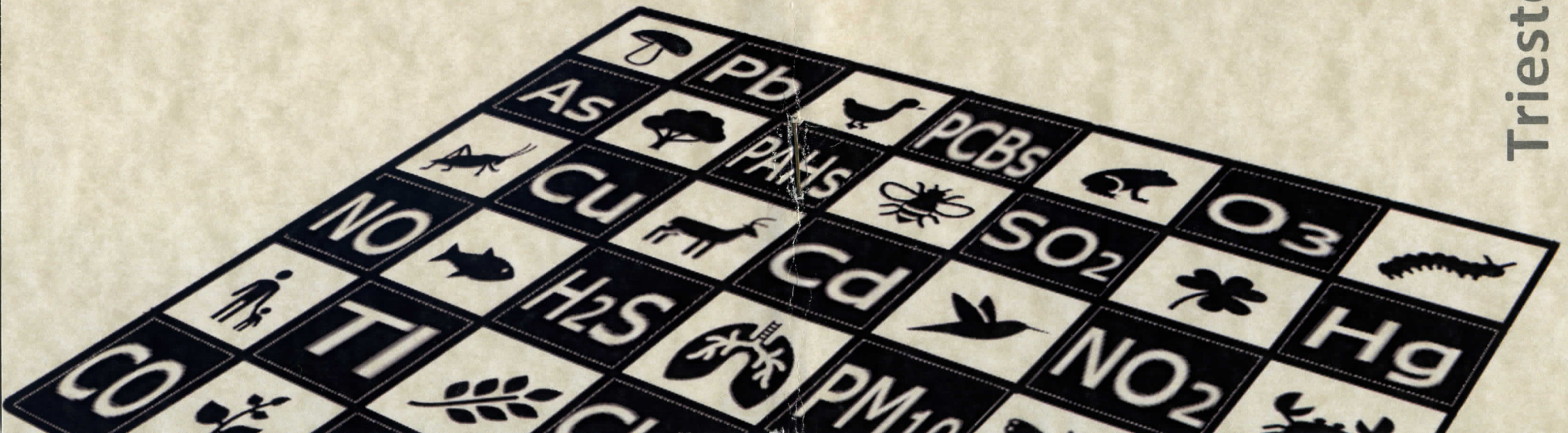
International Association for Biomonitoring of Environmental Pollution

Fundative Conference

BOOK OF ABSTRACTS



Trieste, October 11-13, 2023

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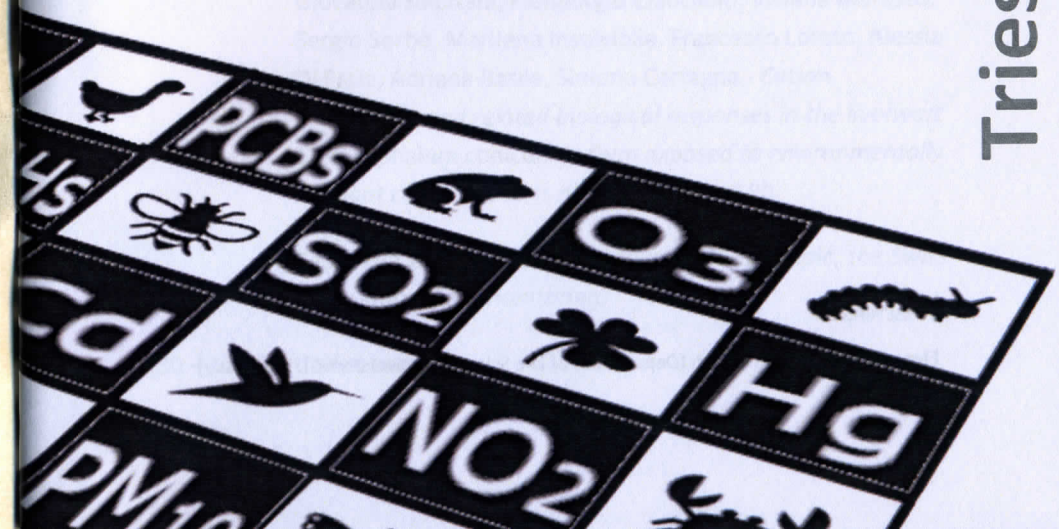

Trieste, October 11-13, 2023

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Programme

October 11, 2023 (Wednesday)

13:30 – 14:30 Registration of participants.

14:30 – 14:50 Opening ceremony with greetings from the Authorities.

14:50 – 16:30 First session, "**Classics**" (chairperson Pedro Pinho, University of Lisboa, Portugal):
(**full talks** of 15 minutes each, plus 5 minutes for discussion.)

Pedro Pinho, Bernardo Rocha, Cristina Branquinho, Paula Matos *Lichens as ecological indicators for the effects of environmental changes in urban context: ongoing research and major challenges.*

Stefano Martellos, Sebastiano Andreatta, Stefano Loppi *Lichens and air quality: a new citizen science approach.*

Elisa Pellegrini, Lorenzo Cotrozzi, Cristina Nali, Giacomo Lorenzini *Standardized biomonitoring protocols to assess the air quality: 30 years of experience from Italy.*

Giovanna Salbitani, Piergiorgio Cianciullo, Viviana Maresca, Sergio Sorbo, Marilena Insolvibile, Francesco Loreto, Alessia Di Fraia, Adriana Basile, Simona Carfagna *Cation localization and related biological responses in the liverwort* Conocephalum conicum *L. Dum exposed to environmentally relevant concentrations of Zn, Cu, Cd and Pb.*

Sébastien Leblond, Caroline Meyer *Moss sample, the Swiss Army knife of biomonitoring.*

16:30 – 17:10 Coffee break.

17:10 – 17:50 First session, "**Classics**" (continued):

Mélanie Jean, Nicole Fenton, Mia Courville-Todorov, Olivier Clarisse *Monitoring atmospheric deposition of pollutant with mosses around point-sources and across the landscape in eastern Canada.*

Tania Contardo, Stefano Loppi *The pitfalls of mapping biomonitoring data.*

17:50 – 18:30 First session, "**Classics in short**" (chairperson: Anna Bérešová Guttova, Slovak Academy of Sciences, Institute of Botany, Bratislava, Slovakia):
(**short talks** of 5 minutes for 3 slides each.)

- Drava *et al.*, It is time to consider time in biomonitoring studies.
- Ait Kaci *et al.*, Exploring natural biocides: Assessing the impact on microorganism diversity in agricultural soils as environmental bioindicators.
- Ghennam *et al.*, Lichen biomonitoring in the botanical garden of El Hamma in Algiers is used to assess the impact of green space structure on air quality.
- Zorza *et al.*, Preliminary evaluation of the algal periphyton biomass and community composition in the Isonzo River
- Amelmann *et al.*, First assessment of the macrozoobenthic community of Ragogna lake.
- Risoli *et al.*, Ozone biomonitoring: A versatile tool for citizen science.
- Mesraty, Lichens CitiSci: A community science project engaging volunteers in air quality.

19:00 – 20:30 Optional tour to the town, with Dr Andrea Moro, University of Trieste.

October 12, 2023 (Thursday)

08:30 – 10.30 Second Session, "**New methods**" (chairperson: Julian Aherne, Trent University, Peterborough, Canada):
(**full talks** of 15 minutes each, plus 5 minutes for discussion.)

Lorenzo Cotrozzi, Ivan Fiaccadori, Giuseppe Quaratiello, Giacomo Lorenzini, Cristina Nali, Luca Paoli, Elisa Pellegrini *The potential of using hyperspectral data for plant and lichen biomonitoring of environmental pollution.*

Lisa Grifoni, Aldo Winkler, Francesca Boldrighini, Marcos A. E. Chaparro, Luigi A. Di Lella, Fernando Marte, Luciano Pensabene Buemi, Alfonsina Russo, Antonio Sgamellotti, Lilla Spagnuolo, Gabriella Strano, Marcos Tascon, Stefano Loppi *Magnetism and environmental biomonitoring: application for the preventive conservation of Cultural Heritage.*

Andrea Vannini, Massimo Chiari, Alessandro Petraglia *A first (small) step towards understanding the ability of biochar to provide information on the environmental availability of potentially toxic elements (PTEs) in atmospheric depositions.*

Fabrizio Monaci, Davide Baroni, Stefano Loppi *Harnessing the potential of biomonitors to assess atmospheric mercury pollution: recent insights and perspectives.*

Mehriban Jafarova, Lisa Grifoni, Monia Renzi, Tecla Bentivoglio, Serena Anselmi, Aldo Winkler, Luigi A. Di Lella, Julian Aherne, Stefano Loppi *The suitability of* Robinia pseudoacacia *L. (black locust) leaflets as biomonitors of airborne microplastics.*

Nuno Ratola, Arminda Alves Pinus *needles as bioindicators of organic micropollutants*.

10:30 – 11:00 Coffee break.

11:00 – 11:40 Second Session, "**New methods**" (continued):

Baptiste Delaunay, Jerôme Ledauphin, Nathalie Sauret *Using a bioindicator plant,* Eleagnus ebbingei*, to predict the concentrations of polycyclic Aromatic Hydrocarbons in the atmosphere of temperate areas in Europe*

Mira Aničič Urošević, Maja Kuzmanoski, Tijana Miličević, Igor Kodranov, Konstantin Vergel, Aleksandar Popovič *Moss bag biomonitoring of airborne elements at a suburban background site in Belgrade (Serbia) during Saharan dust intrusions*.

11:40 – 12:20 Second Session, "**New methods in short**" (chairperson: Lorenzo Fortuna, University of Trieste, Italy).
(**short talks** of 5 minutes for 3 slides each.)

- Cinti *et al.*, The evolutionary importance of stomata and mesophyll traits on adaptation to climate changes.
- Munzi, Engaging citizens in soil monitoring: the project ECHO.
- Paoli *et al.*, Air quality changes witnessed by herbarium specimens of lichens: a case-study in the Western Carpathians.
- Swislowsk and Rajfur, Mosses as bioindicators of indoor air pollution.
- Perri *et al.*, Soil-plant analyses to determine the bioindication and bioaccumulation capacity of native vascular plants in dismissed mining area of Calabria region (S-Italy).
- Stringa Basile *et al.*, Lichen biomonitoring of airborne microplastics in the urban area of Pisa (Italy).
- Santunione *et al.*, Urban forest as a strategy of particulate matter (PM) capture and retention.
- Pisuttu *et al.*, Evaluation of the suitability of *Tillandsia usneoides* as biomonitor of airborne elements in a natural environment of Italy

12:20 – 14:30 Lunch (free).

14:30 – 16:00 Opening of the Assembly Appointment of the president of the Assemby. Presentation of the preparatory work for the foundation of the International Association for Biomonitoring of Environmental Pollution: structure of the statute, advisory and control bodies, election mechanisms. Open discussion. Voting of the Assemby on the Statute.

16:00 – 16:30 Public signing of the founding act, in the presence of a notary and journalists.

16:30 – 17:00 Coffee break.

17:00 – 17:30 Election of the Association bodies. Press release.

20:00 Social dinner in a local restaurant.

October 13, 2023 (Friday)

08:30 – 10.30 Third session, "**Standardisation**" (chairperson· Prof Stefano Loppi, University of Siena):
(**full talks** of 15 minutes each, plus 5 minutes for discussion).

Zbigniew Ziembik, Agnieszka Dołhańczuk-Śródka, Andrzej Kłos, Daniel Janecki, Sławomir Wierzba *Issues in biomonitoring data interpretation and their mitigation.*

Erica Rancati, Alessandro D'Aietti, Arianna Macor, Gabriele Piazza, Alessandra Sinesi, Damiano Virgilio, Elisa Zanut, Raffaella Zorza, Enrico Bressan, Antonello Zanello *Monitoring of priority substances in biota for classifying the environmental quality status of surface water bodies.*

Aldo Winkler, Lisa Grifoni, Leonardo Sagnotti, Stefano Loppi *Magnetic biomonitoring: towards a standardization of the operational and measurement protocols.*

Fiore Capozzi *Toward the adoption of a shared protocol in the moss bag approach: main outcomes from the MOSSclone project.*

Zulema Varela, Jesús R. Aboal, José Ángel Fernández *Mossphere: a new biotechnological passive sampler for environmental air quality management.*

Julian Aherne, Mehriban Jafarova, Stefano Loppi *The good, the bad, and the ugly of biomonitoring of atmospheric microplastics.*

10:30 – 11:00 Coffee break.

11:00 – 12:00 Third session, "**Standardization**" (continued):

Elena Gottardini, Fabiana Cristofolini, Antonella Cristofori, Radek Novotny, Matej Rupel, Vicent Calatayud, Marcus Schaub, Diana Pitar, Marco Ferretti *Visible foliar symptoms as a proxy of ozone impact on vegetation. from the multi species approach of the ICP Forests method applied on European scale to the single bioindicator species approach.*

Mauro Tretiach, Fabio Candotto Carniel, Lorenzo Fortuna *Biomonitoring techniques for testing the pollution impact of Recovered Derived Fuels (RDFs): a ten-year-long study case centred on a cement mill in NE Italy.*

Paolo Giordani, Renato Benesperi, Elisabetta Bianchi, Giorgio Brunialti, Elva Cecconi, Tania Contardo, Luca Di Nuzzo, Lorenzo Fortuna, Luisa Frati, Stefano Loppi, Fabrizio Monaci, Silvana Munzi, Juri Nascimbene, Luca Paoli, Sonia Ravera, Mauro Tretiach, Andrea Vannini *Lichen biomonitoring after standardisation. another step towards systematisation?*

12:00 – 13:00 Round table "**The role of Biomonitoring in a ill world**", with the IABEP Council and invited guests.

13:00 – 13:30 Closing ceremony

CONTENTS

LICHENS AS ECOLOGICAL INDICATORS FOR THE EFFECTS OF ENVIRONMENTAL CHANGES IN URBAN CONTEXT· ONGOING RESEARCH AND MAJOR CHALLENGES

PEDRO PINHO (1), BERNARDO ROCHA (1),
CRISTINA BRANQUINHO (1), PAULA MATOS (2)

(1) cE3c Center for Ecology, Evolution and Environmental Changes & CHANGE Global Change and Sustainability Institute, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal. (2) CEG – Centro de Estudos Geográficos, IGOT – Instituto de Geografia e Ordenamento de Território, Universidade de Lisboa, Lisboa, Portugal.

Although cities are places for human fulfilment, urbanization causes environmental problems, such as atmospheric pollution and the urban heat-island effect. These can be quantified by sensors, but measuring its effects on urban ecosystems biodiversity and provision of ecosystem services remains a challenge. To overcome this, the aim of this work is to present ongoing research, challenges, and application on the use of lichens as ecological indicators in cities. This includes both the use of lichens to measure the effect of environmental drivers and to measure the provision of ecosystem services by urban ecosystems.

Overall, the selection of the more appropriate lichen-based metrics was based on the intensity of the environmental driver· taxonomic-based or trait-based metrics and/or physical-chemical analysis of lichen thallus to understand pollutants deposition and origin in ecosystems. Analysis of lichen metrics over space enhanced the interpretation and application of lichens as indicators for factors working at different spatial scales. Still multi-city studies, across continental gradients, remain challenging, as disentangling the local effects from the large trends observed in a continental scale is still ongoing.

Urban ecosystems are impacted by environmental changes, but also contribute to ameliorating its effects, by providing ecosystem services. We used lichens to quantify how green and blue infrastructure characteristics affect the provision of ecosystem services, e.g. how green areas characteristics (e.g. tree-density or habitat fragmentation) influence the amount of microclimate or air quality regulation. Still, measuring ecosystem services provision under the effects of multiple drivers remains a challenge.

Addressing such challenges could allow us to improve even further the use of lichens as ecological indicators, contributing to the planning and management of cities green infrastructure and to adapt cities to future environmental changes.

Keywords: air pollution, ecosystem services, urban areas, urban heat island.

LICHENS AND AIR QUALITY: A NEW CITIZEN SCIENCE APPROACH

STEFANO MARTELLOS (1), SEBASTIANO ANDREATTA (2), STEFANO LOPPI (3, 4)

(1) University of Trieste, Italy. (2) Natural History Museum of Verona, Italy. (3) University of Siena, Italy. (4) NBFC, National Biodiversity Future Center, Palermo, Italy.

Since a first experience in the UK during the '70 of the past century, Citizen Science (CS) approaches have been adopted also in the field of air quality monitoring, on the basis of indices of epiphytic lichen diversity. Since the identification of lichens in the field may often be quite difficult, especially to laypersons, in the framework of CS approaches volunteers were often involved adopting simplified sampling protocols, which usually require taxon identification at higher level than the species, or even the use of morpho-types, or thallus colors. Even with these simplifications, several studies demonstrated that the data produced with CS approaches were highly reliable and could be useful at least to define general patterns of lichen diversity, with the aim of addressing further finer investigation.

A very simple CS approach has been developed for monitoring air quality through a streamlined index of epiphytic lichen diversity by involving school children. The protocol foresees the identification of monitoring stations of a 50-m radius, in which the trunks of 3 isolated trees, selected among a list of common species, are sampled, checking whether there are only crustose lichens or no lichens at all (score = 0), narrow-lobed lichens (score = 1), broad-lobed lichens (score = 2), or fruticose lichens (score = 3). The Municipality of Verona, which this year hosts the National Conference of the Italian Lichen Society, was selected as the test site. The outcome of this activity, as well as the major constraints faced in the involvement phase and during fieldwork, will be presented and discussed.

The activity is supported by the Municipality of Verona and its Natural History Museum, the National Biodiversity Future Center, the Italian Botanical Society, the Italian Lichen Society, the Cariverona Fundation, the Italian WWF and the Italian Association for Citizen Science.

Keywords: growth form, monitoring, sampling protocol, volunteers.

STANDARDIZED BIOMONITORING PROTOCOLS TO ASSESS THE AIR QUALITY: 30 YEARS OF EXPERIENCE FROM ITALY

ELISA PELLEGRINI, LORENZO COTROZZI, CRISTINA NALI, GIACOMO LORENZINI

Department of Agriculture, Food and Environment, University of Pisa, Via del Borghetto 80, 56124 Pisa, Italy.

Biological monitoring (BM) uses organisms to determine the presence, amounts, spatial/temporal changes, and effects of abiotic and biotic agents in the environment. The huge difference between BM and traditional physico-chemical measures of air quality is that the latter measures take into account emissions/immissions, but only indirectly measure the "health" of the atmosphere because they do not assess/look directly at biological responses. Specific plants, such as *Nicotiana tabacum* cv. Bel-W3 and *Gladiolus gandavensis* are considered to be reliable bioindicators of ambient ozone and fluoride, respectively. These species are "perfect" bioindicators of ozone and fluoride in the air as they are highly sensitive. They develop easily recognizable and quantifiable peculiar foliar symptoms, which are the first indication that a region/area has developed an ozone/fluoride problem. At the same time, *Lolium multiflorum* and *Brassica oleracea* var *acephala* cv. Hammer/Grüsa are considered "perfect" bioaccumulators of heavy metals and polycyclic aromatic hydrocarbons. The entire methodology, from plant cultivation to exposure, injury assessment, data elaboration, and presentation of results, is now standardized. Data collected at 70 sites in Italy by using the Bel-W3/Bel B tobacco biotype system, *G. gandavensis* (cv. Oscar), *L. multiflorum* (cv. Lema) and kale plants during 1993-2023 were analysed in order to assess their efficacy for BM under changing environmental conditions, and variations of visible damage linked to several anthropogenic activities characterizing the studied areas.

Keywords: air pollution, bioindication, bioaccumulation, vascular plants.

CATION LOCALIZATION AND RELATED BIOLOGICAL RESPONSES IN THE LIVERWORT *CONOCEPHALUM CONICUM* L. DUM EXPOSED TO ENVIRONMENTALLY RELEVANT CONCENTRATIONS OF ZN, CU, CD AND PB

GIOVANNA SALBITANI (1), PIERGIORGIO CIANCIULLO (1), VIVIANA MARESCA (1), SERGIO SORBO (2), MARILENA INSOLVIBILE (3), FRANCESCO LORETO (1), ALESSIA DI FRAIA (1), ADRIANA BASILE (1), SIMONA CARFAGNA (1)

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In the present study we assessed the tissue localization, oxidative stress, ultrastructural alterations and photosynthesis efficiency in the gametophyte of the thallose liverwort *Conocephalum conicum* exposed in-vitro to a mix of Zn, Cu, Cd and Pb. For the exposure mixture we choose environmentally relevant concentrations detected in different impacted areas of Savone river First, we investigated the accumulation and conduction pattern of the selected metals in the epidermis, photosynthetic parenchyma and hyaline parenchyma through X-ray microanalysis and the bulk metal concentrations in the whole thalli through ICP-MS. The results showed the heavy metals bioaccumulation in *C. conicum* was dependent by its concentration in the contaminated water X-ray microanalysis evidenced that non-essential metals (Cd and Pb) accumulated mainly in the central portion of the thallus (nerve) and specifically in the hyaline parenchyma, whilst essential metals (Zn and Cu) were more homogeneously distributed between the tissues. After, we investigated ultrastructural alterations, oxidative stress biomarkers (ROS, CAT SOD, GST), and photosynthetic efficiency through PAM imaging in the both nerves and wings tissues. At the ultrastructural level, the exposure to the mix caused alterations of the fine structure of the cells, inducing marked alterations of the chloroplast structure. Accordingly, an enhancement of CAT SOD and GST activities was observed. The PAM imaging shown that the lowest photosynthetic efficiency was localized in the central tissue, in accordance with the ultrastructural alteration observed in the chloroplasts of the photosynthetic parenchyma of the nerve. All these responses were higher in the nerve than the wing tissues of *C. conicum* thalli.

Keywords: *Conocephalum conicum*, environmental pollution, heavy metals, photosynthesis, tissue localization, ultrastructure.

MOSS SAMPLE, THE SWISS ARMY KNIFE OF BIOMONITORING

SÉBASTIEN LEBLOND, CAROLINE MEYER

PatriNat, Office français de la biodiversité, Muséum national d'Histoire naturelle, Paris, France.

France has been taking part in the ICP Vegetation Moss Survey since 1996. Through five-yearly campaigns, around 500 forest and rural sites are sampled throughout the country. To optimize comparisons over time, since 2000, all campaigns have followed the same collection protocol, in terms of both site characterization and moss sample collection and processing methodology. From the beginning, large quantities of mosses have been collected, grinded and packaged, even if this means a lot of work. With over 3100 samples of moss powder stored, this collection is a veritable war treasure. It enables us to revisit samples at a later date, and thus respond to requests or cooperative projects on new themes. Some of the most emblematic uses include: (i) determination of contaminants not usually analyzed (Cesium-137, platinum group elements); (ii) monitoring the physiological state of mosses (metabolomics) in relation to air quality and the possible development of new biomarkers; (iii) compare pollen spectra recorded in mosses with pollen-emitting vegetation; (iv) monitoring changes in microbial biodiversity associated with mosses (testate amoebae) and the possible development of new bioindicators.

Keywords: atmospheric pollution, biomonitoring, moss sample.

MONITORING ATMOSPHERIC DEPOSITION OF POLLUTANT WITH MOSSES AROUND POINT-SOURCES AND ACROSS THE LANDSCAPE IN EASTERN CANADA

MÉLANIE JEAN (1), NICOLE FENTON (2),
MIA COURVILLE-TODOROV (1), OLIVIER CLARISSE (1)

(1) Université de Moncton, Canada; (2) Université du Québec en Abitibi-Témiscamingue, Canada.

Air pollutants from natural and anthropogenic sources, such as heavy metals, are deposited in ecosystems, with adverse effects on both ecosystems and human health. Air quality monitoring in Canada is concentrated around urban areas or emission points, leaving gaps in rural areas. Bryomonitoring, a bio-monitoring technique using mosses, offers a complement to such monitoring. This technique has been used in Europe for several decades, while its use in Canada is still recent. I will present the results of three projects in which we are deploying this technique. First, we launched Canada's first provincial bryomonitoring study to map atmospheric deposition in New Brunswick (NB). We collected mosses at 207 sites to identify regions affected by various trace metal elements. In standardized protocols, a minimum distance from trees is specified since the forest canopy can act as a sink or source of elements. This impact appears to be greater in arid regions than in humid ones, where precipitation releases dust accumulation in the canopy. We therefore established 11 sites in southern NB and found that the impact of trees was minimal for six of the eight heavy metals analyzed. This will enable us to evaluate different approaches to fostering the community involvement necessary for the sustainability of this type of program. Finally, little is known about the indirect impacts of mining, particularly in the boreal forest. We aim to determine the spatial footprint of six mines at different stages of development in Quebec's boreal forest. The spatial footprint of active mines extends to around 500 m from the mine, but this distance varies according to the elements and prevailing winds. The results of these studies have local, provincial, and national significance, filling spatial gaps in air quality data for different regions of Canada. In addition, the mining project will help reduce the environmental impacts of mining activities in the boreal forest.

Keywords: bryomonitoring, boreal forest, Canada, moss, mining industry, trace metals.

THE PITFALLS OF MAPPING BIOMONITORING DATA

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(1) University of Brescia, Italy. (2) University of Siena, Italy.

Every mapmaker knows that dealing with maps means dealing with unavoidable errors due to the transposition of a sub-rounded surface into a flat plane. Moreover, every time a phenomenon is represented, a number of subjective choices are required to the mapmaker· colors, details to be represented, scale, style and many others items could seem just aesthetic and non-crucial features, but for the reader they are "the truth" the map is telling and, unconsciously, everyone draws conclusions through these "non-crucial" features. It turns that a single map carries a number of "errors" or "I would have done differently" choices that could result in different messages to the audience. With the spreading of geographic based information and (open source) GIS software, many of us are dealing with maps to represent pollution, deposition, biodiversity and every kind of natural/anthropic phenomena. Based on our experience, the pitfalls in building reliable maps are numerous, ranging from the not-perfect handling of the software to the clarity of the message we want to communicate with our maps. Moreover, studies presenting interpolated maps very rarely account for the associated uncertainty or present a sensitivity analysis to check the robustness of the outcomes. This work is a brief collection of some of the pitfalls we have encountered but also some common mistakes we have made during the years that could have affected the communication of the biomonitoring campaigns, hoping that sharing those could prevent others to do the same.

Keywords: biomonitoring data, mapping, standardisation.

THE POTENTIAL OF USING HYPERSPECTRAL DATA FOR PLANT AND LICHEN BIOMONITORING OF ENVIRONMENTAL POLLUTION

LORENZO COTROZZI (1), IVAN FIACCADORI (1), GIUSEPPE QUARATIELLO (1), GIACOMO LORENZINI (1), CRISTINA NALI (1), LUCA PAOLI (2), ELISA PELLEGRINI (1)

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Hyperspectral detection has emerged as a promising tool, being a non-destructive, rapid, and relatively low-cost technique to monitor vegetation (as well as other targets). Reflection of light in the visible, near-infrared, and short-wave infrared (350-2500 nm) can provide a comprehensive assessment of shifts in macroscopic symptoms and the underlying morpho-anatomical and physio-chemical responses of plants to environmental constraints. This spectral approach is also scalable from leaf to remote sensing level, using airborne and space platforms. However, the use of this technology for the biomonitoring of environmental changes and/or environmental pollution effects – a well-known low-cost and effective method to estimate levels of air pollutants and their impact on biological receptors – has remained underdeveloped. Therefore, the present work aims to highlight the potential of hyperspectral data for the biomonitoring of environmental changes using plants and lichens. First, it briefly reports basic concepts of vegetation spectroscopy, including the most used approaches for exploiting information from hyperspectral data (e.g., spectral indexes, trait retrieval, spectral classification). Then, it reviews the few available studies on the topic. Finally, it shows that this approach could also be used for lichen biomonitoring, as using hyperspectral data we were able to discriminate with high accuracy (>95%) native specimens of the forest lichen *Lobaria pulmonaria* (L.) Hoffm. under different environmental conditions (i.e., acclimated/exposed or not to sudden increase of solar radiation, in relation to the effects of forest management), as well as to predict with high accuracy key lichen stress makers, i.e., maximal photochemical efficiency of photosystem II (PSII), PSII performance index and chlorophyll content (R2 for validation: 0.6-0.8). We believe that these preliminary outcomes may encourage further research to highlight the potential of the proposed approach.

Keywords: air quality, hyperspectral imaging, machine learning, spectral classification, spectral indexes, spectroscopy, trait retrieval.

MAGNETISM AND ENVIRONMENTAL BIOMONITORING: APPLICATION FOR THE PREVENTIVE CONSERVATION OF CULTURAL HERITAGE

LISA GRIFONI (1,2), ALDO WINKLER (2), FRANCESCA BOLDRIGHINI (3),MARCOS ADRIAN EDUARDO CHAPARRO (4), LUIGI ANTONELLO DI LELLA (1), FERNANDO MARTE (5), LUCIANO PENSABENE BUEMI (6), ALFONSINA RUSSO (3), ANTONIO SGAMELLOTTI (7), LILLA SPAGNUOLO (2), GABRIELLA STRANO (3), MARCOS TASCON (5), STEFANO LOPPI (1)

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In urban contexts, Cultural Heritage (CH) is heavily threatened by particulate matter (PM), which acts on their surfaces creating functional and aesthetical losses. Magnetic and chemical biomonitoring has been applied as an innovative preventive strategy for evaluating the impact of PM and potentially toxic elements (PTEs) on CH. Lichens collected in remote areas are exposed for three months inside and outside CH sites. Plant leaves are collected for checking their role in the removal of airborne pollutants. The magnetic properties of lichens and leaves provide information about the composition, concentration and grain-size of the bioaccumulated magnetic fraction of PM, that is usually linked to anthropogenic, mainly vehicular, emissions. The first application was at Villa Farnesina, in Rome, Italy, where, despite the intense magnetic properties outdoors, the lichens showed a minor accumulation of metallic emissions indoor, due to the combined effects of the distance from the road and the retention properties of roadside Platanus leaves. At the Peggy Guggenheim Collection in Venice, Italy, lichen bags were exposed along a transect from the Grand Canal to the Museum's Garden. In this lagoon context, the accumulation of magnetic PM was moderate outdoors and negligible inside the museum. The leaves of *Pittosporum tobira* were unsuitable for the removal of airborne particles. The bioaccumulation of PTEs was similar in indoor and outdoor lichens and the modest accumulation of magnetic particles outdoors was attributed to long-distance pollution. Further investigations are going on at the Parco Archeologico del Colosseo in Rome, and at two museums in Buenos Aires, Argentina, in busy urban sites where vehicular traffic is by far the main source of metallic emissions, The aim is to test these methods in various urban ecosystems, where the use of lichen transplants and the correct choice of leaves can substantially improve the provision of preventive conservation services.

Keywords: cultural heritage, leaves, lichens, magnetic properties, PM, trace metals.

A FIRST (SMALL) STEP TOWARDS UNDERSTANDING THE ABILITY OF BIOCHAR TO PROVIDE INFORMATION ON THE ENVIRONMENTAL AVAILABILITY OF POTENTIALLY TOXIC ELEMENTS (PTEs) IN ATMOSPHERIC DEPOSITIONS

ANDREA VANNINI (1), MASSIMO CHIARI (2), ALESSANDRO PETRAGLIA (1)

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The aim of this study is to investigate the ability of two wood-derived biochars to accumulate PTEs from atmospheric deposition, using the lichen *Evernia prunastri* as a benchmark. The lichen samples were collected in a remote area of the Tuscan-Emilian Apennines. They were first washed with deionized water, loosely wrapped in a 1 mm2 mesh nylon net, and then transplanted for two months (from 10/03 to 10/05/2023) in three different areas, (i) in the University Park of the city of Parma (outdoor exposure), an area affected by the presence of a ring road in its immediate vicinity (approx. 100m), (ii) in a private office of the Bioscience Plexus of the University of Parma (indoor exposure), an area affected by seismic retrofitting of the facilities in the previous weeks, and (iii) in the living room of a private house (indoor exposure) characterized by a modern pellet heating system. In contrast, the two pools of biochar, once purchased, were first sieved separately to obtain a 2-4 mm diameter biochar batch, and then washed with a warm 1M HCl solution. They were then exposed according to lichen methods, areas, and times.

Samples were analyzed using accelerator-based nuclear analytical techniques, such as ion beam analysis (IBA), for elemental analysis. Two IBA techniques, PIXE (Particle Induced X-ray Emission) and EBS (Elastic Backscattering Spectrometry) were used, with protons (beam energy of 3 MeV, beam spot size of 1 mm) in external beam mode. Using these techniques, the samples were analyzed in a rapid and non-destructive way. Several elements (Mg, Al, Si, S, Cl, K, Ca, Ti, Cr Mn, Fe, Ni, Cu, Zn, Br, Rb, Sr and Pb) were identified in the analyzed samples with detection limits down to the ppm range. Reference standard materials such as NIST 1573A (tomato leaves), NIST 1547 (peach leaves) and NIST 1515 (apple leaves) were also analyzed for quality assurance purposes and to verify the accuracy of the quantitative results presented here.

Keywords: air pollution, biochar, biomonitoring, *Evernia prunastri*, indoor biomonitoring, lichens, outdoor biomonitoring.

HARNESSING THE POTENTIAL OF BIOMONITORS TO ASSESS ATMOSPHERIC MERCURY POLLUTION: RECENT INSIGHTS AND PERSPECTIVES

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Atmospheric mercury (Hg) pollution is a global concern since this metal is ubiquitous and highly toxic. Addressing this issue requires reliable monitoring, as clearly stated in the Minamata Convention. However the quantification of atmospheric Hg is a challenging task, impaired by large uncertainties, mainly due to instrumental constraints to determine the concentration of gaseous elemental Hg, the dominant atmospheric form of this metal. A common approach for overcoming limitations of instrumental techniques and reliably assessing the impact of airborne Hg in terrestrial ecosystems consists in using plant biomonitors and/or passive samplers. The latter has recently seen major breakthroughs, disclosing unprecedented possibilities for gaseous Hg quantification to be combined with, and in support of biomonitoring studies. An effective passive sampler (PAS) was successfully used for the detailed characterization of spatial and temporal variability of atmospheric gaseous Hg concentrations in different environments, including the former Abbadia San Salvatore Hg Mine (ASSM) in Central Italy. Notwithstanding the cessation of mining activities and the ongoing remediation and rehabilitation works, the ASSM remains a globally significant source of gaseous Hg and represents an invaluable open-air lab to establish quantitative relationships between Hg in biomonitors and in the atmosphere. At ASSM, we are currently deploying side-by-side transplanted lichen and moss samples along with the new PAS within a wide array of environmental conditions, from background up to very high concentrations. We are also conducting a tree-ring analysis to reconstruct the centennial history of the atmospheric Hg contamination at the mine site. Here we present comprehensive data from our ongoing research at ASSM, and the perspective offered by the integrated PAS-biomonitor approach to improve the current knowledge of the processes controlling Hg cycling in terrestrial ecosystems, as well as to support the management of contaminated areas.

Keywords: biomonitoring, mercury, mining, passive sampling, terrestrial ecosystems.

THE SUITABILITY OF *ROBINIA PSEUDOACACIA* L. (BLACK LOCUST) LEAFLETS AS BIOMONITORS OF AIRBORNE MICROPLASTICS

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Here we investigated the suitability of R*obinia pseudoacacia* L. (black locust) leaflets for monitoring the deposition of airborne microplastics (MPs, i.e., plastic particles <5 mm), including tire wear particles (TWPs). Leaflets of *R. pseudoacacia* were collected at rural asphalt roadside locations (RO, n = 5), far from residential and industrial areas, and urban parks (UP, n = 5) far from traffic roads (Siena, Italy). MPs were removed by washing the leaflets with deionized water and, after filtration, were examined and identified under a stereomicroscope based on standard criteria. Daily MP deposition was estimated from leaf mass per area. MPs were qualitatively analyzed for their polymers using micro-FTIR (Fourier Transform Infrared Spectroscopy). The mass magnetic susceptibility of samples, as well as the bioaccumulation of traffic-related potentially toxic elements (PTEs, namely Fe, Al, Cu, Zn, Ba, Cr, Sb) were also analyzed. There was a significant difference in the number of MPs accumulated at RO and UP with a total amount of 2962 MPs at RO, mainly due to TWPs, and 193 MPs in UP, where TWPs were not found. However, the number of microfibres was higher in UP compared to RO (185 vs. 86). Daily MP deposition was estimated to range from 4.2–5.1 MPs/m2/d across UP and 29.9–457.6 MPs/m2/d across RO.

The polymer types at RO were dominated by a mixture of natural and synthetic gum (80%) from TWPs, followed by 15% polyamide (PA) and 5% polysulfone (PES), while in UP the proportion of PES (44%) was higher than PA (22%) and polyacrylonitrile (11%). The mass magnetic susceptibility was very modest across all samples, but with much higher values (in the range of -0.55 to 2.80 10–8 m3/kg) at RO than in UP (-0.23 to -0.643 10–8 m3/kg). The content of PTEs was similar across sites, with the remarkable exception of higher concentrations of Sb, a well-known tracer of non-exhaust (brake wearing) vehicle pollution, at RO (0.308 ± 0.008 µgg/g dw) compared to UP (0.054 ± 0.006 µg/g dw). It is concluded that the waxy leaflets and easy determination of surface area make Robinia an effective biomonitor for airborne MPs, including TWPs.

Keywords: atmosphere; biomonitoring; black locust; microplastics; tire wear particles.

PINUS NEEDLES AS BIOINDICATORS OF ORGANIC MICROPOLLUTANTS

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The utility of *Pinus* needles as bioindicators of the presence of organic and inorganic contaminants in the environment has been reported from the 1980s onwards. Their unique properties, based on a superficial waxy layer and a perennial status (lifetime up to several years depending on the species) are particularly helpful to assess airborne gaseous organic micropollutants with a wide spatial and temporal span. For almost 20 years we have been conducting at LEPABE several studies with this matrix which, as almost all natural materials, involves complicated analytical methodologies to extract and quantify the target chemicals. This study intends to show the main highlights of this research line, including the new perspectives we intend to follow. In the beginning, PAHs were our aim, but in time we were able to develop multicomponent protocols that allowed us to study five more families of semivolatile organic compounds (SVOCs), including legacy pollutants and chemicals of emerging concern such as volatile methylsiloxanes or synthetic musks. Green Analytical Chemistry principles have been framing our constant optimization of the sample handling and extraction procedures, that went from commercial alumina solid-phase extraction SPE cartridges, to custom-made glass columns and finally the much more sustainable QuEChERS approach. GC-MS was always the choice for the quantification step. Under this umbrella it was possible to investigate, among others, levels, spatial and temporal trends, sources of several SVOCs in countries like Portugal, Spain, Greece, Norway, the UK, and Iceland, and even incorporate the obtained data into modelling solutions for atmospheric chemistry. After all this time, we still believe Pinus needles are a valuable tool for the monitoring of airborne pollutants, even more now when we need all help to tackle the climatic changes upon us. Future work involves the incorporation of this matrix in the study of wildfires, a devastating problem in many countries, particularly in the Mediterranean basin.

Acknowledgements: This work was financially supported by: LA/P/0045/2020 (ALiCE – Associated Laboratory in Chemical Engineering) and UIDB/00511/2020 and UIDP/00511/2020 (LEPABE – Laboratory for Process Engineering, Environment, Biotechnology and Energy), through FCT/MCTES (PIDDAC).

Keywords: atmospheric chemistry, bioindicator organic micropollutants, *Pinus* needles.

USING A BIOINDICATOR PLANT, *ELEAGNUS EBBINGEI*, TO PREDICT THE CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN THE ATMOSPHERE OF TEMPERATE AREAS IN EUROPE

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Many studies use evergreen trees for Polycyclic Aromatic Hydrocarbons (PAHs) biomonitoring. The most studied trees belong to the genus *Quercus* and *Pinus*. However, these corresponding specimens are not implanted in all European temperate areas, limiting the comparison between regions. The aim of this study is to investigate the potential of the hedge plant *Elaeagnus ebbingei* as a bioindicator. This plant is very common in Europe, regardless of the geographical area. A one-year field campaign targets two French cities with different climates: Caen (oceanic climate) and Nice (Mediterranean climate). In each city, concentrations in plants are determined and compared to atmospheric concentrations for 4 sites.

Results highlight correlations between the atmospheric concentrations and concentrations found in leaves with significative Pearson correlation coefficients for acenaphthene, phenanthrene, anthracene, fluoranthene and pyrene. In addition, the strong negative correlation with temperature and relative humidity highlights the seasonality of PAHs, whether in the atmosphere or in the leaves. These strong correlations allow to set up two models to estimate atmospheric concentrations from the concentrations found in plants. A first model using the plant-air phenanthrene concentration distribution constant and temperature (KPA-PHE) was developed. It estimates atmospheric concentrations of fluorene and phenanthrene from concentrations in plants. In view of the strong correlations between PAHs in plants, a second model using the Partial least squares regression has been implemented. Model validation was performed by studying relative biases as well as Nash Sutcliffe criteria. Field trials using the two models developed seem to give an advantage to the KPA-PHE model, where the estimated concentrations of fluorene and phenanthrene in air are very close to the actual concentrations. *Elaeagnus ebbingei* seems to be a good bioindicator for predicting PAHs atmospheric concentrations.

Keywords: atmospheric concentrations, bioindicator, *Elaeagnus ebbingei*, evergreen hedge plant, model prediction, PAHs, Plant-air partitioning constant.

MOSS BAG BIOMONITORING OF AIRBORNE ELEMENTS AT A SUBURBAN BACKGROUND SITE IN BELGRADE (SERBIA) DURING SAHARAN DUST INTRUSIONS

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During the spring/summer season 2019, characterized by several Saharan dust episodes, two moss species, *Hypnum cupressiforme* and *Sphagnum girgensohnii*, were exposed for twelve consecutive periods of 15-days, and also for one-, two-, three-, four-, five- and six months. In addition, particulate matter (PM10 and PM2.5) was sampled during and after the identified dust episodes. As an estimate of the dust amount to which the moss bags were exposed during 15-day periods, we used MERRA-2 (The Modern-Era Retrospective analysis for Research and Applications) predictions of dust concentrations at ground level, averaged over these periods. The concentrations of Al, Ba, Ca, Fe, K, Mg, Mn, P, S, Sr, Zn, Ni, V, Cr, Co, Cu, As, Cd, Pb, Ga, Y, and Tb were measured in the moss and PM samples. The results showed that 15-day bag exposure at the background location could not provide a valuable "signal" of the elements in the moss transplants, except for Al, V, As, Ga, Y, and Tb. Extended moss bag exposure of a couple of months provided a stabile enrichment of the majority of the elements in the mosses. An increase of the PM mass concentrations, but still below the daily threshold values, was measured at the studied site during two of three recorded Saharan dust intrusions. In the PM10 samples the concentrations of Al, V, Ga, Y, and Tb were increased multifold during one of the episodes that was particularly intense. The same elements in the *S. girgensohnii* moss bags, consecutively exposed for 15-day periods in the season, showed a slight increase of the concentrations that overlapped with these episodes. The ratio of crustal elements (Ca/Al and Mg/Al) in PM10 (dust days) and moss samples (3-month exposed) were in line of those reported for dust transported from western Africa. The As/Al ratio in PM10 and moss samples corresponding to dust episodes were smaller than those for non-dust days/periods, which could be used to distinguish natural (dust) from anthropogenic pollution.

Keywords: air pollution, active moss biomonitoring, bag exposure period, element content, Saharan dust intrusion.

ISSUES IN BIOMONITORING DATA INTERPRETATION AND THEIR MITIGATION

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Living organisms or materials derived from them are used for environmental pollution assessment. Among advantages accumulation of pollutants in the organic matrix is noticed. As a result higher concentrations of an analyte in an organic matrix than in medium are observed. For the analyte concentration lower than a detection limit in the medium, an increased concentration in the matrix makes possible determination of its concentration. The analyte permeates into the matrix according to relevant mechanisms. In laboratory the analyte concentration in the organic matrix is determined, and the results can be used for the medium quality assessment. A number of issues related to application of biosorbents for environmental pollution estimation occur Among them the following are mentioned: different properties of the organic matrices, limited control on the organic matrix composition, differentiated conditions for the analyte permeation into the organic matrix. The mentioned factors substantially hinder comparison of the measurement results, introducing disturbances to the results of the data interpretation. In some extent influence of cumbersome effects can be reduced. An approach to the data analysis based on concentration ratios is presented and discussed. Components concentrations in a sub-composition can be used for comparison of the measurement results from different organic matrices. Results of the presented methods' application for the data analysis are presented. The analysed data come from a survey on seasonal changes in water quality in dam reservoir In the study for biosorbents alga, moss and lichen were used. Financial support for this work was provided by the National Centre for Research and Development, programme BIOSTRATEG (ZBIORTUR, project 3/343733/15/NCBR/2018).

Keywords: accumulation, component's concentration, concentrations' ratio, issues in data interpretation, issues mitigation.

MONITORING OF PRIORITY SUBSTANCES IN BIOTA FOR CLASSIFYING THE ENVIRONMENTAL QUALITY STATUS OF SURFACE WATER BODIES

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The Water Framework Directive 2000/60/CE, implemented by D.Lgs 152/2006 and subsequent amendments, which establishes a shared framework at European level for the implementation of a long-term sustainable policy of use and protection for all waters and establishes environmental quality objectives, provides that monitoring of priority substances is also carried out in water bodies on biota (the list of substances to be searched for was then updated with the subsequent Directive 2013/39 / EU).

Starting from 2018, ARPA FVG implemented the chemical monitoring of the water bodies until then performed in the waters, extending them also to this matrix. In compliance with the indications of the Basin Authority of the Eastern Alps District to which the FVG Region belongs, only with the launch of the III river basin management plan the results of these monitoring were used to contribute to the definition of the quality status.

The present work therefore illustrates the results of the first three year monitoring period that have highlighted, in all water bodies monitored, the presence of priority substances in concentrations higher than the Environmental Quality Standards. The criteria for choosing the traits to be monitored, the target species, the sampling strategy and the considerations arising from the evaluation are presented. Finally, the critical issues still present in the current sampling and analysis protocols (in terms of lack of both standardization and detail), which affect the results and on the final phase of their evaluation, are currently being discussed in the ISPRA working tables.

Keywords: biota, fishes, priority substances, quality status, water bodies.

MAGNETIC BIOMONITORING: TOWARDS A STANDARDIZATION OF THE OPERATIONAL AND MEASUREMENT PROTOCOLS

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During the last twenty years, rock magnetism methodologies have been applied to trees (leaves, bark, wood), mosses, lichens, insects and human tissues for air pollution biomonitoring purposes. Magnetic measurements are now evolving towards very sophisticated and sensitive measurements such as First Order Reversal Curves (FORC) that, on the one hand, may give extremely accurate information for the characterization and the identification of airborne particulate matter (PM) sources but, on the other hand, are partly qualitative, not validated, and may appear very specialistic. Furthermore, magnetic biomonitoring should reach a true multidisciplinary level, in which the chemical and physical properties are investigated and interpreted under a biological and environmental perspective, including a rigorous statistical approach.

Here, we present the basic principles behind magnetic biomonitoring and the main laboratory methodologies involved in the determination of the parameters that are useful for outlining the abundance, the composition and the grain-size of the magnetic fraction of PM. The best practices for sample acquisition and treatment as well as the theoretical and technical aspects behind the determination of the concentration-dependent magnetic parameters (magnetic susceptibility, saturation and remanent magnetizations) will be argued, along with the role of various qualitative diagrams (Day plot, King's plot, FORC diagrams) for recognizing the grain-size of the particles according to their magnetic domain state. The discussion will take into account the wide range of available magnetic instruments, spanning from cheap (2k€) portable magnetic susceptibility-meters, to expensive (200k€) vibrating sample magnetometers.

The aim is to identify standardised parameters and protocols that can be successfully inter-calibrated among different labs, promoting the production of validated, reproducible and comparable data.

Keywords: intercalibration, hysteresis loops, magnetic properties, magnetometers, metals, PM.

TOWARD THE ADOPTION OF A SHARED PROTOCOL IN THE MOSS BAG APPROACH: MAIN OUTCOMES FROM THE MOSSCLONE PROJECT

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The FP7 European project "MOSSclone", aimed at the standardization of the moss-bags approach for biomonitoring of atmospheric pollution, was subdivided into two main objectives: 1) the selection, cloning and growth of a moss species showing a higher bioaccumulation performance; 2) the optimization and standardization of exposure conditions. *Sphagnum palustre* L. was selected, cloned, chemically and genetically tagged, and grown in a bioreactor Parallelly, the native moss *Pseudoscleropodium purum* Hedw. was tested in a systematic experimental design in three European Countries. The investigated characteristics were the shape of the bags, mesh size, moss density with respect to bag surface, exposure height and duration. The shape, the mesh size of the bags and the exposure height did not significantly influence the uptake capacity of the transplanted moss. The aspects more affecting the element uptake were represented by the density (<15mg cm-2) of the moss inside the bags and the duration of exposure, that should not be shorter than 6 weeks. A field experiment was settled to compare the uptake performance of the S. palustre clone with the moss *P. purum*, both exposed in the same conditions inside the Mossphere© a reusable bag developed by the MOSSclone research team.The test was performed in urban, industrial, agricultural and background areas of Italy and Spain. Among the eighteen elements analyzed, *S. palustre* was significantly enriched in 10 elements (Al, Ba, Cr, Cu, Fe, Hg, Pb, Sr, V and Zn), while *P. purum* was enriched only in 6 elements (Al, Ba, Cu, Hg, Pb and Sr), and had a consistently lower uptake capacity than the first. The clone proved to be more sensitive in terms of metal uptake and showed a better performance as a bioaccumulator providing a higher signal and allowing a finer distinction among the different land uses and levels of pollution. The clone represents a preferable choice for its accumulation performance, as well as for its eco-sustainability. The MOSSclone project identified the key points of the method, improving the sensitivity and reliability of this approach. We sustain the adoption of a shared protocol in the moss bag approach, balancing eco-sustainability with optimal performances.

Keywords: active biomonitoring, air pollution, moss bag, potentially toxic elements, standardisation.

MOSSPHERE: A NEW BIOTECHNOLOGICAL PASSIVE SAMPLER FOR ENVIRONMENTAL AIR QUALITY MANAGEMENT

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Up to now, concentrations of atmospheric pollutants determined in moss bags have not been significantly correlated with concentrations determined in bulk deposition. Hence, we evaluated a new type of passive air sampler, 'Mossphere', filled with a *Sphagnum palustre* clone, comparing the atmospheric levels of polycyclic aromatic hydrocarbons (PAHs) collected by this device and those collected in conventional bulk deposition and particulate matter PM10 samplers. The comparison between bulk deposition/Mossphere yielded a greater number of significant regressions with higher coefficients of determination than the comparison between PM10/Mossphere. This means that this innovative device can be used to map intermediate, heavy, and total PAHs levels in both urban and industrial areas by establishing quantitative relationships between air and PAHs concentrations determined in the Mossphere. To test the reliability of these findings, for the first time, intensive monitoring and mapping of PAHs was carried out in a medium-sized European city (Logroño, La Rioja, Spain) where 84 Mosspheres were placed on a 575 m grid for three months. Moss tissue concentrations of 15 priority PAHs, were determined and converted to PM10 and bulk deposition with the equations proposed in the first study. Low PAHs concentrations were detected, with only a few enriched points never exceeding legal thresholds, but despite these low PAHs levels, Mosspheres was able to detect the spatial structure of several PAHs and high-resolution pollution maps were constructed for these compounds. In brief, due to the robustness, the high sensitivity and suitability of this Mossphere biossampling system, we suggest the inclusion of the device in governmental environmental management future programmes and in European Directives on air quality monitoring.

Keywords: air pollution, biomonitoring, mapping, moss, passive air sampler, polycyclic aromatic hydrocarbons.

THE GOOD, THE BAD, AND THE UGLY OF BIOMONITORING OF ATMOSPHERIC MICROPLASTICS

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It is well established that microplastics (plastic particles <5 mm) can travel via the atmosphere before being deposited into receiving ecosystems, potentially far from their emissions sources. While there is growing interest in the assessment of atmospheric microplastics, globally there is limited monitoring infrastructure, and procedures can be labor intensive. In contrast, biomonitoring may provide a simple and reliable approach to assess the role of atmospheric transport in distributing microplastics at regional and transboundary scales.

Here we describe the use of moss as a biomonitor of atmospheric microplastics, focusing on laboratory extraction, identification, and polymer confirmation. Further, we highlight methodological and quality control considerations towards a standardised protocol for the biomonitoring of atmospheric microplastics based on visual identification. These methods are currently being used in the MADAME pilot project (Microplastic Atmospheric Deposition Assessment using Moss in Europe), which will assess the abundance and type of microplastics across Europe and evaluate the reproducibility of results across different methods.

Keywords: density separation, digestion, lichen, MADAME, microscopy, moss, vibrational spectroscopy.

VISIBLE FOLIAR SYMPTOMS AS A PROXY OF OZONE IMPACT ON VEGETATION: FROM THE MULTI SPECIES APPROACH OF THE ICP FORESTS METHOD APPLIED ON EUROPEAN SCALE TO THE SINGLE BIOINDICATOR SPECIES APPROACH

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Tropospheric ozone (O3) is a strong oxidant phytotoxic pollutant that can cause a variety of detrimental effects on vegetation at a biochemical, physiological, and morphological level. Ozone leaves no elemental residue measurable by analytical techniques, but ozone-induced visible foliar symptoms (VFS), instead, represent a direct, specific, and easily detectable evidence of ozone effect on vegetation. VFS, largely observed and reproduced under controlled and semi-controlled conditions, can be considered as a proxy for the actual O3 damage on vegetation.

A Standardized Operational Protocol was developed within the UNECE International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests), to collect high quality and comparable data on ozone-induced visible injury on native vegetation at the intensive Level II forest monitoring sites. The standardized method is based on the assessment of VFS on the native woody plants present in n=13-33 2 x 1 m quadrates randomly selected along the forest edge closest to a Level II forest monitoring site. The method, largely applied across Europe on overall 225 sites in 20 countries since 2002, aims to assess the risk posed by ozone on vegetation, and allows the detection of spatial and temporal trends of the effect of ozone on forests in Europe. The ICP Forests method, with minor changes, has been applied also to detect the effects of ozone on single species identified as particularly sensitive to this atmospheric pollutant. This is the case with the studies carried out on the native *Viburnum lantana*, from the local scale within the same vegetative season, to the regional and larger scale on a pluriannual basis.

Overall, results support the use of *V. lantana* as *in-situ* bioindicator to assess the harmful effect of O3 on vegetation. Provided a large-scale test-phase will confirm the local-to-regional scale results, the single-species approach could complement the ICP Forests program.

Keywords: air quality, ozone impact, ozone bioindicator, tropospheric ozone, visible foliar symptoms.

BIOMONITORING TECHNIQUES FOR TESTING THE POLLUTION IMPACT OF RECOVERED DERIVED FUELS (RDFS): A TEN-YEAR-LONG STUDY CASE CENTRED ON A CEMENT MILL IN NE ITALY

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Recovered Derived Fuels (RDFs) can be burned for thermal recovery as a valid alternative to conventional fossil fuels, reducing landfill disposal of non-recyclable plastics. RDFs are increasingly used by industry following an authorization process that imposes specific emission controls and limits that are typically more stringent than those applicable to other fuels. The potential dispersion of persistent organic pollutants (POPs) and potentially toxic elements (PTE) into the environment resulting from imperfect combustion of RDFs remains, however one of the major public concerns limiting much greater use of RDFs. Therefore, proper assessment of total POPs and PTEs load in an area and the identification of past vs. current emission sources are critical to making RDFs use a common practice on an industrial scale.

Here we describe the results of a multi-organism biomonitoring plan, conducted between 2012 and 2023 around a cement factory that had been in operation since 1950, received approval to use RDFs as a co-fuel in 2014, and became fully operational in 2017 Ante- (2012) and post- (2018, 2023) operam surveys were organized with winter and summer campaigns, based on active biomonitoring of POPs and PTEs at 40 sampling sites systematically distributed over an area of 40 km^2 in the typical mixed land use of NE Italy, with a lichen [*Pseudevernia furfuracea* (L.) Zopf] and a tree (*Robinia pseudoacacia* L.) as target organisms.

Thanks to the high sampling density, a spatial relationship between pollutant concentration in target organisms and sampling site distance from the cement factory was ruled out, while other putative sources were associated to specific pollutant categories: for PTEs, an industrial park; for PCBs, three individual hot-spots interested by past spill-overs; for PAHs, traffic and domestic heating. Overall, the current use of RDFs by the cement plant has a negligible impact on the total environmental perturbation caused by human activities in the area.

Keywords: air pollution, lichen transplants, recovered derived fuels, PAH, POP, PTE.

LICHEN BIOMONITORING AFTER STANDARDISATION: ANOTHER STEP TOWARDS SYSTEMATISATION?

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In recent years, the Società Lichenologica Italiana, in collaboration with other national bodies and European researchers, has been at the forefront of the standardisation process of biomonitoring methods using lichens. From a technical point of view, standardisation has made it possible to make the data obtained more robust, comparable and reproducible, taking into account the details of the process, from experimental design to laboratory procedures. This presentation will give a brief overview of the state of the art of standardising bioindication and bioaccumulation methods using lichens in Italy to stimulate a discussion on their strengths and weaknesses. The latter include, among others: (i) the lack of a large-scale application (national and European) that could make lichen biomonitoring more visible to the general public., (ii) the *de facto* lack of legal recognition of the methods, which would ensure a more systematic and continuous application, even within territorial monitoring bodies; (iii) the lack of standardised recommendations for interpreting the results of some methods (e.g. biondication), which weakens their power and robustness.

Keywords: air pollution, bioindication, bioaccumulation, Italy, standardisation.

IT IS TIME TO CONSIDER TIME IN BIOMONITORING STUDIES

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Despite a huge amount of research into biomonitoring methods over the last few decades, there are still a number of issues that need to be addressed. For example, the temporal aspect of the response of organisms to the effects of pollution is still poorly understood. More generally, the importance of defining the actual time to which the biomonitor's response to the perturbation can be related is often underestimated or ignored in application work.

In this communication, we briefly review the advantages and disadvantages of some biomonitoring methods with respect to the precise temporal definition of the response to the perturbation event, using examples from some of our research group's work. In particular, we will examine inferred responses using measures of lichen biodiversity and measures of bioaccumulation in tree bark, tree branches and lichen transplants.

Based on this review, recommendations will be made to improve the temporal definition of biomonitoring studies and to integrate different biomonitoring methods to compensate for their different limitations.

Keywords: bark, bioaccumulation, bioindication, interpretation, lichens.

Exploring natural biocides: Assessing the impact on microorganism diversity in agricultural soils as environmental bioindicators

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Despite the persistent use of synthetic pesticides in agriculture, there is a growing interest in exploring environmentally friendly alternatives. Plant-derived essential oils, known as natural biocides, have emerged as a potential solution. However, their application may carry unintended consequences, particularly for non-target organisms. In light of these considerations, this study is dedicated to advancing the frontier of research in environmental bioindicators by investigating the effects of various essential oils on microorganism diversity within agricultural soils. Our research begins with a comprehensive analysis of the microorganisms inhabiting diverse agricultural soil types. These microorganisms are categorized into two groups: beneficial and harmful. Subsequently, we assess the toxicity thresholds of essential oils on both categories of microorganisms. Our ultimate objective is to strike a balance between reducing harmful microorganisms while preserving the vital contributions of beneficial ones. This study aims to identify the ideal dosages of natural biocides necessary to maintain this delicate balance. As our research progresses, we hope to make a significant contribution to the understanding of the potential of natural biocides as sustainable alternatives in agriculture, and thus actively shape the ever-changing landscape of environmental bioindicators.

Keywords: biocides, biomonitoring, soil microorganisms, toxicity.

Lichen biomonitoring in the botanical garden of ElHamma in Algiers is used to assess the impact of green space structure on air quality

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Public gardens are the lungs of cities. Their structures vary according to the style of landscaping chosen for their design. In this study we have used the lichen biomonitoring with the IQA indices for the comparison between the two parts of the botanical garden of ElHamma in Algiers. Although this garden is located in the most polluted area of the Algiers bay, it still provides better air quality. French style part of the garden is characterized by open perpendicular alleys, while the other dance is somewhat similar to the English style. The results indicate that the second one has a superior quality and a greater specific richness of lichens.

Keywords: air quality, Algers, biomonitoring, botanical garden, lichen.

PRELIMINARY EVALUATION OF THE ALGAL PERIPHYTON BIOMASS AND COMMUNITY COMPOSITION IN THE ISONZO RIVER

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ARPA FVG, during the GREVISLIN project, carried out a preliminary study on the relationship between the hydrological regime and the abundance and composition of periphyton of the Isonzo river In the present work an experimental approach has been applied to improve the general knowledge of the diatom community not only from a qualitative but also using a quantitative point of view. The purpose is to analyse the methods of colonization of the substrate of these organisms in a strongly hydromorphological impacted context through the use of the BenthoTorch, a portable fluorometer, purchased in the project, which allows to measure the chlorophyll-a concentration of diatoms, cyanobacteria and green algae directly in field. This instrument, placed on the surface of the pebble, emits light pulses at different wavelengths and records the fluorescence emitted by the accessory pigments of the 3 photosynthetic groups considered. Thanks to an algorithm, the fluorescence is converted into chlorophyll-a concentration returning the measure of primary production for each group. The measurements were collected between January and December 2020 in three sites along the Isonzo/Soča River (2 in Italy and 1 in Slovenia). At each site, biofilm measurements are been made at the moment of minimum outflow and in every sampling occasion 3 parallel transects have been defined (upper, medium and lower).
In this preliminary study it is highlighted how the colonization limit of algal community, in the active riverbed, is particularly influenced by the management of the watercourse flow (hydropeaking). This result can be useful for "naturally" delineating the basic river flow rate, relating to the modified hydrological regime, suggesting some new insights into the choice of sampling sites for biological quality element monitoring used to define the ecological status, to sample in areas that are permanently submerged or affected by the alternation of lean, soft, dry.

Keywords: BenthoTorch, chlorophyll a concentration, hydromorphological impact, Isonzo, periphyton, Soča.

FIRST ASSESSMENT OF THE MACROZOOBENTHIC COMMUNITY OF RAGOGNA LAKE

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According to the WFD 2000/60/EC, implemented in Italy by Legislative Decree n. 152/06, the definition of the environmental status of surface waters is necessary to implement measures of water bodies protection. The ecological status of a lake is evaluated using Biological Quality Elements (QBE). Among QBEs, benthic macroinvertebrates are recommended due to their known responses to different environmental drivers. However, benthic macroinvertebrates are commonly used as indicators of the biological condition for rivers, while their use in small lakes is much less studied. The aim of this work was to provide a first detailed overview of the macrozoobenthic community of the Ragogna lake (San Daniele, Udine) the only example of morainic lake in Friuli Venezia Giulia, based on fieldwork carried out by ARPA FVG in 2017 and 2022. The biodiversity of this community was described in terms of composition, density and species richness and the community structure was explored with techniques of multivariate analysis and inferential statistics. Results showed that the composition dynamics and changes in population density mostly rely on the sampling year and season. The concentration of dissolved oxygen plays the main role in selecting the presence and abundance of the different taxa. Differently, species richness is substantially unaffected by seasonal dynamics across the whole observation period. The first application of the Benthic Quality Index for Italian Lakes (BQIES) to the Ragogna Lake classified its ecological status as "bad" as related to the lake eutrophication. A comparison of this study outcomes with those carried out on the same typology lakes in NW Italy (AL5 Shallow and stratified subalpine lakes) showed similar BQIES values due to the perilacual conditions, in addition to the biotic and abiotic characteristics of the lakes.

Keywords: benthic macroinvertebrates, biodiversity, ecological status, eutrophication, Ragogna lake.

OZONE BIOMONITORING: A VERSATILE TOOL FOR CITIZEN SCIENCE

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The wide diffusion of tropospheric ozone is a major environmental problem in urban areas as well as in rural and remote localities. Its increasing man-related levels are connected to severe impacts on human life and welfare, in terms of adverse health effects, damage to manufacts and injury to plants. Biological monitoring is a powerful tool for filling the gap between the causes and the effects of environmental toxic compounds, as bioindication agents may assess in an easy-to-detect process the effects of pollution on (selected) biota. A citizen science project was launched in 2023 to involve some 20 students (ages 11-16) and 20 teachers/stakeholders (ages 40-70) from one school in Southern Italy in biodetection of ozone effects hypersensitive plant *Nicotiana tabacum* Bel-W3. The entire campaign lasted two weeks (27 April 11 May 2023) and consisted of two successive exposure of fresh kits of indicator plants. Results implied the reading of 800 biological data (ozone injury on cotyledons) and were fortified by data captured by one automatic analyser (400 raw data of hourly means). Biological and chemical data were compared favourably and treated with statistical methods. Under the guidance of experts (researchers) and their teachers, the students had several opportunities to practice with many basic and applied study areas and disciplines and were initiated into the scientific method in a simple and absorbing manner However, after a primarily educational training, the survey provided sound research elements and the picture of pollution that emerged has increased the knowledge and awareness of air quality in the area. Biomonitoring is confirmed to be a powerful tool to involve young people and citizens in environmental topics.

Keywords: air quality, atmospheric pollution, community science, *Nicotiana tabacum* Bel-W3, human welfare, participatory monitoring.

LICHENS CITISCI: A COMMUNITY SCIENCE PROJECT ENGAGING VOLUNTEERS IN AIR QUALITY

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Equitable access to air quality knowledge and relevant engagement of non-experts in biomonitoring efforts is vital to ensure the longevity of biomonitoring and the equitability of air quality protection. Lichens CitiSci, a community science project engaging non-experts in lichen biomonitoring work, supports resource-limited air monitoring efforts while making real world connections with people in local communities.

Understanding pollutants in the air, why they matter, and why they need to be monitored can be challenging concepts. Not to mention the interconnected realities between some air pollutants and climate change. Polluted air impacts environmental and human health, and our survival relies on healthy and resilient ecosystem services. The reality is that people in underserved communities are more likely to be disproportionately exposed to higher levels of air pollution. Thus, while it can be difficult to make an argument with society that biodiversity and environmental health matters, it can be more tangible to argue that air quality matters because everyone breathes air and is impacted by air pollution.

Keywords: air pollution, air quality, biomonitoring, citizen science, community science, lichens.

THE EVOLUTIONARY IMPORTANCE OF STOMATA AND MESOPHYLL TRAITS ON ADAPTATION TO CLIMATE CHANGES

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According to the Intergovernmental Panel on Climate Change, without mitigation actions, under the most optimistic scenario, atmospheric CO2 concentrations would reach 420 ppm by the end of the century; under the more pessimistic scenario, atmospheric CO2 concentrations would reach 1100 ppm by 2100 [1]. Therefore, it is essential to understand the impact of rising CO2 on plant growth. This is the background of the Prin project "Evolutionary implications for the development of climate resilient productive plants" (EvoPlant), which aims to elucidate patterns of plant evolution to promote the development of climate-resilient plants through the study of stomatal evolution, photosynthesis, and plant-atmosphere gas exchange. The purpose of our study is to analyze the correlation between leaf anatomy and stomatal patterning. We are currently completing morphological and anatomical analyses of the mesophyll and stomatal apparatus of 20 plant species representing an evolutionary pathway from lycophytes to dicotyledonous angiosperms, via ferns and gymnosperms. Specifically, we are examining the density, distribution, morphology, and size of stomata. These measurements will then be correlated with the surface area of the mesophyll cells exposed to the intercellular airspaces, the size of the mesophyll cells, the thickness of the mesophyll, the fraction of the volume occupied by the intercellular airspaces, and the total cross-sectional area of the cells that make up the mesophyll. A special case is represented by *Triticum* spp., in which we are studying, in addition, mesophyll conductance (Gm), i.e. the transport of CO2 from intercellular airspace within leaf in different CO2 concentration. These data will allow us to identify the most efficient combination of stomata-mesophyll traits for climate change resilience and it could be a bioindicator of environmental CO2 concentration.

ENGAGING CITIZENS IN SOIL MONITORING: THE PROJECT ECHO

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Soil is a vital, yet often disregarded, resource that supports life on Earth by providing the foundation for agriculture, forests, and various other natural ecosystems. However, soil degradation is a growing concern around the world, and it can have severe consequences for our planet like reduced crop yields, increased greenhouse gas emissions, and decreased biodiversity. ECHO aims to prevent this by bringing together citizens and volunteer scientists from around Europe to work towards a common goal of protecting and preserving our soils, thus contributing to the transition towards healthy soils of the EU Mission: "A Soil Deal for Europe" ECHO is a Research and Innovation Action funded by the European Union, under the GA 101112869, Program Horizon Europe topic HORIZON-MISS-2022-SOIL-01-09. The project is based on three main principles: engaging citizens, empowering them with knowledge and an active role in data collection, and enabling them to participate in decision-making on soil issues. ECHO will generate new data on the health status of EU soils, complementing existing soil mapping and monitoring in EU Member States, including the EU Soil Observatory (EUSO). The project will develop and deploy 28 tailor-made citizen science initiatives across EU Member States, taking into account different land-uses, soil types, and biogeographical regions, as well as stakeholder needs. With 16 participants from all over Europe, including 10 leading universities and research centres, 4 SMEs, and 2 Foundations, under the coordination of the Free University of Bolzano-Bozen, ECHO will assess 16,500 sites in different climate and biogeographic regions to achieve its ambitious goals.

Keywords: citizen science, data collection, mission soil, monitoring, soil science.

AIR QUALITY CHANGES WITNESSED BY HERBARIUM SPECIMENS OF LICHENS: A CASE-STUDY IN THE WESTERN CARPATHIANS

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Lichen collections may contribute to a better understanding of past environmental conditions. Concentrations of heavy metals and metalloids, i.e. Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, S, Sb, and Zn were measured in thalli of the lichen Lobaria pulmonaria Hoffm. from remote mountain areas of the Western Carpathians, Slovakia. Old collections as well as recently collected material were selected for a retrospective analysis: in particular twenty specimens covering the period 1960 2022. Lobaria pulmonaria was selected as a model, being strictly associated to remote areas with high environmental quality in the Western Carpathians. The species has suffered a general decline throughout Europe as a consequence of air pollution and intensive forest management. Nowadays, it is widely acknowledged as a model of "umbrella" species, i.e., an indicator of important forest habitat for the conservation of rare species and understudied groups (e.g. bryophytes). Currently, it is threatened and red-listed in several European countries, mainly in Central Europe, where it is also protected by law. This study allows to detect air quality changes in remote areas and the decline of air pollution from heavy metals with reference to the investigated period, as well as characterization of past and current background concentrations for selected heavy metals in the Western Carpathians. Besides a reconstruction of air pollution history, the potential of lichen collections from remote areas combined with freshly collected material to define past background of element concentrations as well as their changes is raised.

Keywords: bioaccumulation, biomonitoring, heavy metals, herbarium specimens, remote areas.

MOSSES AS BIOINDICATORS OF INDOOR AIR POLLUTION

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Air pollution is one of the major problems, because it affects not only the world of fauna and flora, but also people themselves. A quick, cheap, and easy way to study the state of the environment is to use bioindicators living organisms that indicate the level of environmental pollution.

The objective of these studies were to evaluate indoor air pollution (IAP) in using three moss species: *Pleurozium schreberi*, *Sphagnum fallax* and *Dicranum polysetum*. The experiments involved the analysis of air pollution by selected elements during the activity of a car workshop, pollutions from tiled and coal stoves, and the comparison of pollution from the smoke of different tobacco products. The presented examples indicate the importance of measuring and controlling vital parameters of mosses (e.g., chlorophyll content, photosynthetic activity) during exposure in order to be able to talk about bioindicators living organisms indicating air quality. The influence of exposure conditions and environmental factors most influences the quality of the result in biomonitoring studies. On the other hand, human activity (based on the practical examples above) indicates the importance of performing biomonitoring studies analyzing air quality.

We have shown that of the three species analyzed, *P. schreberi* is the most suitable for monitoring indoor air pollution, until now. It works well with several months of exposure to study IAP It is resistant to changing exposure conditions and retains its viability under environmental stress. *Sphagnum fallax*, due to its peat characteristics and the need to function in a moist environment, should only be used in places where it will have adequate access to water *Dicranum polysetum*, on the other hand, should be included in biomonitoring studies for monitoring mercury pollution, where it is the best accumulator of this element compared to other species.

Keywords: active biomonitoring, bioindicators, heavy metals, indoor air pollution, mosses, vitality.

SOIL-PLANT ANALYSES TO DETERMINE THE BIOINDICATION AND BIOACCUMULATION CAPACITY OF NATIVE VASCULAR PLANTS IN DISMISSED MINING AREA OF CALABRIA REGION (S-ITALY)

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Numerous studies identified mining as a primary source of heavy metal pollution. In Calabria region (S-Italy), mining activities date back to the Roman age, up to the early 21st century. The presence of these dismissed mining areas poses potential risks to human and ecosystem health, but it also offers a unique opportunity to investigate the bioindication and bioremediation potential of the related native flora. Indeed, identification of species useful for bioindication and bioremediation is crucial for assessing and mitigating the environmental risk in polluted areas. Nonetheless, no data are currently available on levels of heavy-metal contamination in Calabria dismissed mining areas, nor on the capacity of related vascular flora to bioaccumulate these elements. Therefore, a task including botanists and geologists was recently constituted at University of Calabria.

Here, we show the outcomes of an in-depth analysis of heavy metal concentrations in soils and plants at two different locations: (i) an arsenopyrite mining site found in S-Eastern Calabria, and (ii) an uncontaminated control site (Botanical Garden of University of Calabria). Soils and a set of spontaneous plant species were sampled at both sites and subsequently analysed trough a ICP-MS technique.

The results showed that concentrations of Co, Cu, As, Cd and Pb in the mine soils exceed the legal limits. Among the sampled plants, *Asparagus acutifolius* L., *Cistus salviifolius* L., *Dittrichia viscosa* L., *Erica arborea* L., and *Reichardia picroides* L. collected in the mine site revealed a higher concentration of various heavy metals compared to the control site. Moreover, a translocation factor (TF) >1 was found in *A. acutifolius* for As and Cd, in *C. salviifolius* for Ni, Cu, As, in *D. viscosa* for Ni, Cu, As, Cd, and Pb, and in *R. picroides* for Ni, Cu, As, Cd, and Pb.

This work provided preliminary information on the ability of the surveyed species to accumulate heavy metals, thus offering insights for the phytomanagement of the studied contaminated area.

Keywords: bioaccumulation, bioindication, bioremediation, heavy metals, mining areas, pollution, vascular plants.

LICHEN BIOMONITORING OF AIRBORNE MICROPLASTICS IN THE URBAN AREA OF PISA (ITALY)

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Plastics, microplastics, and their associated chemicals are issues of increasing global concern, because of their potential impact on human health. Microplastics (small pieces of waste plastic less than 5 mm in length) have been found in a variety of environments, but there are currently few studies investigating atmospheric microplastics. The atmosphere is an important medium through which suspended materials are transported and it is now clear that it can also be polluted by microplastics, even in remote regions. In this study, the deposition of atmospheric microplastics in the city of Pisa was studied using lichen transplants (*Evernia prunastri*). The aim was to characterise microplastics on the thallus before and after exposure under different experimental conditions. Lichen thalli were placed in outdoor areas such as parking lots and urban parks for about 7 weeks. Samples of *E. prunastri* from several remote areas in Tuscany were also considered for comparison. Extraction and identification of microplastics were carried out using microscopy and Fourier Transform Infrared spectroscopy techniques. The first results of the study will be presented and discussed.

Keywords: atmospheric deposition, biomonitoring, lichen, microplastics, plastic polymers.

URBAN FOREST AS A STRATEGY OF PARTICULATE MATTER (PM) CAPTURE AND RETENTION

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The significant trend of urbanization is accompanied by a range of serious issues, as air pollution, which is one of the prevalent health problems in numerous countries globally. Particulate matter (PM), is recognized as the foremost pollutants of concern for its adverse effects on human health and the environment. Urban vegetation represents a powerful ally in the fight against air pollution, since plants play a crucial role in capturing and mitigating the impact of PM in the atmosphere. However the capability of PM adsorption by vegetation depends on a lot of factors, including leaf shape, surface wettability and leaf epidermal features, i.e. cuticular striations and epicuticular waxes. Moreover, the deposition process is affected by the canopy characteristics, wind speed, particle size.

This study has evaluated the particle capture efficiencies of four broadleaved species (*Celtis australis, Fraxinus ornus, Morus alba* and *Tilia cordata*) settled as urban forest within a green area in the city of Reggio Emilia, Italy. The airborne particles have been studied through SEM/x-EDS analysis from a quantitative and chemical composition point of view, verifying the role played by leaf micromorphology in the efficiency to intercept PM. The data have been collected on leaves coming from 2 different seasons (spring and autumn) during 3 following years. Results show that *F. ornus* and *C. australis* have captured significantly more particles per unit area than *M. alba* and *T cordata*. Leaf micromorphology proved to be important, however it was no possible to identify a micromorphological trait more influential than others in determining the ability of the species to capture PM. In general, PM trapped by these species was rich in non-toxic or low-toxic compounds, even if in small quantities, like Ni, Cr and Ba. This, along with the fact that these species have largely collected fine particles, has proved the fundamental role of urban vegetation in PM capture and detainment.

Keywords: air quality, leaf micromorphology, particulate matter, urban forest.

EVALUATION OF THE SUITABILITY OF *TILLANDSIA USNEOIDES* AS BIOMONITOR OF AIRBORNE ELEMENTS IN A NATURAL ENVIRONMENT OF ITALY

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The suitability of a rootless Bromeliad species (*Tillandsia usneoides* L.) as biomonitor of airborne trace elements in suburban/urban areas of the Mediterranean basin was evaluated. The study was performed in nine sites of the Pollino National Park (Cosenza and Potenza provinces, Southern Italy) differing for land use, anthropogenic activities and/or proximity to emission sources, mainly a biomass power plant. Fluoride and sulphur were investigated, as the most emitted pollutants. Unwashed and washed samples, collected after 90 days of exposure (May August 2023), were analysed by ICP-MS. Results showed significant differences among sampling sites for both elements suggesting that in our local monitoring network a clear location-specific differentiation of pollutant levels occurred, strictly related to potential emission sources. Concentrations of fluoride were higher in urban/traffic and/or suburban/traffic areas. In the industrial site, sulphur levels were much higher than in rural/remote areas (+70%). The results indicated that *T usneoides* reflects the intrinsic characteristics of each sampling area and allows tracing back differences related to the various emission sources by factor analysis. In particular, *T usneoides* showed: high resistance/tolerance to heavy metal toxicity, specificity, capability to well-definitely represent a sampling site, quantitative response to pollutant exposure.

Keywords: Biomonitoring, heavy metal toxicity, pollutants, rootless plant.

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Printed in-house

Department of Life Sciences, Trieste

October 6, 2023