FAST NEUTRON AND GAMMA-RAY TRANSMISSION IN MIXED SAMPLES. MCNP CALCULATIONS

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ABSTRACT

In this paper the moisture in sand and also the sulfur content in toluene have been described by using the simultaneous fast neutron/gamma transmission technique (FNGT). Monte Carlo calculations show that it is possible to apply this technique with accelerator-based and isotopic neutron sources in the on-line analysis to perform the product quality control, specifically in the building materials industry and the petroleum one. It has been used particles from a 14MeV neutron generator and also from an Am-Be neutron source. The estimation of optimal system parameters like the efficiency, detection time, hazards and costs were performed in order to compare both neutron sources.

INTRODUCTION

The simultaneous transmission and detection of neutrons and gamma rays (FNGT) is a non-invasive method wich is insensitive to temperature, thickness or component distributions [1]. This technique have been used mainly for the determination of moisture in different materials [2,3] due to the transmission of fast neutrons depends predominantly on H concentration and mass per unit area, where as gamma-ray transmission depends only on mass per unit area.
In most cases FNGT is carried out using small radiation sources mainly Cf252, Am-Be and Pu-Be [2,3,4]. Our main goal in this work is to show the possibility of using a 14MeV neutron generator as a combined neutron-gamma beam to perform Neugat experiments in order to determine the water content in certain materials of interest and also the quantity of sulfur in petroleum.
The geometry used in this work is very simple, it consists on a narrow neutron and gamma beam crossing the material of interest. For this geometry and considering the material a mixed of two components, the n-gamma transmission can be describe as follows:

$$\ln \frac{In}{Ino} = -(\mu na \cdot ma + \mu nb \cdot mb)$$
$$\ln \frac{I\gamma}{I\gamma o} = -(\mu\gamma a \cdot ma + \mu\gamma b \cdot mb) \qquad (1)$$

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where µna, µnb , µγa and µγb are respectively the apparent neutron mass attenuation coefficients and mass attenuation coefficient for γ of the materials a and b. In/Ino and Iγ/Iγo are the calculated quantities (n-γ beam attenuation) and ma , mb are the masses per unit area.
By solving the equation above in order to determine:

$$Cb = \frac{100\ mb}{mb + ma} \tag{2}$$

we obtain:

$$Cb = \frac{\mu\gamma aR - \mu na}{(\mu nb - \mu na) - R(\mu\gamma b - \mu\gamma a)} \tag{3}$$

where

$$R = \frac{\ln(In/Ino)}{\ln(I\gamma/I\gamma o)} \tag{4}$$

Calculations were made using the MCNP-4b [5] code in a 450 MHz Pentium PC.
It was assumed that the gamma component from the generator has an average energy of 0.5MeV [6] and for Am-Be it is a more complex spectrum [7] and it was measured in our laboratory with a NaI(Tl) scintillation detector for getting the MCNP input data for such distribution.

DETERMINATION OF HUMIDITY IN BUILDING MATERIALS

Quality control in building materials production in the case of several products is closely related to the water content determination in such mixtures [8,9,10].
The material use for calculations is SiO_2 due to sand it is an obligated component in building materials and it is also available with facility and easy to handle for experiments.
Linear attenuation coefficients for both water and sand were calculated. The obtained results are shown in the following graphics.

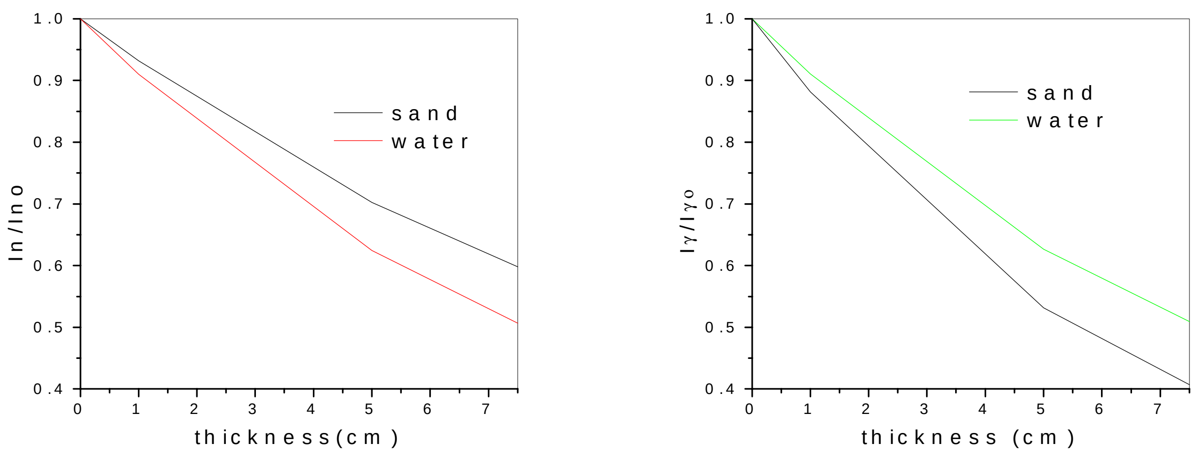

Fig.1 Attenuation of neutrons (a) and gammas (b) from the neutron generator in water and sand.

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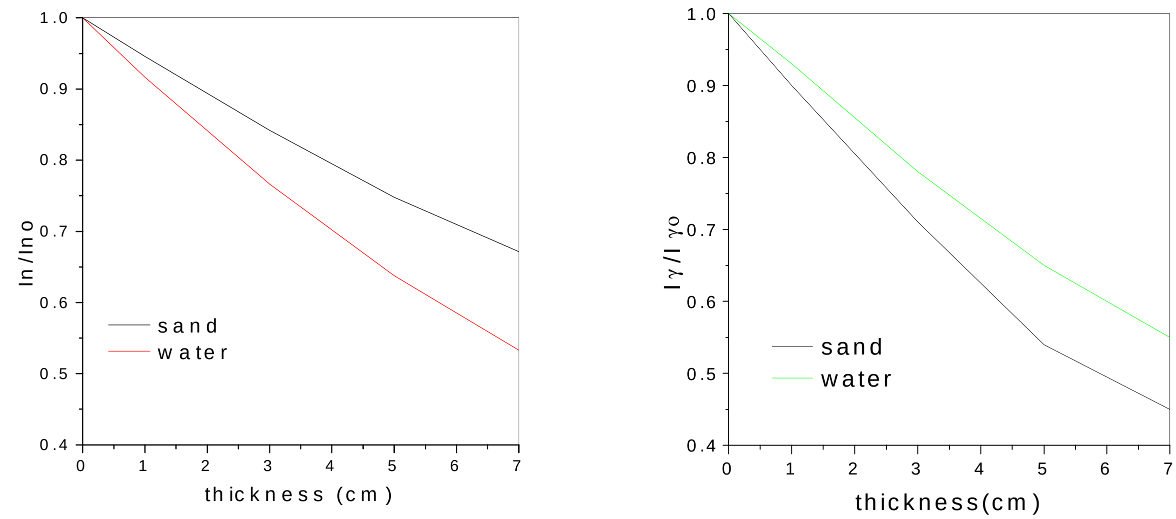

Fig.2 Attenuation of neutrons (a) and gammas (b) from an Am-Be neutron source in water and sand.

The following graphics show the neutron and gramma-ray attenuation in sand with different water quantities for both neutrons sources.

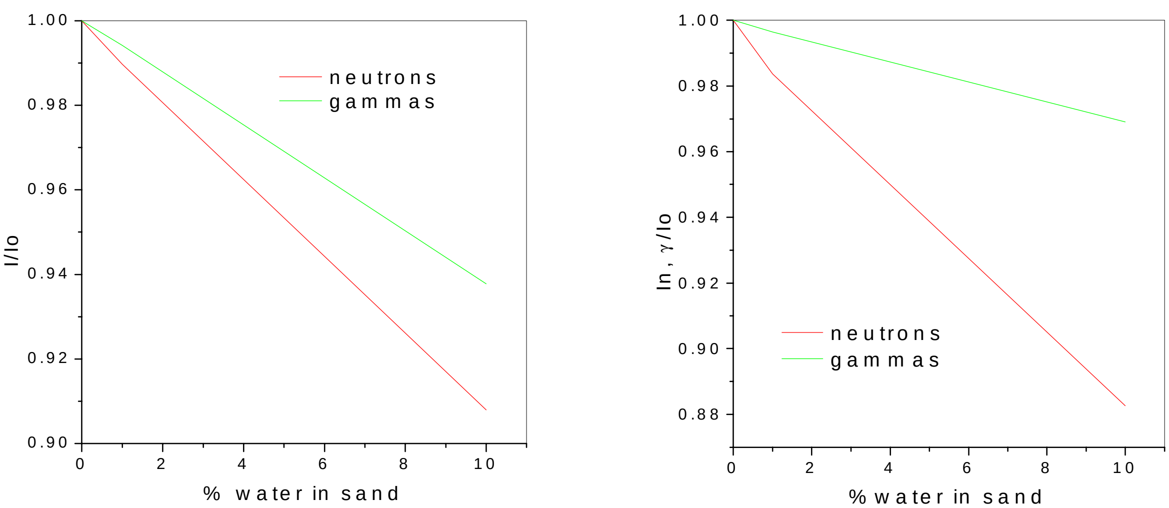

Fig.3 Radiation transmission in a mixture of sand and water for a) 14Mev, b) Am-Be source.

Results show that this method is sensitive for both Am-Be and d+t sources even neutrons are more attenuated by using the firts one due to there are a slow component and the captures in H are increased. There is another advantage of using this particular source: its cost. Nevertheless we have to take in to account the time of measuremente for detecting water on-line is shorter by using the neutron generator due to the flux is larger and also it is more secure due to man can turn it on and off as necessary wich is not possible by using isotopic neutron sources.

DETERMINATION OF SULPHUR IN HYDROCARBURES

The Cuban crude, in the majority of deposits, has a large (until 7%) sulphur content [8,11]. Its efficient combustion on energy plants demands a good knowledge of its composition. This analysis is also important for on-line monitoring of sulphur content on derivative obtaining from national crude.

Even the well knowledge difference in the behaviour of neutrons and gammas mentioned before for the determination of the H content in mixtures is not present in this case, we decided to prove the applicability of the FNGT method to control on-line the sulphur content on hydrocarbon fluids. In this particular, toluene was used as the hydrocarbon matrix.

There were calculated the gamma and neutron attenuation coefficients for toluene and sulphur. Differences in the radiation attenuation in such materials leads to deduce that it is possible to detect small quantities of sulphur in such matrix.

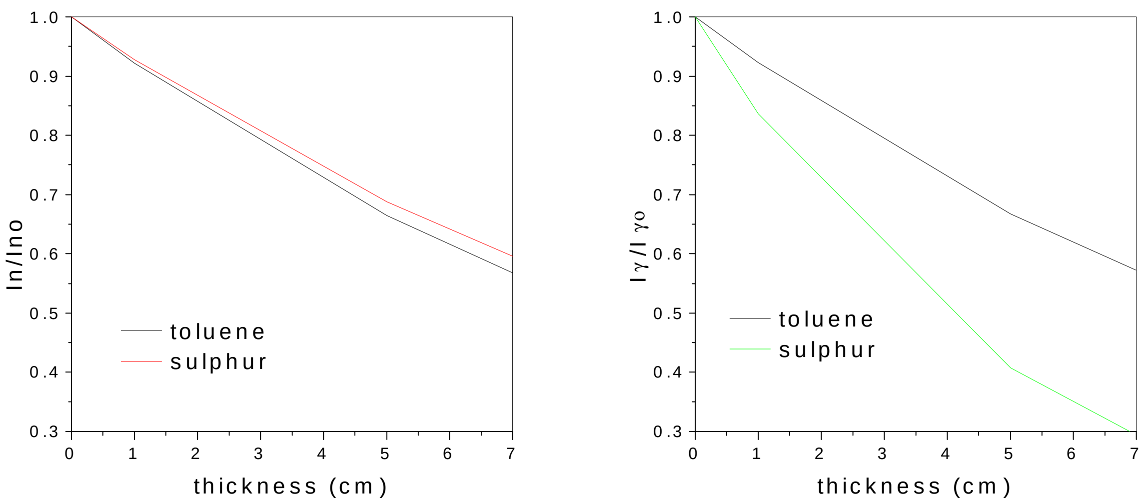

Fig. 4. Attenuation of neutrons (a) and gammas (b) from the neutron generator in toluene and sulphur.

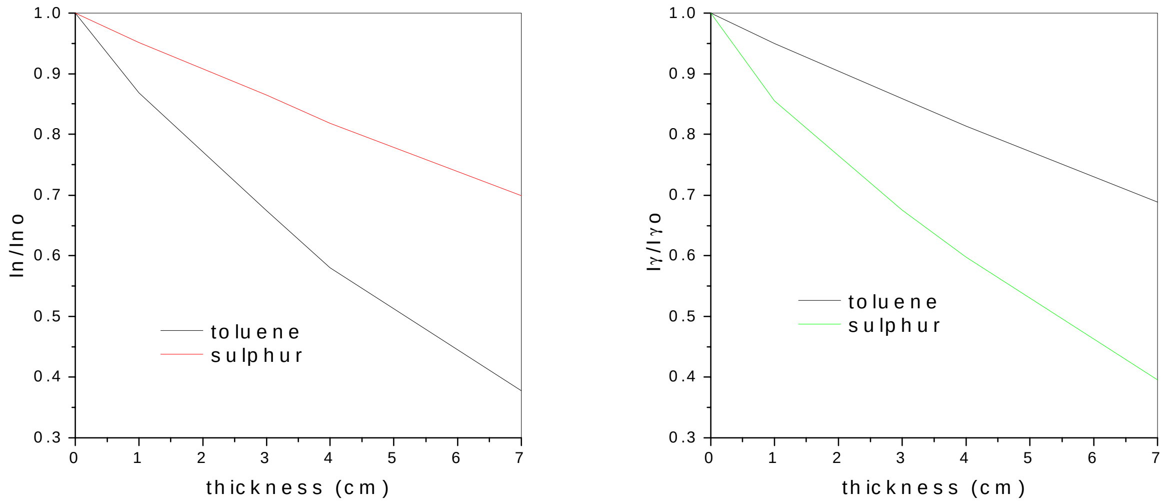

Fig.5. Attenuation of neutrons (a) and gammas (b) from an Am-Be neutron source in toluene and sulphur.

It was simulated the dependence of such attenuation in toluene by adding different quantities of sulphur. Graphics 6 a) and 6 b) show how the response of neutrons and gammas change by crossing samples of toluene containing different sulphur content for the 14 MeV neutron generator and for the Am-Be neutron source.

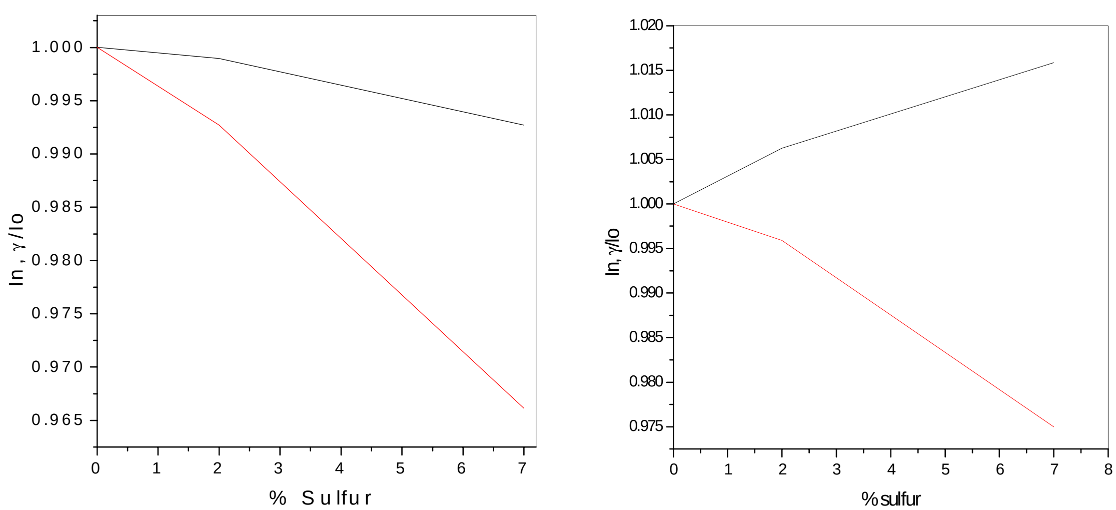

Fig.6 Radiation transmission in a mixture of toluene and sulfur for a) 14 MeV neutron generator, b) Am-Be source.

In the case of Am-Be a different behavior is obtained concerning neutrons; there is not an attenuation but an increment, due to the source is surrounded by the moderator. Therefore, contribution of captures in the H of toluene is notable.

It was also demonstrated that it is possible to calculate sulphur quantity by substituting the mass attenuation coefficients and the R factor (obtained from the simultaneous attenuation) in the equation (3).

RESULTS`

The results obtained above show that it is possible the application of the fast neutron and gamma ray transmission method to the determination of specific materials in compounded samples besides the water content. In this particular the evaluation of the quantity of sulphur in toluene was studied.
There were calculated the gamma and neutron attenuation coefficients for water, sand, toluene and sulphur when gamma and neutron radiation from an Am-Be and a D-T generator source crossing such materials.
It was simulated the FNGT technique for determination of the water content in a no-hydrogenated matrix by using two different sources (Am-Be and neutron generator). Even changes in the moisture of samples generate a better response if Am-Be is used; it is necessary shorter time for the measurement by using a neutron generator, which is so important in the on-line determination.
It was also demonstrated the applicability of this technique for the determination of sulphur in hydrocarbons. In this case, it is predominate the attenuation of gamma radiation due to the element to be determined its heavier than the matrix.
It is important to make note that it is possible to extend this method for determining the concentration of light elements in a heaviest matrix and also to know the content of heavy elements in lower atomic matrix. Potentially the method could be applicable for any mix if preliminary calculation of absorption coefficients for the component elements in the sample point out this possibility.

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