

Poster Communication 83

Ground penetrating radar detection of buried explosive devices in European soil

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Abstract

Background: The detection of buried explosive devices remains a significant challenge, particularly in the context of humanitarian demining in areas affected by armed conflict [1]. In recent years, this issue has become particularly relevant in Europe following the conflict between Russia and Ukraine, reinforcing the need to develop detection methods that are simultaneously effective, safe and operationally viable. In this context, ground-penetrating radar (GPR) has emerged as a promising technique for locating buried objects. However, its performance depends strongly on factors such as soil characteristics, object properties, and burial conditions [2]. **Objective:** Evaluate the performance of GPR in detecting explosive devices buried in sandy loam soil in European environment, specifically in Portugal. **Methods:** A total of 15 inert explosive devices (projectiles, grenades, mines, fuzes, and an improvised explosive device) were buried at different depths ranging from 10 to 70 cm and orientations (horizontal and vertical). Data were collected in March 2026, during the winter season, using a GPR system (NoggIn SmartCart Sensors&Software Inc. 250 and 500 MHz) equipped with 250 MHz and 500 MHz antennas and processed using ReflexW software. **Results:** GPR detected most of the buried objects, with 11 of 15 targets identified using the 250 MHz antenna and 13 of 15 using the 500 MHz antenna. However, both datasets exhibited lower resolution and higher noise levels compared to data acquired in summer 2025. Non-detections observed previously persisted (60 mm mortar round by 250 MHz antenna; coastal artillery round by 500 MHz antenna), with additional targets not detected (Barcarena hand grenade, impact fuze and fuze by 250 MHz antenna; 120 mm training mortar round by 500 MHz antenna). These differences may be explained by the variability in soil moisture conditions observed in the field (1.8–5.2%), indicating spatial heterogeneity in water content. Increased moisture contributes to higher electrical losses and attenuation of the electromagnetic signal, resulting in less well-defined hyperbolas. Additionally, the heterogeneous distribution of water reduces the dielectric contrast between the targets and the surrounding medium and increases signal noise, ultimately affecting target detectability [3]. **Conclusions:** Overall, the results highlight the potential of GPR for detecting buried explosive devices in European soils, while emphasizing the influence of environmental conditions on its performance.

Keywords: buried object detection; geophysical methods; humanitarian demining; radar signal interpretation; soil properties

Acknowledgments/Funding

This research was funded by the annual funding of IH-TOXRUN of the University Institute of Health Sciences (IUCS-CESPU). We would like to thank the GNR of Lisbon for providing the burial material and the training ground used in this study, and the GeoSmartSolution for providing the GPR equipment and the guidance team for their monitoring and scientific support throughout the work.

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