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Optimization of NaI (TI) Assembly for Detecting TNT Sample Using Backscattering system

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Abstract: *Experiment was setup to perform the gamma backscattering detection of the landmine buried in a sample type of dry soil of density equal 1.338g/m. It was done by using NaI(TI) detection assembly system consisting of about different radioactive sources (^{60}Co,$Am^{241}$and Cs^{137}). The optimal configuration was selected to scan the detection along the box contains dry soil. The results in terms of contrast ratios and sample distance position verified the capability of the proposed device to monitor where the target sample localized in different depths. In addition the high contrast ratio was observed in Cs^{137} source where ^{60}Co identifies the sample before reaches the buried point by approximately 30 cm so the ^{60}Co provide a good source for detection.*

Keywords: *Landmine; Backscattering; Explosive; Gamma Radiation.*

INTRODUCTION

Abandoned landmines are serious humanitarian problem in many parts of the world today (Monin and Gallimore, 2002). So the detection of landmines has been a very important research area in recent years. Widely published reports estimate that there are more than 100 million land mines affect more than 70 countries. F.D.Brooks, A. Buffler ,M.S.Allie ,2004) . The number of persons accidentally killed by landmines worldwide each year is believed to exceed 25,000 and even large number are maimed most of casualties are caused by small plastic anti-personnel mines using the technology now available .New technology is now being thought to alleviate this problem and progress for example at meeting such as the recent international conference held in Brussel in September 2003 (Sahli et al,2003) among the new idea that are now being considered for landmine detection are methods that take advantages of the penetrating power of neutrons and gamma rays. A coordinated research project on the development of nuclear-based methods to aid Humanitarian demining (HD) was initiated by the International Atomic Energy Agency in 1999 and is now producing results (IAEA,1999, 2001, 2003). In this research we focus on work in progress in this field. So the land mine detection is not only a problem for military, but also for significant humanitarian concern. This research is motivated by the need of humanitarian purposes to clear up mine fields left after wars.The most common explosive material found in landmines are TNT ($C_7 H_5 N_3 O_6$), Tetryl ($C_7 H_5 N_5 O_8$) and Composition B (TNT+RDX ($C_3 H_6 N_6 O_6$). These aspects clarify that landmine detection is a dangerous process .So the search for buried explosive materials, such as `TNT is one of the most interesting and worthwhile applications of nuclear techniques. TNT ($C_7 H_5 N_3 O_6$) have densities of about 1.65g.cm ^{3} . This makes them lighter than most of metals, but heavier than and different in density from common materials such as polyethylene and air. Therefore, density variations can be used to detect the presence of such explosive material when buried inside soil. Gamma backscatter density gauges use the Compton scattering of photons in bulk material to measure density. Since the cross section for Compton scattering is proportional to the number density of electrons, and the ratio of atomic mass to atomic number is 2.0, or nearly so, for all elements (except hydrogen),the backscattered count rate is a function of the bulk density .Therefore, the change in the flux of scattered photons can be used to indicate the presence of an anomaly, possibly concealment. The magnitude of this can be used to discriminate between different depths and distances while scanning of buried landmine concealment.

A detector is placed a short distance along the surface from the source to count photons scattered out of the material. Shielding of the source prevents photons reaching the detector directly. Unlike transmission densitometer where the linear geometry of source sample and detector can limited, backscatter density gauges that be applied to semi-infinite bulk materials. Several geometries of photon backscattering system for explosive detection has been reported by others (Camphell et al ,1994 ; Van wart 2001; Smith, 1990 ; Harting,2004 ; Vogel, 2007) photon backscattering was used for detecting explosive material . A similar device was developed by Hussein in 2004 for detecting visually obscured objects buried within extended soil. Since for most material Compton scattering is the dominant mode of interaction at photon energies from 50KeV to 1.5 MeV (Hussein, 2004) gamma sources such as ^{60}Co, Am^{241}, Cs^{137} are suited for this purpose. On the bases of such considerations, this work examines the possibility of employing a shielded ^{60}Co, Am^{241} and Cs^{137} sources and a well collimated NaI (Tl) detector in a suitable configuration for detection and localization of TNT ($C_7 H_5 N_3 O_6$) samples, buried in soil that had different density accordingly to its manner of status. The results of measurements are analysed considering indicators: such as the magnitude of the backscattering photon flux (Φ) and the difference between the detector response obtained in the presence of a target and that obtained in target-free soil normalized to that of target-free to define a contrast ratio. Good detection capability was defined by the ability to obtain a contrast ratio greater than 10%(Nassreldeen Elshikh et al., 2016). A high flux reduce the required counting time or source strength (hence shielding requirement and device weight) Therefore, an optimized device should provide simultaneously a high flux and contrast, i.e., a high value of form (Shuo-Sheng Tang and Esam, M.A. Hussein, 2004). To optimize a gamma-ray backscattering system we should also be attention and be aware of two points: isolation of detector from direct signal counts to source radiation and focusing the detector's filed-of view on the region of interest.

1. Modeling and material

In this modelling system of reference where the source was located 5cm above the top surface in the box contains soil of dimensions 130cm length, 50cm in diameter and 60cm in depth. A single NaI (TI) photon detector from LAYBOLD DIDACTIC GmbH (Model: 559901) was employed. The detector was collimated by a centring a lead cube of dimensions 10cm ×10cm ×5cm was located 10cm above the surface of the soil and at different positions along the X-axis away from the source and detector to provide further protection for the operator and the surrounding environment, the vehicle role was dragged by along hand-held located at back sides of the (NaI (Tl) detector) assembly. The samples under test; 30g of TNT ($C_7H_5N_3O_6$) was sealed in plastic discs each of 3 cm radius and 6 cm thick. Then the sample is located inside the box filled with soil the distance begins from position every 10 cm ends to locate buried sample at position 130cm the railway moved on the role vehicle horizontally along the slider to position of the buried sample exactly below the source and record the NaI (Tl) detector response as shown in tables (2-4) below. The compositions of samples and materials of interest are presented in table (1).

Table.1. *Composition of samples and materials of interest, rounded off*

Sample density	Mass fraction H	N	C	O
TNT 1.65	0.022	0.370	0.180	0.423
Air 0.00122			0.780	0.220

II. Methodology

A source of gamma photons is placed at the surface of a soil sample with manner of dry soil 1.338 g/cm^{-3}to eject gamma photons into the material sample by using backscattering system A signal output from the NaI (Tl) detector was processed by The computer-assisted measuring and evaluation system CASSY-S consisting of the CASSY Lab software (524 200), Sensor-CASSY module (524010) and Power-CASSY (524011), connected to a desktop computer. The electronic system was arranged, using suitable operating voltage and gain. Due to the need for sufficient statistics, the acquisition time for all measurements was chosen to be 30/s number of channels equals 256. In the end distance from the initial measuring point of the soil inside depths (10, 20, 30cm) a hidden sample was identified using sources ^{60}Co, Am^{241} and Cs^{137}. A railway was putted over the soil using a small vehicle holding the system.

Table (2) *Sample distance position in dry soil by using ^{60}Co source*

Sample distance Position (Xcm)	Values Without Source N/30	Values With Source ^{60}Co Depth10 cm	Contrast Ratio S/B Rate/s	Values With Source ^{60}Co Depth20 cm	Contrast Ratio S/B Rate/s	Values With Source ^{60}Co Depth30 cm	Contrast Ratio S/B Rate/s
10	306	496	0.620	488	0.594	428	0.398
20	324	504	0.555	471	0.453	446	0.376
30	312	446	0.429	438	0.403	406	0.301
40	289	460	0.591	423	0.463	401	0.387
50	251	397	0.581	436	0.737	408	0.625
60	268	458	0.708	432	0.611	412	0.537
70	278	464	0.768	361	0.298	361	0.298
80	272	432	0.588	389	0.430	378	0.389
90	239	447	0.870	391	0.635	381	0.594
100	241	461	0.912	390	0.618	394	0.634
110	276	483	0.750	502	0.818	407	0.474
120	298	401	0.345	414	0.389	389	0.305
130	244	453	0.446	372	0.524	373	0.528

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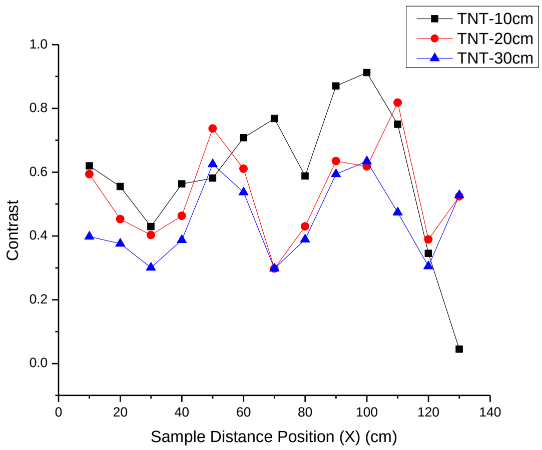

Fig.1. *Contrast ratios as a function of distance sample position (X) for the source ^{60}Co*

Table (3) *Sample distance position in dry soil by using Am^{241}source*

Sample Distance Position (Xcm)	Values Without Source N/30	Values With Source Am^{241} Depth10 cm	Contrast Ratio S/B Rate/s	Values With Source Am^{241} Depth20 cm	Contrast Ratio S/B Rate/s	Values With Source Am^{241} Depth30 cm	Contrast Ratio S/B Rate/s
10	226	316	0.549	293	0.436	287	0.387
20	196	269	0.0253	314	0.137	342	0.239
30	174	251	0.629	252	0.636	210	0.363
40	163	257	0.606	243	0.518	246	0.537
50	173	267	0.579	262	0.550	288	0.497
60	173	229	0.477	249	0.606	272	0.496
70	194	259	0.430	271	0.497	278	0.535
80	149	227	0.609	229	0.504	192	0.361
90	168	228	0.433	260	0.635	237	0.616
100	154	231	0.519	232	0.563	233	0.532
110	176	225	0.388	254	0.567	232	0.432
120	129	235	0.958	206	0.716	200	0.666
130	138	231	0.686	233	0.700	222	0.620

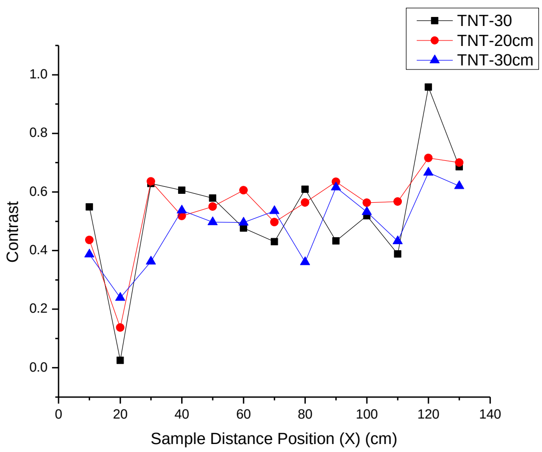

Fig2. *Contrast ratios as a function of distance sample position (X) for the source Am^{241}*

Table.4. *Sample distance position in dry soil using Cs^{137} source*

Sample Distance Position (Xcm)	Values Without Source N/30	Values With Source Cs^{137} Depth10 cm	Contrast Ratio S/B Rate/s	Values With Source Cs^{137} Depth20 cm	Contrast Ratio S/B Rate/s	Values With Source Cs^{137} Depth30 cm	Contrast Ratio S/B Rate/s
10	306	5693	16.604	3278	8.255	2948	8.133
20	324	5369	15.570	3497	9.793	2918	8.006
30	312	5494	15608	3380	9.833	2602	7.339
40	289	5156	16.808	3092	9.698	2432	7.415
F50	251	5327	20.223	3043	11.123	2581	9.282
60	268	5315	18.832	3089	10.526	2641	9.854
70	278	5304	18.079	3131	10.262	2524	8.079
80	272	5207	18.143	5054	17.808	2839	9.437
90	239	5288	21.125	5106	20.364	2823	10.811
100	241	5368	21.273	5048	19.946	2827	10.730
110	276	5369	18.452	4859	16.605	2615	10.927
120	298	5430	17.221	5007	15.808	2610	7.758
130	244	5535	21.684	5278	20.631	2595	9.635

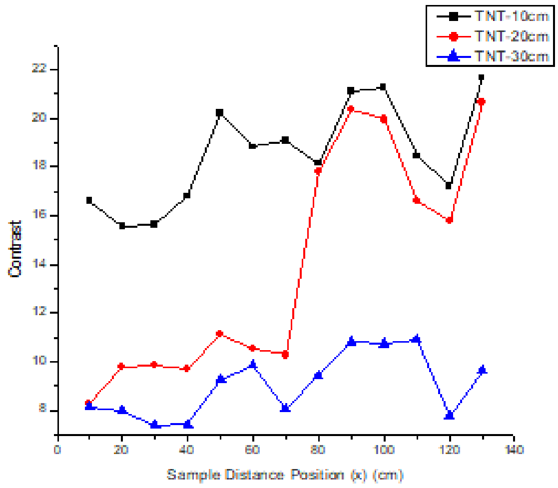

Fig.3. *Contrast ratios as a function of distance sample position (X) for the Cs^{137}*

RESULTS AND DISCUSSION

A performance of a suitable (NaI)gamma backscatter device system was design to be investigated experimentally in the presence of the sources ^{60}Co, $Am^{214}$and Cs^{137} .The optimal configuration of the optimized shield was used to avoid the collimated detector from scatter photons also the operator while scanning the detector along the distance 130 cm .The results be analysed in terms of count rate -to-background ratio (S/B) and sample position with two parameters; the source-detector and the sample position distance with respect to the sources used in the proposed NaI (Tl) assembly showing that Cs^{137} got high contrast value. Also we observed that, the capability of the system localized the sample when buried in dry soil alternatively at different depths .We predict that measurements of the soil in moisture manner with density 1.583g /m^2 higher than the dry which was 1.338g/m^2 will provide goodresults.

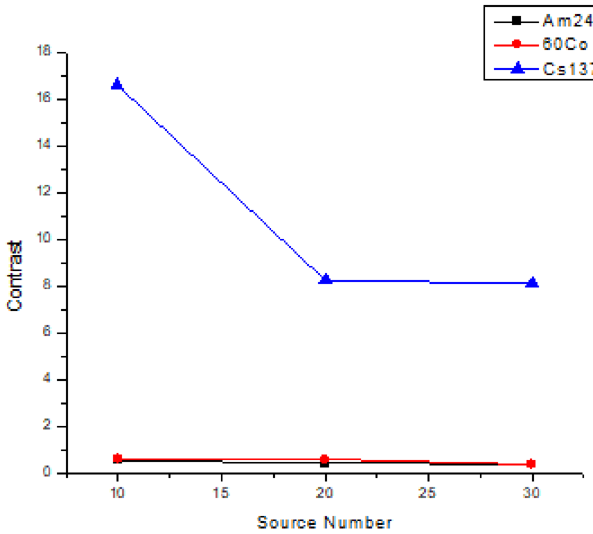

Fig.4. *Contrast ratios obtained for 3 photon sources (practical results*

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International Atomic Energy Agency in 1999 and is now producing results (IAEA, 1999, 2001, 2003).

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