# Photopeak efficiency response function of an underwater gamma-ray NaI(Tl) detector using MCNP-X code

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This work presents a study which aims to calculate the response function of a 1 ¾” x ¼” NaI(Tl) scintillation detector when used in the marine environment. The method takes into account both the scattering of photons in the water and the detection mechanism. The calculation of the response function of the whole system is essential for suppressing the background of the measurement and for estimating the concentration of the involved radionuclides, especially if the great probability of having primary gamma photons undergoing multiple scattering events before they interact with the detector is considered. The experimental photopeak efficiency (PE) measurements for point sources were compared with the simulated results under the same conditions of the experimental setup to validate the simulation of the detector [1]. The MCNP-X code was used for the investigation of gamma-ray absorption in water in different brines. The PE of a NaI(Tl) detector for different radionuclides in the aquatic environment with different brine was calculated. Measurements using energy gamma-ray attenuation show elevated sensitivity to the salinity of water components, mainly at low energy due to the high atomic number of chlorine atoms, which modify the photoelectric absorption. The proposed geometry uses the transmitted beam registered in detector, positioned at 180º diametrically opposed to the source and beam measurement from gamma-ray source with an isotropic beam positioned at 50 cm of detector. The detector has been positioned in a water tank of 1.0 m$^3$ volume, with different brine to investigate the high attenuation of the gamma-rays in water. The measurements reveal different responses from the interaction mechanisms of the radiation and the flowing medium. The spectra calculated water mixed with salt in four different values of the salinity index (0%, 4%, 8% and 16%), as shown in Fig. 1. At 600 keV the PE is decreased by 14.5% when the material around the source and detector is altered from the pure water (without salt) to brine 16%, considering a material layer of 50 cm. It is essential to consider the effect of water and the amount of salt present, as these factors strongly influence the determination of the counting efficiency and obviously the calculation of the activity. The relative errors are shown in Table 1.

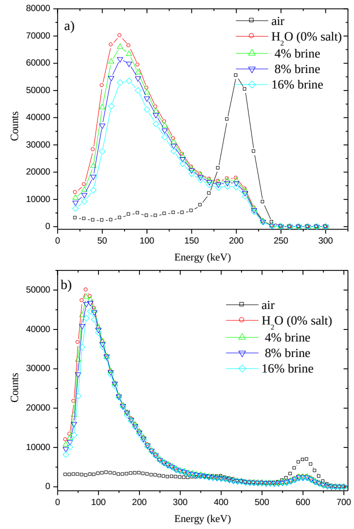


Figure 1. Spectra recorded at different salinities and materials: a) 200 keV; b) 600keV.

Table 1. Relative Error.

| Energy (keV) | Relative Error (%) | | |
|---|---|---|---|
| | gas/water | gas/brine 16% | water/brine 16% |
| 200 | 74.3 | 79.5 | 20.3 |
| 400 | 68.9 | 74.2 | 17.0 |
| 600 | 63.8 | 69.0 | 14.5 |
| 800 | 59.3 | 64.8 | 13.5 |

The PE at 600 keV is decreased by 63.8% when the material around the source and detector is altered from gas to pure water (0% salinity), considered a material layer of 50 cm. The detector’s response shows a non-linear drift in the produced spectra, changing the exact position and the efficiency values. This may probably be caused by the scattering of low energy gamma-rays on water, decreasing the number of photoelectric events while the Compton scattering increases.

## References

[1] SALGADO, C. M. et al. Validation of a NaI(Tl) detector’s model developed with MCNP-X code, **Progress in Nuclear Energy**, Oxford, v . 59, p. 19-25, 2012.