Identification of Materials Hidden Behind or in Front of Dense Organic Goods

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Abstract. It was already shown in the previous work that the tagged neutron inspection system (TNIS), which uses the associated particle imaging (API) technique, was able to detect explosive in a sea-going cargo container filled with an iron matrix with density 0.2 g/cm^3 [1]. It was also shown the possibility of TNIS to detect the explosive in the organic matrix with density ≤ 0.25 g/cm^3 [2]. In this work the possibility of TNIS to identify materials hidden behind or in front of dense organic goods is investigated. A paper target, which is a good explosive simulant, is put close to the flour surroundings. A triangle diagram is made from the number of counts in the carbon peak, number of counts in the oxygen peak and the number of counts in the transmitted neutron peak. Identification of the paper target is possible if some appropriate knowledge about the surroundings is known.

1. Introduction

Fast neutron analysis is a technique which was found to be very useful either as a pulsed fast neutron analysis (PFNA) or as associate particle imaging (API). In both cases fast neutrons with an energy of around 8 MeV (PFNA) or 14 MeV (API) were used to produce the characteristic prompt gamma rays inside the interrogated object. While in PFNA nanosecond pulsing is used for measuring [3] the time-of-flight of neutrons in API, for the same purpose, associated alpha particles produced in the $^{3}H(d,n)^{4}He$ reaction are measured [4]. Inside the sixth European framework program for research and technological development (FP6) the EURopean Illicit TRAfficking Countermeasures Kit (EURITRACK) inspection system has been designed and installed in port of Rijeka in Croatia. The EURITRACK inspection system uses the API technique to investigate the particular part of a sea-going cargo container which was found to be suspicious. The system has been designed to complement the Heimann 300 keV X-ray scanner which also operates in the port of Rijeka. At the moment over 150 containers were inspected and some of the results were published in [5]. In addition, by the help of the Croatian Custom Office and the Ministry of Internal Affairs the EURITRACK system was also checked for the possibility of detecting illicit drugs (heroin, cocain and marihuana). Results are published in ref. [6]. These tests show the ability of the EURITRACK system to detect heroin and cocaine hidden inside a fully-loaded metallic cargo container by measuring the oxygen-to carbon (O/C) ratio. No nitrogen was detected due to insufficient counting statistics. Marihuana cannot be identified because the associated O/C ratio is too close to the benign organic materials. For cocaine and heroin, false alarm is possible because of a relatively large error bar. Nitrogen is also found to be difficult to detect in some kind of explosives. Also, there are explosives which do not contain nitrogen at all. Figure 1 shows the gamma ray spectra of the explosive semtex1a and the paper measured with the top detectors of the system described in [1]. It seems that in addition to the O/C and N/C ratios some other parameters are needed for successful detections of drugs and explosives with the minimal amount of false alarm. It was shown in a previous work [2] that the density could be used as a third parameter. Figure 2 shows the triangle plot. The coordinates were made from the

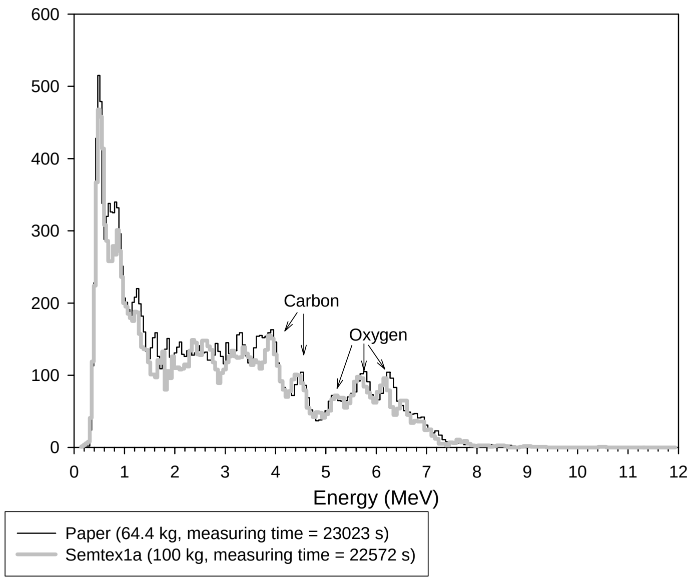

FIG. 1. Gamma ray spectra of the explosive semtex1a (gray) and the paper (black) measured with the system described in [1].

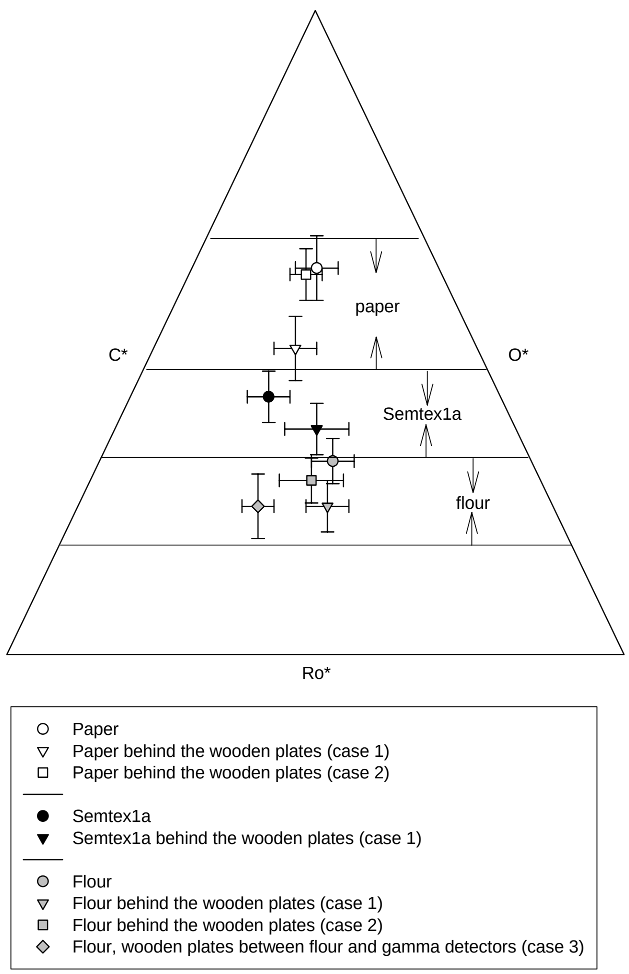

FIG. 2. Triangle diagram [2].

number of counts in the carbon peak, the number of counts in the oxygen peak and the number of counts in the transmitted neutrons peak. The measured points are located in three regions. The first region corresponds to the paper points. The second region corresponds to the explosive semtex1a points. The third region corresponds to the flour points. The paper, semtex1a and flour are measured alone, behind the wooden plates close to the target (case 1) and behind the wooden plates far from the target (case 2). In both cases wooden plates are between the measuring target and the neutron source. In a case 3 wooden plates are between the measuring target and the gamma detectors. Generally, the effect of the organic matrix is to lower down the position of the material in triangle plot proportionally to the organic matrix density. It seems that the dense target could be identified in a fully-loaded organic cargo container if cargo density in average does not exceed 0.25 g/cm^3.

2. Measurements

To investigate further the possibility to detect and identified the measuring target hidden behind or in front of dense organic goods an experimental set-up is made like in figure 3.

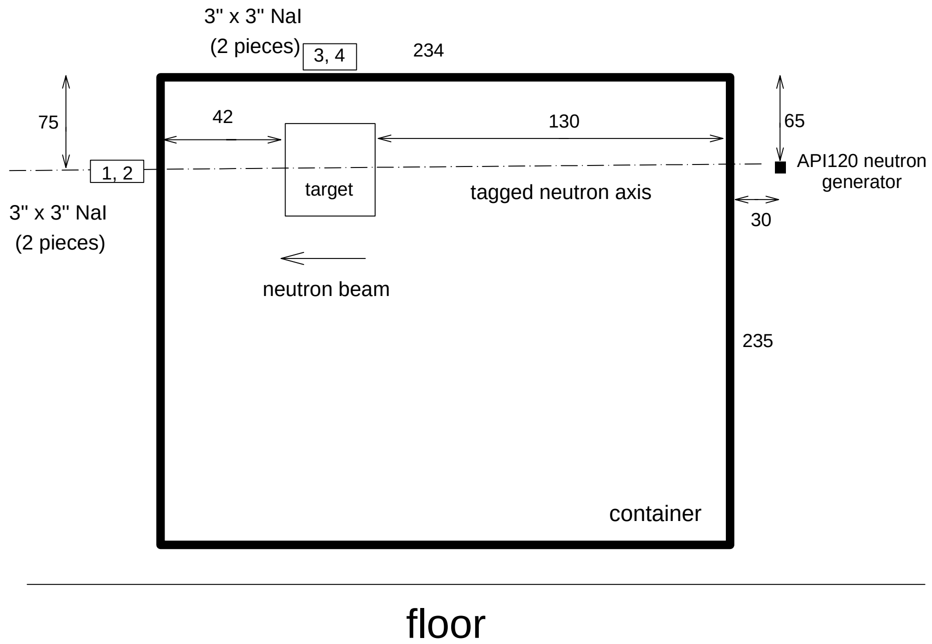

FIG. 3. Experimental set-up.

This set-up is identical to the one described in [2]. A mobile and compact shielded tube neutron generator API120 from Thermo Electron was used as a source of 14 MeV neutron beam. The target was put in container far from the neutron source. At the target position, the diameter of the tagged neutron beam was around 47 cm. Two 3'' x 3'' NaI(Tl) were used as gamma detectors in the so called transmission position. Another two 3'' x 3'' NaI(Tl) were put on the top of the container. Gamma detectors were shielded with 5 cm of lead. The neutron beam intensity was ~ 1.3 x 10^7 n/s. Paper and flour were put inside the container, close to each other (figure 4). In that particular case, the paper was hidden behind the dense organic matrix (flour), or alternatively, we can say that flour was masked with the paper. The aim is to find the paper and the flour target, in an adequate time window. Figure 5a shows the time spectrum for the transmission detector #1. The flour and the paper region are marked with gray and black respectively. Figure 5b shows the associated gamma ray spectra. Carbon and oxygen could be identified. Figure 6 shows the triangle diagram for this two cases. Flour in front of the paper is truly identified as a flour in an organic matrix.

FIG. 4. Paper and flour targets in the container (tagged neutron beam traversed from right to left).

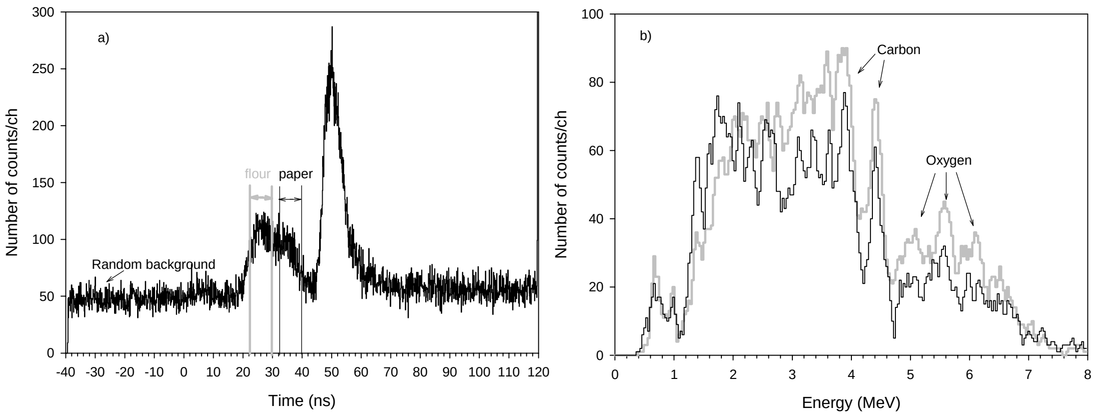

FIG. 5. The time spectrum (left) and the gamma ray spectra (right) of the flour (gray) and the paper (black). Elapsed time was 27 493 s and the total number of detected alpha particles was 146 x 10^7.

But the paper behind the flour (dense organic matrix) is misinterpreted as explosive (falls alarm). Even in that case, it was possible to avoid the false alarm if we take into account that for dense organic matrix explosive semtex1a would be expected deep down in the flour region or even below. Appropriate knowledge about the target surroundings is necessary for true decision.

3. Conclusions

To minimize the false alarm rate and to maximize the possibility to detect contraband in sea-going cargo containers it is necessary to measure the chemical composition of a particular part of container which was previously found to be suspicious. But even in that case, there are different kind of benign organic goods which could be misinterpreted as contraband because of the similarity in chemical composition and the limits in TNIS capability. It was shown that density could be used as another parameter which could help solve this problem in some cases. It is important to know that the according to [7], the mean cargo density is under 0.2 g/cm^3 and 98% of estimated are <0.6 g/cm^3. This data is supported by the cargo manifest analyses of the sea-going cargo containers passing the port of Rijeka [8].

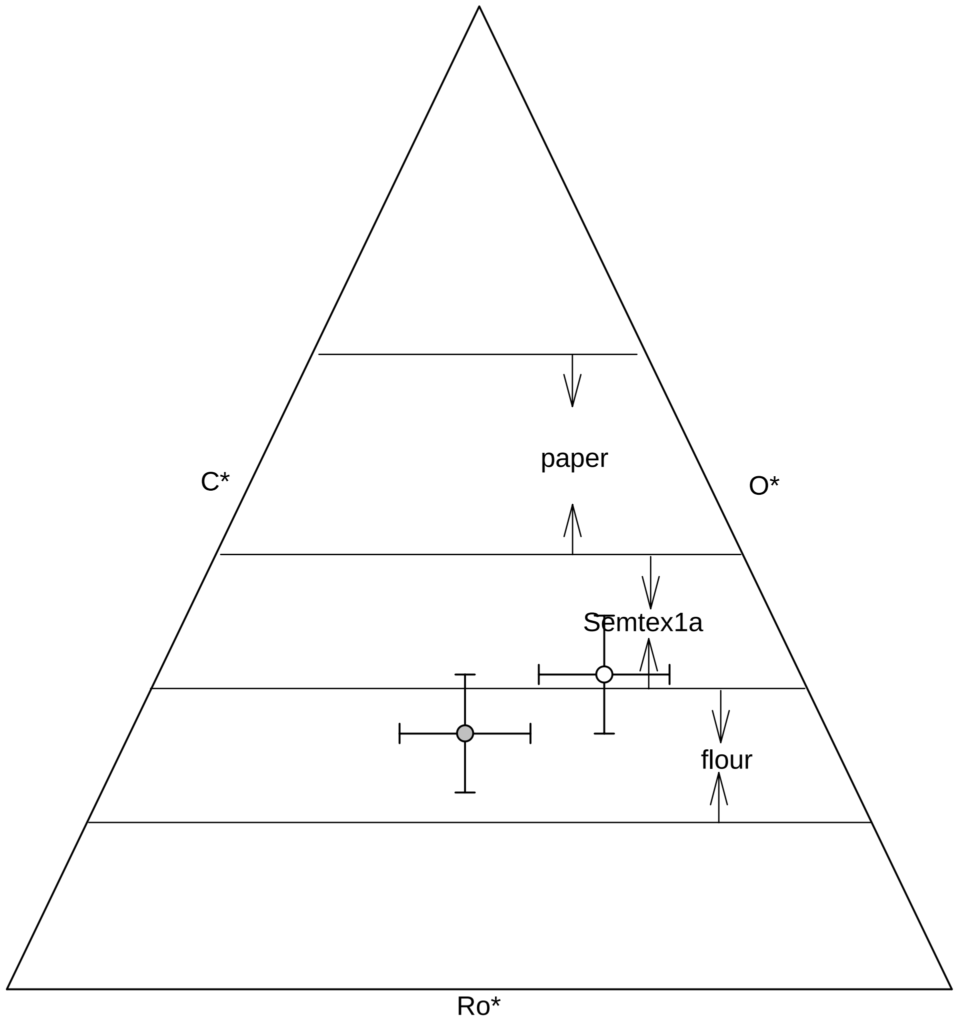

FIG. 6. Triangle diagram, flour (gray) and paper (white, paper misinterpreted as explosive).

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