Erasmus Mundus Program

Activity Report

24/07/2019

Title: Environmental Measurements with the iSpector

Abstract:

In this report the radioactivity measurement of samples usually found in the environment was studied, using iSpector Digital (Intelligent Silicon Photomultiplier Tube with Digital MCA). After the energy calibration of the system based on LYSO crystal and the calibration verification and tuning with Potassium Chloride sample, the data analysis of the Pozzolana Sample Spectrum as well as the Background measurement was done. Furthermore, the test sample radiation was identified.

Purpose of the experiment:

The purpose of the experiment was to get acquainted with the presence of radioactivity coming from the environment, using the intelligent Silicon Photomultiplier Tube with Digital MCA. Natural Radioisotopes are usually gamma emitters and thus, the gamma energy spectrum was created. Gamma rays interact with matter by 3 processes: Compton Scattering, Photoelectric Effect and Pair Production. These processes convert totally or partially, the gamma ray energy into kinetic energy of electrons (or positrons, in the case of pair production). The interaction of the charged particles with the atomic and molecular systems of the medium results in excited states whose decay, possibly mediated, leads to light in the visible or UV region, eventually detected by the light sensor. More details about the scintillator used will be given in the material section of the report.

Following the energy calibration of the system the Pozzolana Sample Spectrum was acquired and analyzed. Pozzolana is abundant in certain locations and is extensively used as an addition to Portland cement in countries such as Italy, Germany, Kenya, Turkey, China and Greece. Compared to industrial by-product pozzolans they are characterized by larger ranges in composition and a larger variability in physical properties. Finally, the energy spectrum of an unknown "test" sample was obtained, and the radiation sources were identified as it can be seen in the data analysis section of the report.

Materials:

For this work we used the i-Spector Digital, which is an environmental measurement kit based on Silicon Photomultiplier detectors (SiPM). This kit integrates a CsI(Tl) scintillator crystal, a SiPM and a digital multichannel analyser (MCA).The CsI(Tl) crystal has a high light output, most of its emission is in the long wavelength part of the spectrum (>500nm), has very good stopping power, is slightly hygroscopic and with good plastic mechanical properties. The SiPM consists of a high-density matrix of Avalanche Photodiodes (APDs) operated in a limited Geiger-Muller regime and connected in parallel on a common Si substrate. The radiation detection process is the following: the gamma rays go inside the crystal and interact with it (by the proceses explained before) producing light. The photosensors of the SiPM detect and transform this light into an electrical signal, which is proportional to the energy released inside the crystal by the interacting particle, or in this case, photon. Then, this signal is analyzed by the electronics of the kit and a spectrum of energy is formed with the MCA. The samples measured in this work were a LYSO Crystal, 140.43 g of Potassium Chloride (KCl), 160.47 g of Pozzolana rock and an unkown test sample. The LYSO (Lutetium-yttrium oxyorthosilicate) is a scintillator crystal used in PET applications and to build screens and electromagnetic calorimeters in particle physics due to its advantages in radiation detection (high light output and density, quick decay time, excellent energy resolution), however, in this work it will be used as a calibration source since 2.6% of the natural Lu is ^{176}Lu , a radioisototope with a long half life ($3.6 \cdot 10^{10}$ y) decaying by two different beta decays followed by gamma emissions with the respective energies: 307 and 202 keV. The KCl has natural potassium and 0.012% of it is ^{40}K, a radioactive isotope which has a long half-life of 1.251×10^{9} y and decays by both β+ and β-, so in the gamma spectrum we will see the gamma photon of the emitted β+ annihilation with an electron (511 keV). The pozzolana contains radioisotopes from the decay chain of natural uranium and thorium, such as the ones shown in Table 1.

Table 1: Radioisotopes found in Pozzolana by gamma spectroscopy.

Chain	Radioisotope	Gamma Energy (keV)	Intensity
Th-232	Bi-212	727.3	6.65%
	Tl-208	510.77	22.6%
		583.2	84.5%
U-238	Pb-214	295.2	19.2%
		351.9	37.1%
	Bi-214	609.3	46.1%
		1120.3	15.0%
		1764.5	15.9%

Measurements:

We did an energy calibration of the system by acquiring the spectrum of the LYSO crystal for 10 minutes and inserting the corresponding energy of the peaks in the software. Then, we verified and tuned the calibration by measuring the Potassium Chloride sample for 30 minutes. We also acquired a background measurement for 30 minutes in order to neglect the background environmental radioisotopes from the samples of interest. Finally, we measured for 30 minutes the Pozzolana and the test sample and performed the radiation identification.

Data Analysis:

Firstly, we made the energy calibration of the detector using a LYSO scintillator. Due to this material has ^{176}Lu, which has a gamma decay, we observed two peaks at 307 and 202 keV. These peaks were used for the calibration of the detector as it can be observed in *Figure 1*:

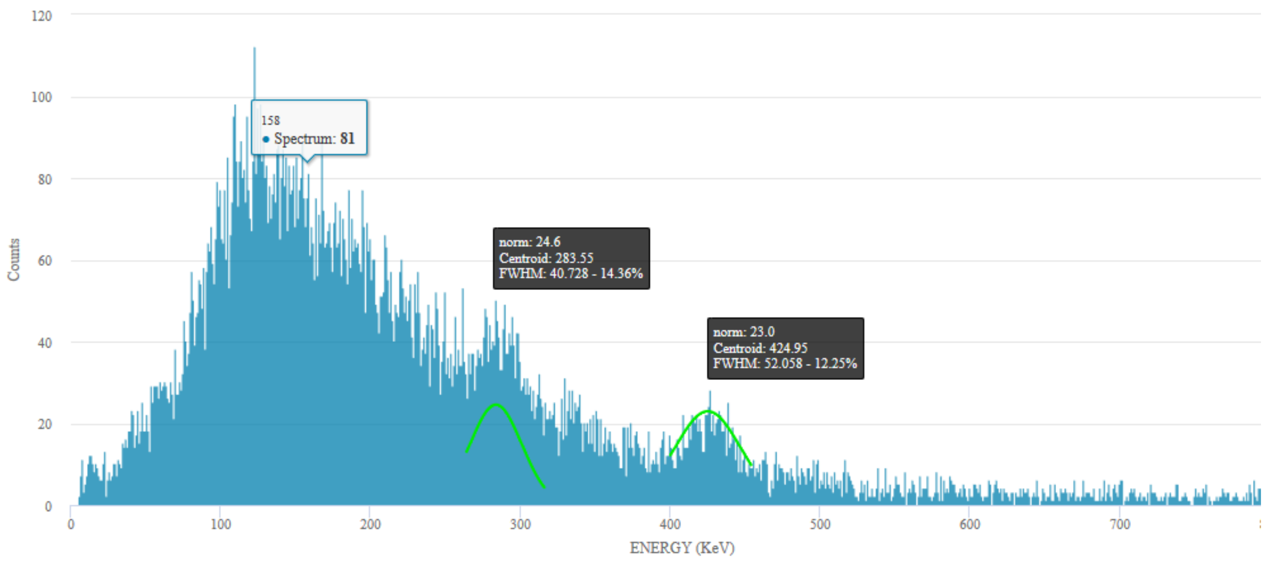

Figure 1: Calibration using LYSO

In the second task of the experiment, we measured the background during 30 minutes (*Figure 2*). Then, we measured spectrum of a KCl source during 30 minutes too (*Figure 3*). The reason why we measured the same time in both cases is to be able to substract the background from the KCl data.

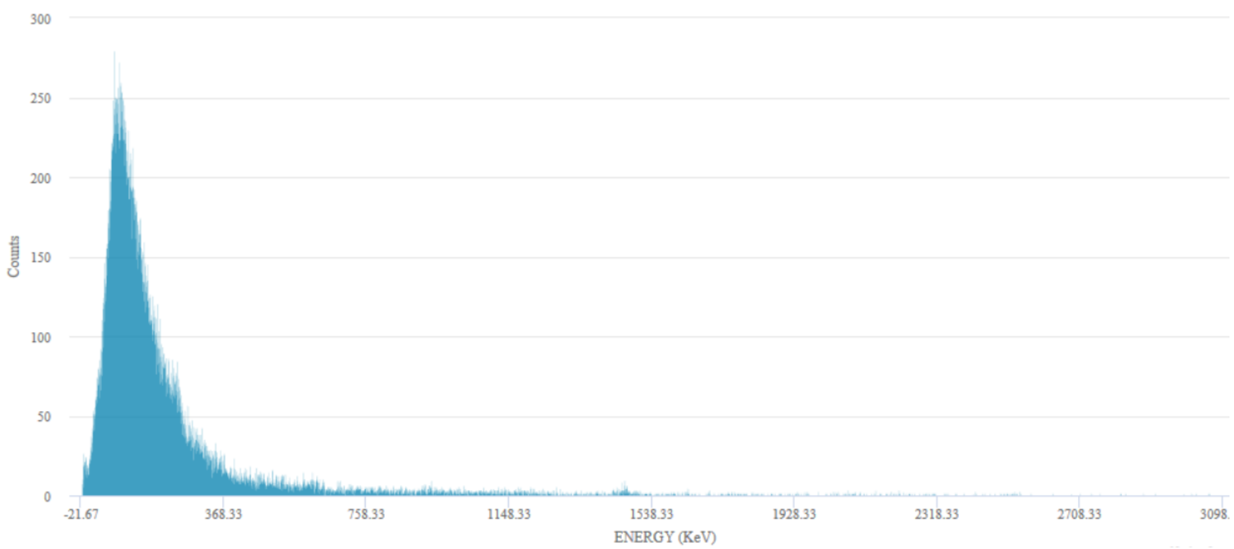

Figure 2: Background Measurement

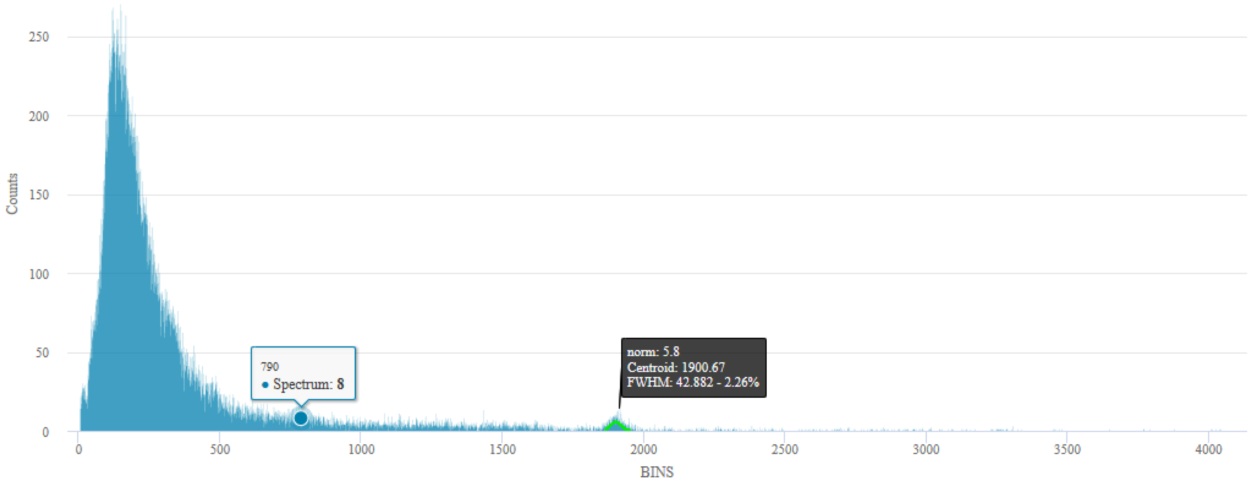

Figure 3: Background Measurement

Due to an error during the saving of the *Figure 3*, the spectrum axis is in number of channels instead of energy. But we observed that a peak appeared in the KCl spectrum. It was proven that this peak was around 511 keV, as we expected, so our calibration was certificated and wen used this peak to improve the calibration line.

The next step of the experiment was to study the spectrum of the Pozzolana. This spectrum is shown in the *Figure 4*:

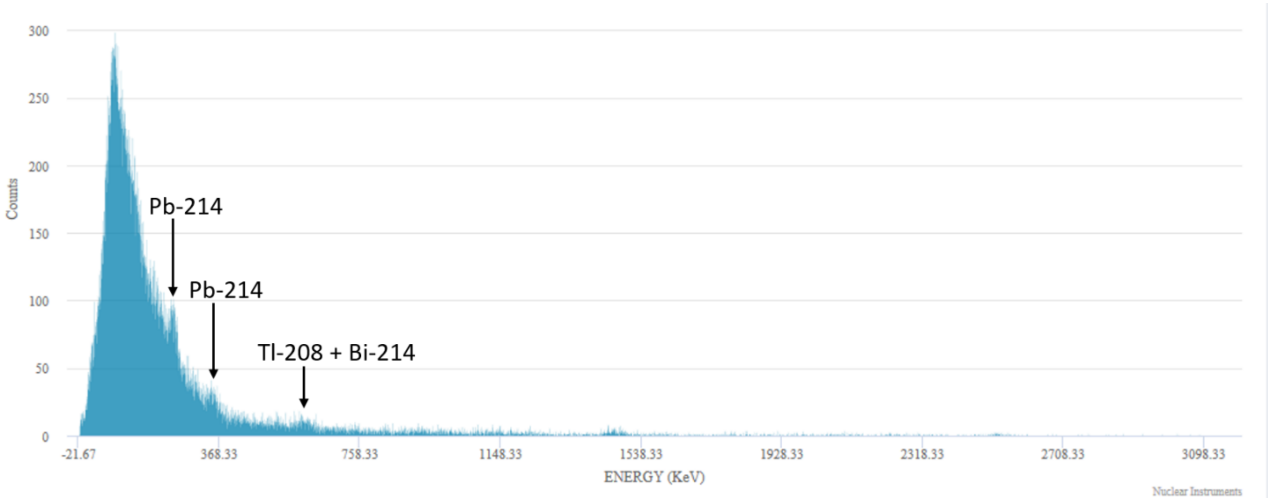

Figure 4: Pozzolana Sample Identification

We observed different peaks which come from radioistopes of the ^{238}U and ^{232}Th chains as it can be observed in the *Table 1*.

Finally, we measured the spectrum of a test sample in order to identificate it:

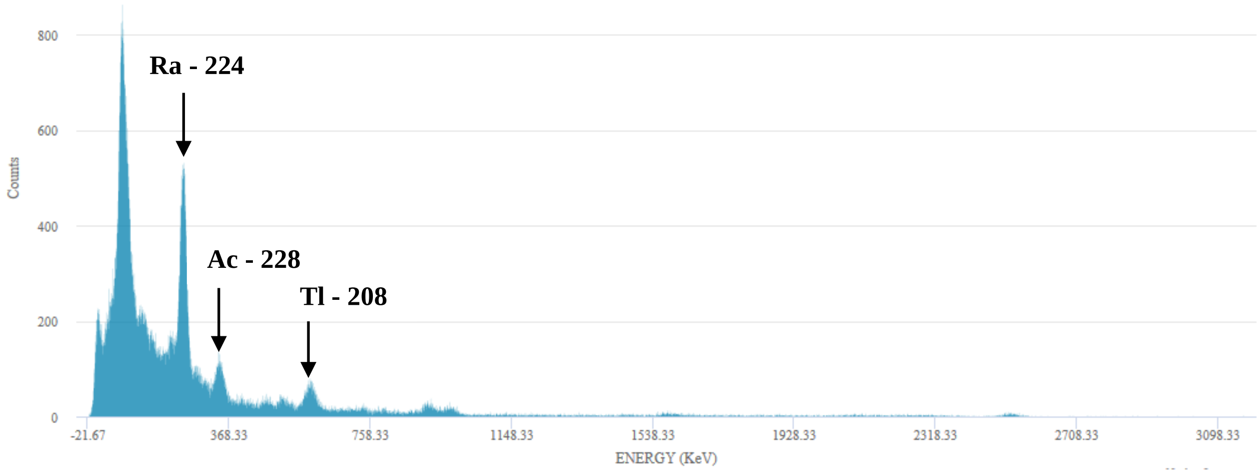

Figure 5: Test Sample Identification

In the ^{232}Th chain, we can observe ^{228}Ac (338 keV), ^{224}Ra (241 keV) and ^{208}Tl (583 keV). This is the reason why we think that the test sample is ^{232}Tl.

Results & Conclusion:

In the first part of the experiment, the calibration of the detector was made using a LYSO scintillator and the decay peaks of the ^{176}Lu. Then, the calibration was tested and improved with the gamma peak of the ^{40}K using a KCl crystal. Finally, we measured the spectrum of a Pozzolana sample and a test sample and some of the observed peaks were identified. In conclusion, during this experiment the measurement and identification of different spectrums were performed successfully.

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