The effect of source shield on landmine detection

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Background: Several landmine detection methods, based on nuclear techniques, have been suggested during the recent years. Neutron energy moderation, neutron-induced gamma emission, neutron and gamma attenuation, and fast neutron backscattering are nuclear-based methods used for landmine detection. The aim of this study is to use backscattered neutron for landmine detection. ***Materials and Methods:*** MCNP code, a well-known Monte Carlo particle-transport code, was theoretically used for backscattered neutron counts. An Am-Be neutron source and a single thermal neutron detector were experimentally applied to detect the buried sample. ***Results:*** The experimental results obtained in this way have been in good agreement with the theoretical results obtained by MCNP. Therefore, the shield of neutron source plays an important role on landmine detection. ***Conclusion:*** Hydrogenous material such as polyethylene and boric acid can be used as suitable shields. They can increase neutron counts in detector and facilitate detection process. **Iran. J. Radiat. Res., 2007; 4 (4): 183-186**

Keywords: *Landmine, Am-Be source, MCNP code, BF_3 detector, polyethylene, TNT.*

INTRODUCTION

According to verified research works, nuclear techniques can be used to detect landmines (1-5). Backscattered neutron method is one of the several nuclear methods offered to detect antipersonnel and antitank mines during the recent years. Using the source shield is a point which separates this research from other works.

There are two reasons for using the shield around the Am-Be neutron source. First, application of the shield around the neutron source absorbs the back scattered neutrons from the landmine sample; it reduces the background noises efficiently and improves the population of neutrons contributing to landmine detection, subsequently. Second, it provides radiation hazard protection for the operator. The source strength that may be used in a prototype device needs to be lower than the admissible radiation dosage for the operator (6).

There are three types of neutron sources that can be applied on commercial applications. The first one is produced by the interaction of high speed ^{2}H ions with 3H atoms in the target of a neutron generator. The second source is spontaneous fission of ^{252}Cf. The last one is of the radioisotope origin mainly using americium (^{241}Am), as an alpha emitter; and beryllium (Be), as a target for neutron production (4).

In this work we have employed Am-Be neutron source and designed a suitable shield around it to detect buried landmine.

MATERIALS AND METHODS

An Am-Be source with 1.49E10^{11} MBq activity was used in our experiments, and MCNP (Monte Carlo N-Particle transport code) simulations, as the only neutron source available in our laboratory. Average and maximum neutron energy of this source is 5 MeV, and 11 MeV respectively. In our experiment, the BF3 detector, a proportional gas counter, has been used. It has a diameter of 2.54 cm and a length of 28 cm.

In MCNP input file the simulation was based on the assumption that two samples of trinitrotoluene (TNT, $C_7H_5N_3O_6$) with a density of 1.8 gr/cm^3 and a dimension of 10^3 cm^3 (10×10×10) are located in the front and at the side of neutron source (figure 1) (7).

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Neutron populations were obtained as a function of polyethylene (PE) and boric acid (BO_2H_3) thicknesses (figures 2 and 3). We have experimentally measured neutron counts in the front and at the side of the source (figure 4).

A box of dry soil, which has a surface of 60×100 cm², and a height of 40 cm with 1.610 gr/cm³ density, has been used in the experiment. The soil generally contains 10 elements (4).

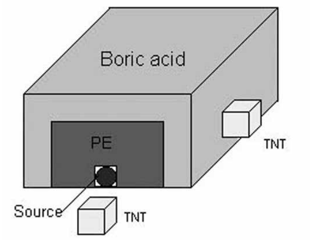

Figure 1. Locations of TNT samples, source and its shield with respect to each other in Monte Carlo simulation.

We have experimentally determined mass percent of elements by nitrogen, carbon, hydrogen, sulfur combustion analyzer (NCHS) and atomic absorption spectrometer (AA) methods. They are listed in table 1. The soil moisture was 0.634% in the experiments.

As seen in figure 5, a set up had been established and neutron counts had been experimentally obtained by moving detection system along the soil box.

RESULTS AND DISSCUSION

Table 2 shows the intensity of particles that are emitted from the Am-Be source (8, 9).

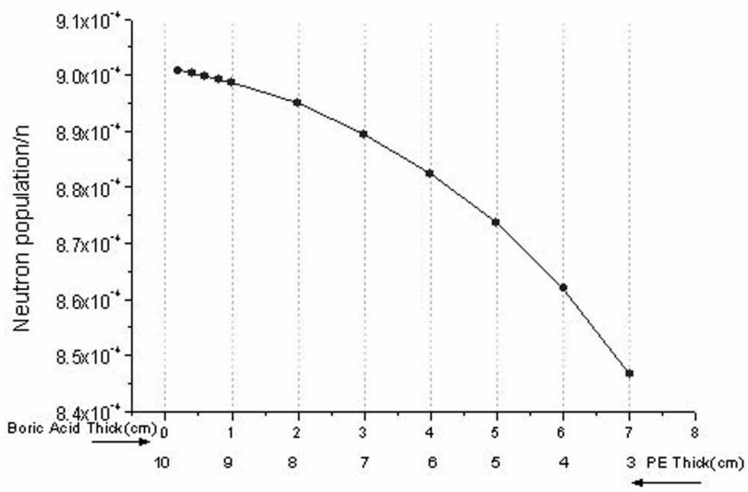

Figure 2. Neutron population variation on the under source sample.

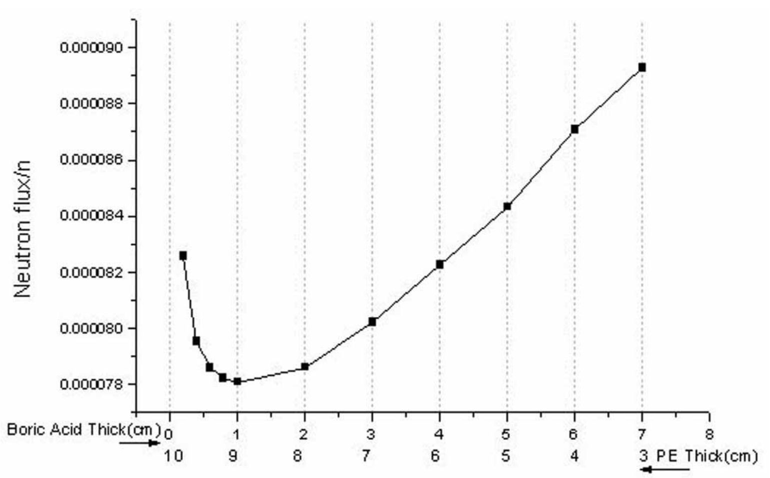

Figure 3. Neutron population variation on the next source sample.

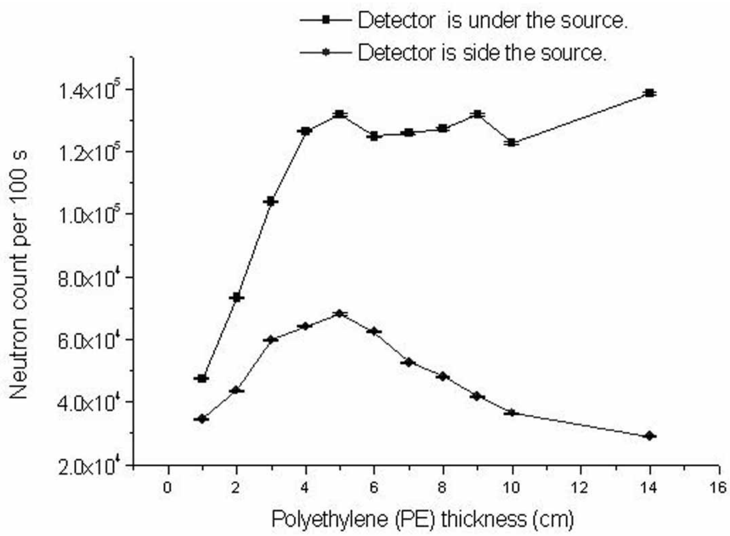

Figure 4. The experimental curve of neutron population variation with PE thickness on under and side the source.

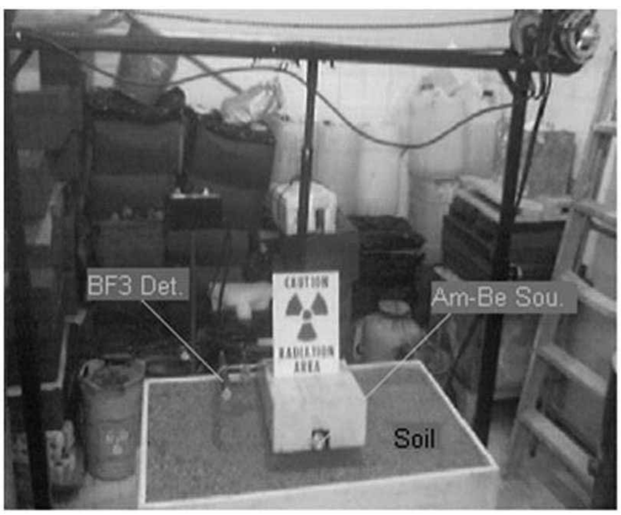

Figure 5. Photograph of landmine detection set-up.

Table 1. Chemical composition of the soil [4].

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

Table 2. Neutron and gamma yield per 106 primary alpha particles of Am-Be source [7].

Particle	Energy (MeV)	Intensity	Emitted from
n	Spectrum (0-12)	70	^{9}Be (α,n) reaction
γ	4.438	41.7	
γ	0.0595	3.59E+05	^{241}AM
γ	.0263	2.41E+04	

Neutrons counts were measured by BF3 detector for 100 s in all experiments. Within the time interval, the number of neutrons emitted from Am-Be neutron source could have been estimated as:

$$S_n = A(\mathrm{MBq})\times(\frac{n}{\mathrm{MBq}})\times T(s) = 1.49\times10^{11}\times(\frac{70}{10^6})\times100 = 1.043\times10^{9} \qquad (8)$$

There is a parameter named *signal-to-noise* ratio. It is the relative excess counts, *signal-to-noise ratio* $=\frac{(N-N_0)}{N_0}$, measured with and without the buried samples. N and N_0 are the neutron counts with and without PE sample in soil, respectively.

Figures 6 and 7 show the MCNP outputs and experimental counts over the soil box. In theses figures, zero point is the location of the buried sample. As expected, there was a good agreement between the experiment and the theory; therefore, it can be concluded that the shield plays an

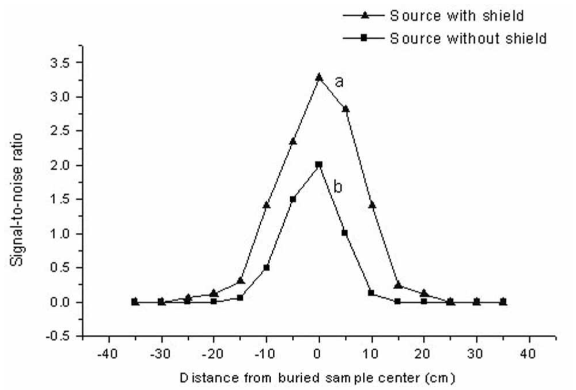

Figure 6. Signal-to noise ratio as a function of distance from center of buried sample when source is (a) with and (b) without shield. One million events used in the simulation (the output of MCNP code).

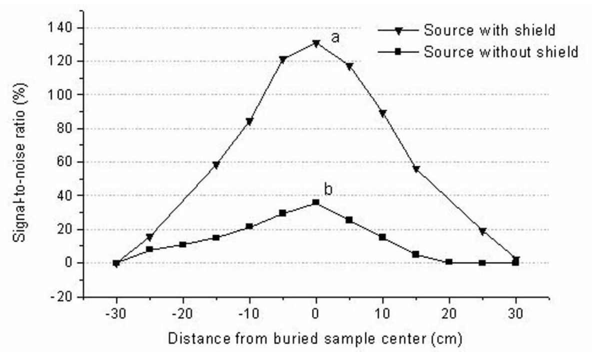

Figure 7. Signal-to-noise ratio variation with Detector distances from landmine center when source is a) with and b) without shield (experimental data).

important role on hydrogenous material buried in soil. The fraction of hydrogen atoms in typical explosives has been between 25-35%, so backscattered thermal neutron method can be suitable for landmine detection.

CONCLUSION

There are two important reasons to apply shield around the neutron source. First, applying the shield around the neutron source causes most of neutrons to participate in landmine detection. Second, it is necessary for the users to be protected from neutron radiation.

We have experimentally obtained neutron counts with and without shield around the source. Apparently that neutron counts had increased due to shield absence. Therefore, the shield could have intensified anomaly of the backscattered neutron flux over the PE sample. We have calculated signal-to-noise ratio by using experimental data. The results show that signal-to-noise ratio is130% with shield, and 40% without shield respectively. Results also indicate that the detection of hydrogenous material such as landmine is facilitated when the source shield is used.

Therefore, neutron backscattering can successfully be used for the detection of landmines. Regard has of its limitations; it is potentially a useful asset to the demining toolbox, especially in areas with relatively dry soils.

The results of detection can be affected by other parameters such as soil moisture, depth, distance from soil surface, and landmine weight. We are going to investigate the effects of other parameters in our forthcoming reports.

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