# HUMANITARIAN DEMINING

## NUCLEAR TECHNIQUES MAY HELP THE SEARCH FOR LANDMINES

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About 60 million abandoned landmines are distributed in more than 70 countries in all parts of the world. They are lethal remnants from often forgotten armed conflicts during the last century. Landmines kill about 26,000 persons every year and maim even more, leaving behind dismembered victims requiring extensive healthcare and rehabilitation.

The victims are usually women, children and farmers in developing countries. For example, in Angola one of every 334 individuals is a landmine amputee and Cambodia has more than 25,000 amputees due to mine blasts. Furthermore, the landmine problem has vast socio-economic consequences as it undermines peace and stability in whole regions by displacing people and inhibiting the use of land for agricultural production. The daily lives of more than 22 million people are directly affected by abandoned landmines.

In December 1997, a total of 123 countries signed the "Convention on the Prohibition, of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction" in Ottawa, Canada. Since then, 16 additional countries have signed the Convention.

The Convention requires, among other things that: "Each State Party in a position to do so shall provide assistance for mine clearance and related activities". In recognition of the inabilities of some countries to do so, the Convention also states that "State Parties may request the United Nations, other State Parties, regional organizations or other competent intergovernmental or non-governmental organizations to assist its authorities in the elaboration of a national demining program."

### MINE DETECTION METHODS

In military demining the objective is to clear a minefield as fast as possible using brute force, and usually a clearance rate of 80% to 90% is accepted.

Humanitarian demining, on the other hand, is more difficult and dangerous, as it requires the complete removal of all mines and the return of the cleared minefield to normal use. Today, most humanitarian demining is done using hand-held metal detectors and/or sniffer dogs. Metal detectors find objects containing metal by utilizing a time-varying electromagnetic field to induce eddy-currents in the object, which in turn generate a detectable magnetic field. Old landmines contain metal parts (e.g. the firing pin), but modern landmines contain very small amounts or no metal at all.

Increasing the sensitivity of the detector to detect smaller amounts of metal also makes it very sensitive to metal scrap often found in areas where mines may be located. Furthermore, metal detectors, however sophisticated, can only succeed in finding anomalies in the ground without providing information about whether an explosive agent is present or not.

One major problem in humanitarian demining is to discriminate between a "dummy" object and a landmine. Identifying and removing a harmless object is a time-consuming and costly process. Dogs have extremely well-developed olfactory senses and can be trained to detect explosives in trace quantities. This technique, however, requires extensive training of the dogs and their handlers, and the dog's limited attention span makes it difficult to maintain continuous operations.

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Electronic chemical sniffers imitating the dog's natural senses are also used. However, minefields are often saturated with vapors from detonated explosives, which limit the use of sniffer techniques for mine detection.

## EMERGING TECHNOLOGIES FOR HUMANITARIAN DEMINING

A number of mine detection techniques are emerging as complements to presently used methods. They include ground penetrating radar, infrared thermography and advanced metal detectors. A common feature of these techniques is that they detect "anomalies" in the ground but are unable to indicate the presence of an explosive agent.

Methods based on penetrating radiation offer features that can be utilized for landmine detection and identification. However, in contrast to conventional radiographic methods, one cannot utilize radiation transmission, as this requires access to two opposing sides of the investigated object. Instead, emission of secondary radiation or scattering of the interrogating radiation have to be used.

## ELEMENTAL ANALYSIS BY NEUTRONS

Analysis by neutron irradiation is one of the few methods available for elemental characterization of hidden objects. Due to their zero charge, even low-energy neutrons can penetrate thick layers of material and interact directly with atomic nuclei. Neutron interactions with matter depend strongly on their kinetic energy. Fast neutron "scattering" (bouncing) off a nucleus and slow neutron absorption into a nucleus can both increase the energy of the nucleus ("excitation"), which leads to the emission of a gamma ray. The neutron's interaction probability with a nucleus (capture cross section) is very high at certain incident neutron energies, which are unique for each element.

Most of the neutron-based techniques for detection of explosives in bulk form rely on the detection of these characteristic gamma rays emitted by excited nuclei. By measuring the energies and the intensities of the gamma rays, the elemental composition of the interrogated object can be established, and characteristic gamma ray spectra for most elements are well known.

Several different techniques have been developed along these lines.

- Thermal Neutron Analysis (TNA) utilizes the fact that all explosive materials contain a large fraction of nitrogen. The capture of a thermal neutron by a nitrogen nucleus results in the emission of a gamma ray with the energy 10.8 MeV. As this is the highest energy gamma ray emitted by a naturally occurring isotope, it gives a very clear indication on the presence of nitrogen. An isotopic neutron source, such as californium-252, is often used for TNA applications.
- The Pulsed Fast and Thermal Neutron Analysis (PFTNA) technique uses a small sealed tube electrostatic D-T neutron generator. In this method, the neutrons are emitted in ten-microsecond bursts. During the bursts, prompt gamma rays are emitted from inelastic scattering reactions on carbon and oxygen. During the roughly 100 microsecond interval between the bursts, gamma rays resulting from thermal neutron reactions are recorded.

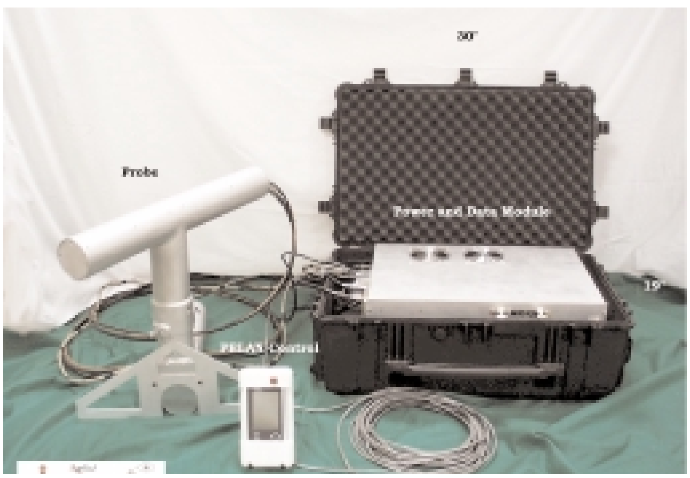
Using sophisticated spectral analysis software, elemental ratios such as carbon/nitrogen, carbon/oxygen and carbon/hydrogen can be established. This enables real-time identification of the explosive material by comparison with reference data stored in the computer. The additional detection of backscattered neutrons gives an indication on the density of hydrogen in the soil, which can be used for further enhancing the mine detection probability.

By using an electrostatic neutron generator, this technique minimizes the risk of accidental release of radioactive material to the environment. Small portable electrostatic neutron generators are commercially available from several companies.

By using a neutron-based method for elemental characterization of a buried object, the demining procedure could be done considerably faster and more efficiently. This is because most of the alarms, from, for example, metal detectors, are emanating from harmless scrap metal pieces, abundant on former battlefields.

## IAEA ACTIVITIES

Many national, international and non-governmental organizations are devoting tens




*Photos: In Bosnia & Herzegovina, another country suffering from landmines, a PMN mine has been exposed on a steep rocky hillside.* *(Credit: Prof. James Trevelyan, University of Western Australia, Australia).*
*In Afghanistan, a country affected heavily by war and mines, a deminer probes the terrain with a metal prodder every three centimeters.* *(Credit: Prof. James Trevelyan, University of Western Australia).*
*The compact PELAN system, developed in the United States, is being considered for deployment in an IAEA-supported field testing programme.* *(Credit: Prof. George Vourvopoulos, Western Kentucky University, USA).*

of millions of dollars for removing landmines and helping mine victims. On the recommendations of an international advisory group the IAEA Department of Nuclear Sciences and Applications has initiated a Coordinated Research Project (CRP) on the "Application of Nuclear Techniques to Anti-personnel Landmines Identification". Twelve research groups, from both developed and developing Member States, are participating in the CRP.

The CRP has shown that methods based on neutron interrogation can identify the explosive content of a buried mine. Several devices based on TNA, PFTNA techniques and neutron backscattering are being developed. A flexible approach is used by assessing these and other nuclear methods applicable for humanitarian demining regularly as they mature. Although several methods have potential, it is clear that a suite of sensors will be needed for any real life demining operation.

The development of better demining instruments is a demanding task, as the instruments have to be sensitive, fast, reliable, cost effective, and easy to operate and maintain in all parts of the world. For example, they have to operate reliably in all types of terrains, including hot sandy deserts and wet rice fields. A single technology will not be able to meet all the requirements. Methods based on neutrons may be complementary to conventional techniques, as one of many tools in a deminer's toolbox. ❒

## FIELD TESTING FOR HUMANITARIAN DEMINING THROUGH IAEA TECHNICAL COOPERATION PROJECTS

The IAEA serves as one of the key international mechanisms for scientific and technical co-operation in the promotion of the peaceful use of nuclear energy and plays an important role in the transfer of nuclear techniques to the developing areas of the world for addressing major problems. The main part of the IAEA's technology transfer to Member States is undertaken through its Technical Cooperation Programme. Very often, these projects utilize nuclear techniques developed as a result of successful coordinated research work involving the IAEA.

For humanitarian demining techniques, however, a new approach is being followed because of the prospect that it will take a very long time before the results of the research will be applied in practice -- bearing in mind the complexity of the task of landmine identification and the scale of the landmine problem. A new regional Technical Cooperation project in Europe -- "Field Testing and Use of Pulsed Neutron Generator for Humanitarian Demining" -- is one step towards practical application and the transfer of know-how where needed. It focuses on one technique only and one geographical region with a view of being more manageable and realistic. The technique selected for the project is Pulsed Fast and Thermal Neutron Analysis (PFTNA).

The first project planning and coordination meeting was held in Vienna 12-14 February 2001 and was attended by experts from more than 20 Member States. The meeting considered various alternatives and came to a conclusion that a PFTNA type instrument called PELAN should be procured under the project and deployed in an extensive field testing programme. PELAN has been developed and successfully used in the USA for detection of unexploded ordnance (UXO), chemical warfare agents and improvised explosive devices. But it needs adaptation for use in landmine identification and the local conditions, and this is where a technical cooperation project can be valuable.

The purchase of the PELAN system has been initiated. The project started with familiarization and training on the PELAN system at the Applied Physics Institute in Bowling Green, Kentucky, USA in 2001. After the experts from Member States have become thoroughly familiar with operation of each PELAN component, they would be able to suggest changes in hardware and software to adapt this instrument for landmine identification.

At a later stage, PELAN will be transferred to a Member State in Europe with a suitable research laboratory, and laboratory tests will be performed using various types of soils, dummy mines and explosives. Subsequently, field trials will quantify the instrument's speed, sensitivity, accuracy, and reliability, in simulated and real mine fields.

If the results of the adaptation are positive, it is expected that PELAN would be widely used for humanitarian demining as part of a multi-sensor system. For this purpose, the IAEA regional project is complemented by a national technical cooperation project in Croatia, "Facility for Testing Nuclear Methods for Landmines and Unexploded Ordnance Detection and Identification".

Croatia is a special case right in the middle of Europe. It is estimated that 6900 square kilometers, or 13% of Croatian territory, is contaminated with landmines and UXO. The Government, through the Croatian Centre for Demining (CROMAC), operates a large-scale national demining programme, but the process is very slow and costly. The Rudjer Boskovic Institute in Zagreb has a long tradition of achievements in nuclear science and technology, and is going to establish a laboratory for testing a number of nuclear methods which could help in the detection and identification of landmines and UXO, thus speeding up the process and reducing costs. The IAEA will support both the Institute and CROMAC in their work related to testing of nuclear techniques for demining.

If successful, the national and regional IAEA projects will help to significantly improve the efficiency and speed of humanitarian demining. They can thereby contribute to bringing the mined land back to normal life earlier and reducing the number of people that might be killed or maimed by abandoned landmines that have yet to be found.