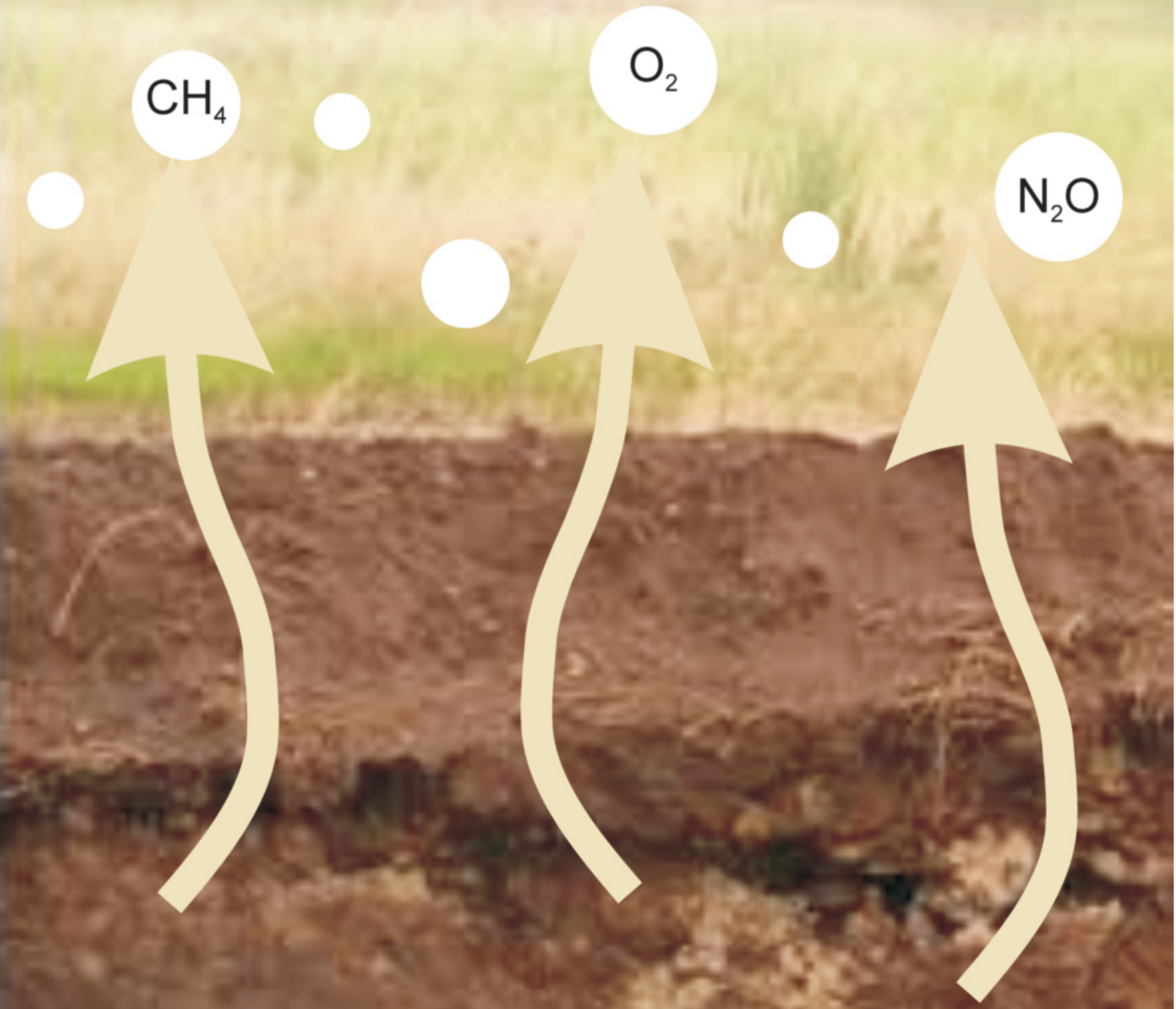
Soil Gases in Environmental and Geological Processes

Budapest, Hungary, 6th, November, 2026



Programme and Abstracts

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Preface

Soil gases provide valuable insights into a wide range of environmental and geological processes, connecting the Earth's deep subsurface with the atmosphere and the living soil system. Their investigation offers important opportunities to better understand natural gas emissions, biogeochemical cycles, geological degassing, and the interactions between geological and biological processes. Recently, soil gas monitoring is becoming increasingly relevant to environmental protection, natural hazard assessment, and the safe implementation of carbon dioxide capture and storage (CCS) technologies.

The aim of this conference is to bring together researchers and professionals from different scientific disciplines to exchange knowledge, discuss recent results on soil gas studies, and explore new approaches to soil gas monitoring. The programme reflects the broad and interdisciplinary nature of this field, covering topics such as CO_2 emissions and source discrimination, natural hydrogen seepage, radon monitoring, soil–atmosphere interactions, and applications in geological and environmental monitoring.

We hope that this conference will be an inspiring meeting point for the soil gas research community and will contribute to strengthening the links between fundamental research and practical applications.

We wish you an enjoyable and fruitful conference!

Csilla KIRÁLY
Chair of the Organising Committee

Lecturers

János Balogh
Susana Barbosa
Eszter Békési
Botond Bodor
Dániel Breitner
James Cogan
Antonnella D'Ciofalo
Zoltán Dévény
Agampodi Gihan Shyamal Dharmendra De Silva
Anita Erőss
György Falus
Ágota Horel
Laura Horváth
Dániel Jurdi
Ildikó Kéri-Schmidthoffer
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Ilham Nahal
Mihály Petrás
Péter Rell
Judith Salupeto-Dembo
Zsuzsanna Szabó-Krausz
Helen Taylor
Balázs Varga
Orlando Vaselli
Niluka Wickramasinghe



Soil Gases
in Environmental & Geological Processes

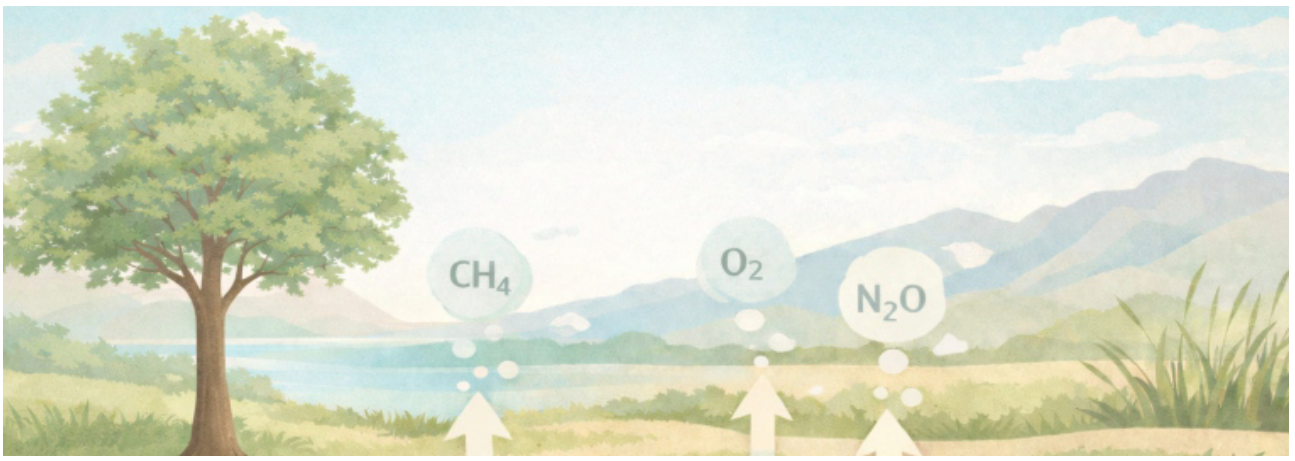
Programme

Soil Gases in Environmental and Geological Processes, 6th 11. 2026.
Budapest, Hungary

8:00-8:55	Registration		
9:00-9:15	Opening Ceremony	Bence Gonda, Zoltán Szalai	
		Lectures & PICO presentations	
9:15-9:45	Keynote: Orlando Vaselli	Revealing Hidden Information by Punctual and Diffuse Soil Gas Chemistry	
9:45-9:58	István János Kovács et al.	Geological CO_2 Emissions in Intraplate Regions: What Do We Know and What Remains Uncertain?	Chair: Márta Berkesi
9:58-10:11	Kis Boglárka Mercedesz et al.	The Challenges of CO_2 Flux Measurements in Inhabited Areas	
10:11-10:24	Mona Maghsoudlou et al.	Soil CO_2 Degassing and Its Source Discrimination in the Bakony–Balaton Highland Volcanic Field, Hungary: Insights from the Eger Creek and Zádor Spring Areas	
10:24-10:27	Eszter Kriska et al.	Soil Enzyme Activity and CO_2 Dynamics at Two Geologically Contrasting Sites in the Balaton Uplands, Hungary (PICO)	
10:27-10:30	Botond Bodor et al.	From Field to Flux: Soil CO_2 Efflux Measurements at Ciomadul Volcano (PICO)	
10:30-10:33	Dániel Kovács et al.	Advanced Soil Gas Monitoring: Integrated Geodynamic Station in the Bakony-Balaton Highland (Pannonian Basin) (PICO)	
	Coffee break with PICO discussions		

		Lectures & PICO presentations	
10:55-11:08	Ágota Horel et al.	Soil CO_2 Emission and Its Relationships with Soil Properties and Vegetation Indices in Grassland Ecosystems	Chair: Gergely Jakab
11:08-11:21	János Balogh et al.	Components and Drivers of Soil CO_2 Efflux in Hungarian Croplands and Grasslands	
11:21-11:34	Niluka Wickramasinghe et al.	Biochar and Plant Presence Regulate CO_2 Emissions and Microbial Resource Acquisition in Metal(loid)s Contaminated Soil	
11:34-11:47	Ilham Nahal et al.	Seasonal Variation in Microbial Carbon-source Utilization and Heterotrophic	
11:47-12:00	Agampodi Gihan Shyamal Dharmendra De Silva et al.	The Effects of Soil Isolated Different Microalgae Inoculants on Soil Carbon Dioxide Emissions in Spring Barely	
12:00-12:13	Antonnella D'Ciofalo et al.	Soil Carbon Dioxide Emissions under Stress Conditions: Maize and Tomato	
12:13-12:16	Adrienn Tóth et al.	Rainfall-induced CO_2 Responses under Various Land Uses in the Top and Subsoil (PICO)	
	Coffee break with PICO discussions		
		Lectures & PICO presentations	
12:30-12:43	Eszter Békési et al.	Exploration and Monitoring of Natural Hydrogen Seepages with Synthetic Aperture Radar Interferometry and Backscatter Analysis	Chair: Dániel Breitner
12:43-12:56	Laura Horváth et al.	Preliminary Soil Gas Results from the Gyód Serpentinite Body: a Natural Hydrogen Case Study	
12:56-12:59	Mihály Petrás et al.	Fairy Circles as Indicators of Natural Hydrogen Seepage and a Potential Example From SW Hungary (PICO)	
12:59-13:02	Ildikó Kéri-Schmidthoffer et al.	Preliminary Results on the Effects of Natural Hydrogen on Photosynthesis in Herbaceous Plants (PICO)	
13:02-13:05	Gábor Kovács et al.	Initial Results of Natural Hydrogen Seepage in Western Hungary in Thick Overlying Sedimentary Layers and Along a Distributed Fault System (PICO)	
	Lunch break with PICO discussions		

		Lectures & PICO presentations	
13:50-14:03	James Cogan	CO_2 Monitoring at CCS Project Danube Removals	Chair: Juraj Francu
14:03-14:16	Dániel Jurdi	Continuous FT-IR Monitoring of Soil Gases for Geological and Environmental Applications	
14:16-14:29	Marco Vasconez-Maza et al.	Is Soil Gas the Last Line of Defence? Lessons from Three Decades of Monitoring at BGS	
14:29-14:42	Zsuzsanna Szabó-Krausz et al.	Geochemical Modeling Approaches for Soil Gas Studies	
14:42-14:55	György Falus et al.	Soil Gas Monitoring - a Key to Safe Energy Transition	
14:55-15:08	Polina Iakunina et al.	Methane Emissions from Abandoned Oil & Gas Wells: Evaluation Using UAV-based TDLAS and In Situ Measurements	
	Coffee break with PICO discussions		
		Lectures & PICO presentations	
15:25-15:38	Dániel Breitner & Bence Molnár	Successful Indoor Radon Mitigation in the Velence Mountains - a Case Study	MS section, Chair: Bence Molnár
15:38-15:51	Judith Salupeto-Dembo et al.	Radon and Thoron Emanation from Soil-Based Building Materials: Revisiting the Angola Case Study	
15:51-16:03	Susana Barbosa et al.	Radon Gas Observations for Multidisciplinar Climate Research: the NuClim Project	
16:03-16:16	Péter Rell	Radon Activity Concentration in Hungarian Soils	
16:16-16:29	Anita Erőss et al.	Radon, as a Groundwater Discharge Phenomenon	
16:30-17:00	Final Discussion and Award Ceremony	From Research to Application: The Future o Soil Gas Studies	Moderator: Anita Erőss



Revealing Hidden Information by Punctual and Diffuse Soil Gas Chemistry

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Investigations into interstitial gas geochemistry and diffuse soil gases have become well-established methodologies from an analytical and monitoring perspective, providing crucial insights into the global carbon cycle, environmental dynamics, and sub-surface fluid migration. While internal soil gases are commonly sampled in the field using specialized probes and specific vials for subsequent laboratory analysis via gas-chromatography, the measurement of diffuse soil CO_2 emissions is conducted directly in situ. This field-based approach has gained widespread acceptance primarily due to two factors: i) the development of highly accurate, portable infrared detectors that provide reliable, real-time flux measurements (e.g., via the accumulation chamber method), and ii) the critical utility of soil CO_2 flux data in assessing volcanic hazards, exploring geothermal resources, and monitoring Carbon Capture and Storage (CCS) sites. In fact, CO_2 represents one of the most prominent gas species migrating through the pedological cover; its signal is heavily influenced by exogenous seasonal variations (such as soil temperature and moisture) but remains strongly correlated with endogenous anomalies induced by deep-seated geological systems. Although soil CO_2 monitoring originally found its roots within agricultural and agronomic research, the geological community has promptly recognized and integrated its structural importance across various disciplines.

This work provides a comprehensive review of the most common and innovative techniques currently utilized to collect, measure, and analyze soil gases, focusing also on advanced methodologies that allow the characterization of carbon stable isotopes in CO_2 and other associated gas species. Soil gas sampling surveys and diffuse CO_2 measurements serve complementary roles: the former is used to evaluate the chemical and isotopic features of fluids released from the pedological cover to identify their origin, while the latter is employed to quantify the total mass output of CO_2 from specific geological systems. While soil gas chemistry offers a straightforward baseline characterization, multi-depth discrete sampling (e.g., at depths of 20, 40, and 60 cm) allows for evaluating vertical gas concentration gradients. Microbial communities in soil layers can strongly alter gas concentrations through processes such as methanogenesis, methane oxidation, and aerobic respiration. Conversely, diffuse soil CO_2 monitoring has proven highly effective in distinguishing between shallow, background biogenic soil respiration and deep-seated, advective gas releases via statistical processing methods like graphical partitioning. Real-world applications across various volcanic architectures, active geothermal fields, and engineered CCS sites are presented to demonstrate the geological relevance and diagnostic capability of these technique. Finally, recent technological advancements in portable detectors for alternative soil gas species, including CH_4, N_2O, H_2S and volatile organic compounds (e.g., C_6H_6 and C_7H_8), are discussed, as they are expected to significantly enhance our understanding of sub-surface gas distribution and multi-component fluid migration in the near future.

Keywords: Interstitial soil gas, Diffuse Soil Gas, CO_2, Analytical techniques, CCS

Geological CO_2 Emissions in Intraplate Regions: What Do We Know and What Remains Uncertain?

István János Kovács[1], Ákos Kővágó[1], Márta Berkesi[1], Dániel Kovács [1], Csaba Szabó[1], Mátyás Hencz[1], Tamás Spránitz[1], Orsolya Gelencsér[1], Thomas Lange[1], Szilveszter Gergely[2], Csilla Király[3], László Palcsu [4] Ágnes Gál[1,5], Sándor Szakács[1,6], Sándor Gyila[1], Dániel Jurdi[6,7]

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Geological CO_2 emissions represent an important but still poorly constrained component of the global carbon cycle. While volcanic degassing has been extensively investigated, diffuse CO_2 emissions in intraplate regions, particularly those without recent volcanic activity, remain largely unexplored. Consequently, the contribution of deep lithospheric and mantle-derived carbon to the global carbon budget is still subject to considerable uncertainty.

The Pannonian Basin provides a particularly suitable natural laboratory for investigating these processes. Recent studies demonstrate that mantle-derived CO_2 can migrate towards the surface along deep-rooted faults and lithospheric deformation zones, even in the absence of active magmatism. Estimated mantle-related CO_2 fluxes of 10^3–10^5 mol km^{-2} yr^{-1} locally overlap with those observed in quiescent volcanic systems. Furthermore, the recently proposed pargasosphere hypothesis suggests that cooling asthenosphere beneath young continental lithosphere may contribute to long-lasting, diffuse CO_2 emissions. Recent xenolith-based investigations also indicate that substantial amounts of carbon can accumulate in the lithospheric mantle during post-rift thermal evolution.

These observations highlight the importance of integrating soil-gas measurements, geochemical and isotopic investigations, and geodynamic modelling to better constrain the origin, migration pathways, and magnitude of geological CO_2 emissions.

Improved quantification of these processes is essential for understanding lithosphere–asthenosphere interactions, reconstructing the long-term geological carbon cycle, and establishing more reliable estimates of natural CO_2 fluxes. Although anthropogenic emissions clearly dominate the present-day atmospheric carbon budget, geological contributions, particularly in intraplate settings, deserve considerably more scientific attention.

Keywords: Geological CO_2 emissions; soil-gas flux; Pannonian Basin; mantle degassing; pargasosphere hypothesis; carbon cycle



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The Challenges of CO_2 Measurements in Inhabited Areas

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Diffuse soil CO_2 degassing can be a hidden hazard in inhabited areas. However, measuring and mapping soil CO_2 fluxes in towns is much more difficult than in natural areas. Roads, pavements and buildings cover large parts of the surface, so measurements are only possible in private gardens, parks and other unpaved areas. As a result, the sampling grid is often irregular and incomplete. Access to private properties also depends on the cooperation of the residents. Construction works compact or disturb the soil, which changes its permeability and can reduce the measured fluxes. Different land-use types produce different biological CO_2 fluxes, which makes it harder to separate the biological and deep-derived CO_2.

At the strongest emission points, the fluxes can exceed the measuring range of the instruments. In addition, soil fluxes measured outdoors do not always reflect the CO_2 concentrations indoors. Gas accumulation in cellars and other closed spaces depends on the construction and ventilation of the buildings, so even moderate fluxes can lead to dangerous concentrations.

Despite these difficulties, statistical and geostatistical analysis of soil CO_2 fluxes can identify the main degassing structures and the areas where deep-derived CO_2 is most likely. Together with indoor measurements, monitoring and public awareness, soil CO_2 flux maps are useful tools for hazard assessment, mitigation and land-use planning in inhabited areas.

In this study, we present examples from soil CO_2 surveys and indoor CO_2 measurements carried out in inhabited degassing areas.

This work was supported by the Bolyai János Scholarship by the Hungarian Academy of Sciences and the project PN-IV-P6-6.1-CoEx-2024-0042, within PNCDI IV

Keywords: CO_2 fluxes, CO_2 concentrations, inhabited areas, hazard assessment

References:

Cardellini, C., et al. 2017: Monitoring diffuse volcanic degassing during volcanic unrest: the case of Campi Flegrei (Italy). – Scientific Reports, 7, 6757

Kis, B. M. et al. 2017: Quantification of carbon dioxide emissions of Ciomadul, the youngest volcano of the Carpathian-Pannonian Region (Eastern-Central Europe, Romania). – *Journal of Volcanology and Geothermal Research* **341,** 119–130.

Soil CO_2 Degassing and Its Source Discrimination in the Bakony–Balaton Highland Volcanic Field, Hungary: Insights from the Eger Creek and Zádor Spring Areas

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In the Bakony–Balaton Highland Volcanic Field (BBHVF), alkali basalt volcanism and post-extensional thinning established crustal pathways that facilitate mantle CO_2 migration through fractured Triassic carbonates and overlying strata (Cornides, 1993; Martin & Németh, 2004). This study assesses whether deep degassing imprints surface environments across two areas: an alluvial-volcanic field along Eger creek near Nemesgulács, Hungary and a fractured Triassic carbonate karst area around Zádor-kút in Pécsely, Hungary (Budai et al., 1999). Soil gas $\delta^{13}C$ is measured in early summer (active growing season) and applied to discriminate between biogenic 13C (typically –27.4‰ to –25.6‰ in local forest soils) and mantle-derived $\delta^{13}C$ (–5.5‰ to –2.1‰ across the Pannonian Basin). In the vicinity of Eger creek, surface soil CO_2 ranges from 365 to 15,517 ppm and sub-surface CO_2 (1 m depth) reaches up to 32,292 ppm. Soil moisture ranges from 7.5% to 28.6%, and localized CO_2 efflux ranges from 0.69 to 2.42 g m^{-2} h^{-1}. The measured CO_2 $\delta^{13}C$ in certain sub-surface soil gas samples ranges from –11.31‰ to –21.32‰. In addition, the measurement of air $\delta^{13}C$ (–10.18‰) and stream water $\delta^{13}C$ (–10.01‰) indicate that this CO2 derives from mixing between mantle and biogenic sources, as well as interaction with the atmospheric CO_2. In contrast, in the surroundings of Zádor-kút, surface soil CO_2 ranges from 664 to 12,930 ppm and sub-surface CO_2 (1 m depth) reaches up to 68,332 ppm. Soil moisture ranges from 10.6% to 39.1%, and localized CO_2 fluxes range from 0.43 to 3.39 g m^{-2} h^{-1}. The measured CO_2 $\delta^{13}C$ in certain sub-surface soil gas samples ranges from –14.86‰ to –25.15‰. In addition, the measurement of air $\delta^{13}C$ (–10.18‰) and spring water $\delta^{13}C$ (–11.4‰ to –12.9‰), along with an elevated Ca^{2+} concentration (88–90 mg/l), indicate that the soil CO_2 reflects an input from carbonate dissolution, whereas biogenic respiration remains the predominant source. These results demonstrate that bedrock lithology and fault connectivity govern the surface expression of deep carbon degassing in the BBHVF, where ascending endogenic fluids undergo extensive mixing, predominantly with biogenic CO_2 during upward migration.

This study is supported by the National Research, Development and Innovation Office (NKFIH), Hungary, under grant agreement No. Starting 152818.

Keywords: Soil CO_2 degassing; Stable carbon isotopes ($\delta^{13}C$); Mantle-derived CO_2; Bakony–Balaton Highland Volcanic Field

References:

Budai, T. et al. 1999: Geology of the Balaton Highland. – *Occas. Pap. Geol. Inst. Hung.* **197.**
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Soil Enzyme Activity and CO_2 Dynamics at Two Geologically Contrasting Sites in the Balaton Uplands, Hungary

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The activity of soil microorganisms is closely linked to soil biogeochemical processes and is strongly influenced by local environmental conditions. The aim of the present study was to investigate how microbial activity is influenced by soil depth, sampling site, and soil CO_2 efflux.

The study was carried out at two geologically different sites in the Balaton Uplands, Hungary: Nemesgulács, with basaltic, and Pécsely, with carbonate bedrock. Soil samples were collected 10 cm from the surface as well as from 1 m depth. Acid phosphatase, dehydrogenase, and catalase activities were measured together with soil CO_2 concentration and CO_2 flux. PCA and PERMANOVA were used for data analysis.

Sampling depth and sampling site both had significant effects on the overall enzyme activity profile. Mean dehydrogenase activity was higher in surface samples than at 1 m depth at both sites, decreasing from 0.152 to 0.028 mU/g at Nemesgulács and from 0.395 to 0.075 mU/g at Pécsely. Catalase activity showed a similar depth-related pattern, decreasing from 61.2 to 26.8 hPa/min at Nemesgulács and from 54.8 to 33.7 hPa/min at Pécsely. Higher dehydrogenase activity was often accompanied by higher catalase activity. This relationship may indicate that higher overall microbial activity, as reflected by dehydrogenase activity, was associated with more pronounced aerobic microbial processes, as indicated by catalase activity.

No clear association was observed between CO_2 concentration and the overall enzyme activity profile. In contrast, higher CO_2 flux was generally associated with higher enzyme activity. This suggests that CO_2 flux may be linked to microbial activity, but this relationship is partly influenced by site-specific environmental conditions.

Overall, dehydrogenase and catalase showed the clearest joint pattern, while CO_2 flux appeared to be more closely related to enzyme activity than to CO_2 concentration.

This study is supported by the National Research, Development and Innovation Office (NKFIH), Hungary, under grant agreement No. Starting 152818.

Keywords: soil microbial activity; dehydrogenase; catalase; phosphatase; CO_2 flux; geological background

From Field to Flux: Soil CO_2 Efflux Measurements at Ciomadul Volcano

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Natural CO_2 emissions from the Earth's surface have been extensively studied worldwide. Large CO_2 emissions are often linked to geological processes, such as volcanic plume degassing, hydrothermal activity and metamorphism. Nowadays, understanding geologically derived CO_2 is particularly important, as it provides the natural baseline for the global carbon budget. The amount of anthropogenic CO_2 emissions can be estimated relatively well. According to estimates, cumulative carbon emissions could reach 5,000 gigatons by the year 2400, with the majority entering the atmosphere in the form of CO_2 (Zachos et al., 2008). In contrast, the amount of geologically derived CO_2 is less well constrained. Based on the studies of e.g., Werner et al. (2019), estimates of CO_2 emissions from subaerial volcanism range from 75 to 112 Mt CO_2 yr ą. Several methods have been developed to quantify the amount of CO_2 efflux from the soil, among which the accumulation chamber method is the most widely used. The West Systems fluxmeter presented here is used in several fields of natural science. It is a portable, battery-powered instrument designed to measure the concentration and flow rate (flux) of diffuse CO_2 and H_2S from the soil. It is equipped with a LI-COR LI-850 CO_2 analyzer, a non-dispersive infrared (NDIR) CO_2 gas analyzer used to measure gases in air, as well as a WS-TOX-H_2S analyzer, which quantifies the amount of H_2S in the air using a high-selectivity electrochemical cell. In this study, we focus on soil CO_2 efflux measured at the Ciomadul volcanic area, at Csiszárfürdő (Băile Balvanyos, Eastern Carpathians, Romania), a site characterized by mofettes and mineral water basins. Our measurements, combined with software-based spatial processing, revealed some spatial patterns in soil CO_2 efflux across the study area. We present the measurement methodology, with particular emphasis on the challenges posed by the complex terrain and variable weather conditions. In addition, we present the software-based processing of the collected data.

This work was supported by the Bolyai János Scholarship by the Hungarian Academy of Sciences and the project PN-IV-P6-6.1-CoEx-2024-0042, within PNCDI IV.

Keywords: Carpathians, soil CO_2 fluxes, soil gas, methodology

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Advanced Soil Gas Monitoring: IntegratedGeodynamic Station in the Bakony–Balaton Highland (Pannonian Basin)

Dániel Kovács[1,3], Ákos Kővágó[1,3], Thomas Lange Pieter[1,2], Márta Berkesi[1,2], Orsolya Gelencsér[3,7], Mátyás Hencz[1,2], Levente Patkó[1,2,8], Tamás Spránitz[1,2], István Bozsó[1], Csilla Király[4], Ágnes Gál[5], Alexandru Szakács[1,6], Csaba Szabó[1,2,3], István János Kovács[1]

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Recent geochemical studies indicate that volatiles (primarily CO_2) can be released from the solidifying melt (through cooling of partially molten asthenosphere) and potential metasomatic alterations in the thinned continental lithospheric mantle, such as beneath the Pannonian Basin. During this cooling process, CO_2 cannot be incorporated into the crystallizing minerals and thus, the fluids become highly enriched in CO_2. The upward migration of these mantle-derived fluids is strongly controlled by the stress building up in the lithosphere. Consequently, monitoring surface gas emissions containing deep CO_2-rich fluids together with seismic activity provides an opportunity to identify anomalies that may precede earthquakes.

The research is based on the Hungarian–Romanian–Dutch Topo-Transylvania collaboration and targets to better understand the regional geodynamics and their surface expressions in the Pannonian Basin. At the core of this international collaboration is an innovative Integrated Geodynamic Station (IGS) established by the HUN–REN Institute of Earth Physics and Space Science, installed at Badacsonytördemic, within the Bakony–Balaton Highland Volcanic Field (BBHVF).

The IGS is currently equipped with a Fourier-Transform Infrared (FTIR) gas analyzing unit, a seismometer, a meteorological station and a soil gas sampling system. The gas analyzing unit provides continuous monitoring of infrared-active soil gas emanations (CO_2, CH_4, N_2O, S species) with a high temporal resolution and ppm-level precision. By correlating gas flux data with additional seismic, meteorological observations and geophysical data, our research aims to identify compositional and concentration anomalies in the gas emanations (as preliminary data) that may precede earthquakes, also helping the better understanding of the global carbon cycle. In this study, we present preliminary data from the Badacsonytördemic station, demonstrating a real potential for earthquake precursor research.

Keywords: Integrated Geodynamic Station; soil gas monitoring; mantle-derived fluids; CO_2; earthquake precursor; Pannonian Basin



Soil CO_2 Emission and Its Relationships with Soil Properties and Vegetation Indices in Grassland Ecosystems

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The study was conducted across two approximately 1 ha research sites located in the Rekovac region of Serbia (RS) and the Balaton Uplands of Hungary (HU). Field measurements were carried out during three sampling campaign events: spring 2025, fall 2025, and spring 2026, allowing seasonal variation to be assessed. At each site, 32 and 35 sampling points, respectively, were investigated. Soil samples were collected for chemical properties of pH, soil organic carbon (SOC), total nitrogen, potassium, and phosphorus. Soil water content (SWC) was measured with a Hydrosense II sensor (Campbell Scientific). Vegetation condition was characterized using normalized difference vegetation index (NDVI) and photochemical reflectance index (PRI) obtained with spectral reflectance sensors. Soil CO_2 emissions were measured in the field using an EGM5 infrared gas analyzer (PP Systems). Additional vegetation indices (VIs) of NDVI and leaf chlorophyll content were measured using handheld instruments.

Comparison of the two grassland sites revealed significantly higher C/N ratio, total N, K, P, SOC, $CaCO_3$ concentration, and soil CO_2 emissions at the HU site, whereas vegetation NDVI and PRI values were significantly higher at the Serbian site during the first two sampling occasions ($p < 0.05$). No significant differences were observed in soil water content (SWC; $p > 0.05$) only at the third field data collection. Cluster analysis separated the measured variables into three distinct groups, with the Serbian site forming one cluster and the Hungarian site represented by two clusters. Pearson correlation analysis showed strong negative relationships between both NDVI and PRI and several soil chemical properties, including pH ($r = 0.83$ and 0.79, respectively) and SOC ($r = 0.79$ and 0.75, respectively). In contrast, soil CO_2 emissions exhibited moderate positive correlations with several soil properties, including pH, potassium, and C/N ratio ($r = 0.63–0.80$). SWC showed no clear relationships with the main soil chemical or vegetation variables, and only moderate with soil CO_2 emission ($r = 0.45$; $p < 0.001$).

We found that the two research sites were separated by its soil properties, with the HU site further divided by its erosion prone area. Our study showed that local heterogeneity strongly affects soil chemical and physical parameters, consequently affecting vegetation and soil health. Both sites were assessed three times, and further SWC, VIs, and CO_2 emission measurements are still planned to provide stronger support for our findings.

The research was funded by the Sustainable Development and Technologies National Programme of the Hungarian Academy of Sciences (FFT NP FTA) and the 2023-1.2.4-TÉT-2023-0009 project.

Keywords: soil health; vegetation indices; soil moisture; CO_2 emission; soil chemistry;

Components and Drivers of Soil CO_2 Efflux in Hungarian Croplands and Grasslands

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Soil respiration (Rs) is a highly complex process involving a wide range of soil biota, including both autotrophic and heterotrophic organisms, as well as multiple pathways of carbon cycling, such as decomposition and carbon allocation. These processes are regulated by a combination of environmental and biotic drivers. The autotrophic component of Rs is determined by the amount of CO_2 produced by plant roots and their associated microorganisms, including rhizospheric microbes and mycorrhizal fungi, whereas heterotrophic respiration represents the CO_2 produced through the microbial decomposition of soil organic matter (SOM).

The responses of soil respiration to major abiotic factors have been extensively studied across a wide range of ecosystems and described using various models. In temperate croplands and grasslands, soil temperature and moisture are generally considered the primary environmental controls. However, numerous studies have shown that the individual respiration components often exhibit different sensitivities to these factors. These differences in the responses of autotrophic and heterotrophic respiration to environmental variables may be explained by variations in the relative importance of their underlying carbon sources.

The two principal carbon sources supporting Rs are soil organic carbon (SOC) and photosynthetically fixed carbon supplied to belowground tissues through plant carbon allocation. Both autotrophic and heterotrophic components of soil carbon cycling receive recently assimilated carbon from plant shoots, linking root respiration and SOM decomposition to plant physiological processes. However, primary productivity exhibits pronounced seasonal dynamics in temperate ecosystems. This seasonal pattern is particularly pronounced in croplands, where living vegetation is often absent from the soil between successive crops.

To explore the responses and interactions of soil respiration with the factors described above, detailed measurements of CO_2 fluxes and their potential drivers are required. In a series of studies conducted in Hungarian croplands and grasslands, we investigated soil respiration components using both physical separation techniques and stable carbon isotope approaches. Our objectives were to quantify the contributions of the different respiration components to total soil respiration and to examine the effects of key abiotic and biotic drivers on Rs.

We found that in a dry grassland[S1.1], rhizospheric respiration accounted for, on average, 36% of total soil respiration, mycorrhizal fungal respiration contributed 9%, and heterotrophic respiration represented 55%, with significant variation among phenological stages. Belowground carbon allocation exerted an influence on Rs comparable to that of the primary environmental drivers across multiple timescales, whereas the effect of SOC was negligible. This finding may be explained by the limited availability and quality of SOC accessible to microorganisms. During certain phenological stages, belowground carbon allocation emerged as the dominant driver of Rs, highlighting the importance of incorporating plant carbon allocation into soil respiration models.

Keywords: components of soil respiration, grassland, cropland, belowground carbon allocation

Biochar and Plant Presence Regulate CO_2 Emissions and Microbial Resource Acquisition in Metal(loid)s Contaminated Soil

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Biochar is a widely studied amendment for the immobilisation of metal(loid)s in contaminated soils; however, its effects on soil CO_2 emissions remain poorly understood, particularly under planted conditions where root-derived and soil microbial respiration interact. The present study was undertaken to quantify the effects of biochar and plant presence on CO_2 emissions and the associated cycling of carbon and nitrogen in a metal(loid)s contaminated Fluvisol. The soil was characterised by a pH of 6.0 and a total organic carbon content of 2.27%, and contained 400, 45, 5730 and 4443 mg kg ą of arsenic, cadmium, lead and zinc, respectively. The soil was amended with 2% (w/w) woody biochar and maintained either without plants or planted with ryegrass (*Lolium perenne* L.). Dissolved organic carbon (DOC), dissolved total nitrogen (DTN), CO_2 emissions, and the activities of extracellular C- and N-acquiring enzymes were determined after 60 days.

The presence of ryegrass markedly increased CO_2 emissions, with values reaching 361 and 430 mg CO_2/kg soil/day in the control and biochar-amended soils, respectively, compared with 161 and 129 mg CO_2/kg soil/day under unplanted conditions. Thus, biochar increased CO_2 emissions in planted soil but decreased them in unplanted soil. In planted soil, biochar induced only a minor change in DOC, from 119 to 125 mg/kg, while DTN declined by 75%. Consequently, the DOC:DTN ratio increased by 368%. This shift was accompanied by pronounced responses of N-acquiring enzymes, with biochar increasing alanine aminopeptidase and leucine aminopeptidase activities by 167% and 240%, respectively. Responses of C-acquiring enzymes were more moderate, with β-D-glucosidase activity increasing from 10.4 to 13.6 µmol/h/g dry soil and cellobiohydrolase activity from 1.43 to 2.00 µmol/h/g dry soil.

The results demonstrate that the effect of biochar on CO_2 emissions depended on plant presence, with biochar increasing emissions in planted soil while decreasing them under unplanted conditions. The substantial depletion of dissolved N, together with elevated activities of N-acquiring enzymes under planted conditions, indicates an alteration in microbial resource acquisition that coincides with enhanced soil and plant respiration. These findings underscore the need to account for plant–microbial interactions when evaluating the effects of biochar on carbon cycling and CO_2 emissions in metal(loid)s-contaminated soil.

Keywords: Extracellular enzyme activity, Remediation, Soil respiration



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Seasonal Variation in Microbial Carbon-source Utilization and Heterotrophic Respiration in a Hungarian Cropland

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Microbial decomposition is a key driver of soil CO_2 emissions, but the functional use of different carbon substrates by soil microbial communities may change substantially during the vegetation period. This study investigates whether seasonal changes in microbial carbon source utilization coincide with temporal variation in heterotrophic respiration (R_h) in a conventionally managed cropland in Hungary. Rh was measured using root exclusion tubes, while total soil respiration (R_s) was monitored under natural field conditions using an automated chamber system. Soil temperature and soil moisture were measured simultaneously with CO_2 fluxes. Soil samples collected at selected dates were analyzed using Biolog EcoPlates™ to characterize microbial functional activity and carbon substrate utilization. The EcoPlate results revealed pronounced temporal changes in the relative contribution of different carbon source groups to total activity. Polymers dominated at some sampling dates, whereas carbohydrates and carboxylic acids became more important during other periods, indicating a clear seasonal shift in the microbial carbon use profile. These changes occurred alongside seasonal variation in R_h and environmental conditions. The results provide a basis for integrating microbial functional indicators with field CO_2 flux measurements to better understand temporal controls on heterotrophic respiration in agricultural soils.

Keywords: heterotrophic respiration; soil CO_2 efflux; Biolog EcoPlate; microbial functional activity; carbon-source utilization



The Effects of Soil Isolated Different Microalgae Inoculants on Soil Carbon Dioxide Emissions in Spring Barely

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The study aimed to assess the effects of isolating various microalgae on soil CO2 emissions during spring barley cultivation. The Study area was located in an agricultural research field at the Smart Farm of the Albert Kázmér Faculty of Agricultural and Food Sciences, Széchenyi István University, Mosonmagyaróvár, Hungary. The experiment contained RCBD[S1.1] design with 10 plots and ten treatments which included two live cyanobacterial strains of MACC-612 (*Nostoc piscinale*) (T_1) and MACC-597 (*Phormidium* sp.) (T_2) and two live green algae strains of MACC-922 (*Chlorella vulgaris*) (T_3) and MACC-788 (*Chlamydomonas reinhardtii*) (T_4) and four powder mass of MACC-612 (T_5), MACC-597 (T_6), MACC-922 (T_7), MACC-788 (T_8), and combine application of two live microalgal strains (MACC-922 and MACC-612) and two powder mass of microalgal strains (MACC-597 and MACC-788) (T_{10}) and without any microalgae treatments (control) (T_9). The live microalgal suspension and the microalgal powder biomass were applied at a rate of 0.5 L per plot. Each treatment was applied to the soil using a 15 L knapsack sprayer 2 weeks before sowing. Soil CO_2 emissions were measured using the non-steady state closed dynamic chamber method. Soil CO_2 emissions were measured across three main growth stages of spring barley: vegetative growth, flowering, and post-harvest. During the vegetative growth stage, weekly average soil CO_2 emissions differed significantly among treatments ($p < 0.05$), indicating a clear, biologically meaningful divergence between the application forms of live and powdered microalgal biomass. All four live microalgal treatments (T_1–T_4; 75.83–81.24 µg CO_2 m^{-2} s^{-1}) recorded significantly lower emissions than the control (T_9; 100.12 µg CO_2 m^{-2} s^{-1}), while all powder biomass treatments (T_5 – T_8; 125.55 – 144.59 µg CO_2 m^{-2} s^{-1}) recorded significantly higher emissions than the control. During the flowering and reproductive stage, no significant differences in weekly average soil CO_2 emissions were detected among any of the ten treatments ($p > 0.05$), with all treatments falling within a single statistical group (Group A) and emissions ranging narrowly from 128.26 (T_9, control) to 144.93 µg CO_2 m^{-2} s^{-1} (T_2, *Chlamydomonas reinhardtii* live). During the post-harvest stage, soil CO_2 emissions showed no significant differences among treatments ($p > 0.05$), with all treatments remaining within a single statistical group (Group A) and emissions converging to an exceptionally narrow range of 77.19 (T_5, *Chlorella vulgaris* powder) to 78.51 µg CO_2 m^{-2} s^{-1} (T_3, *Nostoc linckia* live). Live microalgal inoculants represent a viable strategy for transiently reducing soil CO_2 efflux in temperate cereal systems, with *Nostoc linckia* and C*hlamydomonas reinhardtii* identified as priority strains for future optimization.

Keywords: Carbon dioxide mitigation, Closed dynamic chamber method, Microalgae, Soil carbon dioxide emissions

Soil Carbon Dioxide Emissions Under Stress Conditions: Maize and Tomato

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Carbon dioxide (CO_2) emissions have been increasing since the end of the 18th century. It is indispensable to address all factors that influence this rise of emissions. Agricultural soil represents around 20% of the total greenhouse gas emissions. As land use and climate change are in close relation, analysing how soil CO_2 efflux is affected by different stress conditions is important. In pursuance of analysing this emissions behaviour, the CO_2 efflux under two worldwide crops, maize (*Zea mays* L.) and tomato (*Solanum lycopersicum*), were studied under two different stress conditions. The maize was under a regime of water stress. In tomato, two types of treatments were applied: water stress on a non-drastic basis and biotic stress induced by the parasitism interaction of root-knot nematode *Meloidogyne incognita*. This thermophilic nematode represents a potential threat to crops due to the increase in temperature. This aims to substantiate that a balance within the agricultural soil and CO_2 emissions should be pursued.

The experiment was set up in an open system at the SZIA Agroecological Garden of the Hungarian University of Agriculture and Life Sciences (MATE) in Gödöllő, from August 23 to September 05, 2025. The instrumentation used was an EGM-5 portable gas analyser (PPSystems, MA USA) connected with an SRC-2 respiration chamber and a Hydra Probe sensor (Stevens Water, OR USA) to measure soil temperature and soil water content. Additionally, the environmental conditions retrieved from the meteorological station of MATE university were considered due to the field-based set-up. The dry biomass of tomatoes was contemplated in determining the origin of CO_2 emissions in the tomatoes.

The results obtained in this study confirm that stress conditions influence the CO_2 efflux. It was found that the soil CO_2 emission in maize under water stress was significantly lower than in the control maize. Furthermore, the tomatoes infected with *Meloidogyne incognita* presented a statistically significant difference from the control. Inferring that CO_2 emissions are influenced by microbial activity in the soil, the lack of water inhibits this activity, while the presence of *Meloidogyne incognita* increases the microbial community due to the root damage that releases exudates. Notwithstanding, soil moisture content was recognised as the primary driver of soil respiration in this study.

Keywords: soil respiration; moisture stress; *Meloidogyne incognita*; soil microbial activity



HUN REN CSFK ATK CENTRE FOR AGRICULTURAL RESEARCH Centre for Energy Research MAGYARHONI FÖLDTANI TÁRSULAT 175 1848 MENTE ET MALLEO

Rainfall-induced CO_2 Responses Under Various Land Uses in the Top and Subsoil

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The primary mechanism of soil organic carbon loss is microbial CO_2 respiration. Its temporal and spatial dynamics fundamentally affect carbon sequestration. Land use, tillage, vegetation, as well as soil moisture and temperature, are known drivers of CO_2 emissions; however, little is known about the role of soil depth (subsoil). We compared in situ CO_2 concentrations at Szentgyörgyvár and Battonya, Hungary, using portable infrared probes during the summer of 2026, following a long dry period. At Szentgyörgyvár, measurements covered stubble cropland under minimum and conventional tillage and an adjacent orchard. At Battonya, we studied stubble arable land and grasslands established after cropland abandonment approximately 3, 4, and 15 years ago, as well as a permanent grassland. CO_2 concentrations were measured at the surface and at 75–100 cm depth. Selected Battonya points were measured before and after overnight rainfall. At Szentgyörgyvár, subsurface CO_2 concentrations in cropland were 2.1–2.7 times the surface values. Conventional tillage had higher concentrations than minimum tillage at both depths (2605 vs. 1917 ppm below ground and 1213 vs. 708 ppm at the surface). The orchard had an approximately fourfold subsurface-to-surface ratio and high spatial variability, including one value above 20,000 ppm. At Battonya, subsurface concentrations were three to seven times the surface values. The ratio was 6.8 in the >300-year grassland, 5.6 in the 15-year-old grassland, and 3.3 in the 3-year-old grassland. Rain increased surface CO_2 concentrations at every repeated point by 26–564%. Subsurface responses ranged from a 49% decrease to a 169% increase. These results show that depth, management, land-use history, and recent rainfall affected soil CO_2 patterns.

The study was supported by the NKFIH via Advanced-152750.

Keywords: soil carbon dioxide, carbon sequestration, microbial decomposition, land-use change, tillage, rainfall, soil depth



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Exploration and Monitoring of Natural Hydrogen Seepages with Synthetic Aperture Radar Interferometry and Backscatter Analysis

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As demand for alternative energy sources increases, natural hydrogen (H_2) is attracting attention as a potential commercial resource. However, there is currently only one known natural H_2 field, located in Bourakébougou, Mali, which highlights major knowledge gaps in the behavior of H_2 systems and related exploration and production workflows. Circular depressions called fairy circles are a surface manifestation (mega-seeps) of H_2 that commonly occur in continental cratons and form relatively quickly (in a few years). Besides the topographic imprint of these depressions, which range in diameter from 100 m to 2 km, a major signature of the structures is a vegetation anomaly characterized by a zone of dying vegetation inside the circle and a ring of healthy, enriched vegetation in the surrounding area. Fairy circles are often observed near major fault zones; however, faults without fairy circles can also represent H_2 micro-seepages. While several case studies have implied a connection between surface H_2 seeps and deep-seated H_2 sources, the exact mechanism of fairy circle formation remains largely unknown, as do the underlying generation, migration and accumulation processes of H_2.

Although satellite images are widely used for mapping fairy circles, these observations are mainly restricted to passive satellite sensors and do not monitor any temporal changes in the structures. In this study, we used Synthetic Aperture Radar (SAR) images acquired by the European Space Agency's Sentinel-1 satellites to monitor morphological and vegetational changes in fairy circles in the São Francisco Basin in Brazil. We used radar interferometry (the InSAR method) to map ground motions associated with potentially active surface deformation of the circles. Using SAR backscatter analysis, we extended the ground motion time series to identify any rapid vegetation/soil moisture changes linked to H_2 degassing. The results show that some fairy circles exhibit active features in terms of vegetation and soil moisture variations, as well as ground motion, on relatively short timescales (less than 5 years). These changing factors generally do not appear to be directly linked to each other, and the underlying processes remain unexplored. While large-scale ground motion anomalies were also detected, the Campinas structure exhibited the most pronounced subsidence signal, with up to 1 cm/year. This implies that its active formation is potentially connected to an underlying H_2 system.

In addition to the Brazilian case study, we carried out preliminary analyses of ground motions associated with fault-related H_2 seepages. The investigated areas included the Moora region in Western Australia, where fairy circles align along a well-defined major fault, demonstrating a structural link between deep H_2 generation and surface seepage. H_2 seepages potentially associated with fault zones were also studied in Western Australia, with the aim of detecting ground motion signatures of active faulting.

While a detailed understanding of subsurface processes responsible for the detected anomalies cannot be inferred, the SAR-based mapping provides constraints towards the understanding of H_2 seeps. The presented cases also demonstrate the limitations of the SAR technique, serving as useful experience for future studies.

Keywords: Natural hydrogen seepage, Fairy circle, Vegetation and soil moisture, SAR backscatter, Ground motion, InSAR

Preliminary Soil Gas Results from the Gyód Serpentinite Body: a Natural Hydrogen Case Study

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Natural hydrogen (H_2) is recognized as a CO_2-neutral, potentially renewable energy source primarily generated through rock-porewater reactions (e.g., serpentinization). Successful exploration of natural H_2 integrates a diverse suite of geological and geophysical methods, among which soil gas sampling serves as a practical and cost-effective tool for detecting subsurface accumulations and seepages. H_2 migration driven by diffusion and advection frequently results in surface anomalies and geomorphological expressions ("fairy circles"), thus mapping of soil gas concentrations serves as a practical, tool without the need for large-scale instrumentation.

In the crystalline basement of the Tisia Mega-Unit (Carpathian-Pannonian Region) partially altered serpentinite bodies (Gyód Serpentinite Formation) containing relict olivine and pyroxene are well-known. These few hundred meter scale bodies may have potential for ongoing H_2 generation. To investigate the surface gas expression of this potential source, the Gyód area was selected for a preliminary, thorough in situ soil gas measurement campaign.

Point measurements were carried out in late spring and early autumn along a 2.5-km-long profile at 50 m intervals, oriented to cross the serpentinite body. Three multi-gas analyzers (two Geotech BioGas5000, and a MRU Optima Biogas 7) were used to monitor the concentrations of H_2, CO_2, CH_4, and O_2 through a 1 m soil gas probe. Simultaneously, an AlphaGuard instrument continuously monitored radon (Rn) activities to serve as a complementary subsurface tracer.

Maximum H_2 concentrations in the soil gas reached 40 ppm, while maximum Rn activity concentration reached 83,000 Bq/m^3. Based on the combined interpretation of the multi-gas measurement results, the surface anomaly is consistent with the geometry of the geological source – moreover an active gas upwelling can be assumed. Overall, this study demonstrates that the integration of in situ soil gas measurements, geological and geophysical methods is an effective approach in defining the natural H_2 potential of subsurface serpentinite bodies.

Keywords: hydrogen, radon, serpentinization, Pannonian Basin



Fairy Circles as Indicators of Natural Hydrogen Seepage and a Potential Example from SW Hungary

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Over the past decade, there has been an increasing focus on hydrogen as an energy source. This has led to the development of new methods for its production, but these are energy-intensive and expensive. However, there are continuously renewable hydrogen systems hidden beneath the surface, driven by natural processes which can be explored and potentially exploited. Similarly to hydrocarbon systems, a hydrogen system also consists of source rocks, migration pathways, and may include reservoir rocks and traps. However, hydrogen is extremely mobile, therefore huge amount could be emanated to the surface. Degassing pathways from the cratonic basement through the sedimentary cover commonly generate circular surface depressions with altered vegetation and significant concentrations of hydrogen gas in the soil, mostly along the perimeter. These are called fairy circles indicating the presence of an active subsurface hydrogen system.

In the subsurface hydrogen migrates dissolved in water until it reaches a certain depth, which is determined by pressure, temperature, and the salinity of the water. From that point, it moves in gaseous phase and any subsurface water acts as a temporary trap, halting the migration. As a result, the hydrogen rises to the surface in large, non-periodic pulses in a fairy circle. Generation of the funnel-shaped vent may lead to compaction, and subsequent formation of a central depression. Hydrogen seeps to the surface from a shallow reservoir at specific times each day, primarily regulated by daily temperature and pressure variations. So, the amount of leaking hydrogen varies both daily and on longer time scales.

Diameter of fairy circles typically ranges from a few tens of meters to a kilometre. They are constantly evolving, thereby confirming that the hydrogen system operates on a human time scale. The largest fairy circles may produce a few tens of thousands of cubic meters of hydrogen per day which could fuel a hydrogen-powered bus to travel thousands of kilometres.

Potential fairy circles can be detected by remote sensing methods (e.g., Landsat, Sentinel-2 satellite images and derived indexes, e.g. synthetic aperture radar images, Google Earth), displaying vegetation, water coverage, geometry and surface relief. None of these factors guarantee the presence of hydrogen, so soil-gas measurements are a must.

In the Pannonian Basin there are a few locations where potential hydrogen-generating rocks (e.g., Gyód serpentinite, Baksa Metamorph Complex in SW Hungary), faults and a sedimentary cover coexist. Potential locations of interest are located to the south of Gyód, where several circular, occasionally water-covered depressions of 20–50 m diameter are present. Pilot soil-gas measurements in the largest one indicate the seepage of hydrogen up to 40 ppm along the measured transects. Further soil-gas tests are necessary to reveal the spatial and temporal variations of H_2 concentrations in the structure as a fairy circle.

Keywords: natural hydrogene exploration; fairy circle; remote sensing; Gyód serpentinite, Baksa

Preliminary Results on the Effects of Natural Hydrogen on Photosynthesis in Herbaceous Plants

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Natural hydrogen (H_2) may be present in the soil as a result of various geological and microbial processes, and its environmental, geochemical, and biological significance has received increasing attention in recent years. The plant physiological effects of molecular hydrogen have primarily been studied under controlled conditions, using hydrogen-rich water or through artificial H_2 treatments. In contrast, little is known about how H_2 concentrations occurring in natural soils may be related to the physiological processes of plants in natural vegetation, particularly their photosynthetic activity. The aim of our study is to determine whether spatial variations in the natural H_2 concentration of the soil are correlated with the species composition and photosynthetic parameters of herbaceous plants found in natural vegetation.

During the study, we examined the photosynthetic parameters of meadow foxtail (Alopecurus pratensis) at measurement sites with varying natural soil H_2 concentrations using SPAD and LI-6400 photosynthesis measurement systems. Among other things, we measured the chlorophyll content of the plants' leaves, the gross photosynthetic rate, stomatal conductance, and transpiration.

Based on the initial results, differences were observed in the photosynthetic parameters studied and in the plant species composition at measurement points with different H_2 concentrations. It can be assumed that the presence of natural hydrogen in the soil and its spatial variation may be related to the photosynthetic activity of plants; however, interpreting any potential correlation also requires consideration of other soil properties and environmental factors. In the next phase of the research, we aim to clarify the observed relationships through a combined analysis of H_2 concentrations, the soil's physicochemical characteristics, and plant physiological parameters.

Our study may contribute to the exploration of possible relationships between natural soil gases and the plant–soil system, and may provide new perspectives for investigating the physiological and ecological significance of natural hydrogen in plants.

Keywords: natural hydrogen; soil gas, photosynthetic parameters, meadow foxtail



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Initial Results of Natural Hydrogen Seepage in Western Hungary in Thick Overlying Sedimentary Layers and Along a Distributed Fault System

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Natural hydrogen is increasingly recognized as a potential low-carbon energy resource, with hydrogen generation commonly associated with water–rock reactions involving suitable mineral assemblages in crystalline and metamorphic rocks. In the vicinity of Kőszeg Mountains, metamorphic basement formations may provide favorable conditions for natural hydrogen generation. However, these rocks are locally buried beneath several hundred metres of Pannonian sedimentary cover which is dissected by complex fault systems. Consequently, the potential migration of hydrogen from the basement toward the surface is expected to depend strongly on the presence and permeability of structural pathways. The aim of this study was to investigate whether hydrogen generated within the metamorphic basement can migrate through the thick sedimentary succession and be detected in near-surface soil gas. A further objective was to determine whether spatial maxima in measured hydrogen concentrations coincide with previously mapped fault zones, thereby providing evidence for geologic origin and structural control on hydrogen migration. The general effect of soil gas anomalies on vegetation was also investigated.

Soil gas measurements conducted across the survey area confirmed the presence of detectable hydrogen anomalies, with maximum concentrations reaching approximately 100 ppm. The spatial distribution of these anomalies shows a strong relationship with the previously identified fault system: elevated hydrogen concentrations and local maxima preferentially occur in the vicinity of mapped structural elements. These observations suggest that fracture zones may act as preferential migration pathways, allowing hydrogen to pass through the otherwise relatively thick Pannonian sedimentary cover and distributed fault segments. In a meadow where hydrogen measurements were frequently taken, changes in vegetation density were observed, but a direct link with soil gas anomalies has not yet been established. Repeated observations also demonstrated that hydrogen seepage is temporally variable. In addition, hydrogen and carbon dioxide concentrations exhibit an inverse relationship, with changes in hydrogen release accompanied by opposing variations in CO_2 concentrations. Both gas components show significant temporal variability, indicating that soil gas anomalies represent a dynamic system rather than a stationary surface expression.

The observed spatial association with mapped faults highlights the importance of structural migration routes in controlling hydrogen seepage, even when the faults are distributed and there is no continuous pathway between the source rock and the surface. The results support the use of soil gas measurements as a complementary exploration tool for identifying areas of potential natural hydrogen generation, migration, and fault validation.

Keywords: Natural hydrogen; Soil gas; Distributed faulting; Thick sedimentary cover, Western Hungary

Soil Gas Monitoring for Danube Carbon Removals

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Danube Carbon Removals will capture fermentation-derived carbon dioxide at Pannonia Bio in Dunaföldvár, Hungary, and permanently store it in a deep saline aquifer. Demonstrating containment throughout the project lifecycle requires a monitoring programme that combines subsurface measurements with surface assurance. This presentation examines soil-gas monitoring as a practical, continuous line of evidence for detecting and interpreting anomalous near-surface CO_2 signals.

The proposed approach begins with a robust multi-season baseline, designed to distinguish biological variability, agricultural activity and weather-driven changes from potential storage-related signals. It then retains comparable measurements through construction, injection, post-injection and closure. Station siting, sampling depth, meteorological context, quality assurance and escalation thresholds are central to making the data scientifically useful and regulator-ready.

The presentation will introduce the automated soil-gas profiling solution provided by Engineering Design Group (EDG, edglab.com). EDG's self-powered stations sample soil gases and environmental conditions on a programmed schedule, transmit data by cellular connection to a portal, and preserve raw historical records for analysis and reporting. This enables high-frequency, consistent monitoring without relying on repeated manual campaigns. Integrated with reservoir, well-integrity and atmospheric monitoring, the system can support early investigation of anomalies, evidence of containment and long-term monitoring, reporting and verification for durable carbon removals.

Keywords: CCS, monitoring system, soil-gas monitoring, automated soil-gas profile



Continuous FT-IR Monitoring of Soil Gases for Geological and Environmental Applications

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Soil gases provide valuable information on processes occurring below the Earth's surface and can serve as indicators of geological activity, subsurface gas migration and changes in the carbon cycle. Continuous monitoring of these gases is therefore increasingly important in geoscientific research as well as in environmental applications such as Carbon Capture and Storage (CCS) monitoring.

This presentation introduces an automated soil-gas monitoring solution combining a PerkinElmer Fourier Transform Infrared (FT-IR) spectrometer with the REDshift automated gas sampling system. The system has been developed for continuous, unattended operation and enables long-term monitoring of gas concentrations from subsurface sources together with ambient atmospheric measurements.

The configuration incorporates heated gas-transfer lines and infrared gas cells to minimize condensation, while a nitrogen-purged measurement environment reduces interference from atmospheric humidity and background carbon dioxide. The use of short- and adjustable long-path gas cells provides flexibility for analysing different concentration ranges and IR-active gaseous components. Automated sampling, flushing and measurement cycles, together with remote system control and data acquisition, allow the instrument to operate continuously under field conditions.

Similar systems are currently operating at geodynamic monitoring stations in Covasna, Romania, and Badacsonytördemic, Hungary, where continuous CO_2 measurements contribute to the investigation of deep gas migration, tectonic processes and possible geochemical signals associated with seismic activity.

The same analytical approach can also support environmental monitoring and CCS Monitoring, Reporting and Verification (MRV), where detecting changes in soil gas composition and identifying potential CO_2 migration towards the surface are essential. Automated FT-IR monitoring therefore provides a versatile link between laboratory-grade gas analysis and long-term field observation of geological and environmental processes.

Keywords: soil gas monitoring, FT-IR spectroscopy, CO_2, continuous monitoring, CCS, gas migration, geochemical monitoring



Is Soil Gas the Last Line of Defence? Lessons from Three Decades of Monitoring at BGS

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Soil gas monitoring has been firmly embedded in British Geological Survey (BGS) science for well over 30 years. Understanding the critical interface between shallow subsurface and lower atmosphere through soil gas investigations provides insights into the geological and environmental processes that control the generation, migration and surface expression of gases, and their implications for environmental protection, infrastructure resilience and human health.

Building on systematic national mapping experience, BGS has continued to develop a suite of mobile, multi-scale field methods to meet the changing demands of a modern geological survey, and have contributed multiple-lines-of-evidence approaches for subsurface characterisation and environmental monitoring. We will initially review of the evolution of soil gas capability at BGS, briefly revisiting early applications associated with radon, naturally-occurring and fugitive ground gases, and coal bed methane (CBM), which established many of the conceptual and operational foundations that continue to underpin BGS soil gas investigations today. The primary focus, however, is on lessons learned from geoenergy and decarbonisation applications, where monitoring the behaviour and potential migration of CO_2 has been a recurring theme. We will draw on examples including the landmark ten-year Weyburn monitoring programme and the Kerr Farm incident, controlled-release and engineered-leak experiments, and the use of natural analogue sites to develop and challenge monitoring strategies for detecting and quantifying fugitive emissions. Collectively, these projects have helped define the capabilities and limitations of soil gas monitoring under both controlled and real-world conditions.

We will examine how advances in instrumentation have transformed our monitoring capability. The progression from conventional ground-gas surveying to laser-based systems, open-path analysers, field methods for isotopic measurements and drone-mounted sensors have improved detection, sensitivity, spatial coverage and operational agility. Examples from high-enthalpy geothermal systems within the Trans-Mexican Volcanic Belt, and shallow geothermal environments associated with abandoned coal mines at the UKGEOS site in Glasgow, show how technologies have been adapted to a range of challenging field settings.

Technological progress aside, the central principles of soil gas investigations may have appeared to change little, since practical, resilient and reliable solutions can sometimes be more valuable than technological sophistication, particularly when paired with sound geological understanding and operational flexibility. Robust interpretations continue to depend on direct field observations and access to suitable monitoring locations. While advances in tools and techniques have doubtless transformed monitoring capability, we would advocate that the value of opportunities in scientific credibility, stakeholder confidence, public engagement and 'acceptability' of emerging net-zero geoenergy systems should not be underestimated.

Keywords: Geoenergy monitoring; Carbon capture and storage; Ground gas; Ground-truthing. Acceptability



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Geochemical Modeling Approaches for Soil Gas Studies

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Geochemical and reactive transport modelling are powerful tools for understanding the complex interactions among gases, water, minerals, and organic matter in soil and subsurface environments. These approaches help to identify the chemical processes controlling gas-related changes in environmental systems and predict their evolution under different conditions.

This presentation provides an overview of geochemical and reactive transport modelling approaches, focusing on the capabilities and applications of PHREEQC and TOUGHREACT. Geochemical models can simulate a wide range of processes, including aqueous speciation, mineral dissolution and precipitation, and sorption processes (e.g., ion exchange and surface complexation). By coupling these reactions with fluid flow and solute transport, reactive transport models enable the study of spatial and temporal changes in chemical conditions. These approaches can also incorporate gas–water interactions and biogeochemical processes, offering opportunities to investigate the effects of both natural and anthropogenic gas sources.

Two examples are used to illustrate the potential applications of these modelling approaches. The first example, based on batch geochemical modelling, focuses on the influence of soil organic matter and microbial activity on CO_2 production and soil geochemistry. Biogenic CO_2 production can affect soil pH, mineral equilibria, and the mobility of dissolved elements, whereas sorption processes on mineral surfaces and exchange sites may further influence soil chemistry. The second example addresses the potential impacts of CO_2 leakage from geological storage reservoirs into shallow freshwater aquifers. Reactive transport simulations demonstrate how CO_2 intrusion may alter groundwater composition, trigger mineral reactions, and produce measurable geochemical signals relevant to environmental monitoring.

Together, these examples highlight how geochemical and reactive transport modelling can support the interpretation of gas-related processes and contribute to understanding and monitoring environmental changes in soil and subsurface systems.

Keywords: geochemical modelling, reactive transport, PHREEQC, TOUGHREACT, CO

Soil Gas Monitoring – a Key to Safe Energy Transition

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In the 21st century, the utilization of subsurface pore space is becoming increasingly important, including for CO_2 and hydrogen storage. However, the integrity of these geological systems is a key concern. If gases migrate through faults, fractures, or other preferential pathways, they may eventually reach the shallow subsurface and, ultimately, the ground surface.

Effective monitoring therefore requires a combination of geophysical, geochemical and modelling approaches. Soil gas monitoring has a particularly important role, as the soil is one of the last environments through which migrating gases pass before reaching the atmosphere and may therefore provide an early indication of leakage.

However, interpreting soil-gas signals is challenging because their natural variability is strongly influenced by soil properties, hydrology, temperature, atmospheric pressure, and biological activity. Reliable baseline monitoring is therefore essential; for geological CO_2 storage, at least one full year is generally required to characterize natural spatial and temporal variability before injection.

Additional information can be obtained from tracers and stable isotopes, while geochemical and reactive-transport modelling can help identify gas sources and predict migration pathways.

These requirements are reflected in the regulatory framework, although several practical and methodological aspects of soil-gas monitoring remain unclear. At the European level, Directive 2009/31/EC establishes monitoring requirements for geological CO_2 storage, implemented through national legislation such as SARA Regulation 29/2022 in Hungary. For underground hydrogen storage, however, monitoring requirements are still less developed.

This leads to a key question: How can soil gas monitoring provide a reliable early-warning system for unwanted gas migration from deep geological storage systems to the surface? Answering this requires a better understanding of natural soil-gas variability, gas–soil interactions, tracer and isotopic behaviour, and gas transport through the shallow subsurface. Addressing these questions is essential for developing an effective and scientifically sound regulatory framework.

Keywords: CCS, H_2-storage, monitoring



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Methane Emissions from Abandoned Oil & Gas Wells: Evaluation Using UAV-based TDLAS and In Situ Measurements

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Poorly abandoned gas wells may represent risk of potential source of methane emissions from soil to atmosphere. Our study investigated surface gas emissions in two localities above the abandoned wells V–146 in Vacenovice and SL–2 in Slavkov u Brna, Czech Republic. Well V–146 was drilled as an exploratory well down to 800 m in 1958 during oil and gas prospecting. Gas shows were encountered while drilling through the Neogene (Sarmatian) strata and Paleocene sandstones of the Carpathian Flysch Belt. Structural well SL–2 was drilled for gas to depth of 1400 m in 1964 in Miocene and Devonian reservoirs. In both cases the wells were abandoned and cut and sealed 1.6 m below today's surface.

At each site, CH_4 and CO_2 contents in soil gas were measured up to the depth of 80 cm and mapped across a 1.5 m grid around the wellhead. In addition, gas samples were collected and subsequently analyzed in the laboratories to cross check the field data. Hourly changes in soil-gas composition were tracked through 3 months using autonomous GasClam 2 stations deployed 1 m below the surface. The timely variations are caused by meteorological parameters, mainly by pressure and temperature. Methane flux was quantified using gas chamber coupled to a portable instrument with infrared detector. The field soil gas measurement data were processed in form of contour maps valid for a specified day and time. The shape of the methane and carbon dioxide anomalies depend on the geological structure, soil type and inhomogeneity. The latter depends on how workers cleaned up the site, i.e. how they dumped clay, sand and concrete blocks. This is why the data showed peculiar methane patterns in the gas maps. Carbon dioxide often formed a rim around the methane maximum above the buried well head, what indicates the activity of methanotrophic archea-bacteria.

During the same date and hour as the soil gas campaign, path-integrated CH_4 concentrations in ppm·m (parts-per-million-meter) were acquired using a UAV (unmanned aerial vehicle, drone)-mounted Pergam Falcon laser detector based on tunable diode laser absorption spectroscopy (TDLAS). Based on these measurements, methane plume concentration maps and vertical profiles at heights of 5–20 m were prepared. From the comparison with the soil gas maps it follows, that the UAV data are affected by terrain topography, wind speed and direction, as well as atmospheric and sky conditions. On the other hand, the UAV data provide very valuable picture of the current areal extent of the methane plume. These results are even more useful when coupled with quantitative emissions evaluation based on gas flux measurements by chamber method. Selected localities show different quantity of methane emissions, shape and size of the methane plume. The experience gathered calls for necessity of combination of field works with sampling, lab analyses, UAV-based remote sensing, flux measurements and checking the variability before the final evaluation is completed of greenhouse gas emissions as required by EU Regulation.

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Keywords: Soil gas monitoring, methane emissions, UAV TDLAS method, abandoned gas wells, gas flux

Successful Indoor Radon Mitigation in the Velence Mountains – a Case Study

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High indoor radon concentrations pose a health risk, as radon is a radioactive noble gas. When inhaled, its short-lived alpha- (especially Po–218, Po–214) and beta-emitting daughter products can directly damage the lungs. For this reason, it is important to be aware of the indoor radon concentration in a property. There are places where geological conditions favor the accumulation of radon in buildings. Such a situation can be observed, for example, in the Velence Mountains region of Hungary, where granite contains elevated concentrations of uranium-bearing minerals.

Recognizing this, a property owner requested a radon survey of his home, which was conducted by MS Energy Solutions Ltd. The survey took place during the winter heating season. For the radon survey, accredited and certified AlphaGuard PQ 2000 Pro radon monitors were used. Indoor radon measurements showed that during the winter heating season, radon levels in the property can consistently exceed 1,000 Bq/m^3. During the measurement period, activity-concentration even exceeded 2,000 Bq/m^3. Soil gas radon activity-concentration measurements clearly confirmed that the source of the elevated radon concentration is the soil, which, based on field observations, consists of weathered granite debris. The Rn–222 content of the soil ranged from 50,000 to 60,000 Bq/m^3. Given the elevated radon concentrations, the annual reference level of 300 Bq/mł specified in Regulation 2/2022 OAH may potentially be exceeded at the property. Based on dose estimates calculated for various exposure times, the additional dose of 6 mSv/year could potentially be exceeded by spending time in the property; therefore, we have recommended various radon remediation methods.

Due to the very high indoor radon concentrations, an active radon remediation system was designed. (1) Firstly, next to the building's southwest wall, at a depth of 1–1.5 m below the foundation level, a 10-meter-long drainage pipe with a diameter of 110 mm was installed, to which a fan with an airflow capacity of 950 m^3/hour, a static pressure of 530 Pa, and an electrical power of 154 W is connected. This creates a depression beneath the building, preventing radon from moving toward the property. (2) Secondly, a vent through the basement using a 3.5-meter-long pipe with a 100-mm diameter was created, to which a duct fan with an airflow capacity of 137 m^3/h, a static pressure of 47 Pa, and an electrical power of 16 W is connected.

The installation was completed during the summer. Although radon concentrations in the property are typically lower in the summer, the effectiveness of the remediation system can be clearly demonstrated in the property, where, after 2–4 hours of system operation, the lower summer radon concentrations (a few hundred Bq/m^3) can be reduced to background levels. Its effectiveness can be verified in the basement, where radon concentrations of few thousand Bq/m^3 have been successfully reduced to below 250 Bq/m^3.

Keywords: soil gas radon measurement, indoor radon, radon risk, exposure time, dose estimation, radon remediation

Radon and Thoron Emanation from Soil-Based Building Materials: Revisiting the Angola Case Study

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Radon and thoron are naturally occurring soil gases originating from the radioactive decay of uranium and thorium series radionuclides in minerals. Their release from soil particles and subsequent migration through pore spaces are influenced by material properties such as grain size, porosity, and moisture content. These processes are also relevant to soil-based building materials, including adobe, which are widely used in Angola.

However, the contribution of adobe to indoor radon (Rn–222) and thoron (Rn–220) exposure remains poorly characterized. Here, we revisit emanation measurements of adobe samples from three Angolan regions: Cabinda (Northern Angola), Huambo (Central Angola), and Menongue (Southern Angola).

Emanation was measured with a RAD7 detector in a closed-loop setup. For radon, intact adobe blocks were analyzed with the growth-curve method, which accounts for leakage from the setup. For thoron, fragmented samples were evaluated with a diffusion model that accounts for thoron decay and dilution within the measurement circuit (Csige et al. 2013, Szabó 2013). Of 30 radon measurements, 12 met the leakage acceptance criterion, and 29 thoron measurements were evaluated. Adobe from the Central part showed the highest emanation for both radon (81 ± 39 atoms kg^{-1} s^{-1}) and thoron (7 ± 2 atoms kg^{-1} s^{-1}), followed by the ones from the south (50 ± 9 and 4 ± 1 atomskg^{-1} s^{-1}) and those from the North (34 ± 30 and 5 ± 3 atoms kg^{-1} s^{-1}). The emanation fractions showed the opposite pattern. Samples from the Central part of the country had the lowest fractions (radon 12 ± 4%, thoron 8 ± 2%), and those from the south had the highest radon fraction (28 ± 9%). Across all samples, the mean emanation fractions were 19 ± 10% for radon and 12 ± 6% for thoron. These differences relate to grain-size distribution: samples from the north are sand-dominated (median 62% sand), whereas central and southern adobes contain more fine material.

Beyond their relevance to indoor radiation exposure, these findings contribute to a better understanding of the processes controlling soil gas emanation and highlight how soil properties influence the release of radon and thoron in both natural and built environments.

Keywords: Soil-based building material, Radon, Thoron, Emanation fraction, Adobe, Angola

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Radon Gas Observations for Multidisciplinary Climate Research: the NuClim Project

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Radon is an inert gaseous radionuclide continuously generated in soils and rocks and released to the atmosphere through soil-gas exhalation. Because of its production in uranium-bearing soils and rocks, predominantly terrestrial origin, and short half-life, radon is a unique tracer for assessing the influence of land-derived emissions on marine air masses.

The EU-funded project NuClim (Nuclear Observations to Improve Climate Research and Greenhouse Gas Emission Estimates) aims to establish a baseline for atmospheric greenhouse gas (GHG) concentrations, supporting improved estimates of European GHG emissions, characterize pollution events, and investigate wet deposition and meteorological processes affecting ambient gamma dose rates. To achieve these objectives, NuClim established continuous observations of atmospheric radon activity concentration and selected GHGs (CO_2 and CH_4), together with comprehensive measurements of radon progeny and ambient gamma dose rate, at the Eastern North Atlantic (ENA) facility of the Atmospheric Radiation Measurement (ARM) programme of the U.S. Department of Energy, located on Graciosa Island (Azores Archipelago) in the central North Atlantic Ocean. The resulting radon and GHG datasets, together with the classification of terrestrial influences on marine air masses, support a wide range of climate and environmental applications, including the including the investigation of pollution events, the characterization of marine boundary-layer clouds and aerosols, and improved quantification of natural variability in ambient gamma dose rate to enhance nuclear surveillance networks.

This presentation highlights the objectives, field observations, and ongoing research activities of the NuClim project.

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Keywords: radon; ambient gamma dose; greenhouse gases; climate



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Radon Activity Concentration in Hungarian Soils

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In accordance with international recommendations and European Union legislation, National Radon Action Plan (NRAP) was adopted by Government Resolution 1114/2019. (III. 13.) in Hungary. The NRAP was developed by the predecessor of the Department of Radiobiology and Radiohygiene, National Centre for Public Health and Pharmacy.

The program was launched in 2019. Before that, the Department of Radiobiology and Radiohygiene already possessed decades of experience in the field of radon-related investigations. Within the framework of NRAP, indoor radon activity concentrations and soil gas radon potential were determined, covering the whole territory of Hungary. This presentation will focus on introducing the results of soil gas radon measurements.

Soil probes were hammered at a depth of 80 cm. A total of 9 samples were taken into ionisation chambers from 3 probes at each measurement point, and the average soil gas radon concentration was calculated. RM-2 radon detector was used for the determination of the radon concentration. During the measurement process, soil permeability was also determined at each probe using Radon JOK. The geogenic radon potential (GRP) was calculated from these values using the Neznal formula. The total number of soil radon sampling sites were more than 30,000. The results were delineated on a 10×10 km grid cell map. The number of cells covering the territory of Hungary is 1036. From these, measurements have been conducted in 908 cells. This represents at least one measurement in each cell.

The typical average soil gas radon concentrations were in the ranged of 5 and 45 kBq/m^3. The arithmetic mean was ~20, while the median was ~16 kBq/m^3. Most of the calculated geogenic radon potential values were in the range of 5 and 35. The arithmetic mean of GRP values was ~13, while the median was ~10. Based on the Neznal classification of the geogenic radon potential values, 49% of the investigated areas are classified as low risk (GRP < 10), 46% as medium risk (10 < GRP< 35), and 5% as high risk (GRP > 35).

The soil gas radon survey is ongoing, and the map is being continuously refreshed based on the new results. The soil gas radon risk map can support the estimation of indoor radon risk in areas where only soil gas radon activity concentration has been determined.

Keywords: soil radon gas, geogenic radon potential mapping, national survey

Radon, as a Groundwater Discharge Phenomenon

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Radon is widely used as a natural tracer in hydrogeology because its occurrence and spatial variability provide information on groundwater flow paths, residence times, water–rock interaction and mixing processes. Owing to its noble-gas character, radon is chemically conservative, while its short half-life of 3.8 days makes elevated radon activity concentrations particularly indicative of a local or continuing radon supply.

Groundwater discharge occurs at the termination of groundwater flow systems, and the associated radon concentrations may arise from different mechanisms along flow paths. In local flow systems with shallow penetration depths, radon is primarily derived from the soil zone – from radium-bearing minerals and/or from radium adsorbed onto soil constituents – and may be transported to the discharge zone during recharge events. In karst aquifers, high groundwater flow velocities may allow radon to travel considerable distances before decaying, enabling temporal variations in radon activity concentrations to reveal recharge dynamics and travel times. Thus, in karst springs the peaks in radon and CO_2 concentrations can indicate the arrival of water that has passed through the soil zone and become enriched in these components. In contrast, regional groundwater flow systems are typically characterized by long residence times and commonly reducing conditions. Such waters may become enriched in dissolved radium during their subsurface evolution. When they reach natural discharge zones, a shift from reducing to oxidizing conditions can promote the formation of iron and manganese oxyhydroxide precipitates. These precipitates may form through biogeochemical processes and occur in association with biofilms. These materials efficiently scavenge radium and may subsequently become important secondary sources of radon directly at the discharge site. Similar processes can also occur during groundwater abstraction, when changes in physicochemical conditions induce mineral and biological precipitation in wells, pipelines and pools. Examples from the Buda Thermal Karst demonstrate that radium accumulation on mineral precipitates and biologically active surfaces in thermal-water discharge environments can produce very high radon activity concentrations, locally reaching approximately 1000 Bq/L. Radon anomalies can also identify zones where shallow, oxidizing groundwater mixes with deep, reducing groundwater, providing insight into active hypogene karstification and groundwater discharge processes.

These observations show that integrating radon measurements with hydrogeological and hydrochemical observations can improve our understanding of groundwater flow-systems and overall subsurface dynamics.

Keywords: radon, groundwater flow systems, groundwater discharge, environmental tracers, radium, iron and manganese oxyhydroxides, karst systems



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Szabályozott Tevékenységek Felügyeleti Hatósága (SZTFH)
Supervisory Authority for Regulatory Affairs (SARA)

Informations

Location informations

Organizer: Szabályozott Tevékenységek Felügyeleti Hatósága (SZTFH)

Address: 1123 Budapest, Alkotás u. 50 B wing (middle elevator, left from Medicover)

SZTFH/SARA Central Building:_Alkotás Point Office Building

The building is not exclusively occupied by SZTFH, as several other companies are also located in the office building. The lecture hall will be located on the **first floor of the B Wing in B119/A conference room**.

Use Entrance B, where the revolving door is located. After entering, the reception staff will be on your left, behind the reception desk..

Streetview picture: about B entrances.

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