An Overview of the Current Research Activities for Landmine Detection by Nuclear Techniques in Libya

F.A. El–Bakkoush*
Neutron Physics & Landmine Laboratory Renewable Energies and Water Desalination Centre Tripoli, Libya
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This paper gives a description for the current research activity carried by the research team which is concerned with the application of nuclear techniques for landmine detection. The activities are technically and financially supported by the IAEA through a TC project LIB / 1 / 006. The IAEA has provided the project with two ^{3}He detectors and some electronic equipment to install a detection system based on measuring thermal neutrons backscattered from the buried object. Also a detection system based on measuring the gamma-rays emitted from the hidden object through the interrogation of its elemental nuclei by fast and thermal neutrons was installed.

Further, theoretical studies were performed to calculate the spectra of fast neutrons and gamma-rays emitted from the buried objects when neutrons of different energies are used. Calculations were performed using a Monte Carlo Code MCNP IV or GEANT. This code was also used to assess the thermal neutron flux backscattered from plain soil and soil embedded with landmines with different amount of explosive material and buried in the ground at different depths.

The measured and calculated results are presented in the form of displayed spectra for gamma-rays and thermal neutron fluxes for landmines buried at different depth in the ground. The analyses of the obtained data can be used to show the strength and weakness of the applied methods for landmine detection in different environmental conditions.

I. INTRODUCTION

Libya is a country with millions of landmines buried in very vast areas of land. These buried landmines are a result of the extensive combat operations between allied and axis forces during World War II. This war took place from December 1940 to May 1943. UNICEF has estimated that about 7 million landmine and unexploded ordinances have been left from the World War Two Campaigns [1].

The largest numbers of the buried landmines in Libya are in the Eastern Desert of Libya. Although most of these landmines are Anti Tank Mines (ATM), the long period of burial makes the triggering system very sensitive to explode under the low human pressure due to the erosion of the triggering metallic part. This makes the ATM very sensitive to personnel even for children. Accordingly, these abandoned landmines kill and maim a lot of civilian every year and are ravaging about 300 000 hectares of land in the Eastern Desert (Tobrouk, Amsad, El-Cabal El-Akhdar and more than 70 000 hectares south of Eastern Desert [2].

In Libya the humanitarian de-mining activities which are carried-out to remove landmines from the vast contaminated areas are done by conventional methods. These conventional methods, which are mainly based on metal detectors, make the procedure of removing; these huge numbers of landmines very slow, inefficient, dangerous and costly operation. And, most of these detectors can not distinguish a mine from metallic debris. It is worth to mention that, even the most developed of metal detectors give extremely high false alarm rate, only one out of about a thousand alarms turned out to be a landmine [3, 4].

Neutron based technique based on measuring thermal neutrons backscattered from object buried in the ground is a good measure to hydrogen containing objects, i.e., explosive materials. The backscattered thermal neutrons are usually measured by a detector sensitive to neutrons of thermal energy and insensitive to fast neutrons and gamma-rays. This is the case, which is easily achieved using ^{3}He detectors [5, 6].

II. ACHIEVEMENTS

The following objectives have been achieved through the performance of the following research activities.

Design a soil bed of volume $100 \times 100 \times 75$ cm^3 filled with soil collected from different landmine fields.

Collection of soil samples from different areas of mine fields of Tripoli, El-Gabal El-Akhaddar, north of Tobrouk, south of Sert city. Studying the physical and chemical properties. The obtained results will be used to establish a database for landmine fields in Libya.

– Design and constructing the source housing and detector collimators that suit different experimental arrangements.
– Designing and constructing a soil bed and other needed experimental and mechanical facilities for different measurements.
– Design and constructing a hand held trolley to mount the neutron backscattered system shown in Fig. 1. This figure shows that the two ^{3}He detectors are fixed on the trolley with their axes perpendicular to the direction of motion and at separated

*Electronic address: f_a_bakkoush_tnrc@yahoo.com

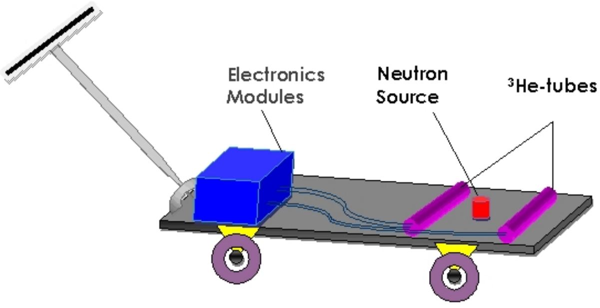

FIG. 1: Schematic diagram of the handheld NBS system.

distance of 20 cm. The ^{252}Cf is fixed at the center of the separated distance between the two ^{3}He detectors.

– Study the thermal neutrons backscattered from plain soil and soil embedded with AP and AT mines of buried at different depths in the ground.
– Measurement the spectra of fast neutrons and gamma rays transmitted through a landmine using collimated beam of ^{252}Cf neutrons. The transmitted neutrons were measured by a neutron gamma spectrometer with NE–213 liquid organic scintillator while he spectrum of gamma rays was measured with a gamma spectrometer with NaI(Tl) scintillator.
– Design the simulator which can be used for calculating the back scattered spectra and fluxes of fast neutrons, gamma rays and thermal neutrons at the detector positions when different neutron sources are used.
– Calculating the spectrum of gamma rays and fast neutrons emitted from soil embedded with an ATM of 2.5 kg explosive material and plastic casing.

III. RESULTS AND DISCUSSION

The average calculated number density (Nd) of soil elements is shown in Table I. This table also shows the calculated Nd for elements of TNT material. It is clear

TABLE I: Number density ($\times 10^{22}$) for elements of a representative soil sample and explosive (TNT) material.

Element	Soil	Explosive, TNT
Carbon	0.24	2.95
Hydrogen	1.4930	6.4
Oxygen	7.2	2.56
Nitrogen	–	1.28
Silicon	3.2	–
Aluminum	0.045	–
Calcium	0.039	–

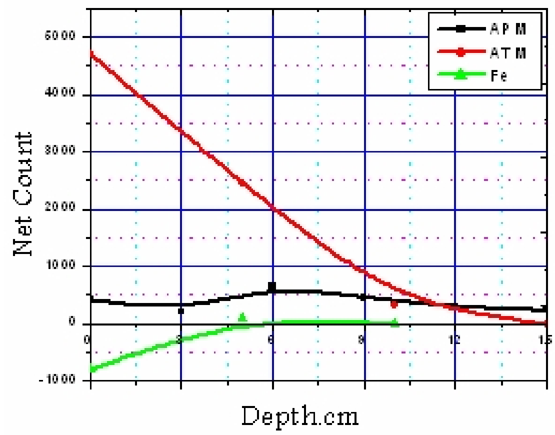

FIG. 2: Measured NBS flux as a function of buried depth.

that the soil collected from different landmine fields of Libya does not contain the nitrogen element. This will make it possible to use a nuclear sensor based on elemental analysis by fast neutrons to distinguish between a landmine and scattered wooden parts in landmine field.

The measured thermal neutron fluxes backscattered from AP mine with 150 g explosive material and AT mine with 2.5 kg explosive material buried at different depths in the ground are presented in the form of attenuation relation shown in Fig. 2. This figure also shows the attenuation relation plotted for the thermal neutron flux back scattered from a steel object buried at different depths. The plotted relation for AP mine shows a small hump for a buried depth of 6 cm. This increase in flux intensity at this position can be attributed to the fact that the number of slowed down thermal neutrons by the elements of the soil above the mine is more than the number absorbed by these elements. For further depths, the flux intensity decreases as the buried depth increases. This

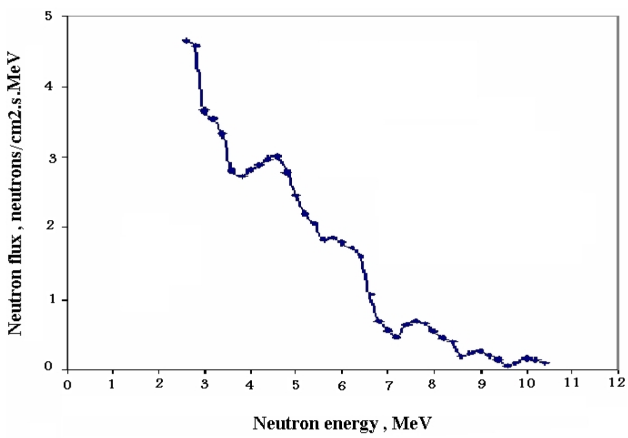

FIG. 3: Measured fast neutron spectrum transmitted through 2.5 kg explosives materials.

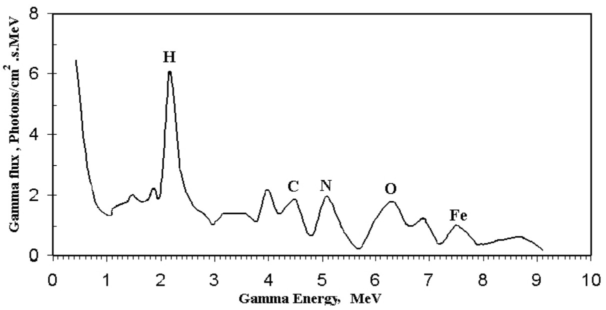

FIG. 4: Measured gamma spectrum transmitted through 2.5 kg explosives materials.

figure also shows that the number of backscattered thermal neutrons is increasing by increasing the amount of explosive material, especially at small depths. The relation plotted for steel object shows a negative or near zero flux response. This indicates the capability of the NBS system for discrimination between hydrogen containing objects, a landmine and metal objects.

Measurements were also performed to study the spectra of fast neutrons and gamma-rays transmitted through a landmine exposed to neutrons from ^{252}Cf source. Measurements were performed using the available neutron/gamma spectrometer which employs NE–213 liquid organic scintillator. The measured spectra of fast neutrons and gamma-rays are shown in Figs. 3 and 4 respectively. Figure 3 shows that the displayed spectrum of fast neutrons contains some positions of maxima and minima at certain energy positions which are in reasonable agreement with the positions of minima and maxima observed in macroscopic total neutron cross sections of explosive material. The spectrum of gamma-rays plotted in Fig. 4 shows the gamma lines emitted from the interaction of fast and thermal neutrons with the elements of explosive material.

A preliminary calculations were performed using the MCNP–IV code to study the back emitted gamma ray and fast neutron spectra at the positions of the gamma detectors according to the simulation shown in Fig. 5. Calculations were done for soil embedded with an ATM containing 2.5 kg explosive material irradiated by neutrons from ^{252}Cf source. The spectrum of gamma-rays is displayed in Fig. 6, while the spectrum of fast neutrons is displayed in Fig. 7. The spectrum of gamma rays shows clearly the gamma energy lines resulting from the interactions of fast and thermal neutrons with the nuclei of the elements of the explosive material. The spectrum of neutrons shown in Fig. 7 shows some maxima and minima at some energy positions which coincide with the positions of minima and maxima in neutron total macroscopic cross sections.

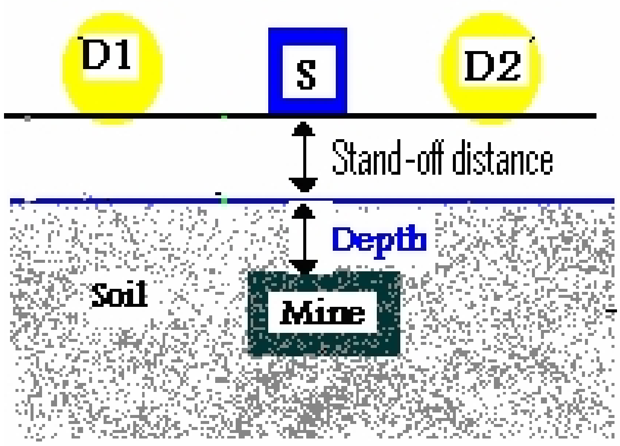

FIG. 5: Simulator designed for theoretical calculation.

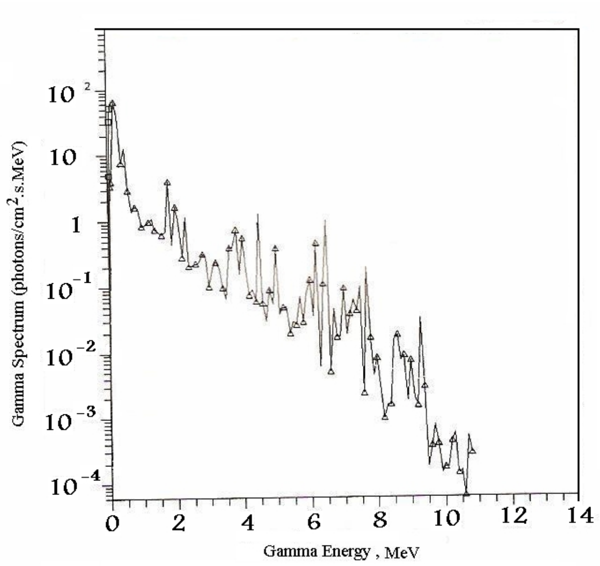

FIG. 6: Calculated gamma spectrum emitted from soil embedded with mine.

IV. CONCLUSIONS

- Nuclear sensors based on using neutrons are very essential to identify the suspected object allocated in ground by conventional sensors.
- Nuclear method based on measuring thermal neutrons backscattered from the ground is an easy and very fast way to recognize hydrogen contain materials from non hydrogen contain ones. Therefore, detection sensors based on measuring the differences in hydrogen density can only be used as filtration sensors.
- Nuclear sensors based on elemental analysis by fast and thermal neutrons must be used with sensors based on thermal neutron backscattering to recognize a landmine from other scattered hydrogen containing objects.

– Collaboration between national and international organizations concerned with the demining operations is highly recommended to help Libya to overcome the problem of landmines.

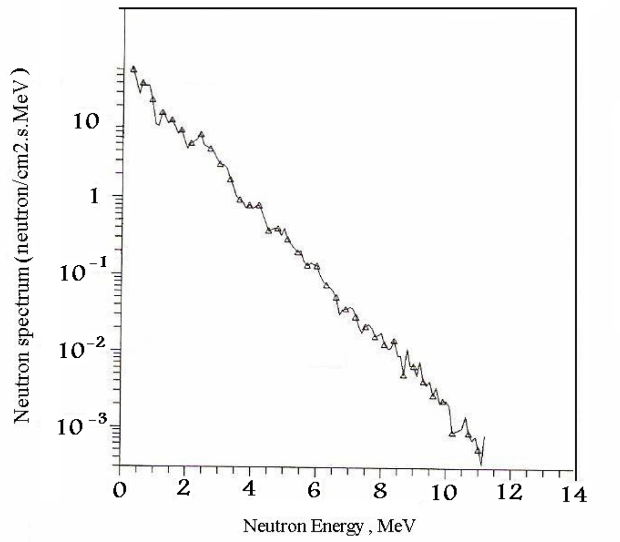

FIG. 7: Calculated spectrum of fast neutrons backscattered from soil embedded with a mine.

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