	light blue
3. Moderately polluted	0,1-0,2	II - 10-50 or III > 50	green
4. Polluted	0,2-0,3	III - 10-50 or IV > 50	yellow
5. Heavily polluted	0,3-0,5	IV - 10-50 or V - 1-100	red
6. Critically polluted	>0,5	Complete absence of lichens	brown

RESULTS AND DISCUSSIONS

Basing on this method, four forest ecosystems were evaluated as clean air (Ocnița-Hădărăuți, Bahmut, Seliște-Leu, and Potoci); the number of ecosystems with slightly polluted air reaches 11, moderately polluted - 31, polluted - 13, heavily polluted - 3 (Criva, Saharna, Copanca), while those with critical pollution level are not present (Fig. 1). The

air quality from the ecosystems which were reported as clean is confirmed by the presence of lichens species very sensitive to pollution, the coverage of which was over 10% of substrate surface (i.e. *Usnea hirta* in Ocnița-Hădărăuți, *Peltigera canina* - in Bahmut and *Ramalina fraxinea* - in Seliște-Leu).

The ecosystems with slightly polluted air ($\text{SO}_2 = 0,05\text{--}0,1 \text{ mg/m}^3$ air) are primarily located in the North of the country (Trebișăuți, Fetești, La Castel, Zabricești, Lipnic, Dondușeni) and some of them in the central part (Bujor, Cimișeni, Logănești) and in the middle part of the Dniester (Lopatna) and the Prut (Cotul Morii) river basins.

The ecosystems with moderately polluted air ($\text{SO}_2 = 0,1\text{--}0,2 \text{ mg/m}^3$ air) are more numerous (31) and have a wide distribution throughout the country, often being subject to impact from local pollution sources (i.e. - Hâjdieni, Criva, Orhei, Seliște, Durlești, Budești, Văleni, Giurgiulești etc.) or from transboundary sources, particularly areas on hillsides with Western exposition (e.g. Bălănești, Cobac). The number of ecosystems with polluted air ($\text{SO}_2 = 0,2\text{--}0,3 \text{ mg/m}^3$ air) is 13, prevailing in the vicinity of the cities and industrial pollution sources (e.g. Trinca, Chetroșica Nouă, Mândrești Noi, Papauți, Șoldănești, Tohatin, Hârbovăț, Cioburciu). Heavily polluted air ($\text{SO}_2 = 0,3\text{--}0,5 \text{ mg/m}^3$ air) is set for 3 ecosystems - Criva, Saharna, and Copanca, which have a location in the immediate vicinity of pollution sources and are positioned in the path of the prevailing winds. The ecosystems with critical polluted air ($\text{SO}_2 > 0,5 \text{ mg/m}^3$ air) were not recorded.

A more pronounced air pollution with SO_2 is specific for the ecosystems located around obvious sources of pollution. Here, the bioindicators with toxitoleration degree II and III do not exceed 5% of the substrate coverage (sometimes over 10% in case of nitrophilous species - Văleni, Giurgiulești, Criva region), and the persistent species with the toxitoleration III, IV, V are most of the times nitrophilous species. In addition, the ecosystems with polluted air are poor in diversity (often only 4 – 6 species).

Typically, the ecosystems with slightly polluted air are located at altitudes above 200 m and those with polluted air - below 200 m, but there are many exceptions, because the distance from the pollution source and the direction of prevailing winds are also important factors (for example the sites Trinca, Călărăseuca, Chetroșica Nouă, Mândrești Noi, Saharna – are situated at altitudes above 200 m but are still rather polluted). Compared with Potoci site (mountain type), most forest ecosystems in the Republic of Moldova are hilly type (200-600 m) or flat (0-200m). Rather enhanced can be considered the effects of pollution in ecosystems located on plain areas for instance those around Valea Mare, Nemțeni, Crihana Veche, Vilcovo (Ukraine), and for Criva, Hâjdieni, Orhei, Tohatin, Copanca, Hârbovăț, Cioburciu; the determining role was played by the distance from the pollution source of and the direction of prevailing winds.

Most of SO_2 emissions from local sources are concentrated in the South East of the country with a mega-source in Tighina - Tiraspol - Cuciurgan area. This led to the pollution of ecosystems located in the SE due to prevailing winds from NW to SE, which were confirmed by us through bioindication. The emissions of SO_2 from Soroca and Bălți sources led to the Hâjdieni ecosystem degradation. The geological exploration of Criva and Trinca, the later being as well affected by unauthorized burning in the lime production process, have placed these ecosystems in the category with highly polluted air. High emissions of SO_2 are characteristic for the town of Hâncești that left their prints on the state of bordering ecosystems air - Sărata Galbena and Sărata-Mereșeni. Chișinău emissions have evidently contributed to the pollution of ecosystems Balmaz - Hârbovăț located in the South East and Tohatin - Budești located towards East. The effects of pollution from the Rezina - Rabnița source were reported only in direct vicinity (Saharna, Ciorna, Popăuți), due to the direction of winds from NW to SE, leaving unaffected the ecosystems Pohribeni and Lopatna. The possible harmful effects, catastrophic for vegetation, from the Cuciurgan source were more pronounced in Copanca and less in Cioburciu - Răscăieți, again due to the direction of winds from the NW to SE. The South part of the country is affected by transboundary pollution (Galați city, Romania), especially Crihana Veche, as well as Giurgiulești and Văleni. The effects of pollution from the sources located in Iași, inseparable from those of Ungheni, strengthen the pollution of ecosystems in the region around - Valea Mare, Nemțeni, less Bălănești, Cobac, but fortunately pollution does not reach Bahmut and Cornești, located NE of the pollution sources; as a result, they are protected by the high relief of Codrii forest reservation.

According to the EMEP Report 1/2003 issued by the Meteorology Institute, Norway, transboundary pollution is manifested in many countries in Europe. Moldova is located in the area of annual SO_2 deposition equal to 700 - 1000 kg/km^2 . The comparison between the results of lichen indication applied to 62 ecosystems, to the EMEP results, presented in table 2, shows that the EMEP network (50x50 km grid) hinders the real environmental state, probably because pollution effects are more pronounced within the 25-30 km from the pollution source. For example, in the 86/64 sectors the 11 studied ecosystems showed the air as clean (e.g. Ocnița), slightly polluted (Fetești, Trebișăuți, Zabricești ecosystems), moderately polluted (Clocușna and Cernoleuca) or polluted (Trinca and Chetroșica Nouă). In the same time, the EMEP matrix characterizes the state of the air as polluted.

The 50x50 km grid is likely to be indicative in large forest areas and/or plain landscape (for instance Belarus, the Baltic states, Poland, Russia, etc.) but is less meaningful for the Republic of Moldova, a country with low forest coverage and fragmented landscape, which can re-direct pollution effects. Thus, at the national level it is recommended the application of 25x25 km grid.

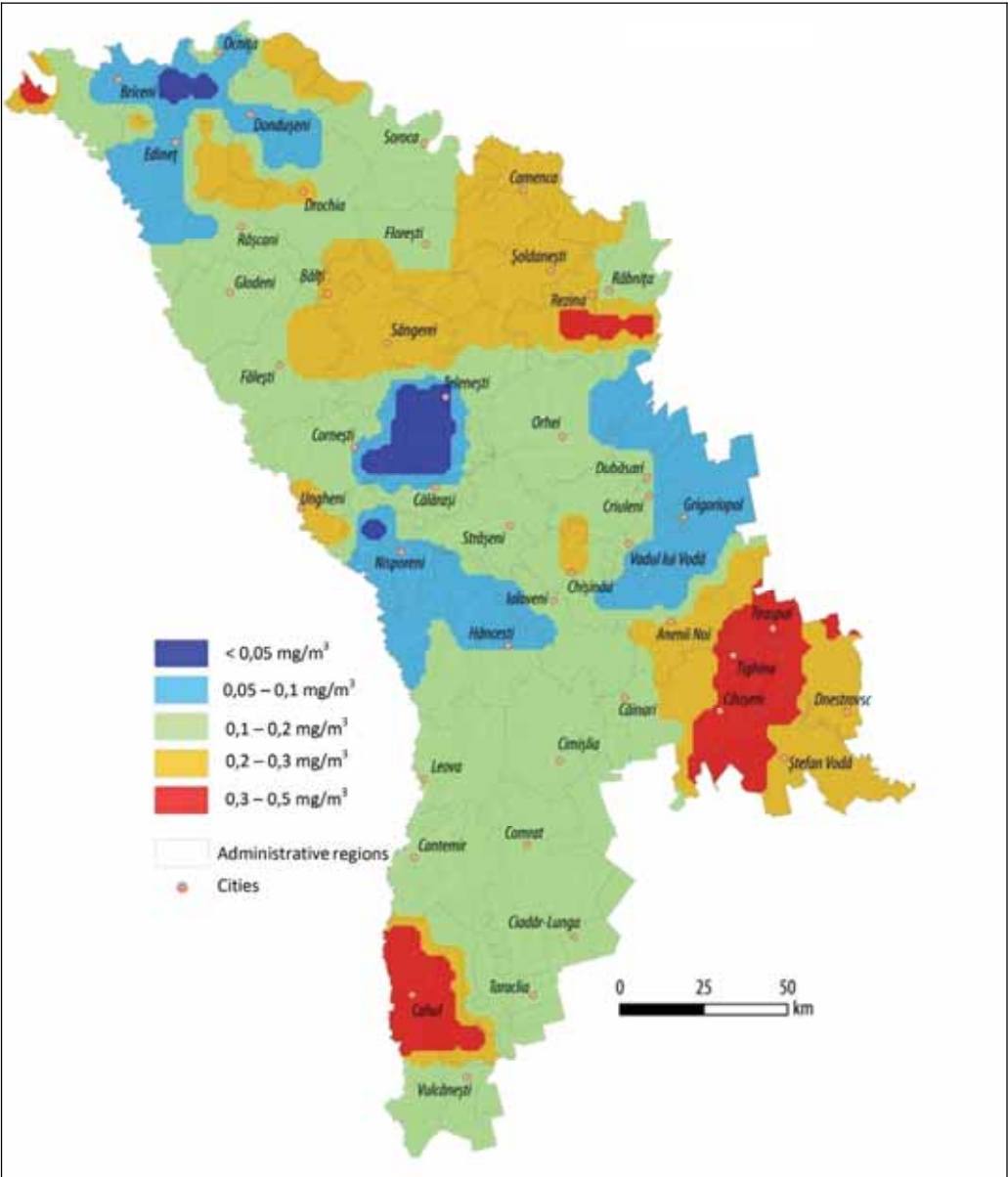


Figure 1. Spatial distribution of air pollution with SO₂, based on lichen indication. / Figura 1. Distribuția spațială a poluării aerului cu SO₂, bazată pe lichenoindicație.

Table 2. Air quality of researched forest ecosystems, according to EMEP 50x50km (large rectangles) comparing to our evaluations based on AQGS (small squares). / Tabel 2. Calitatea aerului din ecosistemele forestiere studiate, conform EMEP 50x50km (dreptunghiurile mari) comparative cu evaluările noastre pe baza GECA (dreptunghiurile mici).

North -South Direction	Ecosystems EMEP networking distribution (32dials 50x50km grid) West – East Direction					Total	Ro, Ua
	62	63	64	65	66		
85	Ro				Ua	1	
86	Ro				Ua	14	
87	Ro				-	5	
88	Ro					7	1- Ro
89	Ro					14	
90	Ro				-	8	
91					-	6	
92			-	-	-	5	
93		Ua	Ua	Ua	Ua	-	
94	Ua	Ua	1- Ua	Ua	Ua	-	1- Ua
Total	3	13	25	14	5	60	2

Legend:

Ro

- Romania
low polluted air

Ua

- Ukraine
moderate polluted air

highly polluted

CONCLUSIONS

1. The Republic of Moldova Lichens Register was elaborated, based on literature review and own research, which includes about 200 species and varieties (22 set by the author).
2. The premises of lichens eco-bioindication were established basing on the presence of 40 indicator species, sensitive to air pollution with SO₂, NO_x, etc.
3. Two criteria for the evaluation of the state of environmental components were proposed: a Lichens Toxitoleration Scale (LTS) with 6 steps, taking into account the degree of air pollution with SO₂, the similarity of geographical conditions, and the results of own testing through gasification, transplantation and studies in the field; and Gradations for Air Quality Assessment (GAQA) in forest based ecosystems, based on indicator abundance/coverage, toxitoleration and correlation between different bioindicator species.
4. The results obtained from the biological monitoring of 62 forest ecosystems allowed us to argue the possibility and efficiency of lichens indication method in air quality monitoring.

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