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Investigations on landmine detection by BF_3 detector

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Abstract Experiments were carried out to investigate the possible use of neutron backscattering for the detection of polyethylene (PE) sample buried in the soil. In detection of landmine by neutrons, the neutron detector and its shield play an important role. In this paper, the effects of graphite, heavy water, polyethylene and boric acid moderators on the flux of back scattered neutrons were investigated. We have also experimentally verified the effect of BF_3 detector shield and obtained good agreement with theory.

Key words Landmine, Am-Be neutron source, Neutron backscattering, Moderator, Heavy water, BF_3 detector

CLC numbers TL816$^+$.3, TJ51$^+$2

1 Introduction

Numerous anti-personal mines (APM) developed after World War II are less than 300g and contain very little metal. Consequently, it is difficult to detect them with metal detectors[1]. As estimated, over 60 million landmines have been buried in many countries[2]. The number of persons accidentally killed by landmines each year is estimated to exceed 25,000 and an even larger number are maimed, with many of the victims being women and children[3]. Many hundred thousands of landmines left buried in the western part of Iran by the end of the eight-year war (1980–1988) with Iraq, resulted in many people, children in particular, to lose their lives or become disable[4].

The International Atomic Energy Agency (IAEA) has encouraged research groups to develop nuclear methods for detecting landmines. These methods have been supported by participants from universities and research institutions in 18 countries. Several landmine detection methods based on nuclear techniques have been suggested in recent years, including neutron energy moderation, neutron-induced γ-ray emission, neutron and γ-ray attenuation, and fast neutron backscattering[3,5,6]. In this work, we have investigated neutron energy moderation method for landmine detection.

Three factors contribute to making neutron scattering useful for detecting APM: a) Hydrogen content in plastic APM is relatively high. The fraction of hydrogen atoms in typical plastics and explosives are between 55%–65% and 25%–35%, respectively. b) For E_n<3 MeV, the total neutron cross section for the interaction with proton is significantly higher than that of other nuclides commonly found in the soil or in metal debris. c) n–p elastic scattering is the dominant process in neutron- proton interactions at these energies (E_n<3 MeV). The n-p elastic scattering has two unique features: the average energy loss per scattering by the neutron is large (50%), which makes hydrogen a good neutron energy moderator; and the angle of scattering neutrons (in the laboratory frame) cannot exceed 90° [7].

Obviously, a landmine detector has to be nondestructive and portable. And it should be simple to operate, and inexpensive.

Other researchers have used 2 or 8 neutron detectors which make the detection set-up very bulky[8]. In this work, we have used an Am-Be neutron source and only one BF_3 detector.

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2 Monte Carlo simulation

The simulation was based on the following assumption: a sample of trinitrotoluene (TNT, $C_7H_5N_3O_6$) with a density of 1.8 g•cm^{-3} and a dimension of (10 cm×10 cm ×10 cm) is buried in a volume of dry soil of 60 cm(l)×40 cm(h)×100 cm(w) with 1.610 g•cm^{-3} density. The soil generally contains 10 elements[9] (Table 1). We have experimentally determined mass percent of elements by NCHS (Nitrogen, Carbon, Hydrogen, Sulphur combustion analyzer) and AA (Atomic Absorption spectrometer) methods and the soil moisture was 6.34 mg•g^{-1}.

Table 1 Chemical composition of the soil

Element	Mass /%
H	3.760
C	5.936
O	44.144
Si	34.560
Al	0.940
Fe	2.381
Ca	4.494
K	0.083
Na	0.075
Mg	3.627

The Am-Be neutron source of ϕ4.5 cm×20 cm was placed 1.5 cm from the soil surface. Only fast neutrons emitted in Z direction interact with soil and landmine. As seen in Fig.1, BF_3 detector, ϕ2.54 cm ×28 cm, placed next to the Am-Be source possesses the same Y-axis direction, normal to paper, to show neutron flux. Backscattered neutron flux as a function of energy was obtained by using Monte Carlo N-Particle transport code (MCNP)[10]. As seen in Fig. 2, most neutrons backscattered lie between thermal and epithermal region.

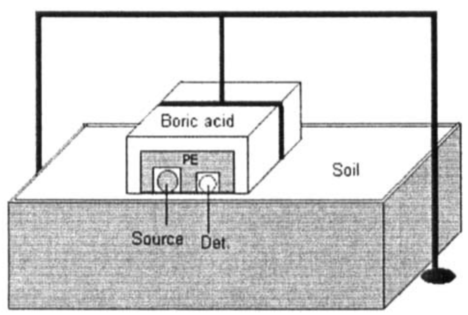

Fig.1 Schematic diagram of Monte Carlo simulation.

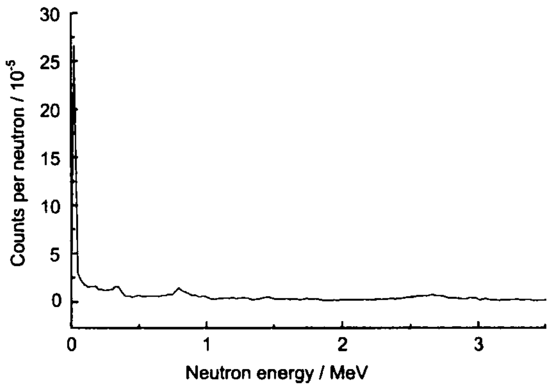

Fig.2 Backscattered neutron flux as a function of the neutron energy. The TNT is buried 3 cm under the soil.

We use the relative counts as the parameter of signal-to-noise. Signal-to-noise ratio=$[(N-N_0)/N_0]\times100$, where N and N_0 are the neutron counts with and without TNT sample in ground respectively. As shown in Fig.3-b, when the detector has no shield, the signal-to-noise ratio increase a little above the TNT sample.

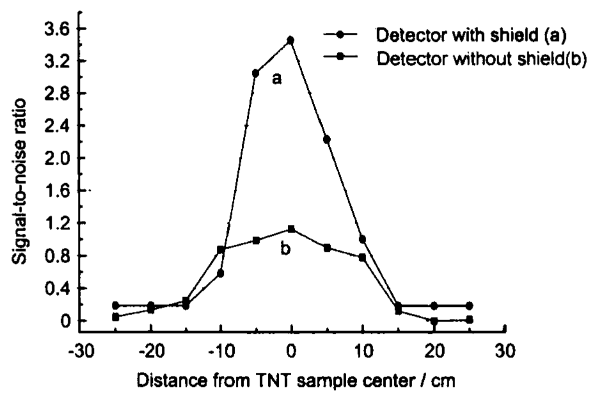

Fig.3 Signal-to-noise ratio as a function of distance from center of buried TNT sample. a)Detector with two layers shields, boric acid thickness=4cm (outer layer) and PE thickness=10cm (internal layer). b)Detector without shield (MCNP code results).

3 Shield description

3.1 Moderator selection

According to accomplished investigations, ^{10}B in borated complexes is suitable absorber and ^{1}H in hydrogenous material is suitable moderators[11,12]. We investigated four moderators by using MCNP code. For this purpose, as shown in Fig.1, moderators covered the detector each turn and the calculation was performed by MCNP code.