Member's Paper

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DETECTION OF LAND MINES : A RADIATION-PHYSICS PROBLEM

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Introduction

In September, 1997, more that 100 countries met in Oslo and successfully developed a treaty to ban future use of land mines. This treaty will be signed in Ottawa in early December. A major humanitarian effort is also underway to raise money for aid to maimed victims of this dreadful weapon. While the treaty deals with the future and the aid helps the victims, the problem will not be completely eradicated until all landmines in the world are removed.

The first step in mine clearing is to locate them. Wars, large and small, are hardly conducted in an orderly fashion and maps are rarely, if at all, available. The detection process may be conducted on a global scale to locate a mine field, or locally to determine the location of a particular land mine. The latter problem is where radiation physicists can contribute.

In this article the detection problem of land mines is discussed, in the hope of simulating interest among members of this society, particularly those in affected countries.

The Problem

Land mines come in all shapes and sizes, and can be encased in metal, plastic, wood or nothing at all. Their fusing mechanism varies from simple pressure triggers to trip wires, tilt rods, acoustic and seismic fuses, or even magnetic influence fuses. They can be embedded in a field cluttered with various materials and objects and buried underground, at various depth, or scattered on the surface.

A land-mines detection system should be able to detect various types of explosives, TND, RDX, etc., distinguish them from background clutter, and detect mines regardless of shape, depth of burial, or type of casing. This is to be done so that it provides good standoff distance, detection probability of almost 100%, a near-zero false-negative alarm rate, an acceptable operational speed, and preferably, viewing (imaging) capability.

With such demanding requirements, it is inconceivable that a single detection technology will be able to meet all the needs. Each technology has however its distinct capabilities, as explained below.

Thermography

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 [1].

Photo-Optics

Laser detection utilizes the difference in the reflectance and polarization of soil when disturbed by laser energy. This requires however a large laser power and a complex data interpretation process [1].

Eddy Current and Microwaves

Since eddy-current can be generated only in metals and microwaves are completely reflected off metallic surfaces, metal encased land mines can be detected by pulse-induction metallic detectors and microwaves (ground penetrating radar). Unfortunately, however, not all mines are metallic.

Nevertheless, microwaves are also scattered, though to a lesser extend, by nonmetallic objects and characteristic refection signatures can be related to material type, and hence can be used to identify explosives. This approach has however significant difficulties, because of the propagation loses 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. The discrimination of mine from clutter under the wide variety of surface and soil conditions remains very difficult [2].

Photons

Penetrating radiation (neutrons and photons) offers another probe for standoff land mine detectors. Unlike conventional radiographic or tomographic methods, one cannot rely on radiation transmission, as it requires access to two opposing sides of the object; a situation not attainable with land mines. Therefore, one

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has to rely on radiation scattering or activation (production of secondary particles). Photons, in the form of x- or gamma-rays, incoherently collide (Compton scatter) with atomic electrons with a probability that is dependant on the electron density, and consequently the mass density, of the medium. As the scattered photons travel back towards the detector, they are removed by further scattering or absorption; with the photo-absorption probability being strongly dependant on the atomic number. The difference between the atomic number and density of mine and soil allows, therefore, the identification of the former. This is the essence of the x-ray backscattering system of Campbell and Jacobs [3]. Gamma-rays can also provide similar information.

Neutrons

Since explosives are usually characterized by their high nitrogen content, neutron activation of nitrogen, and the subsequent emission of characteristic (10.8 MeV) gamma rays, can be used for mine detection. This requires, however, the employment of thermal neutrons, the generation of which necessitates the use of a bulky moderating material, to slow-down fast neutrons emitted from an isotopic source. The soil itself can be used as a moderating material, but then the amount of activation will depend on the type of soil (in particular its hydrogen content). Since the activation probability (cross section) is not so high, a strong neutron source is required. This causes some difficulties in radiological shielding and handling and affects the portability of the device. Moreover, nitrogen is present in fertile soil and tree roots. Under such conditions it becomes difficult to detect mine based on nitrogen content alone.

Conclusion

All the techniques discussed above use a signature "finger-print" signal characteristic of mine. Given the wide variety of mine material, casing and shape, as well as the various type of soil and the non-uniformity of clutter, such a characteristic signature varies widely depending on the circumstances; making it difficult to apply any one technique unless the nature of the mine, soil and background clutter is well known. What is needed, therefore, is a technique that is more specific in its identification of the hazardous material in a land mine, i.e. the explosive material itself.

The explosive material in land mines is most likely, TNT; but RDX and other plasticized explosives are also used. These explosives are rich in nitrogen, which serves as a bonding agent. However, the amount of nitrogen alone is not sufficient to definitely identify an explosive material from other innocuous materials [4]. Explosives are also rich in oxygen (which is simply the oxidizer). Therefore, knowing the nitrogen content together with the oxygen content provides the most unambiguous identifier of an explosive material.

The challenge for radiation physicists is to, not only develop techniques that can meet the demanding detection problem, but also tailor such techniques to their local conditions. After all, detecting land mines in the sandy desert of Egypt or Kuwait is very different from finding them in the fertile soil of Vietnam or Laos.

Can this society undertake it as a mandate to help rid the world of this scourge that kills or wounds 25,000 people a year (about 3 every hour)? A research co-ordination group, a lobbying team, a session in the regular meeting, an electronic- forum, or any other approach will be certainly a welcome step. Can we collectively do something to prevent further suffering and tragedy?

References

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