



Abstract

Future Perspective of In Situ Soil Analysis [†]

Mari-Liis Leinus ^{1,*} , Piia Jõul ¹, Martin Růžička ¹, Jelena Gorbatšova ¹, Merike Vaher ¹ , Ruth Shimmo ² and Jekaterina Mazina-Šinkar ¹

¹ Department of Chemistry and Biotechnology, Tallinn University of Technology, 12618 Tallinn, Estonia

² School of Natural Sciences and Health, Tallinn University, 10120 Tallinn, Estonia

* Correspondence: mari-liis.leinus@taltech.ee

[†] Presented at the International Conference EcoBalt 2023 “Chemicals & Environment”, Tallinn, Estonia, 9–11 October 2023.

Keywords: soil health; soil fertility; nutrients; portable capillary electrophoresis; GHG emissions; fertilization of soils; over fertilization

Soil health monitoring is becoming progressively more important to meet the needs of sustainable agriculture and climate policy goals. Portable capillary electrophoresis (CE) devices could be used to monitor micro and macro nutrients available to plants in soil in real time as anions and cations to make informed decisions about the need for fertilization. These devices could be considered precise, cheap and fast alternatives to time-consuming laboratory analyses and sensors that are currently on the market that can determine only N, P and K, and not other important macro or micro elements [1–5]. Method development for determining cations in soil samples was carried out using commercial CE device coupled to a contactless conductivity detector (C4D) with the intent to later implement the developed method on a portable CE device. The separation of eight cations (NH_4^+ , K^+ , Na^+ , Ca^{2+} , Mg^{2+} , Mn^{2+} , Zn^{2+} and Cu^{2+}) was achieved using a capillary with an effective length of 47.5 cm and an inner diameter of 50 μm . Briefly, a 6 M acetic acid solution was used as a background electrolyte, and we used an applied voltage of 15 kV. The duration of analysis was 20 min (including 3 min of pre-washing). Linearity for analytes was determined to be in the range of 1–10 mM, which encompasses the limit of detection (LoD) (0.1–0.9 mM) and limit of quantification (LoQ) (0.3–1.8 mM) for the analytes. The extraction of cations was tested from 1 min up to 24 h using distilled water and 0.01 M CaCl_2 [6,7]. No remarkable differences in extraction recoveries were observed within the tested timeframe. Therefore, 1–3 min was suggested as an optimum extraction time for the in situ extraction procedure. The developed analysis method is suitable for the qualitative and quantitative analysis of eight cations extracted from soil and can be implemented on portable CE devices. Further optimization of simple and quick sample preparation must be carried out so that it could be easily used directly on the field prior to analysis.



Citation: Leinus, M.-L.; Jõul, P.; Růžička, M.; Gorbatšova, J.; Vaher, M.; Shimmo, R.; Mazina-Šinkar, J. Future Perspective of In Situ Soil Analysis. *Proceedings* **2023**, *92*, 10. <https://doi.org/10.3390/proceedings2023092010>

Academic Editors: Monika Mortimer, Anne Kahru, Ivo Leito, Riin Rebane and Villem Aruoja

Published: 21 November 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Author Contributions: Conceptualization, J.G., M.V. and J.M.-Š.; methodology, M.-L.L. and P.J.; validation, M.-L.L., P.J. and M.V.; hardware, M.R., J.G. and J.M.-Š.; formal analysis, M.-L.L. and P.J.; investigation, M.-L.L. and P.J.; resources, J.G. and J.M.-Š.; data curation, M.-L.L. and P.J.; writing—original draft preparation, M.-L.L.; writing—review and editing, R.S. and J.M.-Š.; visualization, M.-L.L. and M.R.; supervision, R.S. and J.M.-Š.; project administration, J.M.-Š.; funding acquisition, J.M.-Š. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Environmental Investment Centre (KIK), grant number Kliima.3.01.22-0101 (“SmartAGRO”), and Estonian Research Council, grant number MOBJD1015.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

Acknowledgments: Our partners in Ukraine, National University of Life and Environmental Sciences of Ukraine, Agriculture (Farming) Enterprise “Sophiya S+”, and Agriculture (Farming) Enterprise “Roksolana”, are acknowledged for providing soil samples.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Environmental XPRT, Renke—Model RS-NPK-TR—Soil NPK Sensor. Available online: <https://www.environmental-expert.com/products/model-rs-npk-tr-soil-npk-sensor-784865> (accessed on 31 May 2023).
2. Teralytic Soil Probe. Available online: <https://teralytic.com/soil-probe/> (accessed on 31 May 2023).
3. Paul-Tech Soil Station Service. Available online: <https://paul-tech.com/paul-tech-soil-station-service/> (accessed on 31 May 2023).
4. AgroCares Nutrient Scanner. Available online: <https://www.agrocares.com/scanners/> (accessed on 31 May 2023).
5. Bruker, Application Note N526, Online Quality Control of Mineral Fertilizers Using FT-NIR Spectroscopy. Available online: https://www.bruker.com/en/meta/forms/bopt-form-pages/thank-you-an-n526-form/_jcr_content/root/contentpar/twocolumns_copy_copy/contentpar-1/calltoaction.download-asset.pdf/primaryButton/AN_N526_Fertilizer_online_EN.pdf (accessed on 31 May 2023).
6. Pontes, F.V.M.; Carneiro, M.C.; Vaitsman, D.S.; Monteiro, M.I.C.; da Silva, L.I.D.; de Souza, E.D.M.F.; Neto, A.A. Fast and simultaneous ultrasound-assisted extraction of exchangeable-NH₄⁺, NO₃⁻ and NO₂⁻ species from soils followed by ion chromatography determination. *Chem. Speciat. Bioavailab.* **2012**, *24*, 229. [CrossRef]
7. Stanišić, S.M.; Ignjatović, L.M.; Manojlović, D.; Dojčinović, B. The comparison of sample extraction procedures for the determination of cations in soil by IC and ICP-AES. *Cent. Eur. J. Chem.* **2011**, *9*, 481–484. [CrossRef]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.