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ENVIRONMENTAL LOW ENERGY GAMMARAY SPECTRUM IN SÃO JOSÉ DOS CAMPOS, BRAZIL REGION

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ABSTRACT

The city of São Jose dos Campos is in the state of São Paulo in Brazil. It is a region where are the main industries in Brazil. The Technological Institute of Aeronautics - ITA promotes quality higher education teaching and research especially in aeronautics and space science. Given this relevance, in 2011 to 2019 measurements were made of the low energy gamma ray environmental spectra (0.2 - 10.0) MeV in this region. The main factor influencing this spectrum was local rainfall. Through the increase of radon gas in the intense rainfall that occurred at the site, the increase of gamma radiation in this time interval is detected. Also cold-front passages from the Antarctic and Andean mountain regions have shown variations in the low-energy gamma radiation intensities in the region. Other influences become less important.

Keywords*: spectrum gamma radiation, rainfall, radon gas.*

I. INTRODUCTION

At the (soil/air) interface of the Earth's surface, ionizing radiation is mainly composed of radon gas, ground telluric radiation, primary and secondary cosmic rayradiation. However, it is difficult to separate over time the intensity of ionizing radiation emanating from each component as the energies overlap. Telluric radiation is given by ^{238}**U**, ^{235}**U**, ^{40}**K** and ^{232}**Th** that is constant for each region [1]. Radon gas from the disintegration of ^{238}**U** on the earth's crust to ^{226}**Ra** and ^{222}**Rn** arrives in the ^{214}**Pb**, ^{214}**Po** and ^{214}**Bi** isotopes, generating alpha and gamma radiation [2]. Primary cosmic radiation consists mainly of galactic and extragalactic protons and those from the Sun, with very high energy that interacts with the Earth's atmosphere producing Extensive Air Showers (EAS) [3]. The efficiency of this interaction is maximum when it occurs at altitudes between 13 and 17 km in the tropics, which form secondary cosmic rays with muonic, mesonic and neutronic components that reach the Earth's surface in the region [4]. These radiations cause health problems for civil aviation crew and passengers and are present at the beginning of the stratosphere called the Pfotzer maximum. However, this component contributes less to the concentration of radiation on the earth's surface. Another possible source of ionizing radiation in the Earth's lower atmosphere is produced by lightning strikes between earth-clouds, clouds-earth and clouds-clouds. X-rays, gamma rays, neutrons and beta particles are formed by the lightning cone [5]. Other sources of ionizing radiation are those produced in medical, dental and hospital clinics, but these are mainly controlled in small areas. The objective of this work was to monitor low energy gamma rays and rainfall every minute in São Jose dos Campos, São Paulo, Brazil.

II. METHODOLOGY

The gamma ray detector for the 200 keV to 10.0 MeV energy range consists of a3 inch high by 3 inch diameter thallium doped scintillation crystal. This crystal is directly coupled to a photomultiplier (PM) that records the pulses coming from the amplified scintillator and a digital analog converter with signals recorded by a computer [6]. This experimental set (Figure 1) is located in the inner room ofa tower 25 m high relative to the ground (ACA Tower). The scintillator attached to the photomultiplier is wrapped in a thin layer of aluminum to make it portable. The set (scintillator + associated electronics + data acquisition) relies only on laptop with a charged battery to measure radiation for up to 5 continuous hours. However, for long measurement series, electricity or photovoltaic power is used. The scintillator and associated electronics were calibrated for energy and intensity counts per minute in the ITA teaching experimental physics laboratory using radioactive sources and a 0.2 x 10 MeV spectral analyzer (Million electron Volt) [7] and [8].

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Fig. 1: View of gamma scintillator with associated electronics and computer

The scintillator coupled to photomultiplier is wrapped in a thin layer of aluminum to make it portable. The set (scintillator + associated electronics + data acquisition) only depends on a laptop with a charged battery to measure the radiation for up to 8 continuous hours. However, for series of long measurements it uses electrical network or photovoltaic energy. The scintillator and associated electronics were calibrated in terms of energy and counting intensity per minute at the experimental teaching physics laboratory of ITA using radioactive sources and a spectral analyzer of counts versus energy in the range of 0.2 to 10 MeV (Million Volt Electron) [9] and [10].

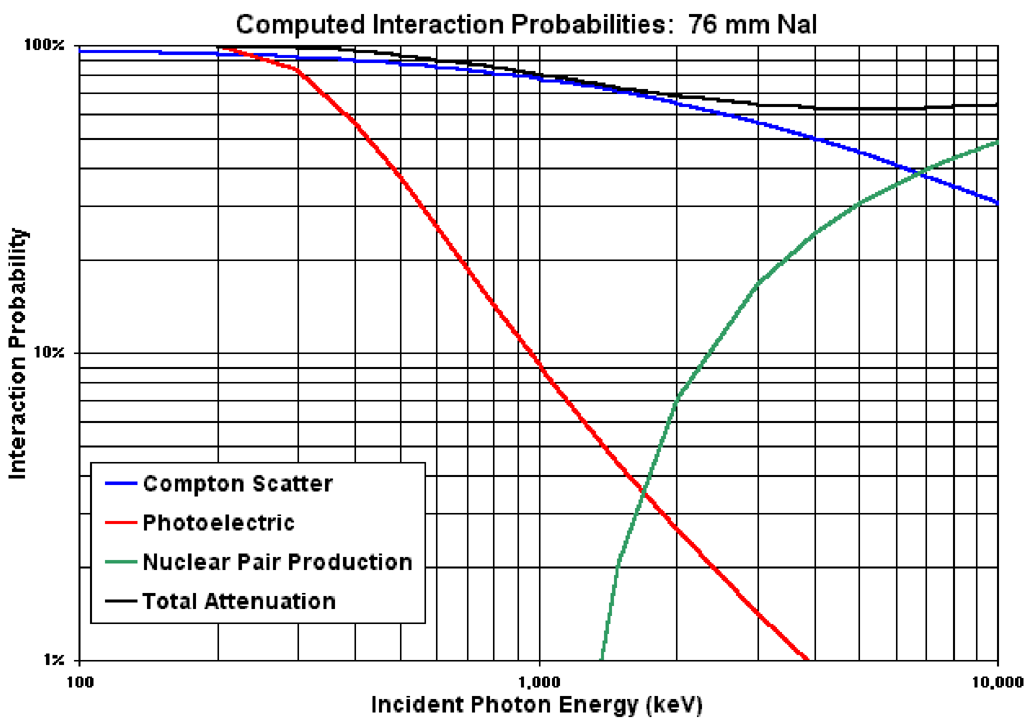

Fig. 2 – Interaction probability of scintillator NaI(TL) with gamma photon energy [10].

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III. RESULTS AND DISCUSSION

Preliminary measurements of the radiation spectra were made in a region without any human and / or electromagnetic interference as shown in Figure 3. They were obtained at various locations and even at 25 meters in the ACA Tower.

Fig. 3 -Aerial and ground view of the tower ACA and his environmental field region in São José dos Campos, SP, Brazil (23° 12'45" S, 45° 52'00" W)

Figure 4 shows the graph of intensity versus channel number of gamma ray spectrum below the ACA Tower, near the green shelter, area without any human interferences.

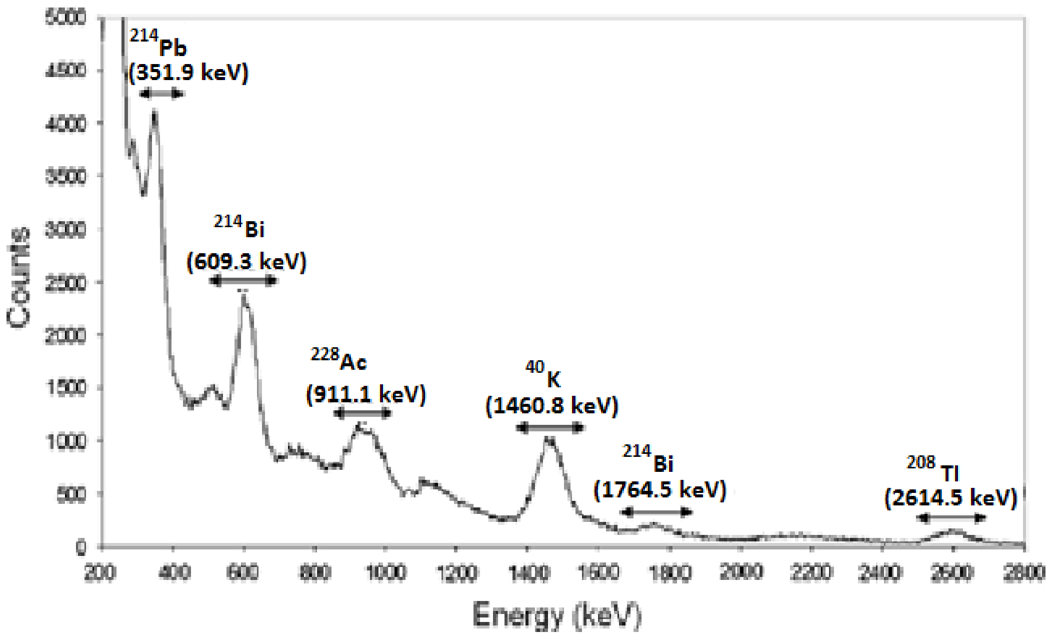

Fig. 4 –Environmental spectrum of gamma rays in the site shown in Figure 3 above, took on 23 April 2011 with net time of one half hour of measurements

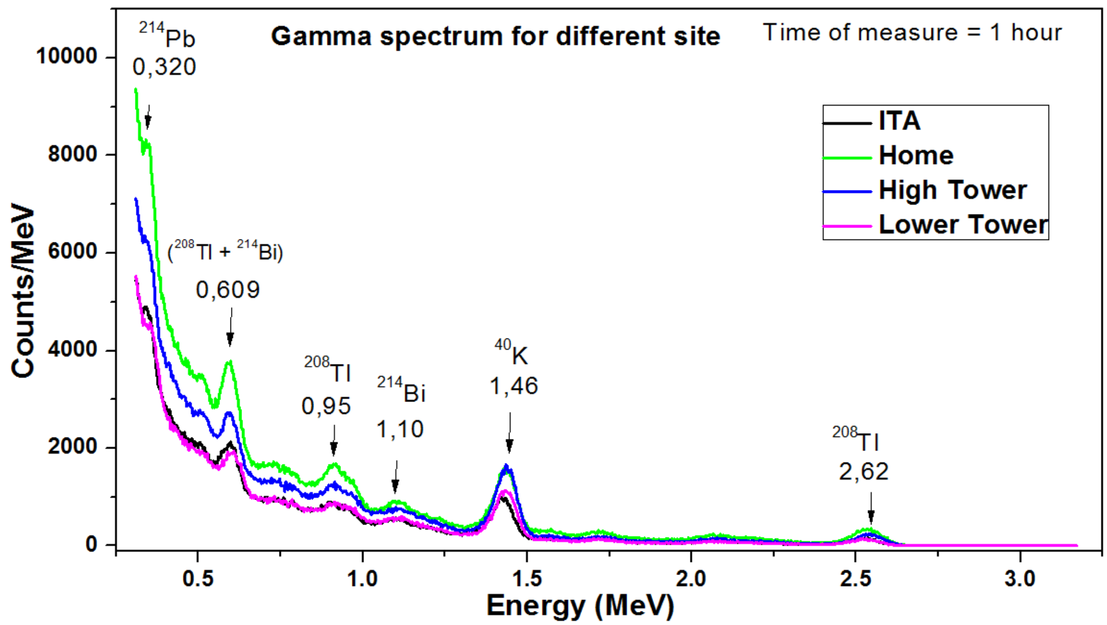

Fig. 5 – Spectra of gamma rays measured during net time of 1 hour each in 4 places in same day (2015-12-08)

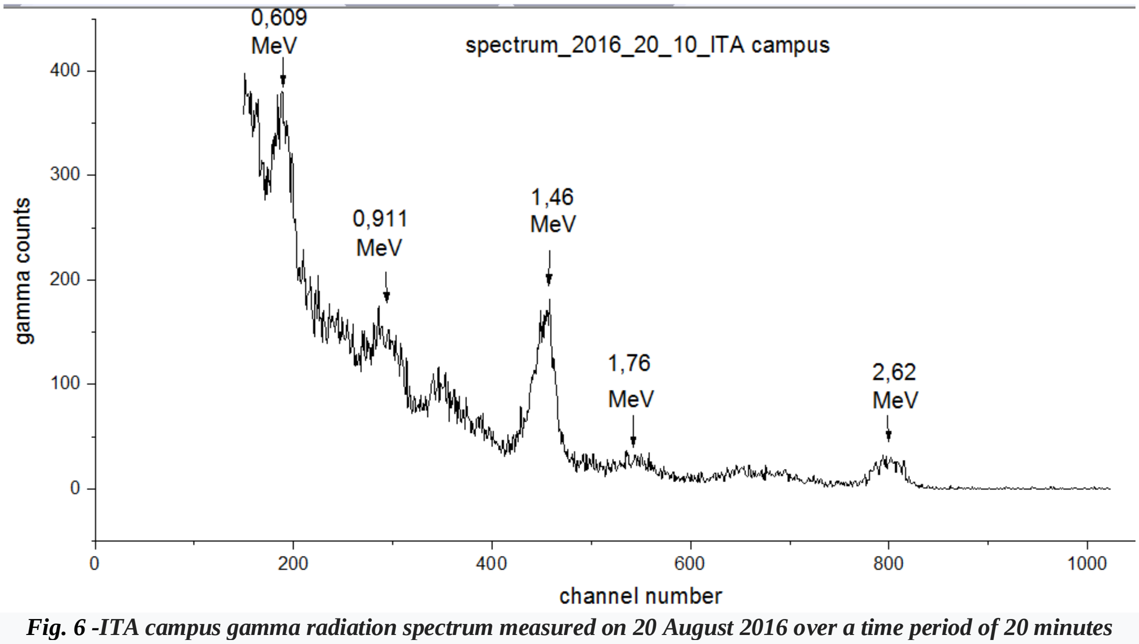

Fig. 6 -ITA campus gamma radiation spectrum measured on 20 August 2016 over a time period of 20 minutes

Figure 7 below shows a gamma radiation spectrum seen directly in the graph already executed by the detector software. In addition to the gamma radiation peaks present at the measurement site, it specifies the total measurement time in seconds and the working voltage of the spectrometer. Besides the graph the software allows to save the data in two extensions in the laptop that later will be used for the detailed analysis of these measures.

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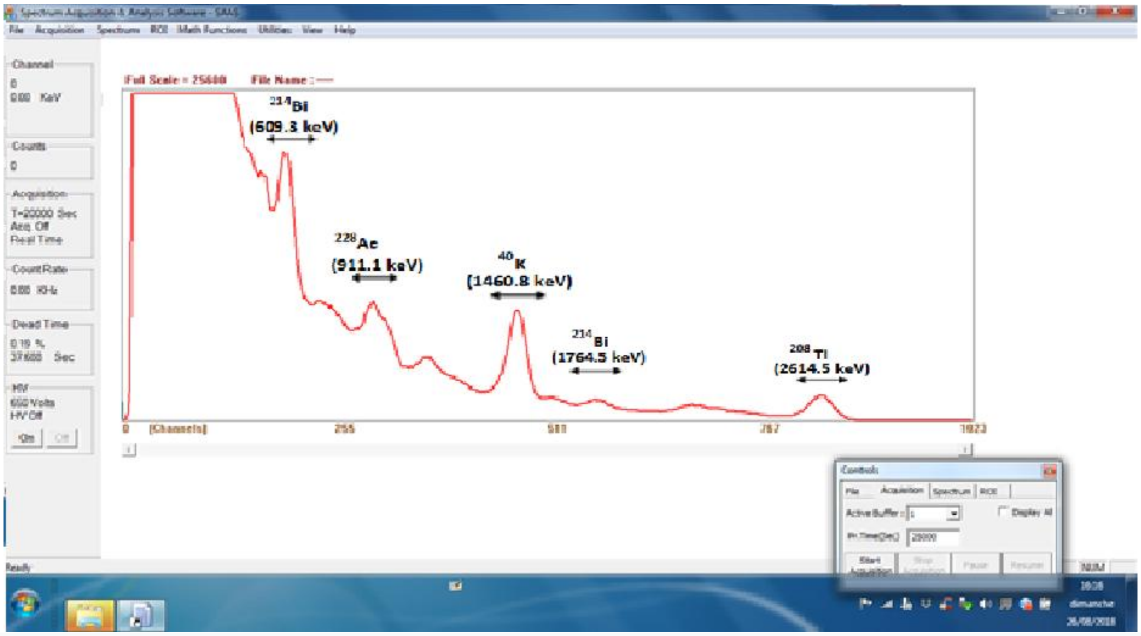

Fig. 7 -Gamma radiation spectrum obtained directly from the Dell Vostro laptop monitor used for monitoring in São Jose dos Campos, for a total time of 20000 seconds on 08/26/2018.

A large number of energy spectra were measured in São José dos Campos from August to December 2011, varying the total integration time (24, 12, 1, 0.5 and 0.2 hours). With a counting time of only 600 seconds the measured spectrum already shows the main spectral lines (^{40}K,^{208}T1,^{228}Bi and ^{214}Pb). Figure 8 below was measured with duration time of 24 hour.

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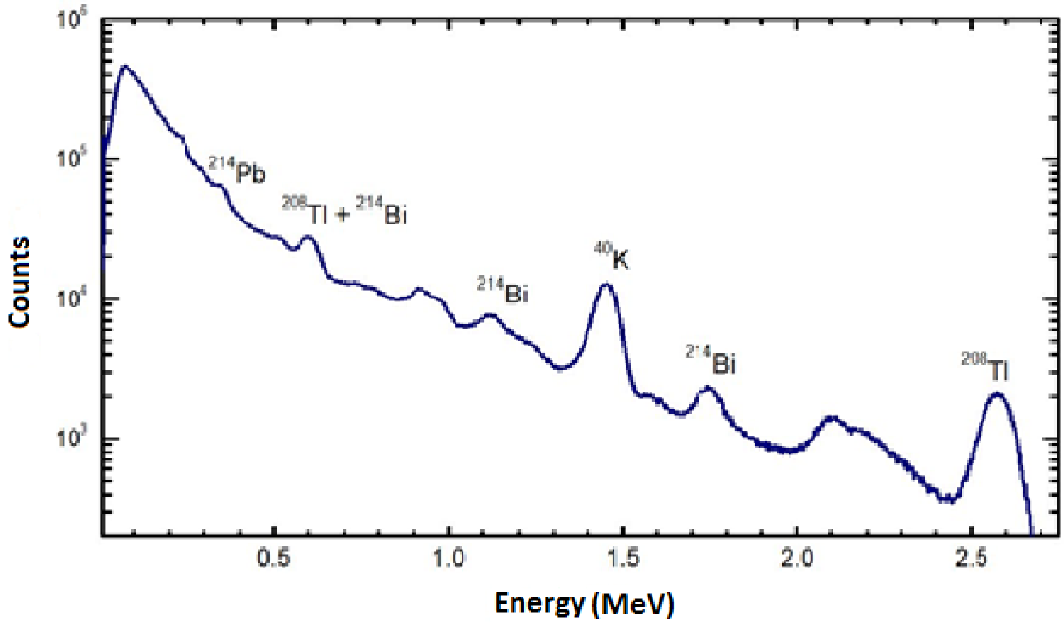

Fig. 8 – Spectrum from 30 keV to 3.0 MeV energy measured in São José dos Campos, SP, during a dry and cumulative time 24 hour period. Energy of some spectral lines photopics: ^{40}K, (1.46 MeV); ^{208}T1, (2.6 MeV); ^{214}Bi, (0.609 MeV).

Figure 9 shows spectrum measurements at a site in the São José dos Campos region during one-hour observation time, i.e. on February 9, 2018. Some spectral lines photopicswere very evident: ^{40}K, (1.46 MeV) ;^{208}T1, (2.6 MeV); ^{214}Bi, (0.609 MeV).

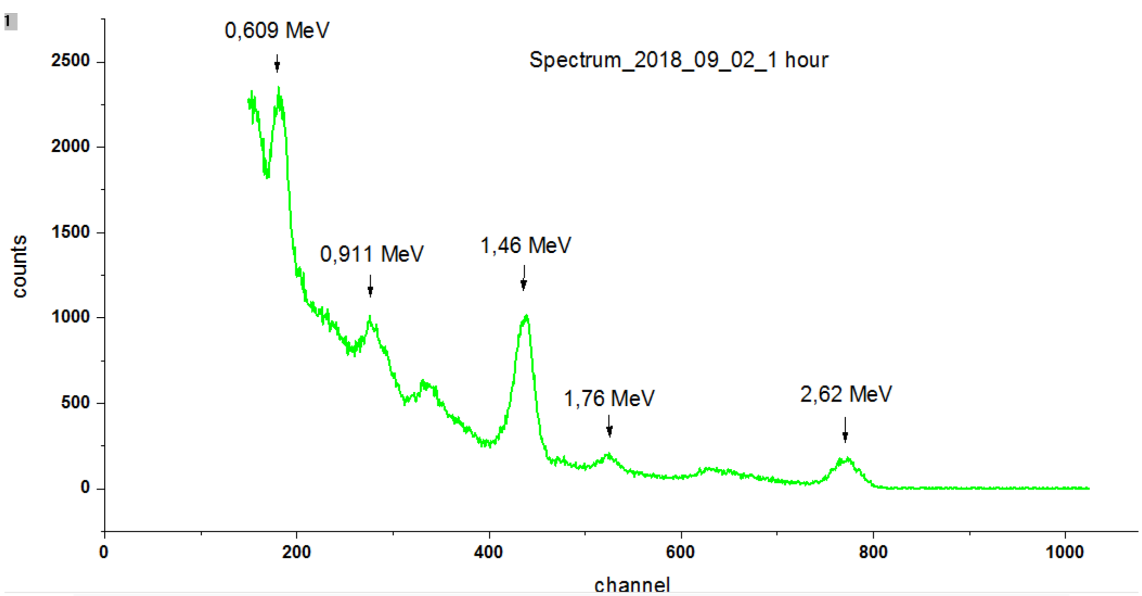

Fig.9 –Gamma radiation spectrum measurements in the São Jose dos Campos region, on 09/02/2018

Figure 10 shows measurements of the gamma radiation spectrum at a point farther from the center of São José dos Campos called Putim where there is still little population in comparison with ITA area.

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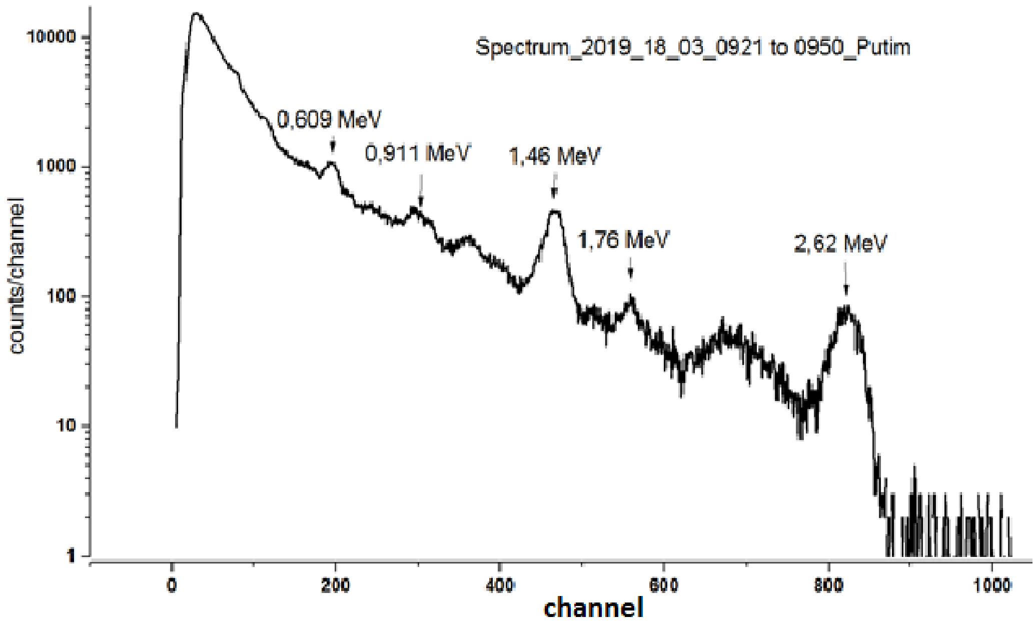

Fig. 10 – Spectrum of gamma radiation on 2019/18/03 showing the environmental peaks of energy

Figure10 above shows gamma spectrum observation in the eastern region of São José dos Campos in the neighborhood of Putim on 03/18/2019 between 09:21 and 09:50 local time.

Figure 11 shows the calibration of the multichannel gamma ray analyzer using a radioactive monoenergetic Cesium 137 (^{137}Cs) source whose gamma photon energy is 662keV.

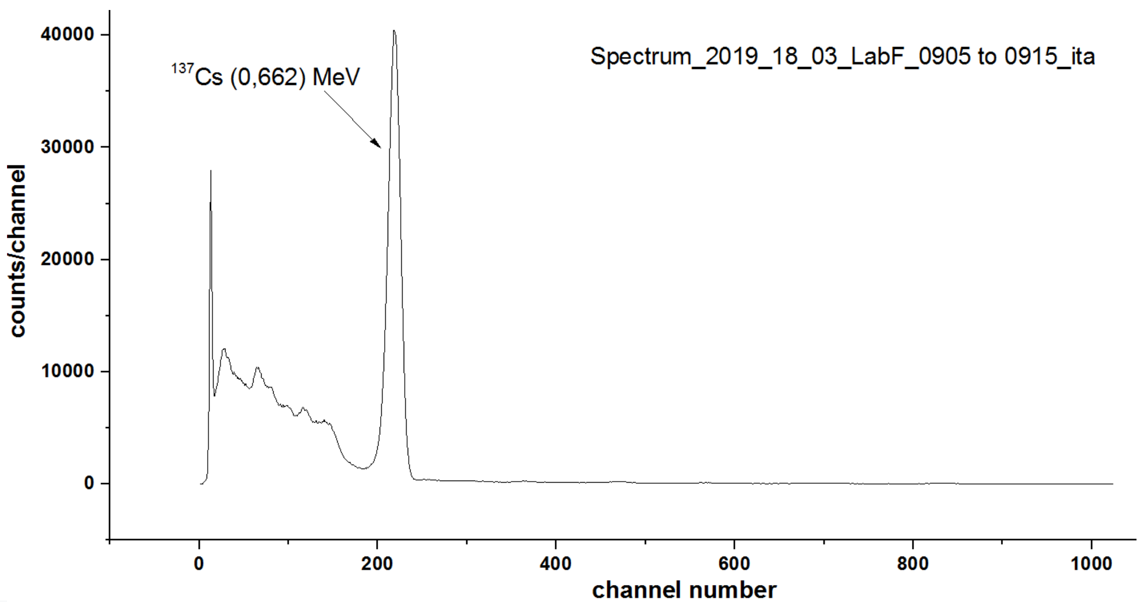

Fig. 11 –Gamma ray spectrum from a radioactive monoenergetic source of Cesium 137 with photopic energy of 662keV and Full Width Half Minimum(FWHM) of 7% [10]

It can be seen from the graph above that the 3 ”x 3” NaI (Tl) scintillator is working very well as the ^{137}Cs line has good resolution at 662 keV energy.

Figure 12 shows the correlation between measurements of gamma radiation counts between 200 keV and 10 MeV per minute and increased radiation due to the incidence of heavy and moderate rainfall in the region [11].

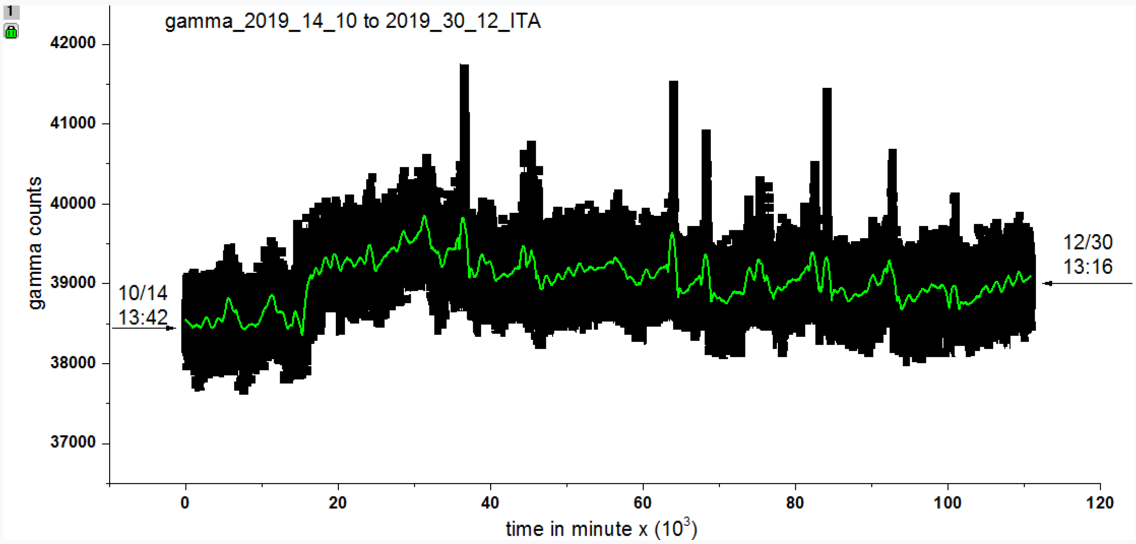

Fig. 12 – Weather spectrum of moderate and heavy rainfall in the region between 10/14 and 12/30of 2019 observed by the 9 evident peaks of the increase of gamma radiation.

IV. CONCLUSION

Using a portable gamma-ray spectrometer for the 0.2 to 10.0 MeV power range and with a Dell Vostro laptop, the channel or energy spectrum was measured at various locations in the São José dos Campos region, Brazil. These were the first large-scale measurements made in the region. The spectrometer was channel versus energy calibrated using ^{137}C (662 keV), ^{60}Co (1.173 and 1.332 keV) and ^{22}Na (511 and 1.200 keV) radiation sources. Analysis of the spectra measured at all points indicates the peaks of environmental gamma radiation of ^{208}Tl (2.62MeV), ^{214}Bi (1.76MeV), ^{40}K (1.46MeV) and ^{214}Bi (0.609MeV). These elements are children of the ^{238}U, ^{232}Th and ^{40}K. Radon gas also coming from the decay of ^{238}U in ^{226}Ra and ^{222}Rn is also quite abundant in this region.

V. ACKNOWLEDGMENT
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