Current Research Activities for Landmine Detection BY Nuclear Techniques in Libya

F. A. El _BAKKOUSH

Neutron Physics & Landmine Division,
Renewable Energies and Water Desalination Center, Tripoli – Libya

Email: f_a_bakkoush_tnrc@yahoo.com

Abstract. This paper gives a description to the current research activities carried by the research team 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 will be installed. Theoretical and experimental studies are performed when neutrons of different energies are used. Calculations are performed using a Monte Carlo Code MCNP IV or GEANT -3 code. This code is used to assess the thermal neutron flux backscattered from plain soil and soil embedded with landmine of different amount of explosive. Measurements are performed to measure the backscattered thermal neutrons from a landmine with1 different amount of explosive material which is buried in ground at different depths. The obtained results are presented in from of displayed spectra for calculated gamma-rays and thermal neutron fluxes of landmines buried at different depths in ground. The analysis of the obtained data can be used to show the strength and weakness of applied method for landmine detection in different environmental conditions

1. Introduction

According to published information by the United Nations, more than 100 million of landmines are laid buried in vast areas of land of several countries world wide (1,2, 3), Libya is the country with millions of landmines result of extensive combat operations between allied and axis forces during World War II that took place between December 1940 to May 1943. UNICEF estimates that about 23 million and unexploded ordinances have been left from the World War Two Campaigns. Result of extensive combat operations between allied and axis forces during World War II that took place between December 1940 to May 1943. UNICEF estimates that about 23 million and unexploded ordinances have been left from the World War Two Campaigns.

The largest numbers of landmines in Libya are buried in the Eastern Desert. Although most of these landmines are Anti Tank Mines (ATM) the long period of buried makes pressure due to the erosion of the 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 ravaging about 300,000 hectares of land in the Eastern Desert and about more than 70,000 hectares southern of Eastern Desert. (Toubrok, Amsad, El-Cabal El-Akhdar) a This leads to a very serious social and economic threat of landmines (4).

Governmental and non-governmental organizations in Libya have recently been active in publicizing the problem of landmines and altering the international community to its responsibility in this regard (5). However, the cooperation between Libya and other international organization, to address the problem is still modest .

Thermal neutron analysis (TNA) technique is based on the neutron capture reaction of ^{14}N nuclei, which are present in common explosive material in a quantity of about 17-38% by weight. This percentage is much larger than in the soil, where it is less than 1 %. The explosive signature is given by the detection of the 10.38 MeV γ- ray emitted with 18 % probability in de-excitation of the populated 15 N compound nucleus (6).

2. Achievements

Landmine research activities which have been carried – out at the radiation physics laboratory Tajuora research center under cooperation with IAEA. The soil constituents are nearly the same as the most mined area in Libya .The soil was very dray for depths down 36 cm. The composition of soil of the tested area has nearly the same chemical composition of soil collected from the major landmine field in Libya.

- Design and constructing the source housing and detector collimators that suit different experimental arrangements other needed experimental and mechanical facilities for different measurement.
- Design and constructing the source housing Design of simulated arrangement for theoretic.
- Determination of the element composition of the soil and TNT explosive materials.
- Determination of the elemental composition and their percentages (wt %) and atomic density for some common explosive materials.
- Determination of the element composition of the different objects in landmine filed in Libya
- Measurement thermal neutrons backscattered from different objects of 150 g weight buried at different depths in soil.
- The neutron spectra from different material with mine where measured by ^{3}He detector.
- Measurements spectrum of gamma-rays transmitted through ATM containing 2500 g explosive material exposed to neutrons from^{252}Cf source .
- Measurement the net gamma-rays spectrum for APM with 50g explosive material.
- Calculating the spectrum of gamma rays and thermal neutrons emitted from soil embedded with an ATM of 2.5 kg explosive material and plastic casing neutrons emitted from soil embedded with an ATM.
- Calculations are performed using a GEANT 3 code. Gamma-rays emitted from thermal neutron interactions with the elements of explosive materials.

3. Experimental Study

Measurements were performed in a ground area at Tajoura Nuclear Research Centre. The soil constituents are nearly the same as the most mined area in Libya .The soil was very dray for depths down to 35 cm. The composition of soil of the tested area has nearly the same chemical composition of soil collected from the major landmine field in Libya. Table 1: This table also shows the calculated Nd for elements of TNT material. It is clear 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. The calculated atom density for a soil sample is given in Table I. The elemental Composition and their percentages, Wt % and atomic density for some common explosive materials are calculated and listed in Table II.

Measurements were also performed using objects of different materials which may exist in landmine fields .These are objects of wood, polyethylene, aluminum; steel, of nearly the same size of small AP landmine type APM-32.The elemental composition and properties of these objects are listed in table III.

TABLE I: Calculated atom density (x 10^{22}) for soil sample.

Soil	Element
1.4930	Hydrogen
0.24	Carbon
—	Nitrogen
7.2	Oxygen
3.2	Silicon
0.045	Aluminum
0.039	Calcium

TABLE II: Chemical compositions for some common types of explosive materials:

Element	O		N		C		H	
Explosives	Nd.	Wt.%	Nd.	Wt.%	Nd.	Wt.%	Nd.	Wt.%
Nitrocelluse		59		13.7		24.8		2.5
RDX	0.29	43.2	0.029	37.8	0.014	16.3	0.029	2.7
TNT	0.026	42.3	0.013	18.5	0.03	37	0.021	2.2
Nitroglycerin	0.037	63.4	0.012	19.5	0.012	15.5	0.021	2.2
Ammonium Nitrate	0.358	60.8	0.239	35.4	--	--	0.468	3.8
Octegen	0.029	46.9	0.018	37.8	0.025	16	0.018	2.7

TABLE III: Characteristics and elemental composition of tested objects present in mine fields.

Material	C %	H% %	N %	O %	Fe %	AL %	CL %
Wood	44.44	6.17		49.38	—	—	—
Water	—	11	—	89	—	—	—
Polyvinyl Chloride	38	5	—	—	—	—	57
steel	—	—	—	—	100	—	—
Al	—	—	—	—	—	100	—

3.1 Neutron Source

Measurements were performed using Californium 252 neutron source of 50 microgram, with total neutron emission = 1.13 x 10^6 n/s. The source has Californium-252 neutron as a palladium cerement capsulated in welded double stainless capsule.

3.2 Detection System

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

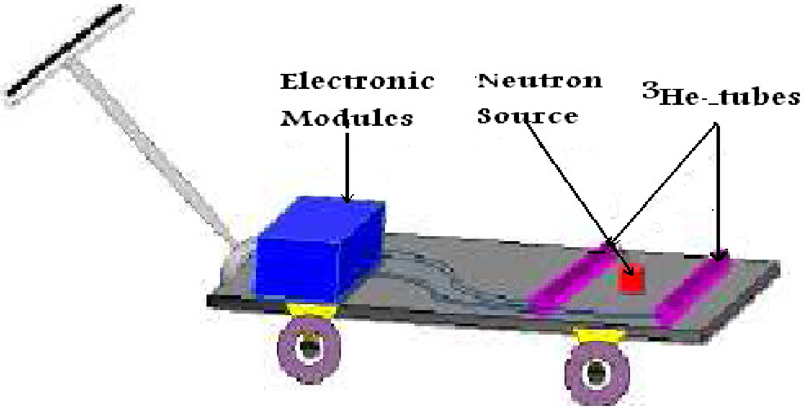

FIG. 1. Schematic diagram of the handheld NBS system.

4. Theoretical Studies

Theoretical studies were performed to optimize the source strength and configurations, detector areas and sensitivity, source and detector shield materials and thickness and measuring arrangements the source strength and configurations. This was carried out using GEANT 3.0 to study the design for 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. Preliminary calculations were performed using the MCNP- IV GEANT - 3 codes to study the back emitted gamma ray at the positions of the gamma detectors according to the simulation shown in Fig. 2.

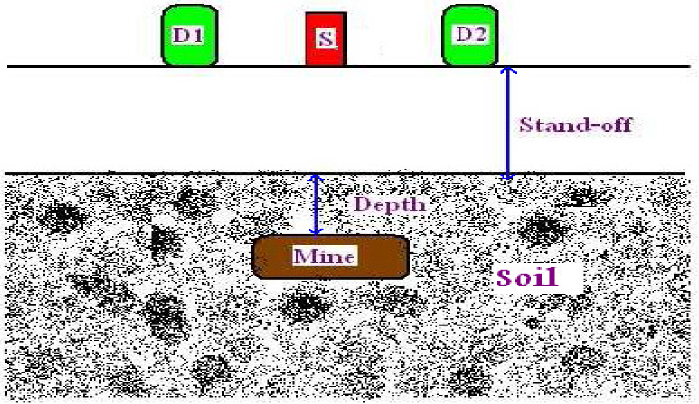

FIG. 2. Designed of simulator for theoretical calculation.

5. Results and Discussion

The average calculated number density (N_d) of soil elements is shown in Table I. It is clear that the soil collected from different landmine fields of Libya show that the moisture content does not exceed more than 3 %. This makes it possible to use a nuclear sensor based on hydrogen differences analysis.

The measured thermal neutron fluxes backscattered from AP mine with 150 g explosive material and different objects material buried at different depths in the ground are presented in the form of attenuation relation shown in Fig.3. This figure shows that the net count rate of thermal neutrons decreases as the buried depth increases for all examined object. They also show that the net count rate of thermal neutrons decreases as the material density increases steel object gives negative flux value for all measured depths, while explosive materials give the highest net count rate compared with other investigated objects. The given results clearly indicate the capability of the NBS system for discrimination between hydrogen containing objects, a landmine and metal objects.

The spectrum of gamma-rays transmitted through ATM containing 2500 g explosive material exposed to neutrons from^{252}Cf source. Measurements were performed using the available neutron/gamma spectrometer which employs NE–213 liquid organic scintillator. Fig.4. shows the gamma lines emitted from the interaction of fast and thermal neutrons with the elements of explosive materials ^{16} O, ^{12} C, ^{14}N and ^{1} H. This figure shows gamma lines of energies 2230, 4440, 5110 and 6130 KeV emitted from 1H, ^{12}C, ^{14}N and ^{16} O.

The calculated net gamma-ray spectrum for APM with 50 g explosive material is shown in Fig.5. The spectrum displayed in this figure shows several gamma lines of energy varies from 1 to 7 MeV. This gamma lines can be attributed to gamma-rays produced from the interaction of fast and thermal neutrons with the nuclei of explosive material, ^{1}H, ^{12}C, and ^{14}N. However, gamma- rays emitted from oxygen by inelastic scattering processes show no contribution in the displayed spectrum since oxygen is present in soil with higher percentage than that in explosive material.

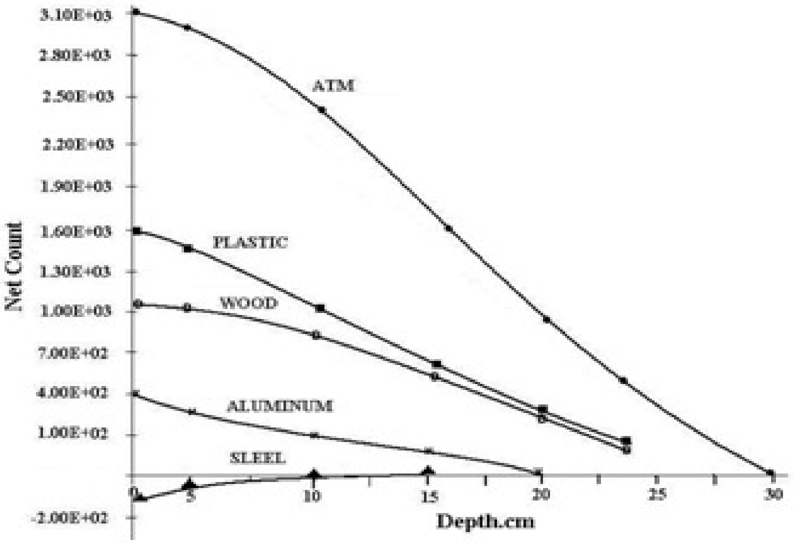

FIG.3. Measured count rate of TNBS flux from different object buried at different depth in the soil.

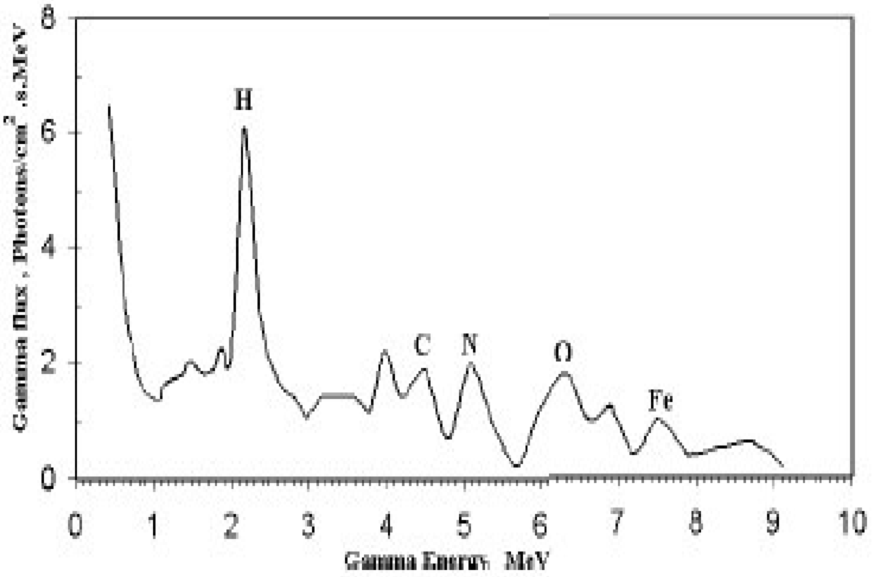

FIG.4. Measured gamma energy spectrum transmitted through 2.5 kg explosive materials.

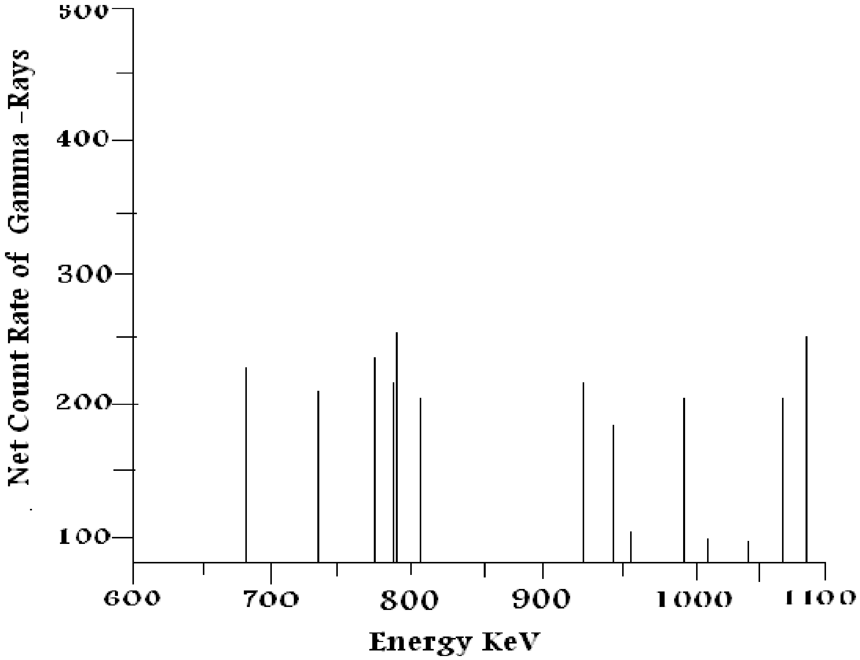

FIG.5 .Calculated net gamma ray spectrum from ATM with 50 g explosive material.

Calculations were done for soil embedded with an ATM containing 2.5 kg explosive material irradiated by neutrons emitted from ^{252}Cf source. The spectrum of fast neutrons is displayed in Fig. 6. While the spectra of gamma-rays for H, C, N and O (main constituent of ATM) are calculated and displayed in Figs 7, 8, 9 and10. These spectra show clearly the gamma energy lines resulting from the interactions of thermal and fast neutrons with H, C, O and N elements generated in GEANT 3.0 code.

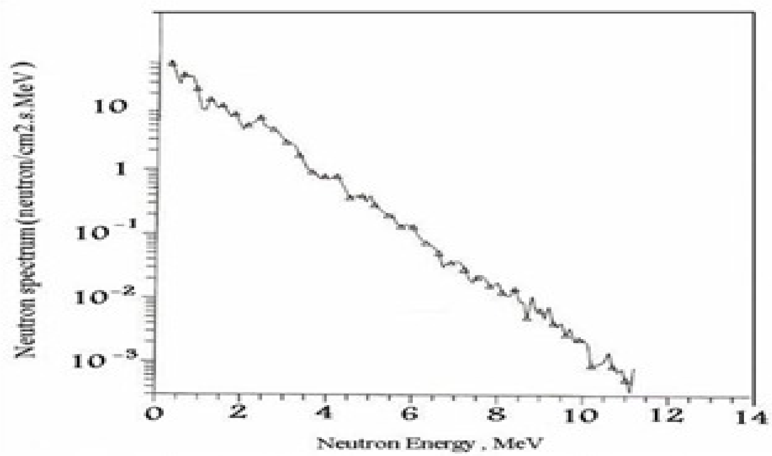

FIG.6. Calculated spectrum of fast neutrons backscattered from soil embedded with a mine.

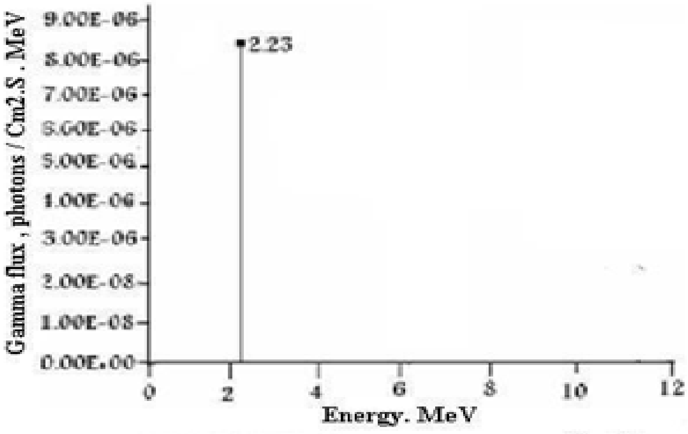

FIG.7. Calculated gamma spectrum emitted from Hydrogen.

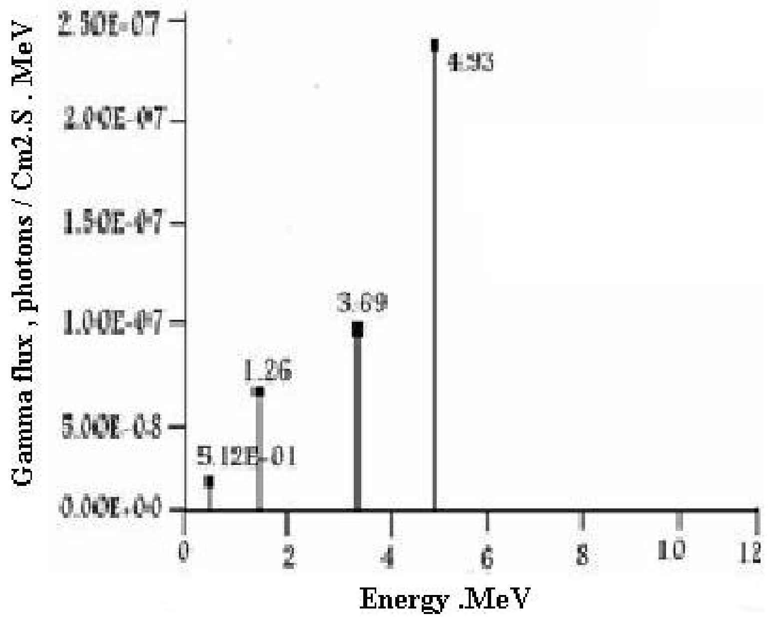

FIG.8. Calculated gamma spectrum emitted from Carbon.

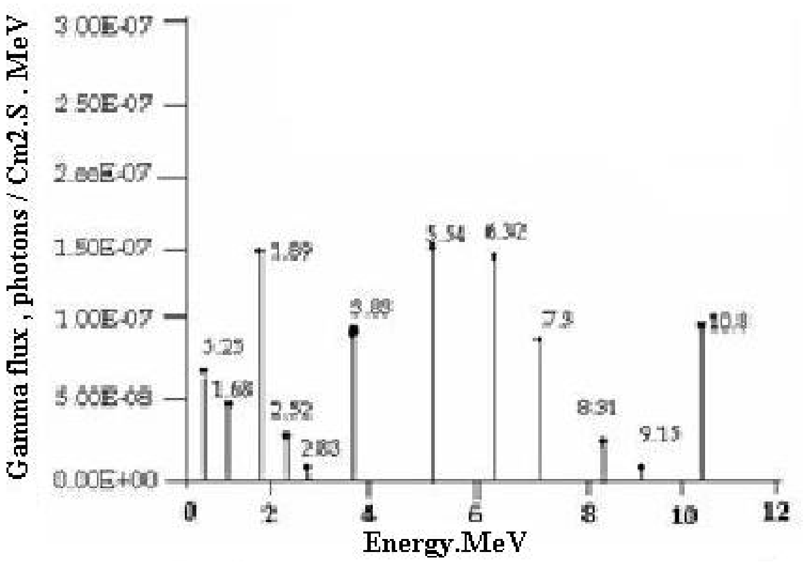

FIG. 9. Calculated gamma spectrum emitted from Nitrogen.

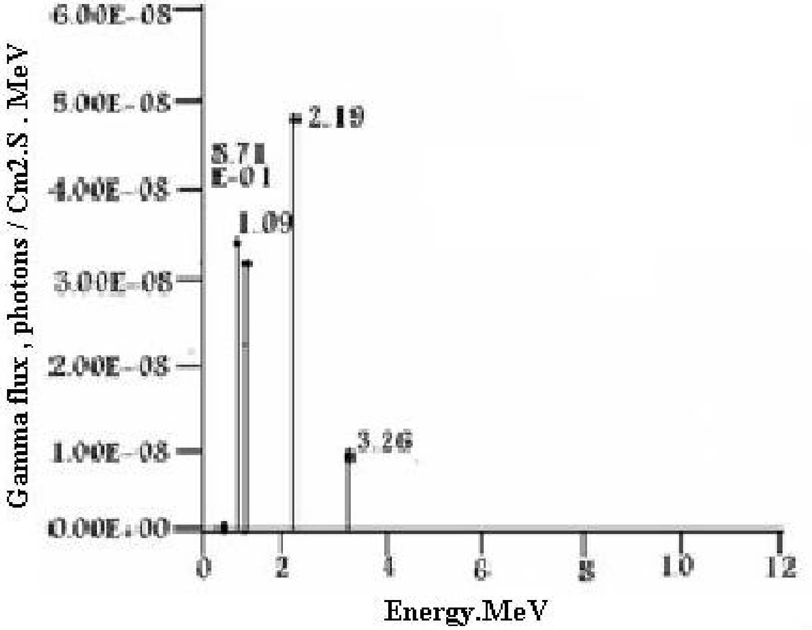

FIG.10. Calculated gamma spectrum emitted from Oxygen.

6. Conclusions and Recommendation

I. The obtained results for physical and chemical analysis indicate that soils of all landmine fields in Libya do not contain nitrogen element or nitrogen compounds. In addition, the moisture content is less than 3%. This gives indication to the validity of applying landmine detection methods based on nuclear techniques.

II. Thermal neutrons capture gamma-ray method is effective for detecting explosives by measuring and calculating 2.23 and 10.82 MeV gamma-rays emitted from ^{1}H and ^{14}N nuclei by (n,γ) reaction. Hydrogen gamma line of 2.23 MeV and nitrogen gamma line of 10,83 MeV are strong indicators of explosive materials buried in soil.

III. Measurement of both density and ratio of elemental composition of the hidden object provide a more definite characterization of an object as if it contains explosive material or not. Whether the detected anomaly contains an explosive material or not.

IV. International and regional collaborations in the field of developing and adopting nuclear techniques and other innovative technologies for landmine allocation and identification will help Libya to overcome the problem resulting from the contaminations of vast areas of land with landmines.

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