# An Applied Study of the Effect of Decay of Fast Neutron in Concrete

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**Abstract**
In this paper, we conducted an applied study of an equation we had previously concluded [3], to investigate the possibility of neglecting the effect of neutron non-decay, on the flux of neutron beams transient through a large-thickness concrete sample, showing that, the probability of non-decay of neutron beam flux can't be neglected for fast energies. This study has been used in order to benefit from a more precise designation of concrete thickness, that can be used in nuclear installations. By finding the assigning error in determination the macroscopic capture cross-section for the studied sample, at neglecting the effect of non-decay of neutron.
**Keywords:** fast neutron, decay neutron, macroscopic capture cross-section.

## 1. Introduction

The prevention of neutron and the search for neutron appropriate shielding, have many complexities, because of the wide range of neutron energy that must be taken into account, when solving these problems. The principles claimed to determine the materials used in neutron shielding differ completely from those used in gamma rays, because the gamma cross sections is very much affected by the gammas energy and the atomic number. But neutron energy can change irregularly from one element to another, depending on the complex response structure, which related by neutron energy [1]. The cement is most important shielding material in a concrete. It is mainly made up from $Ca_3SiO_5$, $Ca_2SiO_4$, $Ca_3Al_2O_6$, $Ca_4Al_2Fe_2O_{10}$, and plaster [2].

The effect of the probability of non-decay of neutron on flux of the neutron beam can't be negligible for fast energies. It is useful to determining more accurately the elements in certain rocks, and thus determine the economic investment in extracting these elements, and determine the best rock type in the cement industry. This study has been used to make use of a more precise designation of concrete thickness, that can be used in nuclear installations. By finding the error in assigning the macroscopic capture cross-section for the studied sample [3].

## 2. Calculating the assigning error

The basic equation of the flux of a transient neutron beam directly through a sample, in which only the capture reaction is taken into account, is given [3]:

$$\Phi(x) = \Phi(0)e^{-n\sigma_c x} \tag{1}$$

Where $e^{-n\sigma_c x}$ is the probability that there will be non-capture reaction when the neutron passed a distance $x$ in the sample and exits directly ($x$ is thickness of sample), and symbolizes it $P_{r'}(x)$, $n$ is the concentration of nuclei in the sample, and $\sigma_c$ is the microscopic capture cross section.

$$P_{r'}(x) = e^{-n\sigma_c x} \tag{2}$$

In a previous study [3], we concluded that, the probability of non-decay of neutron when it was directly passed a distance $x$ is:

$$P_{d'}(x) = e^{-\frac{\lambda}{v}x} \tag{3}$$

Where $\lambda$ is the constant decay of free neutron, and $v$ is the primary velocity of neutron. By taking the decay effect into account, the flux of the directly neutron beam through a sample of thickness $x$ becomes:

$$\Phi(x) = \Phi(0)e^{-\left(\frac{\lambda}{v}+n\sigma_c\right)x} \tag{4}$$

The error in determining $\sum_c = n\sigma_c$ , that results of neglecting of decay, is:

$$\Delta\sum_c = \frac{\lambda}{v} \tag{5}$$

## 3. Results and Discussion

1. Let's applied Eq.(2) and (3) for cylindrical sample of thickness $x$ and radius $r$, made of natural concrete mixture containing rough gravel, yellow sand, white sculptor, Portland cement and water, irradiated with a neutron beam from a source $Am - Be$ with energy $(1 - 10)$ MeV [4].

By calculate the effect of the propriety non-decay of neutron on one of the sample isotopes, for example calcium $^{40}Ca_{20}$, for different thicknesses of the sample and in the fast energy (10 MeV), is:

**Table 1: Probability $P_{r'}(x)$, $P_{d'}(x)$ and ratio $P_{d'}(x)/P_{r'}(x)$, for different thicknesses of a sample in the fast energy (10 MeV).**

| $x(m)$ | $P_{r'}(x)(m^{-1})$ | $P_{d'}(x)(s^{-1})$ | $P_{d'}(x)/P_{r'}(x)(m/s)$ |
|---|---|---|---|
| **0.5** | 0.999663 | 0.996135 | 0.996471 |
| **1** | 0.999326 | 0.992285 | 0.992954 |
| **3** | 0.997979 | 0.977033 | 0.979011 |
| **5** | 0.996634 | 0.962015 | 0.965264 |
| **10** | 0.99328 | 0.925473 | 0.931735 |
| **15** | 0.989937 | 0.890319 | 0.89937 |
| **20** | 0.986605 | 0.856501 | 0.868129 |

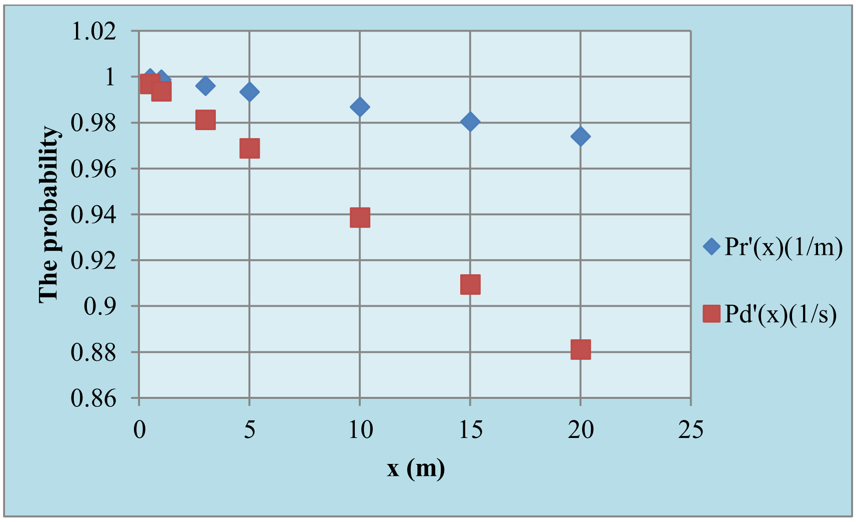


**Figure (1): Probability $P_{r'}(x)$ and $P_{d'}(x)$ as a functions of sample thickness for energy 10 MeV.**

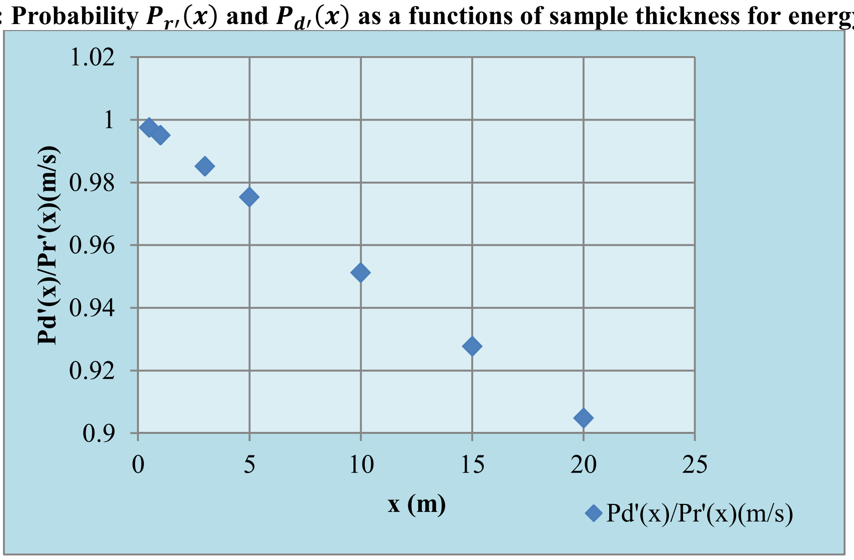


**Figure (2): The rate $P_{d'}(x)/P_{r'}(x)$ as a function of sample thickness for energy 10 MeV.**

Figures (1)and (2) show that, the probability of non-decay, here, is smaller than the probability of non-reaction, and $P_{d'}(x)/P_{r'}(x)$ changes comparative with $P_{d'}(x)$, for different thicknesses of the sample.

The decay constant value of the free neutron is $\lambda = 11.3 \times 10^{-4}\ s^{-1}$ [5].

2.Let's applied Eq. (5) to a cubic sample, described in Table (2) [4].

Table 3 shows the error in the calculation for the neutron energy, for $(Am - Be)$, source, which gives energies ranging from $(1 - 10)$ MeV.

**Table 2: Results of attenuation of a cubic concrete sample of neutron from the $(Am - Be)$ source.**

| Mean reading of the dose from the neutron source $\overline{D_0} = 151.5\ \mu.Sv/hr$ | |
|---|---|
| **Mean $\bar{D}$** | 63.444 |
| **Attenuation (%)** | 58.122 |
| $\sum_c (cm^{-1})$ | 0.087 |
| **Percentage relative error (%)** | 8.4584 |
| **dimensions of sample** | $(10 \times 10 \times 10)cm$ |
| **Weight $(g)$** | 2065 |
| **Density $(g/cm^3)$** | 2.065 |

**Table 3: Calculated error due to negligence the free neutron decay for energy $(Am - Be)$source.**

| $E_n$(MeV) | $\Delta\sum_c = \frac{\lambda}{v}(cm^{-1})$ | $E_n$(MeV) | $\Delta\sum_c = \frac{\lambda}{v}(cm^{-1})$ |
|---|---|---|---|
| **1** | 2.45E-04 | **6** | 1.00E-04 |
| **2** | 1.73E-04 | **7** | 9.26E-05 |
| **3** | 1.41E-04 | **8** | 8.66E-05 |
| **4** | 1.22E-04 | **9** | 8.16E-05 |
| **5** | 1.10E-04 | **10** | 7.74E-05 |

Figure (3) shows that, the error of neglecting $\Delta\sum_c$ decreases with increasing the source energy.

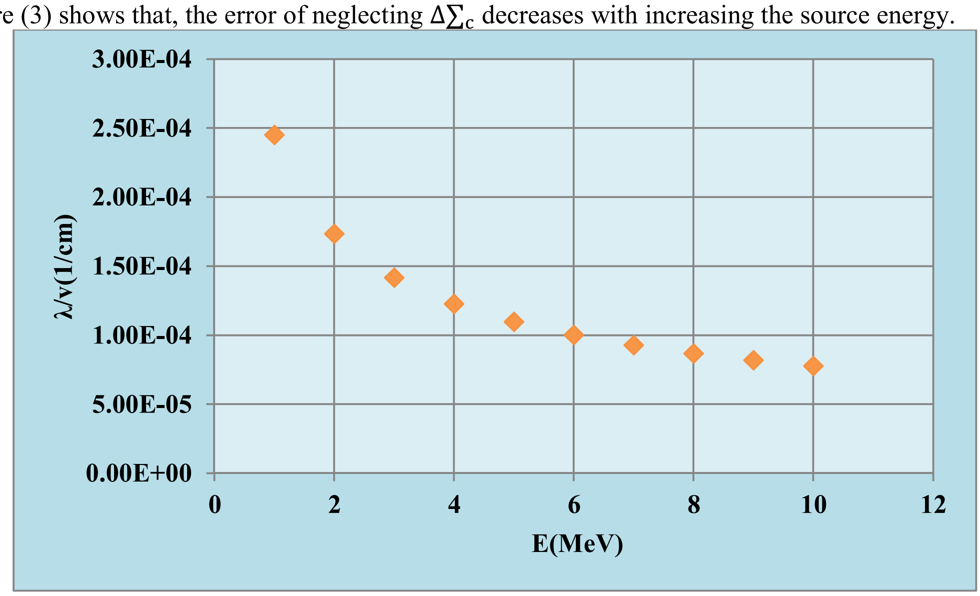


**Figure (3): Neglecting error $\Delta\sum_c$ as a function of neutron energy.**

The percentage relative error calculated at the neglecting for the energy of neutron 5 MeV (the mean energy given by the source) is 0.126%. Neglecting this value from the percentage relative error value in Table 2, will increase the accuracy of the calculations.

## 4. Conclusions and Recommendations

The effect of the probability of non-decay of neutron on the flux of the neutron beam can't be negligible for fast energies. By taking this effect into account, it has become possible to specify more accurately the thickness of concrete, which ensures the safety of workers in such facilities from being exposed to neutron, and the more accurate of the concrete assumed lifetime. We recommend a theoretical study taking into account the effect of scattering probability on the neutron beam flux.

## Reference

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