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Simulation of Landmine Detection Processes Using Nuclear Techniques

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ABSTRACT

A computer models were designed to study the processes of landmine detection using nuclear technique. Parameters that affect the detection were analyzed . Mines of different masses at different depths in the soil are considered using two types of sources , ^{252}Cf and 14 MeV neutron source. The capability to differentiate between mines and other objects such as concrete , iron , wood , Aluminum ,water and polyethylene were analyzed and studied.

Key Words: Landmine Detection/ HCNO Isotopes / Monte Carlo Method /MCNP Code

INTRODUCTION

Land mines are explosive devices buried or placed on the soil surface. Mines may have either metallic or nonmetallic cases enclosing the explosive materials. Explosives , illicit drugs and other contraband materials contain various chemical elements in quantities and ratios that differentiate them from each other and from innocuous substances[1,2].

Neutron induced reactions such as elastic scattering , (n, γ) , (n,p) ,) , (n,n^{-}) and neutron activation can be used to identify the elements of interest either from the energy of the scattered neutrons or from the emission of characteristic - γ rays. The penetrating ability of neutrons and γ-rays provides an effective way for measuring the elemental content of an interrogated material[3,4,5].

Most explosives are rich in nitrogen , which serves as a bonding agent . However the amount of nitrogen alone is not sufficient to definitely and distinguish an explosive material from other innocuous materials . Explosives are also rich in oxygen , the oxidizing agent , therefore ,knowing the nitrogen content together with the oxygen content provide a more unambiguous identifier of an explosive materials. Since a high content of nitrogen is characteristic of most explosives ,thermal neutron activation has been employed for identification purposes. The intensity of γ rays emanated at 10.8 Mev energy from the activated nitrogen provides an estimate of the amount of nitrogen in the interrogated soil.

Landmines usually composed of HCNO isotopes (Hydrogen , Carbon , Nitrogen and Oxygen). Neutrons interact with Hydrogen , Carbon , Nitrogen , Oxygen and emits γ rays with energy 2.22 , 4.44 , 10.83 and 6.13 Mev respectively. Detection of any of these energy bins illustrates the presence of landmine[6,7,8].

COMPUTER MODEL

MCNP computer code[9] was used to design a theoretical model for the detection of buried landmine. The model consists of 4 main parts : a neutron source (14 Mev source or CF-252 neutron source) , soil , landmine and detector. The back scattered neutrons and gamma ray spectra from the soil with and without landmine are compared at detector position to detect landmine. The composition of West Soil desert in Egypt was used to perform the calculations.

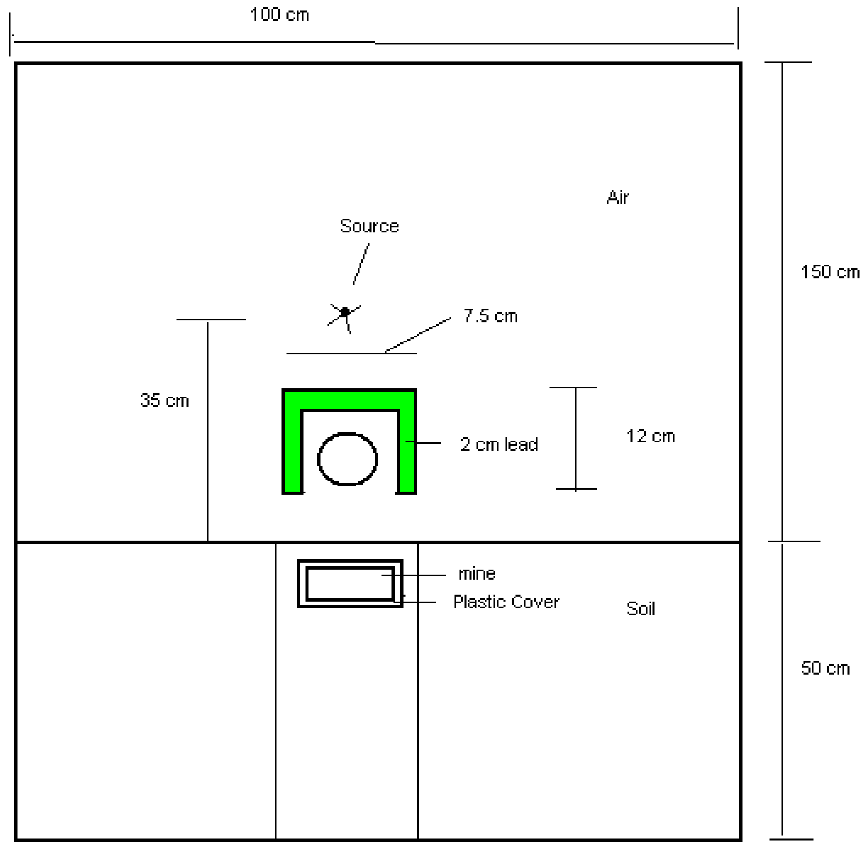

Fig. 1 MCNP Code Model For Land Mine Detection

The neutron source of strength 10^9 n/s far 35 cm from earth, which assumed to be a point source . The detector is enclosed by 2 cm lead shield. The mine is buried at 1 cm depth which is subject to change and enclosed in plastic cover. The neutron and γ rays spectrum are divided into 200 energy group to obtain fine , detailed and accurate results. To optimize the results ,the point detector techniques are used to determine both the neutron and γ ray tally.

RESULTS AND DISCUSSIONS

For Land mine of mass 100 ,1000 gm buried at 1.0 cm depth in the soil due to neutron source of 14 Mev. The ratio of gamma flux with and without mine at certain energy groups at 2.22 Mev , 4.44 Mev and 10.82 Mev which indicates the presence of H , C and N respectively
Response Ratio = gamma flux with mine / gamma flux without mine

Table 1 the response ratio for buried mines at depth 1 cm of masses 100 gm and 1000 gm for 14 Mev Neutron source

Energy bins (Mev)	Response ratio Mine mass 100 gm	Response ratio Mine mass 1000 gm
2.2 –2.3 (H)	1.093	1.627
4.4 – 4.5 (C)	1.1	1.417
10.8 –10.9 (N)	1.245	2.11

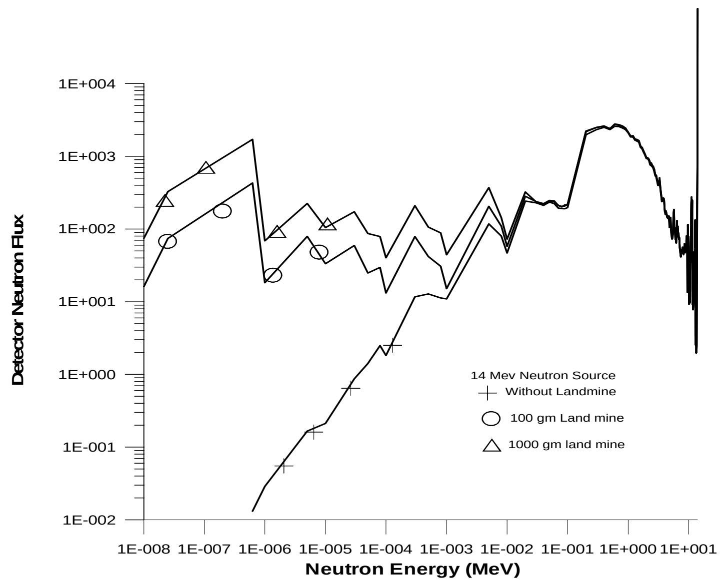

Fig.2 Neutron spectrum at the detector due to presence of Land mine buried at 1 cm depth for 14 Mev neutron source .

Table 2 the response ratio for landmine buried at 1 cm and CF neutron source

Energy bins (Mev)	Response ratio Mine mass 100 gm	Response ratio Mine mass 1000 gm
2.2 –2.3 (H)	3.56	15.5
4.4 – 4.5 (C)	1.26	2.3
10.8 - 10.9 (N)	44.3	237

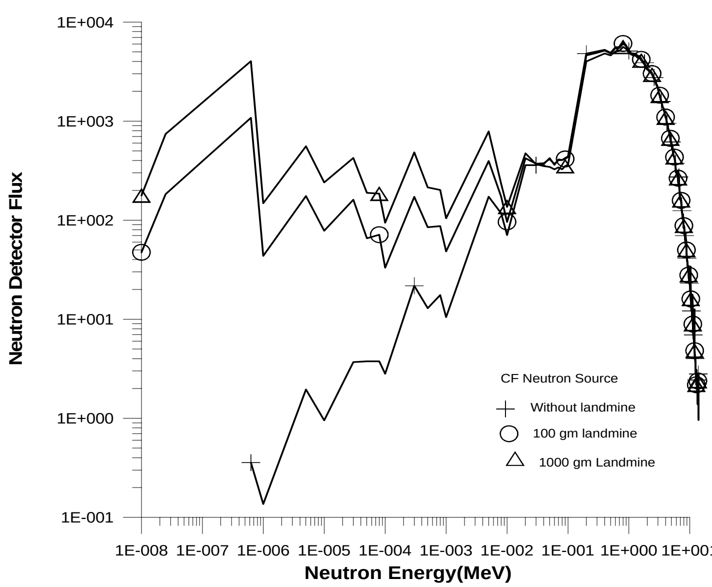

Fig. 3 Neutron spectrum at the detector position due to landmine buried at 1 cm for CF neutron source.

Table 1 illustrates the response ratio for buried mines at depth 1 cm of masses 100 gm and 1000 gm due to 14 Mev Neutron source . The results indicate that as the mass of mine increases the response ratio increases. Figure 2 illustrates the corresponding neutron spectrum at the detector due to presence of Land mine of masses 100 and 1000 gm of TNT respectively buried at 1 cm depth for 14 Mev neutron source . The results indicate that larger masses of mines have higher capability to backscatter more neutrons especially at thermal region.

Table 2 illustrates the response ratio for landmine buried at 1 cm , with masses 100 and 1000 gm for CF neutron source. Figure 3 illustrates the corresponding neutron spectrum at the detector position due to landmine buried at 1 cm for CF neutron source. The results indicates that the case of CF neutron source have higher backscatter neutrons and γ-rays than 14 Mev neutron source .

Mines Buried at Different Depths for 14 MeV Source

For mines buried at different depths , the response ratio for gamma rays at certain energy bins which indicats the presence of H , C and N are illustrated in Table 3. For energy group 10.8-10.9 Mev the response ratio at different depths are given , the results indicates that the response ratio decrease with increasing mine depth at 1,5 ,10 ,20 and 50 cm , the ratio are 2.11,1.752 , 1.376 , 103 and 1.002 respectively which indicates that for mine buried more than 10 cm the response ratio is very small. Figure 4 illustrates the corresponding backscattered neutron flux at the detector.

Table 3 response ratio at different energy bins for mines buried at different depthes

Energy bins (Mev)	1 cm mine depth	5 cm mine depth	10 cm mine depth	20 cm mine depth	50 cm mine depth
2.2-2.3 (H)	1.627	1.288	1.103	1.025	1.002
4.4-4.5 (C)	1.417	1.17	1.066	1.026	1.012
10.8 - 10.9 (N)	2.11	1.752	1.376	1.03	1.002

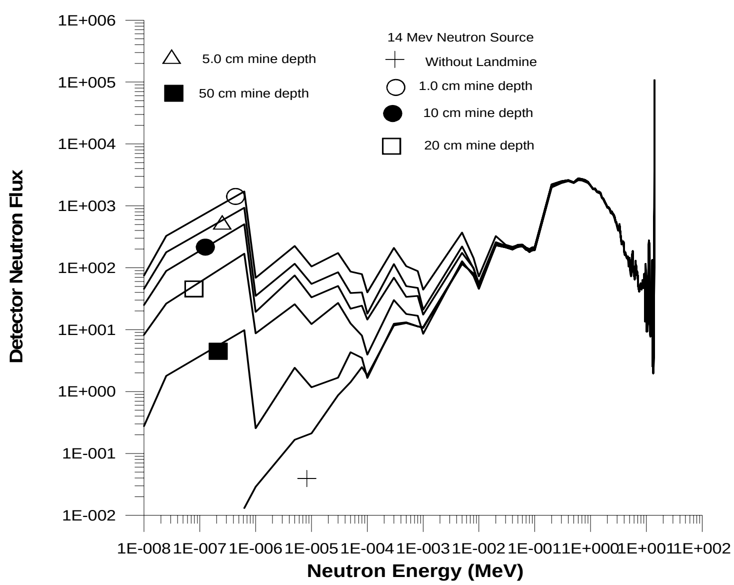

Fig. 4 Detector Neutron flux at different mine depthes for 14 Mev neutron Source

Mines at Different Depthes for CF Neutron Source

Table 4 illustrates the gamma response at different energy bins for CF neutron source with mines buried at different depths. The results indicate that for CF source the response at bin 10.8-10.9 (which indicate the presence of N) is higher than that for 14 Mev source , this due to CF source emits fission spectrum which include thermal neutron than 14 Mev source , and the thermal neutron is responsible for Nitrogen interaction. Figure 5 illustrates the corresponding neutron spectrum.

Table 4 response ratio for mine buried at different depths for Cf source

Energy bin(MeV)	1 cm	5 cm	10 cm	20 cm	50 cm
2.2-2.3 (H)	15.46	6.49	3.21	1.41	1.006
4.4-4.5 (C)	2.3	1.85	1.58	1.29	1.026
10.8-10.9 (N))	237	132.99	43.33	14.06	1.326

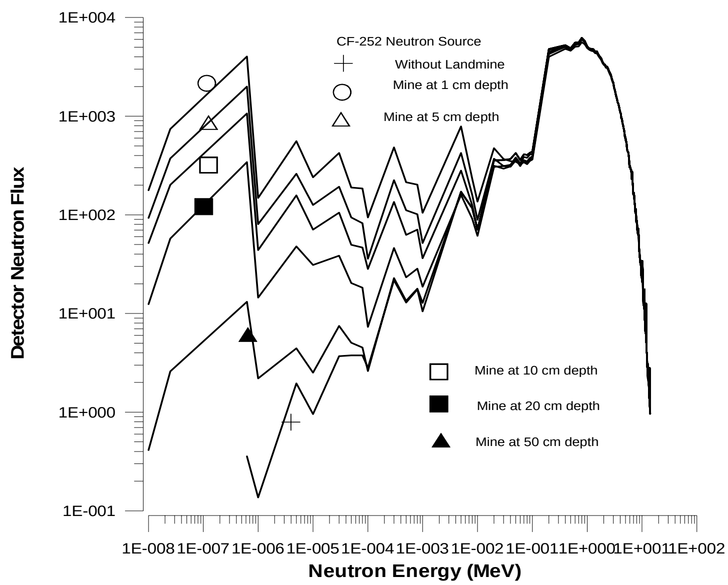

Fig. 5 Detector Neutron flux at different mine depthes for CF neutron Source

The Effect of Soil –Source Distance on the Detector Flux for 14 Mev Source

The distance between the source and soil surface are varied between 35 ,60 ,100 cm . The response ratio for different energy gamma bins are determined , the results are normalized to 35 cm distance . The gamma responses are illustrated in Table 5 and the corresponding neutron spectrum are given in Figure 6.

Table 5 response ratio for different source – soil distance

Energy bins (Mev)	35 cm	60 cm	100 cm
2.2-2.3 (H)	1.0	0.344	0.13
4.4-4.5 (C)	1.0	0.344	0.152
10.8-10.9 (N)	1.0	0.57	0.49

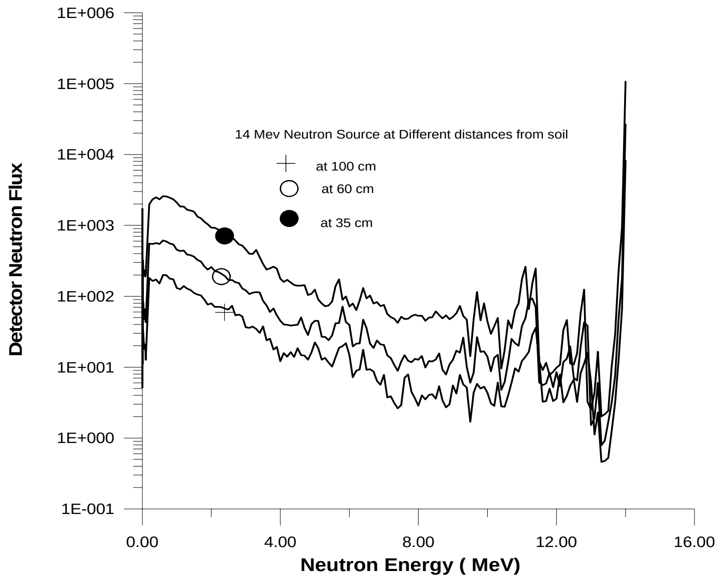

Fig. 6 Neutron spectrum at the detector due to different soil - source distance

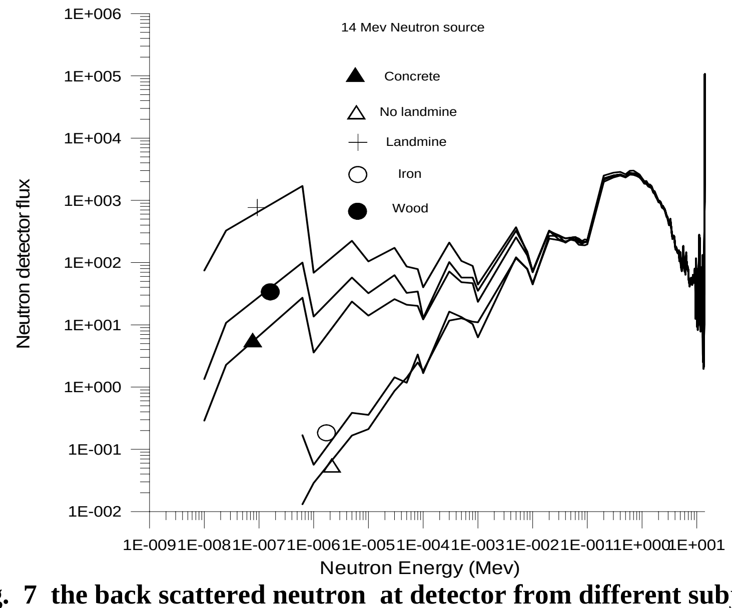

Fig. 7 the back scattered neutron at detector from different subject

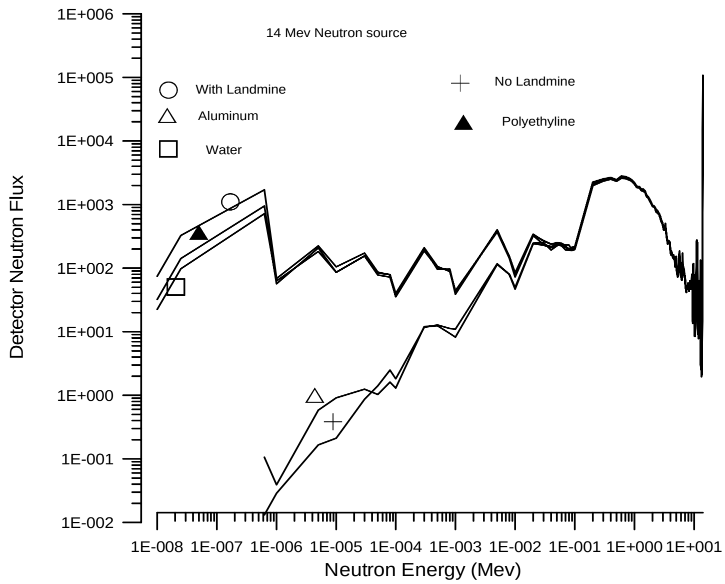

Fig. 8 the back scattered neutron at detector from different subject

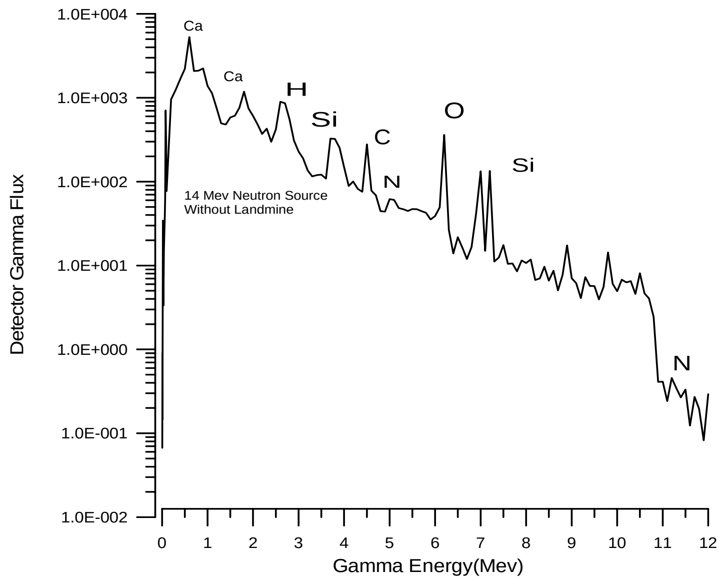

Fig. 9 Detector gamma flux without land mine

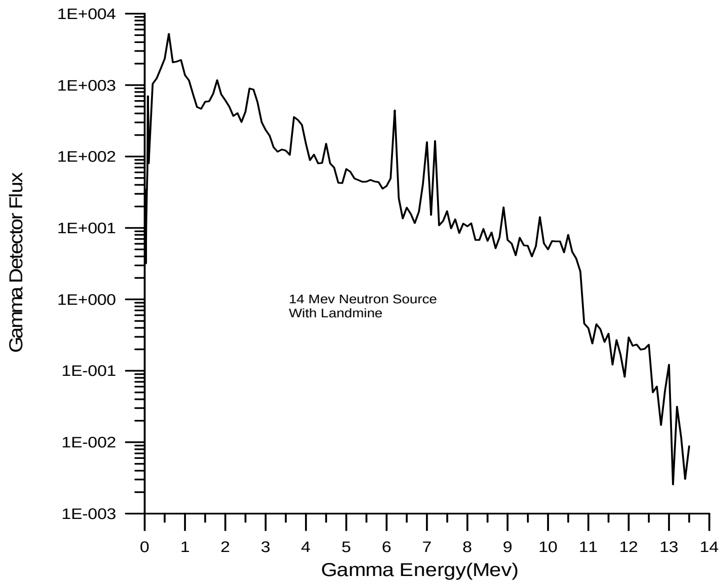

Fig. 10 Detector gamma flux with land mine

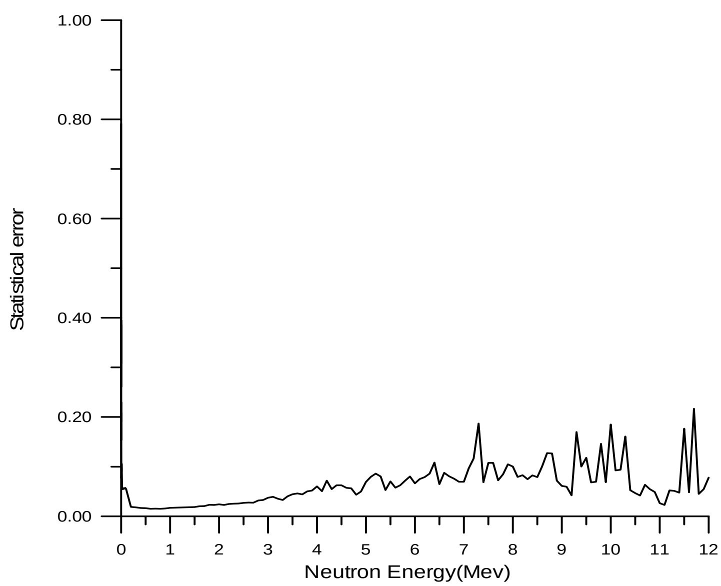

Fig. 11 Statistical neutron error

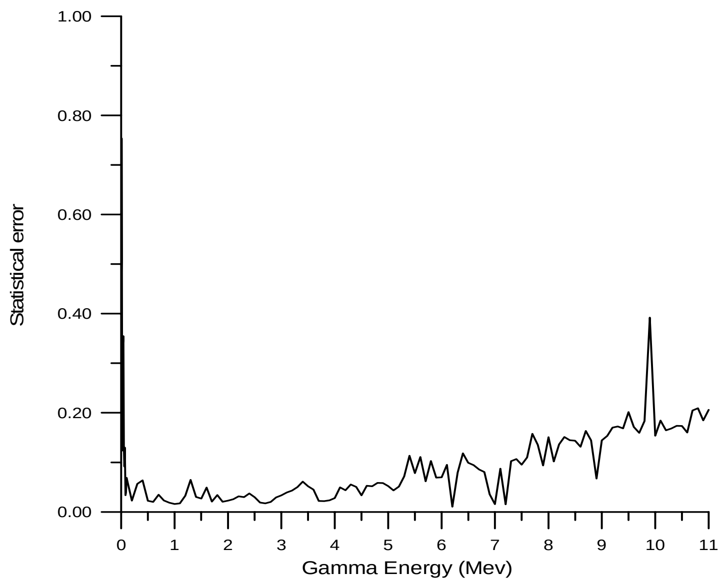

Fig. 12 Statistical gamma error

Figure 7 illustrates the neutron flux at the detector position due to different object (concrete , mine , no mine , iron and wood) buried at 1 cm depth inside the soil for 14 Mev neutron source. The results indicate that the case of mine have higher back scattered thermal neutrons superior to all cases.

Figure 8 illustrates the neutron flux at the detector position due to different object (mine , no mine , Aluminum , water and polyethylene) buried at 1 cm depth inside the soil for 14 Mev neutron source. The results indicate that the case of mine have higher thermal flux and polyethylene which have HC composition are approximately close to landmine.

Figure 9 and Figure 10 illustrate back scattered gamma at the detector , the peaks indicate the presence of different isotopes at the soil due to emission of gamma rays from (n,γ) reaction. The peaks at 2.23 Mev for Hydrogen , 4.44 Mev for Carbon , 10.82 for Nitrogen , 6.12 Mev for Oxygen

Figure 11 and Figure 12 illustrate the statistical error for neutron and gamma flux respectively. For neutron statistical error up to 5 Mev the error below 5 % and after 5 Mev it is below 12 % except at certain energies which shows peaks. For gamma rays , the statistical error behaves similar to neutron but indicate peaks at certain energies. These error peaks occur due to little neutrons and gamma accounted at the detector at these energies.

CONCLUSION

- A Computer Model Which Study Parameters That affect the Detection of Landmine with Nuclear Techniques was Designed Using MCNP Code Based on Monte Carlo Method.

- The Detection of Landmines of Different Masses at Different Soil Depths Using Two types of Neutron Sources CF and 14 Mev (D-T) Neutron Source Were analyzed and Studied.

- The Results indicated that for 14 Mev Neutron Source , The Response ratio of Back scattered gamma spectrum at 10.82 Mev which indicate the presence of Nitrogen at Depths 1 cm , 5 cm and 10 cm is 2.11 , 1.752 and 1.376.

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