HUMANITARIAN DEMINING

IAEA Co-ordinated Research Project

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Abstract

Considering the importance of landmine detection all over the world, the advantages and limitations of conventional demining methods, we describe emerging techniques and the use of penetrating radiations. The International Atomic Energy Agency devotes a lot of effort to introduce and develop the most promising nuclear techniques in this field of research.

I. Introduction

More than 70 countries have landmines hidden in the ground. Some of the most mine-affected countries are Afghanistan, Angola, Bosnia, Croatia, Cambodia, Ethiopia, Mozambique, Nicaragua, Somalia, and Sudan. From 15,000 to 20,000 people worldwide are maimed or killed by landmines each year. 80 percent of the victims of abandoned landmines are civilians, many of them children and farmers, who are killed or injured after hostilities come to an end

At present most of the humanitarian demining is done using conventional methods, such as metal detectors, prodders and sniffer dogs, making the procedure of removing 60 million abandoned anti-personnel landmines very slow and dangerous. New techniques are needed in order to speed up the process.

The International Atomic Energy Agency (IAEA) Physics Section organized the first Coordinated Research Project (CRP) in 1999 in Zagreb (Croatia) for the development of novel methods to identify the anti-personnel landmines [1]. This meeting was followed by an international research program with several discussions [2, 3].

II. What are being searched?

There are two different types of landmines: anti-personnel (AP) and anti-tank (AT) mines. Both can be encased in metal, plastic, wood or nothing at all. AP landmines are typically disk shaped with diameters from 20 to 125 mm, length from 50 to 100 mm, and can weigh as little as 30 g, which is a very small amount to detect. AP landmines are usually buried at a maximum depth of about 50 mm because a thicker layer of soil would decrease the damage significantly.

AT landmines show a big variety, their diameters vary from 150 to 300 mm and the thickness is about 50-90 mm. AT mines can be buried at different depths in the ground, even deeper than 150 mm.

III. Common landmine detection methods

The most basic approach to mine detection is prodding. Using prodders, rigid metal sticks of about 25 cm long, the deminer scans the ground at a shallow angle of typically 30° to avoid the explosion. Each time he detects an unusual object, he assesses the contour, which indicates whether the object is a mine or not. Though effective, this technique is slow and dangerous.

In spite of the very strict safety regulations there have been a lot of accidents, mainly caused by PROM-1 type mines. This mine is initiated by tilting the prongs at the top of the fuze. This can be done by direct pressure or by pulling a tripwire. On initiation, the mine body is thrown into the air leaving the base plate in the ground. The body is tethered to the base plate with a wire (of around a meter long). When the wire is pulled tight, that initiates the main charge and the body of the mine fragments in a 360 degree radius. This mine has been responsible for the deaths of more deminers than any other mine on record.

Metal detectors usually consist of a search head, containing one or more coils carrying a time-varying electric current. The latter generates a corresponding time-varying magnetic field which propagates towards the metallic target and in other directions as well. This incident field reacts with the electric and magnetic properties of the target, usually the soil itself and any metallic object situated in it. The target responds to it by modifying the primary field, i. e. by generating a secondary magnetic field. This effect links back into the receiver coil in the search head, where it induces an electrical voltage which is detected and converted, for example, into an audio signal.

However, landmines typically contain a small amount of metal, on the other hand these detectors can only succeed in identifying the presence of an anomaly without identifying the presence of explosives.

Dogs have the incredible ability to detect landmines by "*sniffing out*" the explosives in the mines. The dogs are trained to locate the scent, sit still, stay safe, and alert a human partner to mark the spot so the mine can be removed or destroyed. This detection skill, as well as the dog's agility and size, makes the dog one of the most versatile and valuable partners in the landmine removal team. In areas where metal content is high–either in the soil content or from human activities–dogs represent an indispensable alternative to metal detectors. The drawback of the method is the limited attention span and operating time. In addition, the air above a minefield usually contain vapor of detonated explosives, which may confuse the dogs' senses.

IV. Detection methods under development

1. Emerging techniques

The thermal capacity of mines and the soil is different therefore, their infrared emission is also different. Infrared thermography relies on the difference in the thermal capacitance between soil and mine, which affects their heating and cooling rates and the accompanied infrared emissions. This technology has the advantage of being passive, can be performed remotely, by aerial search, and can cover a large area in a short time. Infrared thermography is best suited for identifying minefields, rather than searching of individual mines. It cannot however work when the soil and mine are in thermal equilibrium [4].

Laser detection is based on the difference in the reflectance and polarization of soil when disturbed by laser energy. Large laser power and complex data interpretation process are needed.

Since microwaves are completely reflected off metallic surfaces, metal encased land mines may be detected by microwaves (*ground penetrating radar*). Microwaves are also scattered by nonmetallic objects and the refection properties render the material identification possible. However, this method has great difficulties, such as the propagation loss in the soil, the low contrast between target and soil, and the large variety of echoes from the rough surface and other shallow contrasts such as rocks, tree roots, etc [4].

Of course there some more emerging techniques than those mentioned above, for example recent research by the University of Montana has revealed that honey bees can, with minimal training, be used to detect landmines with a far greater accuracy and far higher clearance rate than dogs or rats [5].

2. Penetrating radiation

Results of various tests indicate that nuclear techniques have a big potential for identification of explosives in landmines. Not only the presence of an anomaly but also the chemical composition can be analyzed using photons (X-rays or gamma-rays) or neutrons. Since the source of the radiation and the detector can be placed only at the same side of the examined sample, transmission techniques cannot be applied. Methods based on secondary radiation emission and scattering processes are under development.

For landmines, TNT ($C_7H_5N_3O_6$), tetryl ($C_7H_5N_5O_8$) and Composition B (TNT+RDX ($C_3H_6N_6O_6$)) are the most important explosives. These compounds are rich in nitrogen, however, fertilization may confuse an analytical method.

Compton scattering of photons is dominant in most materials. The probability of the scattering depends on the electron density and, through it, the mass density of the medium. An X-ray backscattering system was worked out [6], which can provide a density map to identify anomalies only. While scattered photons travel back towards the detector further scattering and absorption occur. The probability of the photo-absorption strongly depends on the atomic number. This fact renders the material characterization possible.

Neutrons can be applied in many different ways. Simple devices containing a small intense neutron source (^{252}Cf or Pu-Be) and small BF_3 proportional counters were developed for the identification of plastic landmines through the observation of anomaly in the reflected thermal neutrons.

The spectra of elastically backscattered neutrons are affected by the structures present in the energy dependence of elastic scattering cross sections of C, N, O, therefore studies of the backscattered spectra using a pulsed height response spectrometer may give new results is the qualitative analysis.

Since explosives contain a big amount of nitrogen, thermal neutron activation of nitrogen, and the subsequent emission of characteristic (10.8 MeV) gamma rays, also can be used for mine detection.

Fast neutron activation renders the determination of two major elements in explosives possible, since nitrogen and oxygen have characteristic resonances in the energy range from 1 to 3 MeV.

However, the activation cross section of both thermal and fast neutrons is low for the elements of interest, thus a high intensity neutron source is required.

The PELAN (Pulsed Elemental Analysis with Neutrons) technique [7] uses a 14 MeV neutron pulse from a sealed tube portable D-T generator to activate the C and O in the sample. When the pulse is stopped, the fast neutrons will diffuse into the sample and slow down. If the neutrons have energy less than 1 eV they are captured by H, N and Fe. The gamma-rays emitted during and after the neutron pulse are detected and the elemental ratios can be determined. The range of the C/O, C/H and C/N ratios are well defined for explosives. The PELAN is suitable for analyzing an anomaly only in a limited depth in the case of bigger samples.

V. The IAEA Coordinated Research Program

The latest developments on the application of nuclear techniques to anti-personnel landmines identification are summarized in a Special Issue of the Applied Radiation and Isotopes [8]. 14 countries were involved in the CRP of the IAEA between 1999 and 2003. The majority of the investigations are focused on the neutron techniques, i. e. fast neutron scattering and measurement of the energy spectra of gamma-rays from neutron interaction with the explosive materials, utilizing small isotopic sources, D-T or D-D generators. Detection methods based on Compton scattering and positron annihilation were also studied.

Elemental analysis was performed by pulsed fast and thermal neutrons, by the associated–particle technique and by fast–neutron backscattering. The hydrogen content was measured by neutron moderation. Neutron/gamma attenuation provides density and hydrogen depth profile. The gamma-/X-ray scattering technique is a density indicator while positron annihilation provides 3-D imaging.

Since the 1940s, many countries have worked on the solution of the problem of detecting nonmetallic landmines. The research has encompassed an extremely wide range of technologies and hundreds of millions of dollars have been spent. Despite all these efforts, there is still no operationally satisfactory detection solution. This lack of success is attributable only to the extreme difficulty of the problem.

At present landmines cost $3-$30 to deploy and $300-$1000 to remove.

References

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