ICP VEGETATION

34th Task Force Meeting

22 - 25 February 2021

Hosted by UK (*online*)

Programme & Abstracts

Working Group on Effects
of the
Convention on Long-range Transboundary Air Pollution

Organisers:

ICP Vegetation Programme Coordination Centre
UK Centre for Ecology & Hydrology
Bangor, UK

Felicity Hayes, Amanda Holder, Mike Perring, Josie Foster

PROGRAMME

Venue: UK (Online)
Times listed in Central European Time zone

Monday 22nd February, 2021

Session: **Plenary** **Chair:** **Felicity Hayes**

14:00 Welcome address

14:15 *Isaura Rabago (Chair WGE)* - Recent developments in the Air Convention: Challenges, critical factors and opportunities for action.

14:45 *Alice James Casas and Christin Loran* - Update on the process "Review and revision of the empirical critical loads for nitrogen for natural and near-natural ecosystems".

15:05 *Felicity Hayes et al.* - Overview of activities and achievements of the ICP Vegetation.

15:30 ***Comfort break***

15:40 *Ignacio González-Fernández et al.* – Modelling of phytotoxic ozone doses for risk assessment at European and plot scales using the soil moisture index.

16:00 *Marina Frontasyeva et al.* - Moss survey 2020-2021-2022. Sampling in COVID year of 2020.

16:20 *Stefano Loppi et al.* - Lichen biomonitoring and environmental justice. A case study from Milan, Italy.

16:40 *Carter Bertrim & Julian Aherne* - Active moss biomonitoring of microplastic deposition in urban environments.

17:00 ***General Discussion***

17:30 ***Session End***

Tuesday 23rd February, 2021

Session: Moss 1 **Chair:** Konstantin Vergel

10:00 *Nikita Yushin et al.* - Mosses as Bioindicators of Heavy Metal Air Pollution in the Lockdown Period Adopted to Cope with the COVID-19 Pandemic.

10:20 *Biljana Balabanova et al.* - An effective tool for monitoring the deposition of surface dust in the cross-bio-indication process of metals in moss tissue.

10:40 *Mira Aničić Urošević et al.* – Moss bag biomonitoring of polycyclic aromatic hydrocarbons in urban areas during winter season.

11:00 ***Comfort break***

11:10 *Stefan Nickel & Winfried Schröder* - Pilot Studies on the Suitability of Bioindication with Mosses for the Detection of Atmospheric Deposition of Persistent Organic Pollutants and Microplastics in Germany: Measurement Network Planning and Implementation.

11:30 *Carmen Wolf et al.* – Pilot studies on the suitability of bioindication with mosses for the detection of atmospheric deposition of persistent organic pollutants and microplastics in Germany: Method development, sample preparation, and preliminary investigation on microplastics.

11:50 *Arlinda Cakaj et al.* – Accumulation of Platinum elements in *Taraxacum officinale* collected in urban areas of Pristina (Kosovo) and Poznan (Poland).

12:10 ***General discussion, including questions about posters.***

13:00 ***Session End.***

13:30 ***Breakout rooms open (aimed at moss survey participants, but others can join too).***

14:00 ***Session End.***

Session: Ozone 1 **Chair:** Håkan Pleijel

14:00 *Kent O. Burkey & Thomas E. Carter, Jr*. - Progress in breeding to improve the ozone tolerance of crops.

14:20 *Cristina Sausor Carmona et al.* – Effect of tropospheric ozone and water stress on spring wheat biomass and soil microbial communities under Mediterranean conditions.

14:40 *Melissa Chang Espino et al.* – Ozone response of a Mediterranean bread wheat under different nitrogen fertilization levels.

15:00 *Yanru Feng et al.* - Genetic variation of wheat responses to ozone treatment.

15:20 ***Comfort break***

15:40 *Pritha Pande* – Developing Ozone Flux-Response Relationships for wheat using different stomatal conductance (gsto) models.

16:00 *Jo Cook* – Incorporation of a nitrogen dynamics module into the DO_3SE model to simulate wheat grain quality parameters.

16:10 *Malin Broberg et al.* – Harvest index and remobilization of 13 elements during wheat grain filling: Experiences from ozone experiments in China and Sweden.

16:30 ***General discussion, including questions about posters.***

17:30 ***Session End.***

Wednesday 24th February, 2021

Session: Moss 2 **Chair:** Inga Zinicovscaia

10:00 *Pranvera Lazo et al.* – Study of air quality by moss biomonitoring and trace elements content.

10:20 *Guntis Tabors et al.* - Results of moss biomonitoring of atmospheric deposition in Latvia in 2020.

10:30 *Sebastien Leblond & Caroline Meyer* – Spatial distribution of platinum group elements in French mosses.

10:50 *Alexander Uzhinskiy et al.* - Prediction of air pollution by potentially toxic elements by combining satellite imagery, Moss Biomonitoring Data and Machine Learning: Limitation and Perspectives.

11:10 *Camiel Aggenbach et al.* – Moss survey 2020-2021 in The Netherlands.

11:30 *Ayse Nur Esen et al.* - Review of moss biomonitoring in Turkey.

11:40 ***General discussion and future workplan, AOB***.

12:30 ***Session End.***

12:30 ***Breakout rooms open (aimed at ozone session participants, but others can join too).***

13:30 ***Session End.***

Session: Ozone 2 **Chair:** Rocio Alonso

14:00 *Zhaozhong Feng et al.* - Introduction on new Ozone-FACE system in China.

14:20 *Raquel Ruiz-Checa et al*. – Current studies on atmospheric nitrogen deposition and effects in Spain.

14:40 *Samuel Prieto-Benítez et al.* – Ozone effects on visual pollinator attraction flower traits of the Spanish endemism *Erodium paularense*.

15:00 *Yasutomo Hoshika & E. Paoletti* - Comparison of sensitivity to O_3 between native poplars and poplar clones -Working Progress.

15:10 *Muhammad Adrees et al.* - Efficacy of silicon nanoparticles for wheat growth under combined effect of ozone and salinity.

15:30 *Amanda Holder & Felicity Hayes* - Impact of tropospheric ozone on sweet potato.

15:50 ***General discussion and future workplan, AOB.***

17:00 ***Session End.***

LIST OF POSTERS

OZONE

Author(s)	Title	Break-out Room
Ueno Andrea C. et al.	Maternal ozone increases survival of the progeny depending on plant symbiotic status and current environmental condition.	1
Durgesh Singh Yadav et al.	Diurnal variations in physiological characteristics, photo assimilates, and total ascorbate in early and late sown Indian wheat cultivars under exposure to elevated ozone.	1
Felix Leung et al.	Evidence of Ozone-Induced Visible Foliar Injury in Hong Kong using Phaseolus vulgaris as a Bioindicator.	2
Li Li et al.	Response of gas exchange, biomass and nonstructural carbohydrates (NSC) allocation in Indocalamus decorus to experimental atmospheric O_3 enrichment in a suburb of Beijing, China.	2
Falk S. et al.	Characterizing subarctic biomes for land surface modeling of pollution and climate risk.	2

MOSS SURVEY

Author(s)	Title	Break-out Room
Mehrabova M.A. et al.	Moss biomonitoring of air pollution with heavy metals and radionuclides.	1
Koroleva Yulia et al.	Features of the trace element composition of bryophytes in coastal landscapes (southern Curonian Spit, Russia).	1
Ramazanov Bakhruz et al.	Using of Mosses *Hylocomium splendens* and *Pleurozium schreberi* for assessment of atmospheric deposition of PAH in the Kaliningrad region.	2
Trajče Stafilov et al.	Atmoferic mercury deposition in Macedonia from 2002 to 2015 determined usung the moss biomonitoring technique.	2
Lisiak-Zielińska Marta et al.	Comparison of rare earth elements content in *Taraxacum officinale* collected in urban areas of Poznan (Poland) and Brno (Czech Republic).	3
Borovská Jana et al.	Atmospheric deposition of Heavy metals in Slovakia.	3
Shaniko Allajbeu et al.	Temporal trend of sea spray elements in two different periods survey 2010 and 2015 in Albania by moss samples growing in natural condition.	4
Ilić M. et al.	Can *Hypnum cupressiforme* be easily found within urban areas? – a case study in Serbia.	4
Stihi C. et al.	Moss surveys in Romania: 2010/2011, 2015/2016, 2020/2022. Results and perspectives.	5
Saxena D.K. & Saxena A.	Atmospheric Metal Load By Mosses During Pre-Lockdown And Lockdown Pandemic Period.	5

PLENARY

MOSS SURVEY 2020-2021-2022. SAMPLING IN COVID YEAR OF 2020

Fronasyeva M.[1], Chaligava O.[1], Uzhinskiy A.[1], Zinicovscaia I.[1],[2],[3], Culicov O.[1],[4], Vergel K.[1], Yushin N.[1], Hramco C.[1],[3], Loppi S.[5], Ehrenmann Z.[6], Aggenbach C.[7], Geurts J.J.M.[7], Nikolaev I.[8], Khetagurov Kh.[8], Lavrinenko Yu.[8], Okazova Z.[9], Stukalo V.[10], Blinova E.[11], Ionnidou A.[12], Betsou Ch.[12], Tsakiri E.[12], Ioannidou E.[12], Diapouli E.[13], Radnović D.[14], Krmar M.[14], Ilić M.[14], Aničić Urošević M.[15], Schroeder W.[16], Nickel S.[16], Barandovski L.[17], Stafilov T.[17], Stihi C.[18], Ene A.[19], Tepanosyan G.[20],Sahakyan L.[20], Neirynck J.[21], Izakovičová Z.[22], Borovská J.[22], Florek M.[23]

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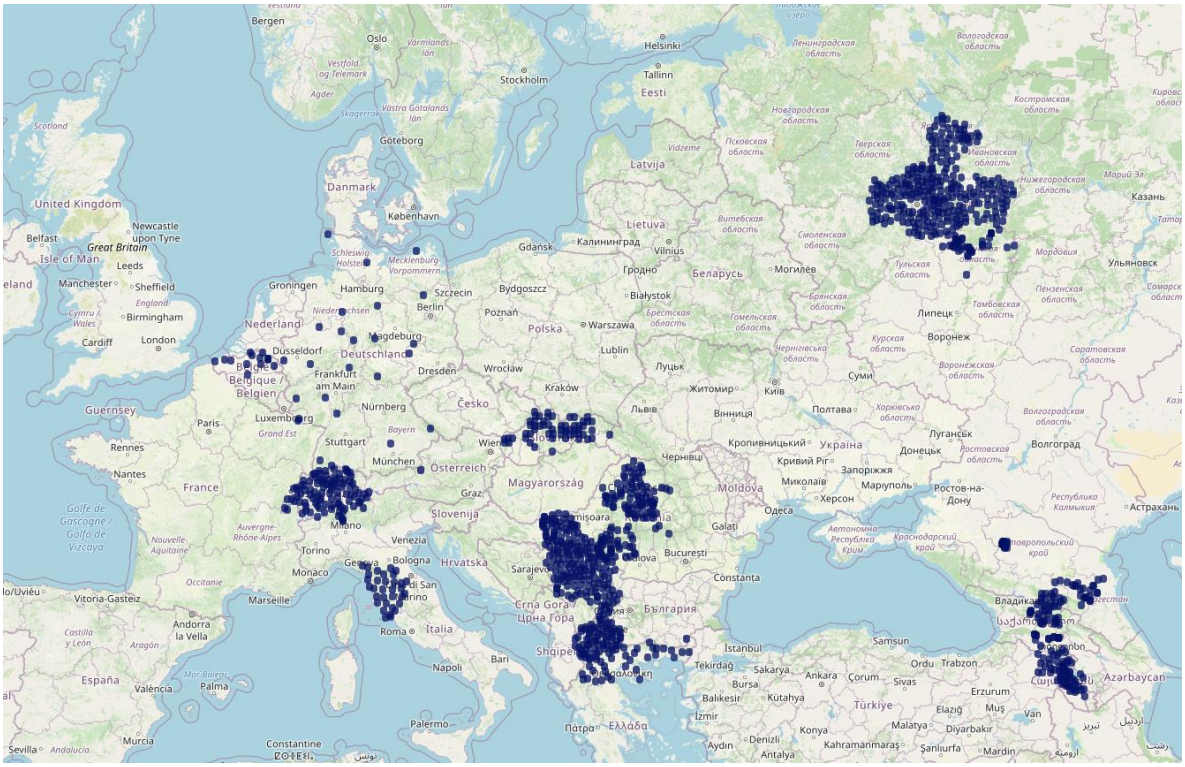
Since 1990, mosses have been used as biomonitors on a regular basis to study trends in the atmospheric deposition of trace elements in Europe [1, 2]. It was announced in 2020 that the planned moss survey for 2020/2021 was extended for 2022 because of the COVID-19 pandemic. Nevertheless, scientists in several European countries managed to start fieldwork despite the hard pandemic conditions in the summer and autumn of 2020. An overview of this sampling campaign is presented and illustrated with a total sampling GIS map, as well as with individual sampling maps for their countries as they were created by the co-authors of this presentation. The issue of the compatibility of using different types of mosses will be discussed [3].



Sampling map of 2020 (*Compiled by O. Chaligava*)

References

1. Frontasyeva M. V., Steinnes E. and Harmens H. Monitoring long-term and large-scale deposition of air pollutants based on moss analysis. Chapter in a book "Biomonitoring of Air Pollution Using Mosses and Lichens: Passive and Active Approach – State of the Art and Perspectives", Edts. M. Aničić Urošević, G. Vuković, M. Tomašević, Nova Science Publishers, New-York, USA, 2016, pp.246.

2. Frontasyeva M., Harmens H., Uzhinskiy A., Chaligava O. and participants of the moss survey (2020). Mosses as biomonitors of air pollution: 2015/2016 survey on heavy metals, nitrogen and POPs in Europe and beyond. Report of the ICP Vegetation Moss Survey Coordination Centre, Joint Institute for Nuclear Research, Dubna, Russian Federation, pp. 136. ISBN 978-5-9530-0508-1. http://www1.jinr.ru/Books/Books_rus.html

3. Nickel S., Schröder W. Correlating elements content in mosses collected in 2015 across Germany with spatially associated characteristics of sampling sites and their surroundings. Environ Sci Eur 31(80), 2019, p. 1-21. https://doi.org/10.1186/s12302-019-0260-7

MODELLING OF PHYTOTOXIC OZONE DOSES FOR RISK ASSESSMENT AT EUROPEAN AND PLOT SCALES USING THE SOIL MOISTURE INDEX

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The assessment of the risk of ozone effects on natural vegetation and crops in support of the coming revision of the Gothemburg Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution will need to model the response of plants to ozone under future (2030 and 2050) climatic conditions. Setting aside the potential changes of ozone sensitivity of plants under future climatic conditions, as a result of physiological changes induced by prevailing meteorological conditions, the phytotoxic ozone dose (POD) index seems the best suited for the estimation of damaging stomatal ozone deposition under future climate. However this methodology still needs adjustments in order to be able to model POD under future climate scenarios.

Soil moisture is one of the main drivers of POD and its importance is foreseen to increase in the coming decades due to climatic change in large areas of Europe. Modelling of soil moisture is complex and recent developments of the EMEP MSC-W Chemical Transport Model have made use of modelling products for this parameter such as the European Centre for Medium Range Weather Forecast Soil Moisture Index (SMI). A joint ICP-Vegetation – EMEP collaborative exercise was established aiming at testing and improving the modelling of soil moisture influence on POD estimation for different vegetation types in the EMEP MSC-W Chemical Transport Model for large-scale and in the DO_3SE Interface (https://www.sei.org/projects-and-tools/tools/do3se-deposition-ozone-stomatal-exchange/) for plot-scale applications.

Modelled and observed time series of SMI at six different sites in Italy and Spain covering cropland, forest and pastures have been compared and sensitivity analysis of the SMI parameterization have been performed. Analyses results will be presented and recommendations for POD modelling and future activities will be discussed.

Funding provided by EMEP under UN-ECE, the Spanish Ministry of Ecological Transition (MITECO 17CAES009) and AEI/MICINN EDEN-Med (CGL2017-84687-C2-1-R/AEI) and ELEMENTAL (CGL2017-83538-C3-3-R/AEI) projects is acknowledged.

LICHEN BIOMONITORING AND ENVIRONMENTAL JUSTICE
A CASE STUDY FROM MILAN, ITALY

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In this study, the bioaccumulation of selected trace elements (Al, As, Cd, Cr, Cu, Fe, Pb, Sb, Zn) in lichen samples (*Evernia prunastri*) transplanted for three months in Milan (Italy) was investigated to assess the main airborne contaminants and their sources. The results pinpointed Cr, Cu, Fe and Sb as the main contaminants and suggested a common origin for these elements from non-exhaust sources of vehicular traffic, such as brake abrasion. These conclusions were confirmed also by magnetic analysis of lichen samples, which showed intense magnetic properties driven by magnetite-like minerals associated with Cr, Cu, Fe and Sb. Additionally, the composition and the magnetic domain state / grain-size of the samples suggest that brake abrasion from vehicles is the main source of the bioaccumulated particles. Notably, the lowest contamination corresponded to the main green areas, confirming the important protective role of urban forests against air pollution.
These results were used for environmental justice assessment. To this purpose an overall contamination index and as a synthetic socio-economic deprivation index were calculated, the latter on the basis of census data of national statistic institute (ISTAT) and calculated for the 6,085 census units of the city. The results showed that the pollution pattern was more related to the streets size and characteristics, rather than to the socio-economic status of the neighborhoods. Nevertheless, a clear increasing trend of air pollution from the periphery to the city centre, where the lowest values of the deprivation index were found, suggests that in Milan a good life quality is however linked with high traffic emission.

OZONE SESSIONS

EFFICACY OF SILICON NANOPARTICLES FOR WHEAT GROWTH UNDER COMBINED EFFECT OF OZONE & SALINITY

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Climate change is a global concern of the day. Our Earth witnessed an increase of 0.60ºC in global temperature during the century. Currently, our atmosphere is saturated with higher concentrations of carbon dioxide (CO_2), methane (CH_4), and tropospheric ozone (O_3), which accelerate the global temperature rise. Wheat is a major staple food crop with a two-third population directly dependent upon for their dietary needs. Wheat yield should increase at a rate of 2% annually to meet the consumptive need of a rapidly growing population till 2020. Salinity emerged as one of the severe abiotic stresses negatively swaying crop productivity directly or indirectly. Natural and anthropogenic factors incremented soil salinization problems at a rapid pace by swapping 2 million hectares of global cultivable land per year. It reduces the yield by perturbing the biochemical and physiological attributes of crops. The application of silicon nanoparticles developed resistance in plants against the hostile impacts of ozone and salinity stress. A pot experiment was conducted in the research area of Government College University Faisalabad, Pakistan to investigate the effect of elevated ozone concentration and salinity on wheat crops and the role of foliar application of SiO_2 nanoparticles in alleviating these stresses. Wheat crop grown under saline conditions is exposed to two levels of ozone (filter air & 100 ppb) & supplemented with two levels of SiO_2 nanoparticles (0 & 100mg/L) foliar application at various stages of crop growth. Results revealed that elevated ozone and salinity stress decreased the overall growth and yield performance of plants. However, these detrimental impacts were ameliorated by exogenous supplementation of silicon nanoparticles at the rate of 100 mg/L.

HARVEST INDEX AND REMOBILIZATION OF 13 ELEMENTS DURING WHEAT GRAIN FILLING: EXPERIENCES FROM OZONE EXPERIMENTS IN CHINA AND SWEDEN

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Wheat crops efficiently remobilize and partition a large fraction of aboveground biomass into their grains during maturation. This senescence process has been streamlined through crop breeding and increasing the harvest index (HI). With field data from ozone exposure experiments, we derive HI for 13 elements, both nutrients and non-essential, to determine how efficiently these elements are partitioned into the grain in two different agro-ecological environments (Sweden and China) and under various ozone exposure regimes. Element HI ranged from 10 to 90 %, with highest rates for P, N and Zn (90 %, 80 % and 70 % respectively), while HI was low for the non-mobile elements Ba, Sr and Ca (<10%). HI for biomass was about 50%, and the non-essential and toxic element Cd was in the same range (~40%). Overall, HI was very similar in China and Sweden for almost all elements. This was also the case when the two Chinses genotypes were compared. There was a significant relationship between element HI and leaf remobilization (Swedish experiment), indicating that remobilization rates are of high importance for element HI. We conclude that element HI for wheat crops are highly element specific and not strongly dependent on site (Figure 1) or cultivar. ozone exposure significantly reduced HI for both macronutrients (Ca, K, Mg, N, P) and micronutrients (Cu, Mn, Mo, Zn), but also Cd, while there was no ozone effect on the total aboveground pool for any element except P and Ba. Consequently the ozone induced reduction in grain element yield, observed in previous studies[1], can be explained by lower remobilization rates rather than reduced total uptake. Our results provide new insights of nutrient use efficiency in wheat crops that are of importance both for understanding of element flows in the agro-ecosystem, but also central for crop breeding that aims to increase the nutritional value of food crops.

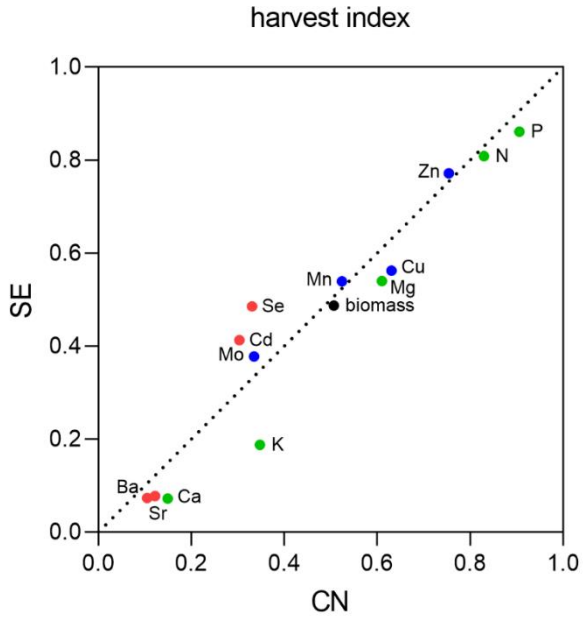

Figure 1. : Correlation of element and biomass harvest index comparing experimental sites in China (CN) and Sweden (SE), Pearson r = 0.9549 (CI 0.8523 to 0.9867), p <0.0001. CN observations are the average of the two cultivars from the aO_3 treatment and SE observations are NF+ treatment which had a similar ozone concentration as aO_3. Marker colors denotes element type, green: macronutrient, blue: micronutrient, and red: non-essential element.

[1] Broberg, M.C., Feng, Z., Xin, Y., Pleijel, H., 2015. Ozone effects on wheat grain quality - a summary. Environ. Pollution 197, 203–213.

PROGRESS IN BREEDING TO IMPROVE THE OZONE TOLERANCE OF CROPS

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Adapting agriculture to climate change includes developing crops with improved ozone tolerance. Traditional breeding is one approach toward this goal. The first step is to develop a screening strategy to identify genotypes exhibiting ozone tolerance. The second step involves transfer of ozone tolerance into breeding lines that exhibit the stress tolerance trait along with the required agronomic characteristics. Previously, we have screened diverse soybean germplasm for ozone response using foliar injury assessments and open-top chamber yield trials. Fiskeby III, a plant introduction developed in Sweden, was identified as a source of ozone tolerance [1] as well as tolerance to drought, salt stress, and iron deficiency chlorosis. The tolerance to multiple abiotic stresses was the basis for selecting Fiskeby III as source of stress tolerance genes that could be employed to develop improved soybean cultivars.

Fiskeby III (low productivity, but excellent ozone and drought tolerances) was hybridized with Holladay (a commercial cultivar with high productivity, but sensitive to both ozone and drought) using traditional breeding methods. Twenty F1 plants were advanced by "bulk breeding" for four generations. Approximately 800 plants with good agronomic characteristics and yield potential were selected for further development. From these, 120 breeding lines were tested for slow wilting under drought stress in the field. This approach was based upon physiological studies linking the drought and ozone tolerance in Fiskeby III to a leaf gas exchange trait that appears to contribute to both ozone exclusion and increased water use efficiency [2].

Eleven breeding lines with the slow wilting trait were screened for ozone-induced foliar injury in the greenhouse. Several breeding lines exhibited low injury scores similar to the tolerant Fiskeby III parent and significantly different from the sensitive Holladay parent. Seed yield of the Holladay parent and five of the breeding lines was assessed in open-top chambers under field conditions in 2019. Under a season-long elevated ozone exposure (80 ppb 12-hour mean), Holladay exhibited a yield loss of 33% while yield loss in the most tolerant breeding line was only 4%. The results suggest that ozone tolerance genes from Fiskeby III have been transferred into agronomically adapted soybean germplasm.

This study provides a strategy that could be adapted for enhancing the ozone tolerance of other crops. The key is to develop working groups that combine expertise and facilities for assessing ozone response in plants with expertise in plant breeding and genetics.

References

[1] Burkey, K.O. and T.E. Carter, Jr. (2009) Foliar resistance to ozone injury in the genetic base of U.S. and Canadian soybean and prediction of resistance in descendent cultivars using coefficient of parentage. Field Crops Research 111: 207-217

[2] Bailey, A., K. Burkey, M. Taggart, T. Rufty (2019) Leaf Traits that contribute to differential ozone response in ozone-tolerant and sensitive soybean genotypes. Plants 8: 235

OZONE RESPONSE OF MEDITERRANEAN BREAD WHEAT UNDER DIFFERENT NITROGEN FERTILIZATION LEVELS

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Ozone can modulate nitrogen fertilization effectiveness in wheat (Broberg *et al.*, 2017). In the present study the O_3-sensitive modern Mediterranean cultivar Arthur Nick, was exposed to 4 ozone levels and 2 nitrogen fertilizations to study the interaction between both factors on the foliar pigment content (chlorophyll and polyphenols, through SPAD and DUALEX measures) throughout the exposure period, and on yield parameters at the end of the plant cycle. Special focus was put on the study of the foliar and grain isotopic signatures of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) to explain the integrated effect of O_3 and N on C and N metabolism through the exposure period.

The pot experiment was carried out at the CIEMAT Open Top Chamber facility, located in central Iberian Peninsula. Ozone treatments consisted of charcoal-filtered air (FA), non-filtered air (NFA) and NFA+20 and 40 ppb ozone (NFA+, NFA++). Plants were exposed from anthesis to grain maturity. Fertilization treatments consisted on 100 and 200 kg N ha^{-1} distributed on 2 partial doses.

Preliminary results are presented. Increasing N produced bigger plants due to more hay biomass but without affecting yield significantly, causing an HI reduction. Fertilization also produced bigger flags leaves with more N content. On the contrary, O_3 reduced grain weight but HI was not affected, although a trend was observed ($p<0.1$) where fertilization enhanced the O_3-induced effect on hay biomass. The pollutant also reduced flag leaf size, but without affecting the foliar N content significantly.

Nitrogen had a significant effect on chlorophyll only in the younger leaves, with higher amounts under lower N. Meanwhile, the effects of ozone reduced chlorophyll both in young and older leaves, but more significantly in the latter. Finally, for this parameter nitrogen affected the O_3-response pattern of the older leaves.

Regarding the isotopic response, fertilisation reduced $\delta^{15}N$, but the pollutant did not affect the signal. Both $\delta^{15}N$ and N% correlated well with the N supplementation: the more N is applied, the higher foliar N is observed and the more discrimination is seen against $\delta^{15}N$. Contrary to what has been observed for grain $\delta^{13}C$ in previous studies, O_3 did not have a significant effect on leaf $\delta^{13}C$.

Funding was provided by AGRISOST-CM (P2018/BAA-4330), OZOCAM (G.Os. IMIDRA, CAM) and ERANET-SUSCROP SUSCAP (PCI2019-103521) projects, and the Agreement between the Spanish Ministry of Ecological Transition and CIEMAT for Advice on CLRTAP Convention (MITECO 17CAES0009).

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INCORPORATION OF A NITROGEN DYNAMICS MODULE INTO THE DO3SE MODEL TO SIMULATE WHEAT GRAIN QUALITY PARAMETERS

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Wheat is a staple food in India, with 75-80% of the country consuming it in the form of chapatis and rotis (Singh, 2019). The cereal provides carbohydrates, protein (including essential amino acids), fibre, B vitamins, minerals and iron (Shewry and Hey, 2015). Deficiencies in these nutritional qualities have a detrimental impact on an individual's health. Given wheat is a staple food source in India, it is important to consider factors which affect its nutritional value. Two such factors are ozone and climate change. Ozone and climate variables affect both the yield of wheat and the quality of the grain (Broberg *et al.*, 2015; Broberg, Högy and Pleijel, 2017). Ozone decreases grain yield but increases protein (and some nutritionally important mineral) concentrations in wheat, whereas elevated CO_2 has the opposite effect (Broberg *et al.*, 2015; Broberg, Högy and Pleijel, 2017). Crop models are used to simulate the effects that future climate and ozone scenarios will have on the yields of crops and hence provide estimates of their impacts on production and food security (e.g. Kumar et al., 2014; Emberson et al., 2018). Currently few models consider crop nutritional quality and, of those that do, none incorporate ozone effects. Given that CO_2 and tropospheric ozone concentrations are rising, driving increasing temperatures over the coming years, it is critical to assess how these climate variables and ozone will interact to affect wheat quality and hence nutrition. I plan to build on the existing stomatal ozone deposition model - DO3SE - and incorporate a nitrogen dynamics module to simulate grain nitrogen content. The effects of ozone and climate variables on grain nitrogen will be incorporated through their effects on photosynthesis. By modelling the grain nitrogen content, I will be able to calculate protein and amino acid concentrations. This will provide insight into how ozone and climate change could affect the quality of nutrition obtained from wheat in India.

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GENETIC VARIATION OF WHEAT RESPONSES TO OZONE TREATMENT

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Rising tropospheric ozone concentrations necessitate the breeding of adapted crop varieties to ensure food security. To this aim, the monitoring of ozone damage is important for crop breeding and estimation of crop yield losses through crop modelling. While the effects of ozone on bread wheat have been widely explored, the genotypic diversity in ozone tolerance or sensitivity has often been neglected in ozone impact assessment, and has barely been exploited in crop breeding. In this study, we first pre-selected 18 contrasting wheat genotypes from a larger population of 150 genotypes that had been screened in a previous study(Begum et al. 2020). We exposed those 18 genotypes to elevated ozone (average 70ppb for 7h daily) and control conditions throughout the growing season in open top chambers (OTCs). In order to obtain season-long continuous data as a basis for crop growth modelling, we monitored biomass development, leaf area index, gas exchange, photosynthetic efficiency, and vegetation indices at regular intervals throughout growth, while yield components were measured at harvest. Averaged across all genotypes ozone treatment reduced grain yields by 18.7%, but there was large phenotypic variation with values ranging from 2.7% to 44.6%. Similar phenotypic variation was observed in physiological and biomass parameters we determined. Subsequently we conducted correlation analysis and principal component analysis in order to identify traits that were strongly correlated with grain yield losses. Subsequently we selected characteristic tolerant and sensitive genotypes in order to fit a modified version of the SIMPLACE (LintulCC-Ozone) crop model to represent tolerant and sensitive responses (Rodriguez et al. 2001). Our results will facilitate the model-based development of ozone tolerant crop ideotypes for wheat breeding, and will increase the accuracy of ozone impact assessment by considering typical sensitive or tolerant responses in crop growth models.

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INTRODUCTION ON OZONE-FACE SYSTEM IN CHINA

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Here, we introduced two O_3-FACE systems in China. One is the Poplar Plantation O_3-FACE in Yanqing, Beijing. This FACE plot was a square, with a side length of 16m, surrounded by a 30m × 30m Poplar Plantation. There are 8 plots with two O_3 treatments (one is ambient O_3 (AA), the other is elevated O_3 with 1.5×AA) and each O_3 treatment has four replicated plots. In each plot, there are two poplar lines (107 & 546) and two N deposition levels (0, 60 kg N/ha), totally four sub-plots. The main purpose is to investigate the single and combined effects of O_3 and N on the structure and function of plantation ecosystem.

The other O_3-FACE is cropland O_3-T-FACE. It is an Octagon ring, with a side length of 4 m. There are 8 rings with two O_3 treatments (one is ambient O_3 (AA), the other is elevated O_3 with 1.5×AA) and each O_3 treatment has four replicated rings. In each ring, there are three warming treatments, i.e. ambient temperature (AT), AT+2 ^oC during night time and AT+2 ^oC during day and night. The purpose is to investigate the combined effect of elevated O_3 and warming on growth, yield and grain quality of rice and wheat, especially for soil microbiology role in regulating the C and N cycle in cropland.

IMPACT OF TROPOSHERIC OZONE ON SWEET POTATOES

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Sweet potato *(Ipomoea batatas)* is an important and versatile tropical root crop providing dietary energy and nutrients. It is grown in ~110 countries worldwide, including many developing countries (FAOSTAT, 2019). Even though it is widely grown in locations deemed to be most at risk from high ozone concentrations (e.g. sub-Saharan Africa), the impact of tropospheric ozone pollution on different sweet potato varieties is largely unknown.

Two varieties of sweet potato were grown and exposed to Low, Medium and High ozone treatments (daytime average hourly ozone concentrations of around 30, 80, and 110 ppb respectively) using heated glasshouses (solardomes) over the main growing season. Observations were made of foliar injury and weekly measurements were taken of leaf stomatal conductance, chlorophyll content (index), and soil moisture. The stomatal conductance data (covering varying environmental conditions over the season) was utilised to parameterise the DO_3SE (Deposition of O_3 [ozone] for Stomatal Exchange) flux model. The yield of sweet potatoes (fresh weight) was also recorded.

Some foliar injury was noted after only 5 days of exposure in the High treatment. However, throughout the exposure period the higher ozone treatments generally resulted in fewer leaves, due to early senescence rather than leaf damage. During August and September stomatal conductance was found to be lower in the Medium and High ozone treatments compared to the Low treatment ($p < 0.01$) and the chlorophyll index was also reduced at times ($p < 0.05$). Yield was significantly reduced at both the Medium and High ozone levels compared to the Low.

After an initial parameterization of stomatal conductance in response to light, temperature, vapour pressure deficit and soil water potential the constants obtained enabled the DO_3SE model to be run specifically for sweet potato as a species. When combining yield data from this experiment along with the yields reported in Keutgen et al. (2008), significant species specific (SPEC) relationships for both the concentration based (AOT40, accumulated ozone above a threshold of 40 ppb) and flux based (POD_y, accumulated stomatal flux of O_3 above a threshold of *y* nmol m^{-2} s^{-1}) results were found (AOT40 $p = 0.02$; POD_6SPEC $p = 0.02$). A critical level of 6 (POD_6SPEC) was determined using the relationships obtained.

Data from this study can be used to improve model predictions of the impact of tropospheric ozone on this crop, along with associated assessments of implications for economic yields and subsistence agriculture.

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COMPARISON OF SENSITIVITY TO O_3 BETWEEN NATIVE POPLARS AND POPLAR CLONES –WORKING PROGRESS-

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Poplars are widely used for wood production and as model plant in plant biology. They are generally known to be ozone-sensitive. However, our knowledge of ozone dose-response relationships is still limited both when investigating exposure-based and flux-based dose-responses. To address these issues, in 2020, we targeted two artificial hybrid clones (Oxford; I-214) to examine their physiological, biochemical and morphological responses to ozone in a free-air ozone exposure experiment at Sesto Fiorentino, which is a unique facility in Europe. Interestingly, I-214 clone accelerated new leaf formation to compensate productive decline while Oxford clone tended to maintain old leaves to cope with ozone stress. Since the major part of analysis is still ongoing, we will show the present working progress. In addition, it has been known that not only hybrid clones but also native poplars are widely distributed in Europe. An important question has thus raised whether there are different sensitivities to ozone between native poplars and hybrid clones. It seems that hybrid clones might be more sensitive to ozone than native ones. However, the mechanisms of ozone susceptibility between native and hybrid poplars are not fully elucidated. In 2021, we will target three native poplars (*Populus nigra*, *P. alba*, and *P.* × *canescens* [a natural hybrid of *P. alba* and *P. tremula*]) in addition to Oxford clone. We will introduce the working plan in this year for the Scientific background document B "Critical levels for ozone-sensitive clones of poplar".

ESTIMATING THE IMPACT OF OZONE AND AEROSOL ON WHEAT CROP IN INDO-GANGETIC BASIN (IGB) REGION IN INDIA

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Ozone is causing 3-40% relative yield losses across the Indo-Gangetic plain in India, as evidenced from empirical data and modelling studies. (Ghude et.al.,2014) Aerosol concentration, which is represented as columnar aerosol concentration known as AOD was measured across northern hills (which comprise IGB) to see its impact on crop yield and reveals spatial change in yield decrease ranging from 3-23%. (Nahar et.al.,2010) Aerosol also alter the meteorological parameters important for crop growth for eg. shown in Nahar et.al.,2010. 5% and 4% cut off in incoming solar radiation in Varanasi and Ranchi respectively during daylight hours due to high load of BC in AOD. Further, estimated the loss of more than a quintal per hectare of wheat crop in the IGB region during February and March which corresponds to anthesis and maturity month-period of the wheat crop. Climate extremes are also well known to be affecting crop productivity in the IGP region. Gupta et.al.,2017, has shown that due to 1°C rise in both Tmean and Tmax decrease in 2-4% of wheat yield. The combined influence of these ozone, aerosol and climate stress is little known and is therefore the focus of this research, where will develop and evaluate the DO3SE (Deposition Of Ozone for Stomatal Exchange) model so that is able to assess the effect of a combination of stresses on crop yield. The research assumes that by understanding the interacting effects of ozone, aerosol and climate variables on photosynthesis (a fundamental plant process) it is possible to assess the effect of these stresses in combination on yield. This research aims to answer the three main questions i) Can the Ewert model of ozone effects on photosynthesis, which will be incorporated in DO3SE crop model used to simulate losses in crop yield. How does this compare to more empirical (e.g. POD6 based) estimates of yield loss? ii) Can the DO3SE model be developed to simulate the influence of changes in the quantity of solar radiation on canopy photosynthesis? iii)Can the DO3SE model be applied to understand the relative threat of each stress in combination to yield Application of this model will provide novel risk assessment for the region and help identify the levels of stress and associated yield loss to inform mitigation policy.

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OZONE EFFECTS ON VISUAL POLLINATOR ATTRACTION FLOWER TRAITS OF THE SPANISH ENDEMISM ERODIUM PAULARENSE

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The effect of tropospheric ozone (O_3) on the biomass or number of flowers has been used as a response variable for the definition of O_3 critical levels for some semi-natural vegetation communities indicating potential effects on the reproductive capacity of plants with consequences for biodiversity conservation. However O_3 effects on the reproductive capacity of insect pollinated species can extend further those indicated by the biomass of flowers alone if complex pollinator-plant interactions are also affected, but these are less well understood. Moreover, most published studies about O_3 effects have focused on abundant and widely distributed species. However, information about the O_3 sensitivity of endemic or endangered vegetation species can be of interest to assess the risk of O_3 effects on biodiversity as well as for conservation purposes of particular species.

In this pilot study, *Erodium paularense* plants, a Mediterranean endemic and endangered species, were exposed to different O_3 treatments in an OTC experiment. Two visual pollinator attraction traits of flowers, color and size, were studied. UV-VIS-NIR spectral reflectance was used to measure treatment effects on petal color and anthocyanins content (anthocyanin reflectance index, ARI). The possible change on the visual perception of the main guilds of *Erodium paularense* pollinators was studied in bee, fly and butterfly color spaces. Also, to determine the effects of O_3 on flower size, petal area was measured.

Petal reflectance and ARI values showed an increasing trend at ambient and elevated O_3 treatments compared with charcoal-filtered air. Color spaces showed that these color changes could only be partially perceptible by butterflies but not for bees or flies. Ozone reduced the petal area and thus the possible perception of the petals and the flower detectability from afar by pollinators. Temperature increases induced by OTCs had no effect on petal color or area.

This study shows that floral spectral reflectance and flower size measurements can be used as novel methods for studying O_3 effects on pollinator visual attraction traits. Further studies will be needed to consider other pollinator attraction traits such as olfactory (floral scents) and main pollinator reward (nectar quantity and quality and pollen) in order to understand the potential consequences of O_3 exposure on pollinator attraction.

Funding was provided by FEDER/AEI/MICINN EDEN-Med (CGL2017-84687-C2-1-R/AEI) and BioDiv-Support (PCI2018-093149) projects, and the Spanish Ministry of Ecological Transition (MITECO 17CAES009).

CURRENT STUDIES ON ATMOSPHERIC NITROGEN DEPOSITION AND EFFECTS IN SPAIN

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Tropospheric ozone (O_3) and atmospheric nitrogen (N) deposition are two of the main air pollutants affecting natural and semi-natural ecosystems in Spain, according to risk assessments based on exceedances of empirical critical loads and levels. While interactive effects of O_3 and N are being experimentally addressed, there are still some processes related to atmospheric N deposition and effects that need further investigation in Mediterranean ecosystems. This is particularly important due to the increasing trend in atmospheric N deposition registered in Spain in the last years. Some ongoing studies that are being developed to clarify some of these processes and preliminary results, when available, will be presented.

One of the characteristics of atmospheric N deposition in Mediterranean environments is the dominance of dry deposition processes. No standard method is available yet to experimentally estimate dry deposition, even if this information is needed to correctly associate the level of N deposition with its effects, Different approaches are being tested and will be discussed in order to improve the estimation of N dry deposition on Holm oak forests. Previous results raised the awareness that nitric acid (HNO_3) vapor is an important component of atmospheric N dry deposition in these environments, thus further research is being developed and will be explained to quantify the contribution of oxidized versus reduced N forms in atmospheric dry deposition.

Another important challenge is the quantification of atmospheric deposition in mountain areas, where the highest risk of N effects has been detected. Methods adopted to investigate the contribution of N deposition due to snow precipitation will be presented.

The strong seasonal variability is another key factor affecting atmospheric N fate and effects in Mediterranean ecosystems. Intra-annual variability in canopy uptake processes and asynchrony between nutrient availability and demand have been previously described. New experiments are being developed in Spain to quantify these N fluxes from the atmosphere, through the phyllosphere and into the leaves, trying to complete the N cycle in holm oak forests.

Funding was provided by the projects EDEN-Med (CGL2017-84687-C2-1-R/AEI-FEDER), MODICO (Fundación Biodiversidad-MITECO), BioDiv-Support (PCI2018-093149) and the Spanish Ministry of Ecological Transition (MITECO 17CAES009)

EFFECT OF TROPOSPHERIC OZONE AND WATER STRESS ON SPRING WHEAT BIOMASS AND SOIL MICROBIAL COMMUNITIES UNDER MEDITERRANEAN CONDITIONS

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Tropospheric ozone (O_3) is an atmospheric pollutant and has been shown to directly affect plants as well as interactions between plant and soil microbial communities (Andersen, 2003; Agathokleous, 2020). Ozone effects in below ground processes may result in changes in nutrient cycling affecting crop resource use efficiencies such as nitrogen utilization, like those reported in Broberg et al. (2017).

In the present study, the interactive effect of O_3 and drought stress was tested on plant biomass and soil microbial diversity in a Mediterranean spring wheat crop (var. Califa Sur). An O_3 fumigation experiment in open-top chambers (OTC) was developed with field-grown plants in central Spain. The plants were exposed to four O_3 concentrations from February to June (from seedling stage to maturity) and to two irrigation levels from April to June (from stem elongation to maturity). Ozone treatments consisted of charcoal-filtered air (FA), ca. 50% filtration efficiency; non-filtered air (NFA), ambient ozone concentrations; NFA+20ppb ozone (FUA); NFA+40ppb ozone (FUA+). Irrigation treatment levels were applied by hand at each half of the OTCs: optimal irrigation and water stress. The later received support watering at grain filling at half dose of the irrigated area.

The crop was harvested 6 times at different growing stages for determination of above ground biomass. Soil samples were taken at the grain filling phase. Two soil samples were taken per half OTC from the vertical of two previously harvested plants by inserting an 8 cm diameter sampling cylinder up to 20 cm depth. Samples were subdivided into 0-5 cm and 5-20 cm subsamples. Microbiological analyses were performed on rhizosphere, soil in direct (<1mm distance) from the root, and bulk soil. The abundance and composition of soil microorganisms were estimated by quantification of the copy number of phyla specific molecular markers of fungi (ITS region) and bacteria and archaea (16S rRNA gene) by qPCR. Bacteria and fungi were grown on selective media to estimate the abundance of fungi and bacteria and the colony-forming unit (CFU) per gram of soil was calculated.

Preliminary results will be presented and discussed.

Funding was provided by AGRISOST-3 (P2018/BAA-4330), OZOCAM (G.Os. IMIDRA, CAM) and ERANET-SUSCROP SUSCAP (PCI2019-103521) projects, and the Agreement between MITECO and CIEMAT for Advice on CLRTAP Convention (Exp.nº17-CAES0009).

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MOSS SURVEY SESSIONS

MOSS SURVEY 2020-2021 IN THE NETHERLANDS

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Background

Atmospheric deposition of nitrogen is exceeding the critical loads of vulnerable ecosystems in many Dutch N2000 areas. Therefore, in 2015 a governmental program (PAS) was initiated that aims at a long-term decline of N-deposition and a short-term application of extensive mitigating measures in N2000 areas in order to preserve the current habitat area and quality at high N-deposition levels. The elaboration of this program is based on fine-scale modeling of N-deposition with atmospheric transport-deposition models and knowledge on the ecological effects of mitigating measures. Currently the only monitoring activity in N2000 areas related to atmospheric N-input is a fine-scale monitoring network for measurements of atmospheric NH_x concentrations. The Netherlands participated in the moss survey of ICP only in 2005 for measurement of N-content. Therefore, the prospect on a sound evaluation of the effect of PAS measures on the actual N-deposition in N2000 areas is weak. For this reason, KWR initiated a project for measurements of N-content in mosses with the financial aid of drinking water companies that manage vast N-sensitive nature areas and provinces responsible for implementing the PAS program. Recently the lock down due to the COVID-19 pandemic may have had a (temporary) effect on the N-deposition, mainly by a reduction of traffic. The initiated project also attempts to measure this effect.

Besides N-deposition, heavy metal deposition used to be high in the Netherlands exceeding critical loads. The evaluation of policies and measures for reducing emissions is mainly based on monitoring of atmospheric heavy metal concentrations and modelling of this deposition. Currently fine scale monitoring of metal deposition is lacking and the Netherlands only participated in the ICP moss survey for heavy metals in 1990 and 1995. Therefore, in the moss survey of KWR also heavy metals will be measured.

Activities

- 2020: sampling of 40 sites; 34 scattered along the coast in dune areas, 4 in an inland heathland area, and 2 reference sites with low N-deposition in Denmark.
- 2021: resampling of ca. 20 sites in 2021 for the COVID-19 lock down effect
- Sampling and lab procedures according to the ICP moss survey protocol with additional samples of moss tips.
- Measurements of CN, heavy metals with ICP and N-isotopes. (Radboud University).
- Multi-element analysis by NAA and possibly AAS (JNIR) on a selection of the samples.
- Spatial pattern of N, heavy metals, and N-isotopes in mosses.
- Temporal changes of N (2005-2020) and heavy metals (1990, 1995 and 2020).
- Changes of N-content in moss tips between 2020 and 2021.
- Relation of N-content and N-isotope profile with modelled N-deposition (N-total, NH_x, NO_x) and with measured atmospheric NH3 concentrations.
- Effects of N-deposition on nutrient stoichiometry in mosses.

In the presentation primarily results will be discussed.

MOSS BAG BIOMONITORING OF POLYCYCLIC AROMATIC HYDROCARBONS IN URBAN AREAS DURING WINTER SEASON

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Moss bag biomonitoring has been applied for the investigation of organic pollutants in the air. In this study, two moss species, *Hypnum cupressiforme* and *Sphagnum girgensohnii*, were exposed in bags for two months at nine urban and one rural site in two countries (Serbia−RS, Montenegro−ME) during the winter period 2019/2020. The bags were placed at the air quality monitoring stations, except at the rural site, to be representatively positioned and the biomonitoring data possibly compared with the instrumental measurements of polycyclic aromatic hydrocarbons (PAHs). After exposure, 16 EPA PAHs, naphthalene (Nap), acenaphthylene (Acy), acenaphthene (Acp), fluorene (F), phenanthrene (Phen), anthracene (Ant), fluoranthene (Fl), pyrene (Pyr), benzo[a]anthracene (B[a]A), chrysene (Chr), benzo[b]fluoranthene (B[b]F), benzo[k]fluoranthene (B[k]F), benzo[a]pyrene (B[a]P), indeno[1,2,3-c,d]pyrene (I[cd]P), dibenzo-[a,h]anthracene (DB[ah]A) and benzo[ghi]perylene (B[ghi]P), were determined in the moss samples by gas chromatography−mass spectrometry (GC-MS). To identify of PAH pollution sources, the moss PAH diagnostic ratios were calculated.

The concentrations of all PAHs were significantly higher (up to 23 times) in the exposed moss bags than in the initial (unexposed) moss tissue. Total PAHs (∑PAHs) varied in the range 1163−2291 μg kg^{-1} in RS and 62−3187 μg kg^{-1} in ME in moss *H. cupressiforme* while the range 610−1561 μg kg^{-1} in RS and 136−2269 μg kg^{-1} in ME characterised *S. girgensohnii*. Both moss species recognised the most polluted sites and those with the least PAH content in the air. Specifically, at the rural studied site (far away from any pollution source), the content of PAHs was substantially lower than at the urban sites, at the level of the initial PAH concentrations in the unexposed mosses. At the typical urban sites, the mosses were mostly enriched by Phen, Fl and Pyr, a low- and two medium-molecular-weight PAHs, respectively. This enrichment rate was followed by high-molecular-weight PAHs: B[k]F, B[a]P, I[cd]P, B[ghi]P, etc. The mentioned PAHs represent so-called combustion PAHs (∑COMPAHs), which represented about 70% of ∑PAHs in the moss samples. Markedly higher concentrations of medium- and high-molecular-weight PAHs in the moss samples could be attributable to both, meteorological conditions, and increased emissions from residential heating during the winter season. Thus far, the instrumental measurements for the studied period are available only for ME, and according to particulate matter (PM10), ∑PAHs and B[a]P measurements, the moss bag biomonitoring indicated the same order of air pollution at the studied sites.

To conclude, both moss species show sensitivity to air concentrations of PAHs. The mosses enriched their tissue with PAHs comparable to the air pollution level recorded by the instrumental measurements in ME, and prior knowledge about the site pollution in RS.

Keywords: PAH air pollution, moss bags, *Hypnum cupressiforme, Sphagnum girgensohnii*

AN EFFECTIVE TOOL FOR MONITORING THE DEPOSITION OF SURFACE DUST IN THE CROSS-BIO-INDICATION PROCESS OF METALS IN MOSS TISSUE

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Mosses have been used for biomonitoring in a number of different ways which may lead to rather different results, and some kind of classification seems necessary at this point. *Epigeic* mosses (growing on the ground) are preferred in the regional surveys in Europe. Trace elements may be absorbed on the moss from the atmosphere either as soluble chemical species in wet deposition or contained in particles from dry deposition. Part of the trace element content of particulates may eventually be released by weathering and reabsorbed by the moss. Whereas uptake efficiencies for particulate-bound trace elements are generally poorly known, Ions may be subject to active uptake into cells or attached on the moss surface by physical and chemical forces. Methods are available to distinguish between intracellular and surface-bound fractions of elements. Main problem with issue moss-biomonitoring are reveal as: a) transport of soluble compounds from the soil into moss tissue, particularly during periods withexcessive soil/water contact. Although mosses do not have a root system, influence from this source cannot be disregarded, in praticular in areas with low atmospheric deposition and b) windblown mineral dust from local soil. As far as the surface bound fraction is concerned, little is known about the binding mechanisms, but the fact that different metals show rather large differences in their retention capacitie, indicates that both simple cation exchange on negative surface charges and complex formation with ligands on the moss surface are involved. Laboratory analysis using scanning electron microscopy has been involved for determination of the dry deposition occurred within moss bioindicators. Moss surface screening can give us very useful information of the dust composition, and moss tissue accumulation of potentially toxic elements. Moss samples of *Hypnum cupressiforme* (Hedw.) and *Homalothecium lutescens* (Hedw.) were collected at the critical mining areas in the Eastern part of the Republic of North Macedonia (copper mine and Pb-Zn mine). Three sampling point were selected two critically affected and one control site. The scanning electron microscopy (SEM) was used for observation of specimen surfaces. Both types of moss, which have been proven to be effective bioindicators, were used in this study. But when examining large areas, it is necessary to use them alternately given their specific geographical distribution. Analyzes have shown that they have similar surface adsorption to dust particles, as well as insignificant variability in the chemical composition plant surface: extracted for the biogenic elements carbon and oxygen, macroelements Mg, Al, Si, K, Ca, and microelements Fe, Cu and Zn. Both moss species can be used interchangeable for dust deposition investigation.

Keywords: Moss bio-indication, *Homalothecium lutescens*, *Hypnum cupressiforme*, Toxic metals, Air deposition, SEM

ACCUMULATION OF PLATINUM ELEMENTS IN *TARAXACUM OFFICINALE* COLLECTED IN URBAN AREAS OF PRISTINA (KOSOVO) AND POZNAN (POLAND)

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Increasingly platinum elements are being used, among with their use their discharge in the environment is increasing. In the environment, the main anthropogenic sources of platinum group elements (PGEs) are automobile catalysts which they emit platinum elements during vehicle operation. Their emission can lead to elevated levels in environment; therefore, it is important to research numerous biological and environmental materials and their content. Frequently for such purposes, bioindicators are examined. Among bioindicators, dandelion (*Taraxacum officinale*) is very promising.
The aim of this research is to examine the common dandelion (*Taraxacum officinale*), as a biomonitor of platinum group elements and their amount of accumulation in Poznan (Poland) and Pristina (Kosovo) in various land use. The samples of dandelion (*Taraxacum officinale*) and soils were collected within 10 different research sites in Poznan and Pristina. Total concentrations of Pd, Pt, Ir, Rh, Ru and Os in the plant material and soils were determined.
Inductively coupled plasma optical emission spectrometry were used to determine the level of element determination and concentration. Furthermore, with the aim of statistical analyses were realized the relations between plant organs and research sites and differences in platinum element concentrations between the two cities. In Pristina, different land uses revealed higher concentration of platinum elements in comparison to Poznan. In Pristina near the lake and near airport, the highest level of platinum elements was observed, while in Poznan the highest accumulation of platinum elements were recorded near the train station. Analysis of spatial distribution revealed differences in Pristina and Poznan, which proposes dandelion as a suitable biomonitor of PGEs in the urban environment regarding the type of land use.

Keywords: PGEs, biomonitoring, *Taraxacum officinale*, urban areas, land use

REVIEW OF MOSS BIOMONITORING IN TURKEY

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Air pollution is one of the most significant problems in the world caused by the rapid increase of population, energy consumption and industrial activities due to major threats to human health and the environment. The distribution of airborne pollutants in ecosystems has been studied using by moss biomonitoring. Moss is a commonly used biological indicator that has many advantages for air pollution monitoring.

This study covers literature published between 1994 and 2019 to ascertain the status of the heavy metal and radioactivity biomonitoring with mosses in Black sea, Marmara, Aegean and Central Anatolia regions of Turkey. In these studies, many elements (Al, As, B, Ba, Ca, Cd, Fe, Co, Cr, Cu, Hg, K, Li, Mn, Na, Ni, P, Pb, Sb, Se, Sr, Mg, Ti, Zn) and natural and artificial radionuclides were determined by Atomic Absorption Spectrometry, Energy dispersive X-ray Fluorescence, Inductively Coupled Plasma Mass Spectrometry and Neutron Activation Analysis and alpha and gamma spectrometry, respectively. The results of these studies were evaluated and discussed across Turkey to indicate the major sources of pollution.

MONITORING ATMOSPHERIC DEPOSITION IN URBAN ENVIRONMENT – A MOSS-BAG APPROACH

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Abstract: A biomonitoring campaign with moss-bags was accomplished in the three largest cities of Bulgaria to study if the geography affects the urban air pollution.
Hypnum cupressiforme Hedw. was collected from a pristine background mountain area (41.6574, 24.7716, 1260 m a.s.l.). About 3 g of air-dried moss in nylon mesh (10×10 cm) were hung on holders at approximately 10 m above the street level. The moss-bags were exposed for 4 weeks in the city centers of Sofia (42.7001, 23.3363) and Plovdiv (42.1375, 24.7625) during 2019-2020, and Varna (43.2035, 27.8985) in 2020.
Sixteen macro- and microelements were determined by ICP-AES (Ca, Fe, K, Mg, Na) and by ICP-MS (Al, As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb and Zn).
After the exposition period a slight increase of the airborne pollutants was registered in all moss-bags with no statistical differences between the moss-bags and the background, except for Cd accumulated in the moss-bags located in Plovdiv (4 times higher). Moss-bags exposed in Varna were 4 times enriched in Na (335 mg/kg).
In general, urban air quality do not differ between the 3 studied cities despite their geographical specifics.
Comparison between 2019 and 2020, revealed that among macroelements, Ca, Fe, K, Mg had similar concentrations in moss-bags, while Mn had almost 2 times lower content in moss samples from 2020; in contrary Na had 2 times higher concentration during the second year in moss-bags exposed in Plovdiv. Aluminium, As, Co, Cr, Cu, Hg, Pb and Zn did not show different levels between the two years. Elements with elevated levels of accumulation in moss-bags during 2020 were Ni (2 times). Lower concentration after the exposition period in 2020 was registered for Cd (20 times in Sofia, above 2 times in Plovdiv).

Keywords: Airborne pollutants, Urban air pollution, *Hypnum cupressiforme*, moss, Bulgaria

Acknowledgements: This work was supported by the Bulgarian Ministry of Education and Science under the National Research Programme 'Young scientists and postdoctoral students' approved by DCM # 577 / 17.08.2018 and by the NPD – Plovdiv University 'Paisii Hilendarski' under Grant No FP19-BF-013, 'Live water, air and health with transplants – LIFE'.

PILOT STUDIES ON THE SUITABILITY OF BIOINDICATION WITH MOSSES FOR THE DETECTION OF ATMOSPHERIC DEPOSITION OF PERSISTENT ORGANIC POLLUTANTS AND MICROPLASTICS IN GERMANY: MEASUREMENT NETWORK PLANNING AND IMPLEMENTATION

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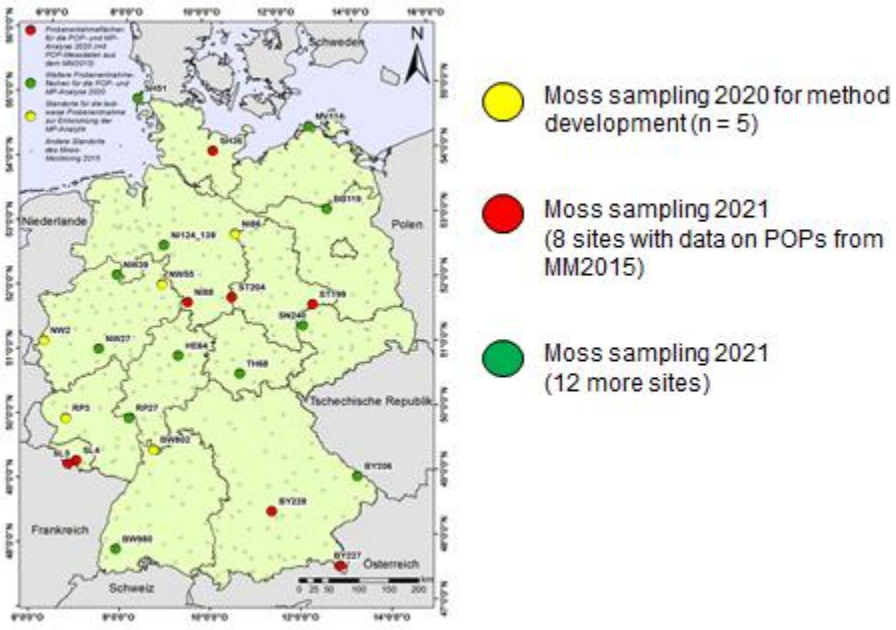
The studies funded by the Federal Environment Agency for the German Moss Survey 2020/2021 focus exclusively on persistent organic pollutants (POPs) and microplastics (MPs). These will be determined analytically in moss samples from 20 sites. Chemical and spectroscopic methods will be used for MP. In addition to this measurement program, the research participants will analyse the moss samples for heavy metals and nitrogen without financial support. For the chemical and spectroscopic analyses of moss specimens the eight sites where POPs were determined in MS2015 (Schröder et al. 2019) should be included in the MS2020/20221 monitoring network. In addition, twelve further sites should be selected from the pool of the total 400 sites of the MS2015. The criteria underlying the sample selection were as follows: Comparability with analyses from previous campaigns; Comparability with analyses from other environmental monitoring networks; Priority moss species: *Pleurozium schreberi*; Sufficient moss occurrence; Different ecosystem types; Different distances to potential emission sources; Different administrative spatial units; Spatial representation of ecoregions, land use, atmospheric deposition. Based on these criteria, a corresponding decision algorithm was developed and implemented in R. The parameters of the decision model were varied many times and the spatial distribution of the selected sampling sites was mapped in each case to support the decision. The final selected sites for the 2020/2021 MS are shown in **Figure 1**.

Figure 1. Sites for moss sampling 2020/2021 in Germany



References. Dreyer A et al. *Environ Sci Eur* 2018 30(43): 1-14; Schröder W et al. *UBA-Texte* 91/2019; Wosniok W et al. *Environ Sci Eur* 2020 32(9):1-14

STUDY OF AIR QUALITY BY MOSS BIOMONITORING AND TRACE ELEMENTS CONTENT

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Moss biomonitoring (*Hypnum cupressifforme (Hedw) sps.)* and metals atmospheric deposition were used to evaluate air quality in Albania. Metals concentrations were determined by different instrumental analysis. The elements considered in this study (As, Cd, Cr, Co, Cu, Fe, Hg, Pb, Ni, and Zn) are mostly affected by anthropogenic sources, derived by coal and metal mining, metal high temperature processing, smelting, vehicle emissions, fertilization and pesticide spraying, waste incineration etc. Data analysis and GIS maps made possible to identify the most polluted areas and trace metal pollution sources. The concentration data of the elements were standardized bringing the data at the same digits numbers, and are normalized to compensate the natural variability and to distinguish the anthropogenic contribution of the elements.

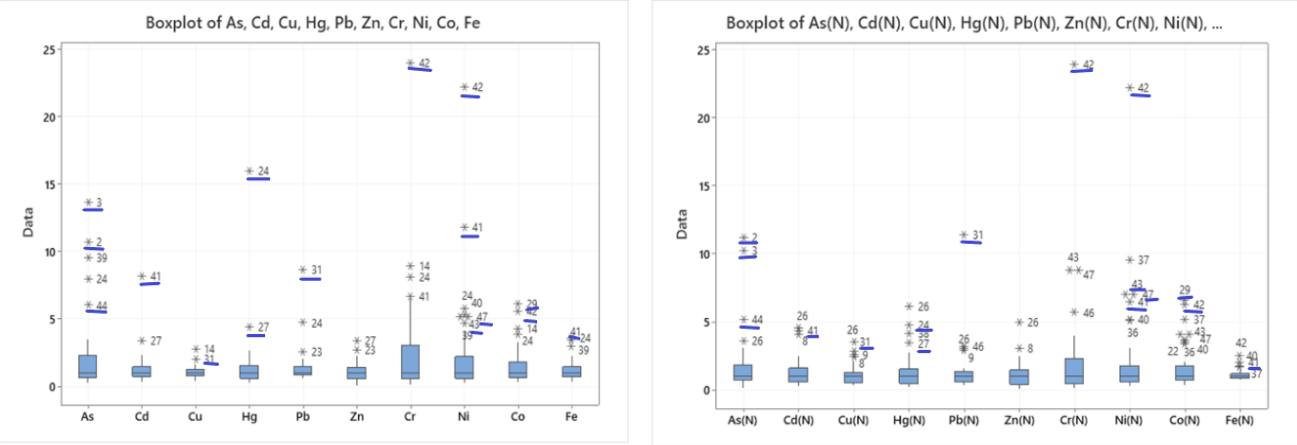

Figure 1 Boxplot diagram of concentration data and the normalized data

Table 1. The sites with high values of elements content

Location	Elements	Location	Elements	Location	Elements
Saranda, Borsh	As	Zogaj	Cu, Pb	Librazhd	Cd, Cr, Ni, Fe
Milot, Gramsh	Cu, Cr, Co	Pogradec	As, Fe, Ni	Bulqiza	Ni, Cr, Co, Fe
Peqin	Pb, Zn	Kruja	Cd, Hg, Zn, Cr	Burrel	Ni, Cr
Elbasan	As, Hg, Pb, Ni, Co, Cr, Fe	Rreshen	Co		

The original and the normalized concentration data were statistically processed to understand the variability in space, the relationship between the elements and under investigation. Significant variations were detected onto concentration data of the elements (except Cu, Fe and Zn). The normalization process of the original data of the elements indicates that the anthropogenic sources of Cr, Ni and Co are likely higher than their natural sources. The statistical associations of the elements, factor analysis and the inventory of emission sources made possible the identification of the sources of the elements under investigation.

Keywords: Air Quality, Moss Biomonitoring, Trace Metals Content, Statistical Analysis, Albania.

SPATIAL DISTRIBUTION OF PLATINUM GROUP ELEMENTS IN FRENCH MOSSES

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The sources of atmospheric emissions of platinum (Pt), palladium (Pd) and rhodium (Rh) are mainly anthropogenic and attributed to the transport sector. They have been steadily increasing since the 1980s, mainly due to the mandatory use of catalytic converters in many countries. Industry is also an important source of emissions.

Few data are available in France and in Europe on emissions' assessment, long-range transport and biological availability of Platinum Group Elements (PGEs) in the environment. The main objective of this study is to characterize PGEs (Pd, Pt and Rh) transport at more or less long distance from the emitting sources. To do this, we used the latest French moss survey. We analyzed our 445 moss samples collected in 2016 in rural and forested areas throughout metropolitan France. The 445 moss sampling sites were selected to be representative of the background level, i.e. a priori not subject to local sources of contamination. The moss samples are dehydrated, grinded, wet mineralized (HNO_3 / HF) and analyzed by ICP-MS.

Among the different sources of uncertainty related to the measurement of PGEs concentrations in mosses, we have quantified uncertainties related to the analysis, to the use of different species of mosses and to those related to the performance of the sample processing chain, from sampling to analysis.

The PGEs concentrations measured in the same moss sample provide different values for the 3 elements. Regardless of the sampling site, the Pd concentration is always higher than that measured for Pt and Rh. The concentration mapping shows more contaminated geographical areas in relation to 2 emitting sources: traffic and industry.

Table: Statistical description of the PGEs concentrations measured in 445 moss samples

	Pd (µg.g^{-1})	Pt (µg.g^{-1})	Rh (µg.g^{-1})	Pt/Pd	Rh/Pd	Pt/Rh
median	0.0120	0.0003	< 0.0002	0.029	0.018	2.125
minimum	0.0010	< 0.0002	< 0.0002	< 0.002	< 0.002	< 0.108
maximum	0.1330	0.0033	0.0036	0.508	0.633	> 10.800

The concentration values of PGEs measured in 2016 far from sources of contamination are significantly higher than those found in the literature in European rural areas, and in urban areas for some studies. The ratios between elements differ greatly from those found in the bibliography. These differences in ratios, particularly with regard to the year of the studies but also to distinct geographical areas, can be explained by changes in the composition of the catalytic converters, with in particular a replacement of Pt by Pd, a different composition of the fleet of light vehicles (petrol or diesel engines) or a change in industrial processes.

This study was funded by the French Agency for ecological transition.

RESULTS OF MOSS BIOMONITORING OF ATMOSPHERIC DEPOSITION IN LATVIA IN 2020

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The moss was applied as a bioindicator of air pollution deposition to differentiate various sources of the pollution and estimate the regional differences in the deposition of the atmosphere. The aim of this research was to describe the territorial distribution of emissions of heavy metals and to assess its changes over a five-year period in the entire territory of Latvia. In Latvia, the monitoring using moss has been conducted in six national surveys, in 1990 using *Hylocomium splendens* collected in 81 plots located in the entire territory of Latvia, and in 1995, 2000, 2005, 2015 and 2020 using *Pleurozium schreberi* in 101 plots. The transition from *H. splendens* to *P. schreberi* was necessary considering the wider distribution of the latter. In 1990 the moss was collected in various types of pines and mixed forests, while in 1995, 2000, 2005, 2015 and 2020 the sampling was conducted only in dominant pine stands.
All the sampling and analysing process strictly followed to the Monitoring Manual 2020 Survey of the ICP Vegetation. Total Cd, Cr, Cu, Fe, Ni, Pb, V, Zn were determined using a "Thermo Scientific" Inc. ICP-OES spectrometer "iCAP7000" and element concentration calculated in mg/kg. Moss standards M2 and M3 were included in the analysis.
Concentrations of the heavy metals compared with those obtained from the previous surveys. The dominant anthropogenic impact of air pollutants of heavy metals in Latvia explained by industrial activity and transport.

PREDICTION OF AIR POLLUTION BY POTENTIALLY TOXIC ELEMENTS BY COMBINING SATELLITE IMAGERY, MOSS BIOMONITORING DATA AND MACHINE LEARNING: LIMITATION AND PERSPECTIVES

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Air pollution has a significant impact on human and environmental health. Regulatory monitoring of air pollution by potentially toxic elements (PTEs) is not implemented with a satisfactory resolution of measurements. The challenge is to introduce new methodologies for assessing air pollution and their complementary applications. Modeling of air pollution can be a good option for overcoming gaps in the data gathering, while moss bag biomonitoring has been recognized as a technique for highly spatially resolved measurements of PTE air pollution. In the latest study, the combination of satellite data, biomonitoring measurements, and statistical models was used to predict PTE air pollution in urban area of Belgrade. Moss bag biomonitoring data, provided from 137 sampling sites across the city during the summer of 2013 and data from several satellite programs used to predict the PTE air pollution in the following winter season (2013/2014) and the summer of 2018 by machine learning techniques. The model showed qualitative prediction performance of $R2 = 0.79$.
The perspectives of expansion of our approach to the global scale to create models that will be able to predict PTE air pollution for most of the ICP Vegetation countries will be presented.

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PILOT STUDIES ON THE SUITABILITY OF BIOINDICATION WITH MOSSES FOR THE DETECTION OF ATMOSPHERIC DEPOSITION OF PERSISTENT ORGANIC POLLUTANTS AND MICROPLASTICS IN GERMANY: METHOD DEVELOPMENT, SAMLPLE PREPARATION, AND PRELIMINARY INVESTIGATION ON MICROPLASTICS

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Mosses were and are applied as biomonitors, mainly for nitrogen and heavy metals (Schröder 2019) and although less often, for organic contaminants (Dreyer et al 2018). Whether they can also be used as biomonitors for micro-plastics is still unknown/unclear.

Microplastic have been defined as plastic particles smaller than 5 mm (Arthur et al. 2009). Research on microplastic have shown, that it can be found in all environmental compartments (Möller et al. 2020), whereas the data base for aquatic systems being the largest, followed by soils and air.

In this study, founded by the german environmental agency, it will be tested if mosses can be used for the detection of atmospheric deposition of micro-plastic.

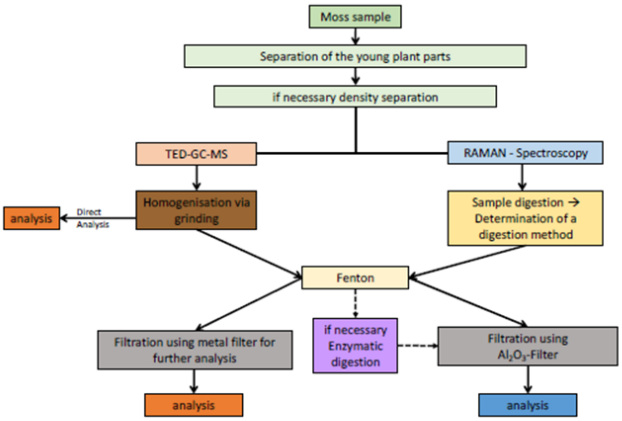

Figure 1: Sample preparation steps

Therefore, a method for sample preparation, identification and quantification using TED-GC-MS and RAMAN spectroscopy is under development (Figure 1). First samples from the German Moss Survey 2020/2021 will be used for validation and to get a first impression on the suitability. Concerning POPs, the suitability of mosses as bioindicators are going to be re-evaluated after the first investigating during the pilot study in the moss monitoring 2015. A flotation device to separate the moss and plastic particles was developed and preliminary tests were conducted. For these tests moss samples were spiked with PMMA (50 µm) particles. After the separation procedure, first qualitative SEM images show a good separation between the moss sample and the spiked PMMA particles (Figure 2). These qualitative results must be validated by quantitative measurements and with further polymer particles and environmental samples.

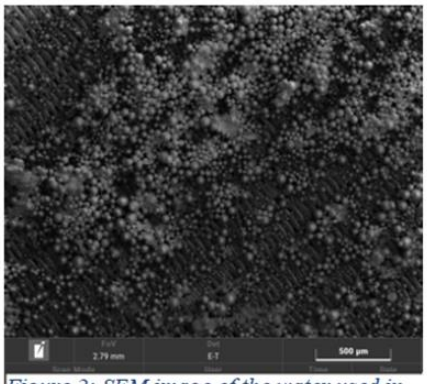

Figure 2: SEM image of the water used in the flotation device. The samples were filtered on a metal mesh.

Schröder W., Nickel S. Environ Sci Eur 2019 31(33): 1-15; Dreyer et al. *Environ Sci Eur* 2018 30(43): 1-14; Arthur et al. *NOOA Technical Memorandum NOS-OR&R-30*: Tacoma, WA, 2009; Möller et al., *Environ Sci Technol* 2020 54(4): 2078–2090

MOSSES AS BIOINDICATORS OF HEAVY METAL AIR POLLUTION IN THE LOCKDOWN PERIOD ADOPTED TO COPE WITH THE COVID-19 PANDEMIC

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The coronavirus disease, COVID-19, has had a great negative impact on human health and economies all over the world. To prevent the spread of infection in many countries, including the Russian Federation, public life was restricted. To assess the impact of the taken actions on air quality in the Moscow region, in June 2020, mosses *Pleurosium shreberi* were collected at 19 sites considered as polluted in the territory of the region based on the results of the previous moss surveys. The content of Cd, Cr, Cu, Fe, Ni, and Pb in the moss samples was determined using atomic absorption spectrometry. The obtained values were compared with the data from the moss survey performed in June 2019 at the same sampling sites. Compared to 2019 data, the Cd content in moss samples decreased by 2–46%, while the iron content increased by 3–127%. The content of Cu, Ni, and Pb in mosses decreased at most sampling sites, except for the western part of the Moscow region, where a considerable number of engineering and metal processing plants operate. The stay-at-home order issued in the Moscow region resulted in a reduction of vehicle emissions affecting air quality, while the negative impact of the industrial sector remained at the level of 2019 or even increased.

OZONE POSTERS

CHARACTERIZING SUBARCTIC BIOMES FOR LAND SURFACE MODELING OF POLLUTION AND CLIMATE RISK

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Here we assess the importance of characterization of key meteorological variables and air pollution profiles on the modeled susceptibility of subarctic vegetation to ozone. Changes in climate (e.g. temperature, water availability) will manifest in both direct and indirect effects influencing the species' sensitivity to air pollution. A likely increase in frequency of persistent heatwaves in the future, will inflict heat related stress while generating favorable conditions for the formation of ambient air ozone, e.g. due to wildfires.

We have monitored ambient air ozone concentrations at the Norwegian Institute of Bioeconomy Research (NIBIO) Environment Centre Svanhovd in Northern Norway in the vegetation period 2018/19. Due to data acquisition problems, ozone concentrations for two weeks in July 2018 were missing from our record. We present a reconstruction based on probability density function with respect to the Swedish and Finnish atmospheric monitoring sites and compare with available surface ozone products for the region. Over all, ozone concentrations did not differ significantly between the two years. While temperatures and global irradiance diverged substantially from the multi annual mean precipitation varied only to some extend.

We investigate the difference in uptake of ozone using the DO3SE model, for typical vegetation at the location. We find that bespoke parameterization for subarctic vegetation is essential for an accurate estimation of Phototoxic Ozone Dose (POD) and an assessment of damage risk. Accurate estimates of the start and length of growing season are also crucial.

We find that temperature and its derivative vapor pressure deficit are likely the most important climate variables while the variability of ozone concentration within climatologically reasonable limits plays a minor role.

The use of subarctic parameterization suggests an improvement in risk assessment as POD values are increased in 2018; corroborated by evidence of visible injury in the Svanhovd ozone garden.

EVIDENCE OF OZONE-INDUCED VISIBLE FOLIAR INJURY IN HONG KONG USING PHASEOLUS VULGARIS AS A BIOINDICATOR

Felix Leung, Amos P. K. Tai, Jacky Y. S. Pang, Timothy Lam, Donald K. C. Tao, Katrina Sharps

The Chinese University of Hong Kong, Hong Kong and felix.leung@cuhk.edu.hk

Hong Kong is one of the most densely populated cities in the world, with millions of people exposed to severe air pollution. Surface ozone, mostly produced photochemically from anthropogenic precursor gases, is harmful to both humans and vegetation. The phytotoxicity of ozone has been shown to damage plant photosynthesis, induce early leaf death, and retard growth.

We use genotypes of bush bean *Phaseolus vulgaris* with various degrees of sensitivity to ozone to investigate the impacts of ambient ozone on the morphology and development of the beans. We use ozone-induced foliar injury index and measure the flowering and fruit production to quantify the ozone stress on the plants.

We expected that the ozone-sensitive genotype would suffer from a reduction of yield. Results, however, show that the ozone-sensitive genotype suffers higher ozone-induced foliar damage as expected but produces more pods and beans and heavier beans than the ozone-resistant genotype.

It is postulated that the high ozone sensitivity of the sensitive genotype causes stress-induced flowering, and therefore results in higher bean yield. A higher than ambient concentration of ozone is needed to negatively impact the yield production of the ozone-sensitive genotype. Meanwhile, ozone-induced foliar damage shows a graduated scale of damage pattern that can be useful for indicating ozone levels. This study demonstrates the usefulness of bioindicators to monitor the phytotoxic effects of ozone pollution in a subtropical city such as Hong Kong.

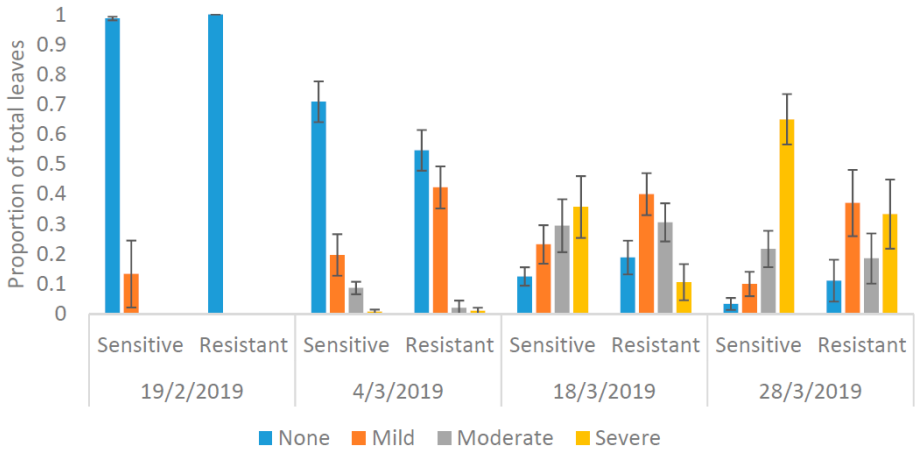

Figure 1. Average proportion of the total number of leaves per genotype showing leaf injury due to O_3 damage in Phaseolus vulgaris. None is no O_3 injury, mild is <5% injury, moderate is 5% to 25% injury, and severe is >25% injury. Standard error is shown.

RESPONSE OF GAS EXCHANGE, BIOMASS AND NONSTRUCTURAL CARBOHYDRATES ALLOCATION IN INDOCALAMUS DECORUS TO EXPERIMENTAL ATMOSPHERIC OZONE ENRICHMENT IN A SURBURB OF BEIJING, CHINA

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To determine the effects of O_3 on non-structural carbohydrate (NSC) concentrations and allocations in different bamboo organs, four-years old dwarf bamboo (*Indocalamus decorus*) was exposed to three O_3 concentrations (Ambient-AA, AA+70ppb O_3 and AA+140 ppb O_3) for one growing season by using open-top chambers in Beijing,China. Gas exchange, biomass, soluble sugar, starch and NSC contents were all investigated. The results indicated that: 1. The foliar injury symptom of *Indocalamus decorus* appeared when AOT40 was 52.26 $mmol.h^{-1}$ in AA+140 and 62.76 $mmol.h^{-1}$ in AA+70 with yellow, dotted, chlorotic stippling, reddening on the interveinal areas of upper leaf surfaces 2. Pn declined was induced by non stomatal limitation and the , new rhizome performed the most serious biomass reduction by 47.57% in AA+70 and 61.09% in AA+140, but aboveground biomass were not affected. 3. Contrary to rhizome and leaf, the soluble sugar and NSC contents of rhizome buds were increased 36.84% and 44.99% in AA+70 and AA+140 while starch in rhizome contents declined significantly. In conclusion, although photosynthesis, growth and total biomass were restrained when growing under elevated O_3, *Indocalamus decorus might* allocated more NSC from new rhizome to new buds for ensuring the regeneration growth as high priority.

DIURNAL VARIATIONS IN PHYSIOLOGICAL CHARACTERISTICS, PHOTO ASSIMILATES, AND TOTAL ASCORBATE IN EARLY AND LATE SOWN INDIAN WHEAT CULTIVARS UNDER EXPOSURE TO ELEVATED OZONE

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Early and late sown wheat (*Triticum aestivum* L.) cultivars, grown under ambient (AO_3) and elevated ozone (EO_3) treatments in open top chambers (OTCs), were investigated to understand the changes in diurnal pattern of gaseous exchange, chlorophyll fluorescence, carbohydrates and ascorbic acid in flag leaves. Results showed that the stomatal fluxes of O_3 were highest during midday in all test cultivars under AO_3 and EO_3 treatments. All the test cultivars of wheat showed maximum physiological activities during late morning under both AO_3 and EO_3 treatments. Higher reduction in photosynthetic rate was observed in early sown (ranging from 12 to 30%) than late sown cultivars (9 to 18%) under EO_3. The lowest photochemical efficiency was found around 14 h (under natural high light intensity) in all the cultivars under both treatments. Elevated O_3 reduced the photochemical quenching and induced the non-photochemical quenching which showed diurnal fluctuations among the cultivars. In early sown cultivars, relatively greater reduction (11 to 25%) in sucrose content was observed than late sown cultivars (3 to 20%) under EO_3 treatment. The starch content was progressively increased from morning to afternoon in all cultivars under both the treatments. Ascorbic acid content in early sown cultivars was increased maximally by 29% during the late morning, while an increase of 10% was observed in late sown cultivars during the early morning under EO_3. The present study suggested that elevated O_3 concentration caused more negative effects on photosystem II in early sown compared to late sown cultivars. The greater loss of photosynthesis led to lower levels of photo-assimilates in early sown cultivars, which also utilized more assimilates in ascorbic acid formation for detoxification of excess O_3 molecules inside the leaf.

Keywords: ascorbic acid content; chlorophyll fluorescence; photo-assimilates; photosynthesis; ozone; wheat cultivars

MATERNAL OZONE INCREASES SURVIVAL OF THE PROGENY DEPENDING ON PLANT SYMBIOTIC STATUS AND CURRENT ENVIRONMENTAL CONDITION

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Ground-level ozone (O_3) is a secondary pollutant that results from anthropogenic activities. Due to its high phytotoxicity, the gas impairs plant growth and yield. Plants can increase performance under stress through associations with beneficial microorganisms. While research has commonly focused on the impact of O_3 on aspects of plant performance, little is known about its transgenerational effects. Since certain endophytic fungi are inherited by growing hyphae in seeds (vertical transmission), we proposed they play a role in linking environmentally induced maternal plant phenotypes with that of the progeny (i.e. transgenerational effects). Here, we used the symbiosis between the annual grass *Lolium multiflorum* and its common *Epichloë* fungal endophyte as study model to test for the transgenerational effect of ozone on the progeny. We exposed symbiotic and non-symbiotic plants to low (≈0ppb) and high (≈130ppb) ozone levels, and evaluated the survival of the progeny at two stages (seedling and young plant) under both ozone levels. Overall, progeny plants with history of high ozone displayed higher oxidative damage and level of proline (a stress-protective metabolite) than plants with history of low ozone exposure. However, symbiotic plants showed lower biochemical disruption than non-symbiotic plants. Transgenerational ozone did not drive variation in biomass of the progeny in any of the stages. No deleterious effects were observed of maternal ozone on the survival of the progeny. On the contrary, it had an overall positive effect on seedling and young plant survival. At seedling stage, symbiosis with fungal endophytes increased survival irrespective of the current ozone level. Maternal ozone increased survival on both endophyte-symbiotic and non-symbiotic young plants but only under high ozone level. Our work shows that ozone-induced transgenerational effects on plant survival are not straightforward and may depend on the symbiotic state with microorganisms and the current condition of stress. Thus, vertically-transmitted microorganisms may play an important role in modulating the capacity of plants to transgenerationally adjust the progeny phenotype to air pollutants in the context of global change.

MOSS SURVEY POSTERS

TEMPORAL TREND OF SEA SPRAY ELEMENTS IN TWO DIFFERENT PERIODS SURVEY 2010 AND 2015 IN ALBANIA BY MOSS SAMPLES GROWING IN NATURAL CONDITION

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In the framework of the International Cooperative Program on Effects of Air Pollution on Natural Vegetation and Crops (UNECE ICP Vegetation), the second moss survey was performed at 2015 in the Albanian region at 55 sites. Previous moss survey was conducted in 2010 at 47 sites throughout Albanian. The sea spray elements (Ca, K, Mg, Na and Mn) under investigation were determined by using ICP-AES analytical technique performed in *the Institute of Chemistry, Faculty of Science, Sts. Cyril and Methodius University, Skopje, North Macedonia,* in both periods survey. Moss species *Hypnum cupressiforme* was used as bioindicators in 2010 and 2015. The goal of the present study was to compare obtained data of sea spray elements in two monitoring periods.
The 2015 and 2010 atmospheric moss survey concentration data were statistically tested for significant differences by applying descriptive statistics and Mann-Whitney Test ($\alpha = 0.05$).
Table 1. Descriptive statistics of concentration level of Ca, K, Mg, Na and Mn in two monitoring moss survey

Elements	Albania 2015, n=55		Albania 2010, n=47	
	Median	**Range**	**Median**	**Range**
Ca	6509	3543-11188	6532	4859-12433
K	2577	1435-5824	2973	1831-10043
Mg	1550	910-2970	2878	1161-5152
Na	114	76-297	87	28-338
Mn	63.2	25-244	56	22-284

The order of sea spray elements in moss samples was the same in two periods (Ca>K> Mg> Na > Mn). No significant differences ($\alpha < 0.05$) were found between 2010 and 2015 moss elements median concentration of Ca, and Mn. The content of these elements was likely stable for both moss monitoring periods. Significant differences ($\alpha > 0.05$) were found between median concentration of K, Mg and Na in moss samples collected on 2010 and 2015.
Those differences in metal concentrations in mosses between years may partly be affected by variations on meteorology, affecting for example the amount of dry and wet deposition. To minimize effects of meteorological variability on deposition rates of metals in wet and dry conditions, sampling should be conducted, as far as possible, in similar climatic conditions each survey year.

ATMOSPHERIC DEPOSITION OF HEAVY METALS IN SLOVAKIA

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The representative moss samples for the last completed Survey 2015/16 were collected on 68 sampling plots. The network of moss monitoring plots has been developed since 1990 in a design to cover the whole SK territory in a grid of 16×16 km. In the current Survey 2020/21 were collected mosses on 58 sampling plots so far. The collection will be continued.
Mosses collected in the last Survey were analysed in Joint Institute for Nuclear Research in Dubna, Russia by INAA method and in National Forest Centre in Zvolen, Slovakia were analysed N by EA method, Cu, Cd, Pb by ETA AS method.
In the last Survey was detected high mean value of nitrogen deposition (20,7 g/kg) in the territory of SK ranging from 8,52 to 39,6 g/kg. Increased depositions of mainly reactive nitrogen compounds cause ecosystem eutrophication and may cause loss of sensitive species and disrupt ecological stability.

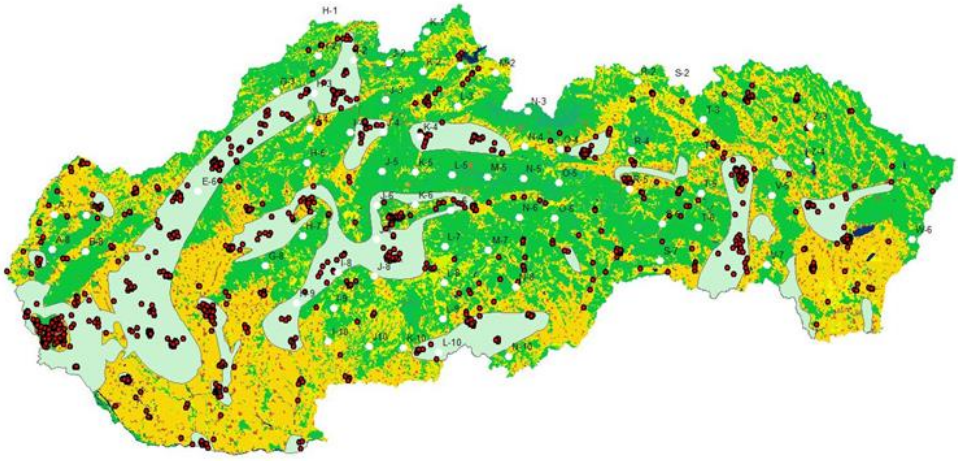

Fig. 1: Map with sources of pollution (red), areas with high pollution (blue) and sampling points (white).

In Slovakia many pollution sources are overlapping (fig.1). Among the most significant anthropogenic sources belong power stations located in the Upper Nitra and Vojany. Metallurgy, nonferrous ores processing and cement factories located in Central Spiš, Central Pohronie, in the area of Rožňava, and Lower Orava. Dumps of stone chips, manufacture of basic metals and fabricated metal product, chemical and military products located in Snina, Strážske, Stropkov, Volovské Mts., Kremnické Mts. and Štiavnické Mts. Aluminium factories located in the area of Žiar nad Hronom. Since 2000 has decreased the concentration of Cd, Cr, Fe, Ni, Zn, V, Al and increased Cu (tab.1).

Tab. 1: Concentrations of heavy metals in mosses in 2000 and 2015.

Median [mg/kg]								
Years	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Zn**	**V**	**Al**
2000	0,60	6,50	9,00	1560,00	3,20	50,00	5,60	3817,78
2015	0,30	3,81	10,81	858,59	2,78	47,24	2,03	1036,84

CAN *Hypnum cupressiforme* BE EASILY FOUND WITHIN URBAN AREAS? – A CASE STUDY IN SERBIA

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Passive biomonitoring of air quality using pleurocarpous bryophytes is well established in Europe, and implemented in heavy metal surveys within ICP Vegetation Programme. According to the monitoring manual, the sampling sites are representatives of non-urban areas. But, what about urban areas? Large cities in Serbia have developed good air pollution monitoring, but it is hard to establish an instrumental monitoring network with high resolution. The major problem of passive biomonitoring in urban areas is lack of recommended bryophyte species due to their vanishing from these sites. On the contrary, urbanization creates preconditions for the existence of specific microhabitats, which can be inhabited by bryophytes (Sabovljević and Grdović, 2009; Skudnik et al. 2013). Bryophytes can be abundant in urban areas due to the absence of competitively superior vascular plants (Sabovljević and Grdović, 2009).

In this research we wanted to answer to the following question: Whether recommended bryophyte species can be easily found in urban areas (towns and villages)? The following species were object of our interest: *Hypnum cupressiforme, Hylocomium splendens, Pleurozium schreberi, Pseudoscleropodium purum, Abietinella abietina, Homalothecium lutescens, Homalothecium sericem* within 34 urban sites (towns and villages) of Fruška gora Mountain (Northern Serbia).

H. splendens and *P. schreberi* were not recorded at any of the investigated sites. This is not surprising since these species prefers coniferous forests or very humid, swampy habitats. The most common species was *H. cupressiforme*. and it was present at 18 sites. The fact that this species can be frequently found in investigated sites is a good starting point for its usage in passive biomonitoring of air pollution within urban areas. The absence of this species from remaining sites was probably influenced by various human activities and urbanization. Additionally, *P. purum*, *A. abietina* and *H. sericeum* were found on 2, while *H. lutescens* on 3 sites.

Our findings showed that one of the recommended species can be found in majority of urban sites, therefore it can serve as biomonitor of air pollution within these areas. However, the question that arises is how the lacking of this species can be overcome. Several studies showed that active moss biomonitoring ("moss bag" technique) can serve as a good alternative for such obstacles (Vuković & Aničić Urošević, 2017).

To conclude, pleurocarpous bryophytes can be found within urban areas. For sure, researches on these species within large cities are still necessary.

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FEATURES OF THE TRACE ELEMENT COMPOSITION OF BRYOPHYTES IN COASTAL LANDSCAPES (SOUTHERN CURONIAN SPIT, RUSSIA)

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The features of the element's accumulation in mosses (Fe, Mn, Ni, Zn, Sr, Rb, Br and Ca) are listed in relation to some natural landscapes in the Curonian Spit (Baltic Sea coast). Coastal marine ecosystems are transformed by natural and anthropogenic processes, which cause variations in the content of trace elements in the bryophytes. To identify the features of elements accumulation in various ecosystems in southern part of the Curonian Spit (Russian sector), two plots were selected. Three biotopes were allocated on each plot. These are a green moss pine forest, an alder carr, a raised bog at the root of the spit. In the second plot, a green moss pine forest, a wet alder forest, and a dry grassland on an open slope of the foredune were studied. The species composition of mosses includes the taxa: *Brachythecium rutabulum, Bryum argenteum (mixed), Brachythecium albicans. Ceratodon purpureus, Dicranum polysetum, Hylocomium splendens, Hypnum cupressiforme, Leucobryum glaucum, Mnium hornum, Plagiomnium undulatum, Plagiomnium affine, Pleurozium schreberi, Pseudoscleropodium purum, Polytrichum formosum, Sphagnum magellanicum, Sphagnum rubellum, Sphagnum cuspidatum, Sphagnum palustre. Syntrichia ruralis, Rhytidiadelphus triquetrus.*
The X-ray fluorescence spectrometry was used to determine the trace element composition in specimens of mosses. The results were processed by descriptive statistics using correlation analysis and principal component analysis (PCA). Spatial differences of microelements accumulation by mosses of biotopes are established. Mosses have a pronounced affinity for certain elements: manganese accumulation is typical for pine forests; nickel, strontium and iron are for the foredune; and rubidium is for the raised bog. Correlation dependencies and PCA are supposedly associated with the effect of wind transport, marine aerosol and leaching processes from plant residues.

COMPARISON OF RARE EARTH ELEMENTS CONTENT IN *TARAXACUM OFFICINALE* COLLECTED IN URBAN AREAS OF POZNAN (POLAND) AND BRNO (CZECH REPUBLIC)

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Rare earth elements (REEs) are one of the most important parts of modern technology and their concentration in the environment has increased recently. However, publications have indicated different levels of REEs accumulation. So far, there is no limit to these elements in the components of the environment, so it is important to monitor their concentration and understand the relationship between the accumulation of REEs and human activities, in particular in urban areas. The aim of the presented study was to compare rare earth elements content in dandelion (*Taraxacum officinale*) and soils collected from urban areas of Poznan (Poland) and Brno (Czech Republic).

The sampling period was 10-20 May 2018, when the weather conditions were similar for both cities. The samples of soils, roots and leaves were collected in each city from 10 research sites. The sites were selected nearby typical facilities for cities, such as: residential areas, roads, parks. All elements were analysed by inductively coupled plasma optical emission spectrometry followed by microwave-assisted sample digestion by concentrated nitric acid. The statistical analyses were performed to identify relations between plant organs and sites.

The REEs content in *Taraxacum officinale* and soil was varied in the cities. The differences in the spatial distribution of REEs were also observed in particular cities. In both cities, the higher content of REEs were found in soils than in plant organs. In Brno, the REEs level in soils was twice as high as in Poznan. In both cities, the highest value for the soil was found near the lake. In Poznan, the highest concentration of REEs in roots was noted near the highway while in Brno near the river. In Poznan the highest level of REEs in leaves was noted in low-density housing areas while in Brno near old-town. In both cities, the HREEs content was lower than the LREE content. The highest concentration of LREEs was noticed in low-density housing areas in Poznan and near the old-town in Brno. For HREEs, the highest values were also observed at the same research sites.

Variability of REEs (LREEs and HREEs) content in *Taraxacum officinale* organs and soils was found. The higher level of REEs for both cities was recorded in soils which are influenced by land use and anthropogenic factors. In the future, it is necessary to create maps of analysis detailed factors which can influence REEs content.

MOSS BIOMONITORING OF AIR POLLUTION WITH HEAVY METALS AND RADIONUCLIDES

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Content of heavy metals and radionuclides in mosses provide valuable information for the monitoring of air pollution. Mosses, soil and water in Dashkesen, Mingechaur and Sumgait cities of the Azerbaijan Republic were studied to identify the bioindicator properties of mosses. The concentrations of heavy metals and activity of radionuclides in samples were determined.

Concentrations of heavy metals were defined on an Agilent Technologies 7500 Series ICP-MS (7500cx) instrument, using inductively coupled plasma mass spectrometry (ICP-MS, USA). The analyzed tests allowed us to define content of Cr, Fe, Mn, Cu, Zn, Cd, Ba, Pb, Ni, Hg in the composition of investigated samples.

The activity of radionuclides in the tests of moss, soil and water was carried out at "Canberra" (USA) γ-spectrometer with germanium detector (HP Ge). It was determined the activity of radionuclides ^{7}Be, ^{40}K, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{214}Bi, ^{212}Bi, ^{212}Pb in the samples.

It was defined, that the content of Cr, Mn and Fe in samples of mosses and soil, collected from Dashkesen were more than in Mingechaur and Sumgait. Content of Cu, Zn,Cd, Ba, Pb, Hg, Ni in samples of mosses and soil, collected from Mingechaur and Sumgait were more than in Dashkesen. It was revealed, that the activity of ^{40}K was more than other isotopes. On the other hand it was found out that ^{7}Be, ^{214}Pb, ^{214}Bi, ^{137}Cs, ^{134}Cs, ^{60}Co were more in Mingechaur region than in Sumgait and Dashkesen (Table 1).

Table 1. Activity of radionuclides in the studied samples collected from the most polluted area near the city of Dashkesen, Mingechaur, Sumgait.

Elements, Bq/kg / Mosses	^{7}Be	^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{214}Bi	^{212}Pb
Dashkesen	78.4	512.1	11.4	16.3	11.5	15.2	50.2
Mingechaur	89.6	673.2	15.4	19.1	12.6	18.2	52.6
Sumgait	81.7	562,3	13.6	18.2	12.1	17.8	51.4

Keywords: Mosses, bioindicators, air pollution, heavy metals, radionuclides.

USING OF MOSSES *HYLOCOMIUM SPLENDENS* AND *PLEUROZIUM SCHREBERI* FOR ASSESSMENT OF ATMOSPHERIC DEPOSITION OF PAH IN THE KALININGRAD REGION

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Mosses are natural bioaccumulators and can be used as biomonitors to assess ambient air pollution. Their prevalence makes them an accessible material for analysis. In the Kaliningrad region, the "moss technique" has been used to study the atmospheric deposition of heavy metals since 1995, and in 2017, this technique was used to study the transport and deposition of PAHs. Pleurocarpic mosses: *Hylocomium splendens* (Hedw.) Schimp and *Pleurozium schreberi* (Brid.) Mitt were chosen as PAH indicators.
Objective of work - spatial assessment of atmospheric deposition of PAHs by brioindication method on the example of the Kaliningrad region.
In the territory of the region six sites in the direction of the influence of prevailing wind directions from west to east, from the coast of the Baltic Sea to the borders with Lithuania and Poland were laid during the period from 2017 to 2019. The first one is in the western part of the region, on the Baltic Sea coast (landmark Yantarny); the second one is in the central part of the region at the same latitude as the first point (landmark Gvardeisk); the third point is the north-east of the region (landmark Krasnoznamensk); the fourth point is the south-east of the region (landmark Lake Vishtynetskoye), the fifth and sixth points are the Baltic and Curonian Spit respectively.
Sampling of mosses was carried out according to the recommendations of the international program ICP Vegetation. The sample preparation process consists of the traditional Soxhlet extraction method, concentrating the extract on a rotary evaporator with subsequent purification on an adsorbent column or on an SPE C18 cartridge. Analytical determination of PAHs was performed using an Agilent 1260 high-performance liquid chromatograph with a fluorimetric detector and an AgilentOpenLAB CDS ChemStation data processing system.
The carcinogenic activity is determined by the toxicity index. Benzo(a)pyrene was taken as a reference compound whose value was taken as 1, and the carcinogenicity of other compounds was calculated relative to it. In the work, a toxicity index was found for each type of indicator and a hazard coefficient associated with it, considering the concentration of each pollutant. According to the results of the study, the total hazard coefficient of the considered indicators turned out to be the maximum for the Baltic Spit and was 22,55. At the same time the lowest level of atmospheric air pollution is observed for Gvardeysky forest, the total coefficient of PAH is 12,89. However, high values of total PAH content in the samples are typical for the eastern part of the region. The trend is traced towards an increase in the ΣPAH content to the east, in accordance with the southwestern transport characteristic of the region.

ATMOSPHERIC METAL LOAD BY MOSSES DURING PRE-LOCKDOWN AND LOCKDOWN PANDEMIC PERIOD.

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The authors demonstrate a possible relationship between metals accumulated in mosses and their presence in the environment. This is possible as the characteristic of mosses meets the specifications required for biomonitoring of atmospheric metals. The advantages of using biological monitor are that they do not require expansive instruments, manpower and power supply.

The present study aims to measure the changes in atmospheric metal load using moss analysis during the two phases of the COVID-19 pandemic (pre-lockdown and lockdown period) and to establish their relationship to the environment. The study is based on an average metal load measured from moss samples. *Brachythecium kamounense* and *Isopterigum elegans* were harvested from study areas during two different time periods. As routine moss samples were transplanted for monitoring of atmospheric metals in the first and last week of March 2020, a nationwide lockdown was declared by the Government of India due to the pandemic. The exposed moss transplants were harvested in August 2020 and were transported to the lab for metal analysis from two cities, Nainital & Almora. The metal data obtained from the analysis of these moss samples belonged to lockdown duration which were compared with moss transplants already analyzed from pre-lockdown periods of March 2019 to August 2019. The study revealed that the metal level dropped sharply immediately after the lockdown and the concentration of pollutants touched the saturation level within a few days, beyond which probably further decline was not possible. A drastic fall in metal accumulation in moss samples measured during the complete lockdown period could be due to a very minimal or no vehicular movement, halted operations of the factories and construction sites which led to a shutdown of the major polluting sources. The study confirms the application of mosses for the monitoring. The results further strengthens the study proving that mosses as a biological monitor of atmospheric metals appears to be an adequate method for monitoring of atmospheric metals.

Figure 1. Nainital's metal load in pre-lockdown (2019) and lockdown (2020).

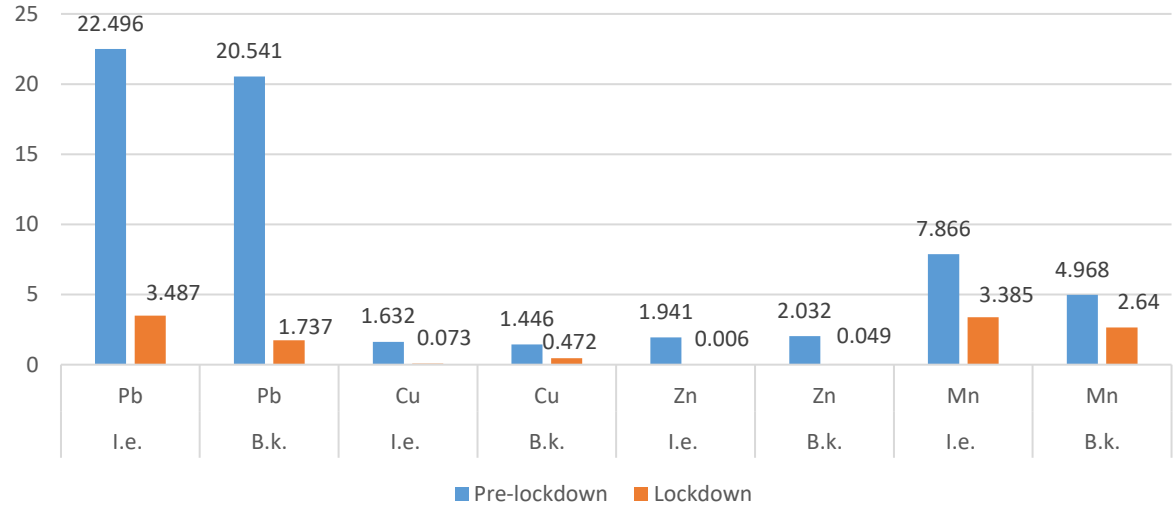
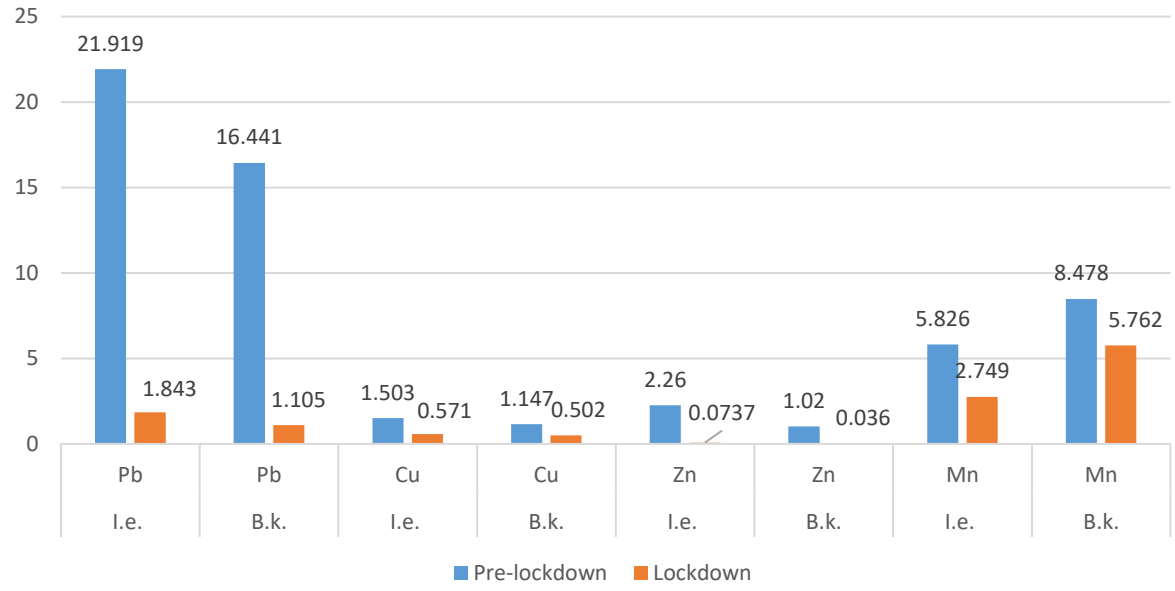


Figure 2. Almora's metal load in pre-lockdown (2019) and lockdown (2020).



TRENDS OF ATMOSPHERIC MERCURY DEPOSITION IN MACEDONIA FROM 2002 TO 2015 USING THE MOSS BIOMONITORING TECHNIQUE

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The moss biomonitoring technique was used in 2002, 2005, 2010 and 2015 in a potentially toxic elements study (PTEs) in Macedonia. For that purpose, more than 70 moss samples from two dominant species (*Hypnum cupressiforme* and *Homalothecium lutescens*) were collected during the summers of the mentioned years. Total digestion of the samples was done using a microwave digestion system, whilst mercury was analyzed by cold vapour atomic absorption spectrometry (CV–AAS). Analysis of the median values shows the increase of the content in the period 2002–2010 and a slight reduction of the air pollution with Hg in the period 2010–2015. Mercury distribution maps show that sites with increased concentrations of mercury in moss are likely impacted by anthropogenic pollution. The results were compared to similar studies done during the same years in neighboring countries and in Norway—which is a pristine area and serves as a reference, and it was concluded that mercury air pollution in Macedonia is significant primarily in industrialized regions.

MOSS SURVEYS IN ROMANIA: 2010/2011, 2015/2016, 2020/2022. RESULTS AND PERSPECTIVES

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In Romania, several nationwide atmospheric deposition surveys for trace metals based on sampling on the terrestrial mosses have been conducted at regular intervals since 2010, when researchers from Targoviste, Galati, Iasi and Baia Mare universities joined the European Moss Survey conducted within the framework of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops.

The moss surveys undertaken in 2010/2011 and 2015/2016 campaigns comprised 303 and 214 sampling sites, respectively, over the Romanian territory. The results of heavy metals concentrations in mosses were reported to ICP Vegetation Programme and synthesized in this review.

A new campaign already started in summer of 2020 and moss samples were collected from 128 sampling sites, the sampling work continuing in 2021. Two complementary methods - Instrumental Epithermal Neutron Activation Analysis (INAA) at the IBR-2 reactor in Joint Institute for Nuclear Research at Dubna, Russian Federation, and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in the Multidisciplinary Research Institute for Science and Technologies from Valahia University of Targoviste, Romania - will be used to complete the atmospheric pollution database with heavy metals and to assess the temporal trends of heavy metal and toxic element pollution.