Spectrum gamma radiation, rainfalls and radon gas measurements during 2019 and 2020 in tropical region of Brazil

Radiação gama espectral, chuvas e medições de gás radônio durante 2019 e 2020 na região tropical do Brasil

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ABSTRACT
Environmental gamma radiation spectra close to the ground, rains and radon gas were monitored during the years 2019 and 2020 in the city of São Jose dos Campos, SP, tropical region of Brazil. The measurements showed the presence of Talium-238, Potassium-40, Bismuth-214 and Lead-214 in the photon energy range between (0.2-5.0) MeV with the time of one-hour measurement of sampling. The typical integrated count rate between each minute of gamma radiation in the same energy interval was 39000 counts / minutes, mean value, during all time of 110000 minutes of net measurements. The peaks observed in the gamma radiation count in this time and energy interval correspond to the presence of intense rains present in the region. With 1 hour of measurement in the region as a minimum sampling time and using a (3x3) inch sodium iodide spectrometer, it was possible to distinguish the radioactive elements in that region. Up to a height of 30 meters above the ground there was no difference in the radiation spectrum measured. The appearance of gamma ray peaks during rapid and intense rains on the site is due the presence of radon gas in these rains is increasing. It is the phenomenon of washing the radon gas in air during the rains. With weak and continuous rains in the place this phenomenon does not appear. Right in this tropical region of Brazil, the presence of radon gas ejection from the soil was the main responsible for the intensity and variation of x and gamma radiation.

Keywords: gamma radiation measurements, rainfalls measurements, radon gas measurements

RESUMO
Espectros de radiação gama ambiental próximos ao solo, chuvas e gás radônio foram monitorados durante os anos de 2019 e 2020 na cidade de São José dos Campos, SP, região tropical do Brasil. As medições mostraram a presença de Talium-238, Potássio-40, Bismuto-214 e Chumbo-214 na faixa de energia fóton entre (0,2-5,0) MeV com o tempo de uma hora de medição da amostragem. A taxa típica de contagem integrada entre cada minuto de radiação gama no mesmo intervalo de energia foi de 39000 contagens / minutos, valor médio, durante todo o tempo de 110000 minutos de medições líquidas. Os picos observados na contagem da radiação gama neste intervalo de tempo e energia correspondem à presença de chuvas intensas presentes na região. Com 1 hora de medição na região como tempo mínimo de amostragem e usando um espectrômetro de iodeto de sódio (3x3) polegadas, foi possível distinguir os elementos radioativos naquela região. Até uma altura de 30 metros acima do solo, não houve

diferença no espectro de radiação medido. O aparecimento de picos de raios gama durante chuvas rápidas e intensas no local é devido à presença de gás rádon nessas chuvas está aumentando. É o fenômeno de lavagem do gás rádon no ar durante as chuvas. Com chuvas fracas e contínuas no local, este fenômeno não aparece. Bem nesta região tropical do Brasil, a presença de ejeção do gás rádon do solo foi o principal responsável pela intensidade e variação da radiação x e gama.

Palavras chave: medições de radiação gama, medições de chuvas, medições de gás rádon.

I INTRODUCTION

In the ground level of the Earth's surface, ambient ionizing gamma radiation is mainly composed with ground telluric radiation, primary and secondary cosmic ray radiation. However, it is difficult to separate over time the intensity of ionizing gamma 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 coming from the disintegration of ^{238}**U** on the earth's crust to ^{226}**Ra** and ^{222}**Rn** that arrives in the ^{214}**Pb**, ^{214}**Po** and ^{214}**Bi** stable isotopes, generating alpha and gamma radiation [2]. Primary cosmic radiation consists mainly of galactic and extragalactic protons and those from the Sun, with high energy that interacts with the Earth's atmosphere producing Extensive Air Showers (EAS) [3]. Another possible source of ionizing radiation in the Earth's lower atmosphere are produced by lightning strikes between earth-clouds and clouds-earth. The lightning cone forms x-rays, gamma rays, neutrons and beta particles [4]. Other sources of ionizing radiation are those produced in medical, dental and hospital clinics, but these are mainly controlled in small areas. Radon (222Rn) are recognized as a major contributor to the dose due to natural radioactivity in the soil, being responsible for approximately half of all human exposure to ionizing radiation, [5]. Radon is a noble gas, emitting alpha particles, produced in the series of natural decay of uranium and thorium, which occur in varying concentrations in diverse geological materials, especially in rocks, soils and waters. Its diffusion and convection in the air occur at low altitudes (approximately <100 m). Radon migrates from rocks and soils to the atmosphere through cracks, holes and pipes and it enters homes and other buildings. Evidence of oscillations in the emission of Radon gas in periods of day and night in moderate doses of gas emission in days of intense rain and dry days with intense sunshine in the region [6, 7]. Another important source of indoor radon is construction materials. The progeny of radon has received considerable attention in recent decades due to its potential causative effect of lung cancer if deposited in the upper respiratory tract when constantly inhaled [8].

The rainfall intensity in (mm) was measured with a pluviometer (bascule/bucket) rain gauge and data logger acquisition developed in ITA according to the international recommendations.

2 MATERIAL & METHODS

2.1 GAMMA RAY DETECTOR AND RADONEYE IONIZATION CHAMBER FOR RADON GAS

A Thallium-doped Sodium Iodide crystal scintillator [NaI (Tl)] were used to measure gamma photon counts between 200 keV to10.0 MeV [9]. The scintillator-associated electronics consist of a 1700 VDC continuous source and a minute data acquisition system. All of this electronics and crystal scintillator were designed and calibrated in energy and intensity by Aware Electronics Inc, USA [10]. One photomultiplier-coupled scintillator was used in this work. Both radiation measurements (counts / minute) and rainfall intensity measurements (mm / minute) were recorded during this work in (.txt) files and saved to PC computer. Detector and associated electronics were previously calibrated in ITA (Technological Institute of Aeronautics) laboratory using radioactive sources Cs-137, Sr-90 and Po-210 in terms of energy from emitted photons and particles: 1.17 MeV, 0.90 MeV and 5.4 MeV respectively [11]. The rainfall intensity in (mm) was measured with a pluviometer (bascule/bucket) rain gauge and data logger acquisition developed in ITA according to the international recommendations. The data acquisition in terms of ionizing radiation and intensity of rainfall was performed using 1-minute time interval between each measurement [12].

To monitor the variation of radon gas at the ground level interface it is choose the detector consisting of a RadonEye RD200 portable ionization chamber manufactured in South Korea. The RD200 has sensitivity 20 times higher than other portable radon detectors and has the system in which it releases dual-structure pulses and a highly accurate detection circuit designed by FTLab's own technology. A first reliable 1 hour data view is required, where its sensitivity is 1.35 counts per minute equivalent to 0.5 Becquerel / m3. The measurements were performed in the ACA tower at 25 meters high from the ground level and other at the physics laboratory of ITA Institute, both located at the Technological Institute of Aeronautics (ITA). Data acquisition was possible through the available RadonEye application, only on smartphones. Power was supplied via 120 or 220 V to 12 VDC source connected to the detector, where the setting starts automatically. With an Iphone device, the data generated by the RadonEye RD200 detector was transferred through the Itunes software. One Origin 1.5 software was used to graph the curves measurements of the radon intensity versus time realized on ITA campus [13].

2.2 RAIN MEASUREMENTS

The rainfall intensity in (mm) was measured with a pluviometer (bascule/bucket) rain gauge and data logger data acquisition developed in ITA according to the international recommendations. The data acquisition in terms of ionizing radiation and intensity of rainfall was performed using 1-

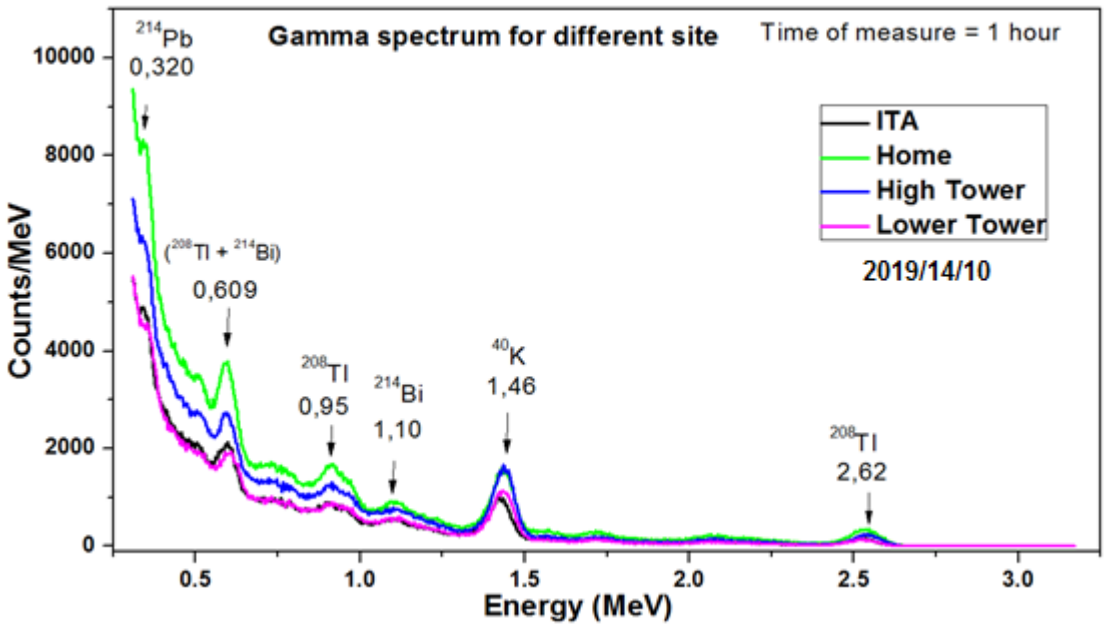
minute time interval between each measurement [14]. We also took advantage of the forecast of rainfall intensity provided by the simulation of the Ventusky website [15].

Fig. 1 – Aerial view of the site of measurements made in 2019 and 2020 on the ITA campus.

3 RESULTS AND DISCUSSIONS

Using the portable gamma-ray spectrometer described in the chapter above, material & methods, we performed measurements with a sampling time of 1 hour, in the four locations described in the spectrum of Figure 2. Note that 6 peaks were clearly visible.

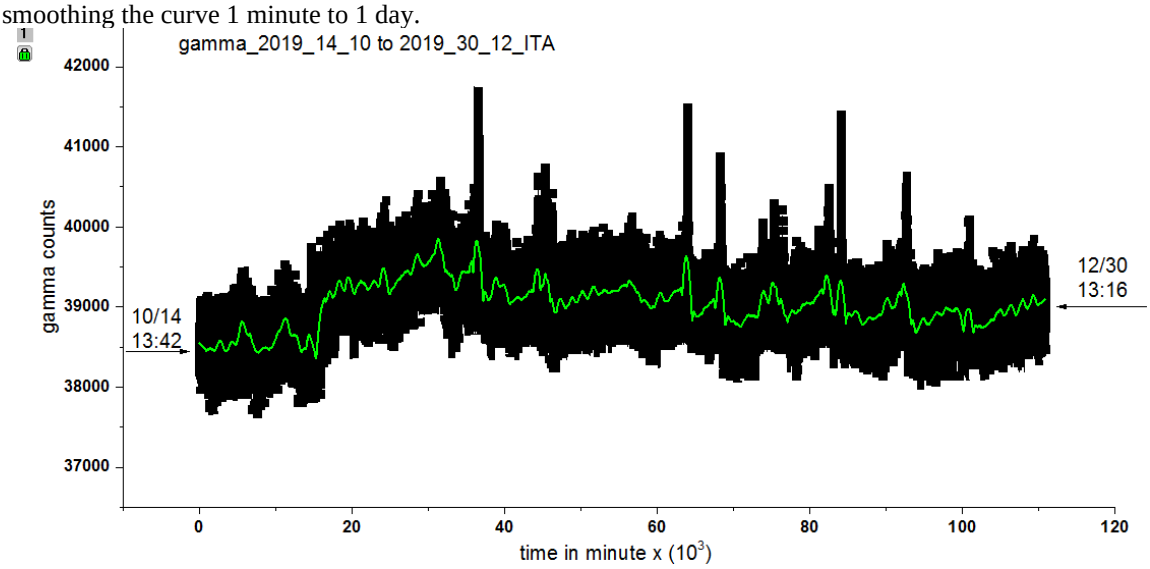
Fig. 2 – Spectra of natural gamma radiation observed in 2019/14/10 on the ITA campus.



in the 4 different measurement positions. The peaks coming from Thorium-232, Potassium-40 and Uranium-238 are very visible, showing the good performance of the detector and its associated electronics. The peak at 1.46 MeV from Potassium-40 and 0.609 from Uranium-238 and Thorium-232 are very visible in this region.

Figure 3 shows the radiation measurement now integrated from 0.2 to 4.0 MeV without specifying spectra this for the year 2019 in the same location In this graph, 9 peaks related to the increase in gamma radiation counts that correspond to the arrival of intense rains in this measurement region will be observed.

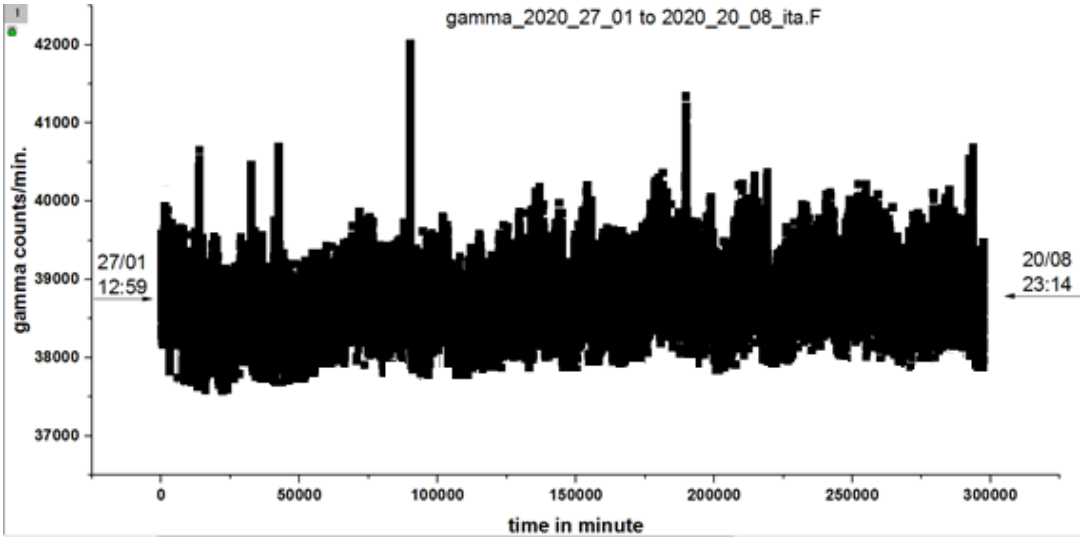
Fig. 3 – Counts per minute of gamma radiation in the same place and in the period described in the figure itself. The green line is smoothing the curve 1 minute to 1 day.



In the entire period from January to August 2020, Figure 4 shows the radiation count per minute showing only 6 radiation peaks. This meant less intense rain at the measurement site. This year 2020 was one of the driest in the last 40 years in the

region, it rained in January and February and three local heavy rains between March and August, raining again in November and December 2020.

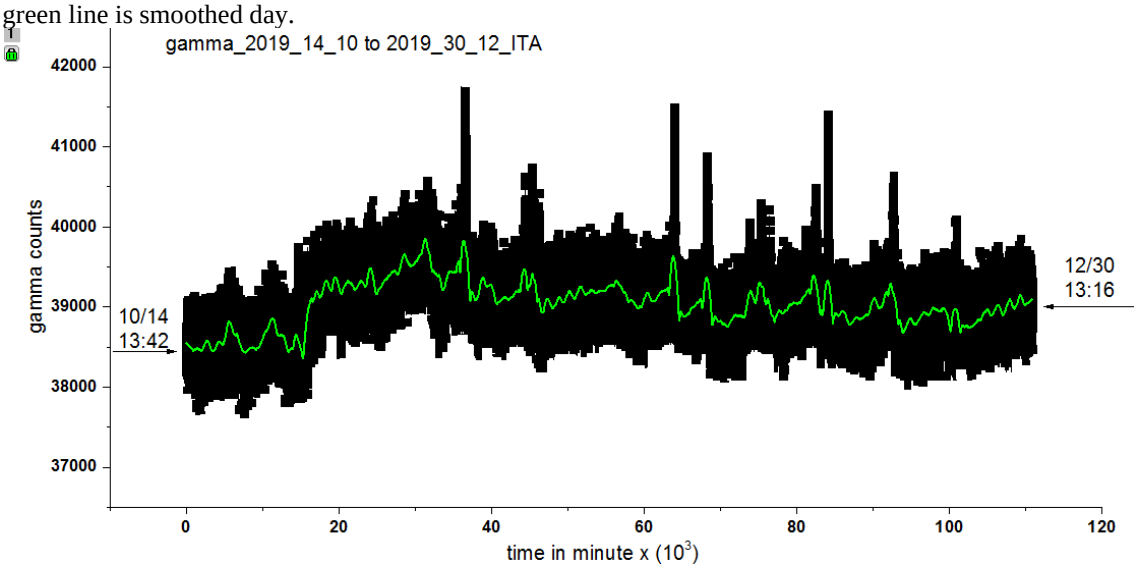
Fig. 4 – Radiation measurements in counts / minute in the period between January and August 2020, showing 6 mainly radiation peaks in this measured interval.



From the 14th of October to the 31st of December 2019, the presence of gamma radiation was monitored at the same location on the ITA campus. Figure 5 shows the variation of this radiation as a function of time. Note the presence of 9 peaks in the entire measurement period, always with counts greater than 45000 counts / minutes.

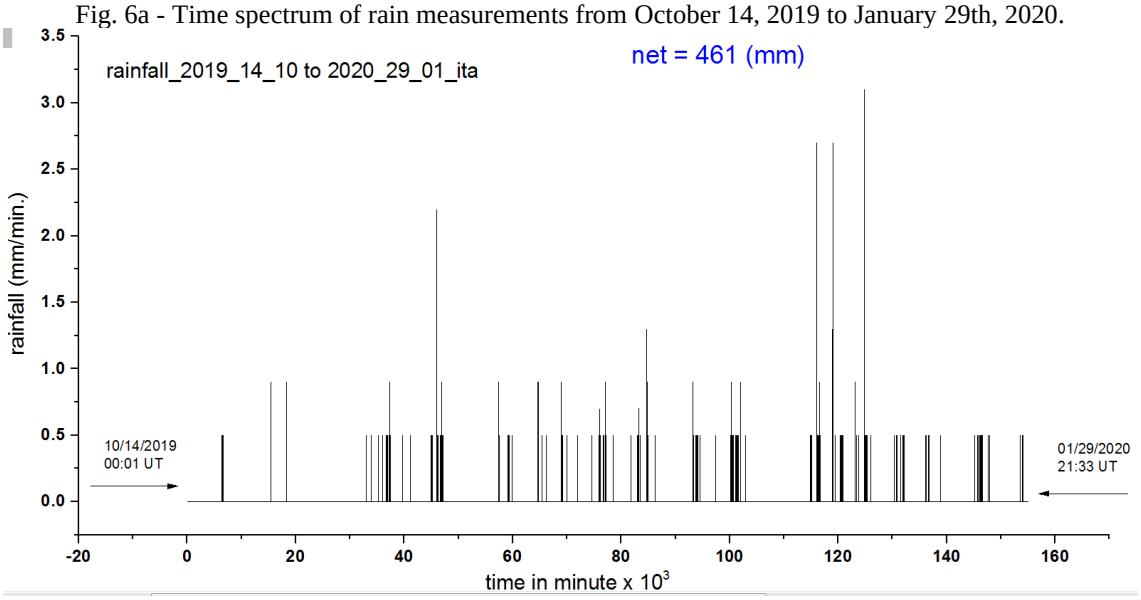
It can be noticed in the integrated measurements of x and gamma radiation that there is a variation day / night, variations in intensity per minute when there is intense rain and other small variations due to other phenomena. This fact can be better visualized when choosing the region of the graph to be studied with a zoom in the curve in the chosen time. In this article we show x and gamma rays with rains and radon gas variability.

Fig.5 - Gamma radiation measurements from October 14 to December 30, 2019. Black line correspond to counts per minute and the green line is smoothed day.



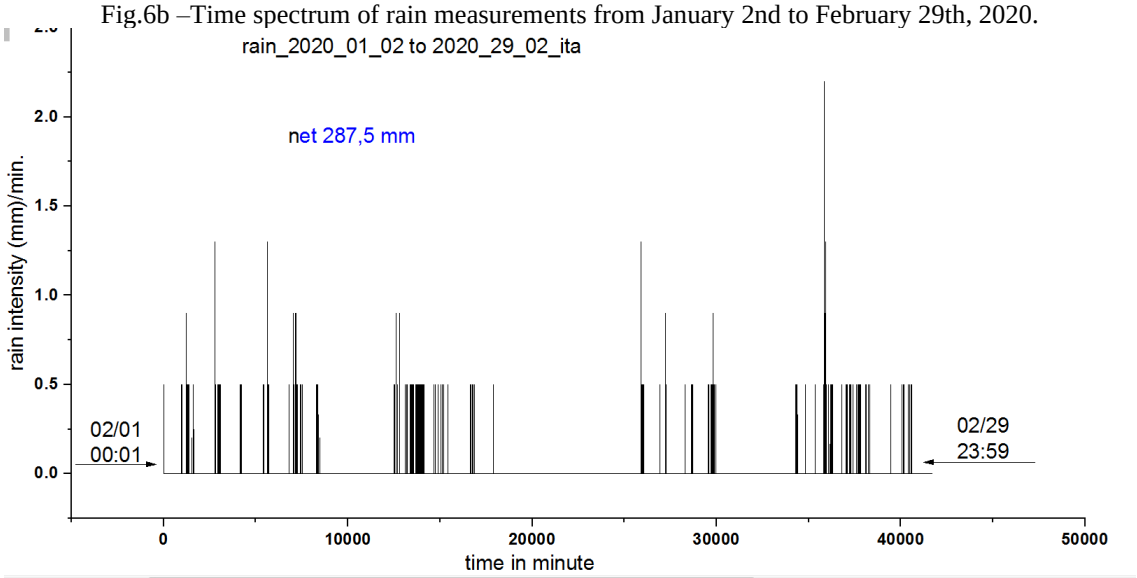
As a reference, Figure 6a shows the time spectrum of the rains measured between October 14 2019 to January 29th, 2020. This period was extremely rainy with a total of 461mm.

Fig. 6a - Time spectrum of rain measurements from October 14, 2019 to January 29th, 2020.



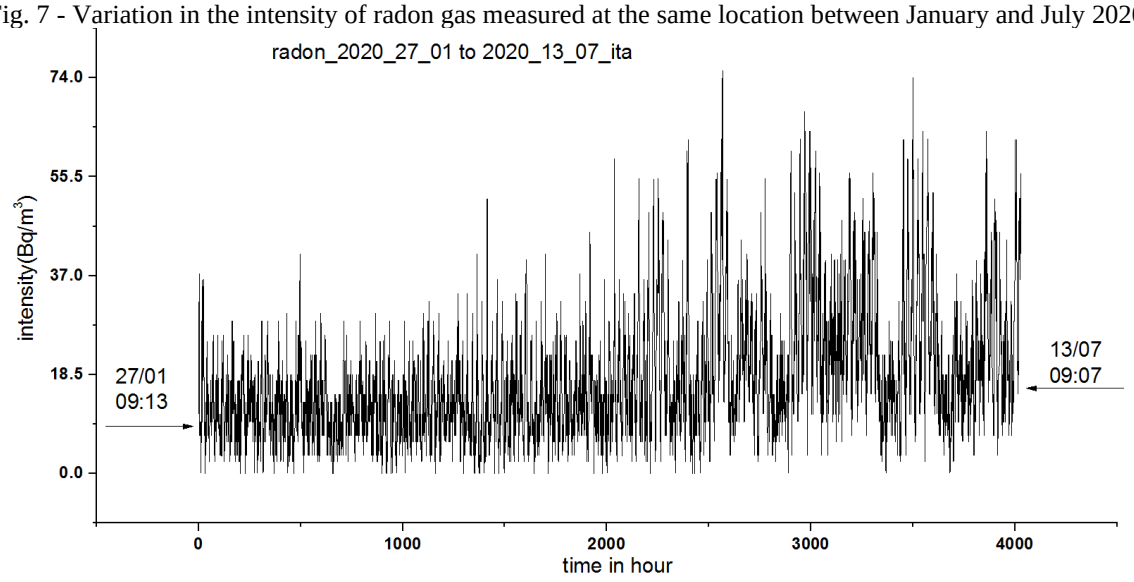
The first two months of 2020 were very rainy while the rest of the year was very dry. Figure 6b shows the dynamics of these rains as a function of time with a total of 287.5 mm. With the soil very soaked during this period, there will be little exhalation of radon gas from the soil.

Fig.6b –Time spectrum of rain measurements from January 2nd to February 29th, 2020.



Radon gas in the first two months of 2020 was almost constant due to a lot of rain. This prevents the exhalation of gas from the terrestrial pores. However, in the dry months from March to July 2020, due to insolation and dry land, there was a greater intensity of exhalation of this gas in the region, as shown in Figure 7.

Fig. 7 - Variation in the intensity of radon gas measured at the same location between January and July 2020.



In the same place and in the years 2019 and 2020 the measurements of gamma radiation, radon gas and rainfall intensity can be summarized that:

a) The measured gamma radiation depends a lot on the greater or lesser exhalation of the local radon gas,

b) The intensity of local radon gas depends on the local geology and the meteorology, that is, rain, dry weather and sunshine.

4 CONCLUSION

Using a simple and portable spectrometer to measure x and gamma radiation close to the ground, a simple ionization chamber to measure radon gas and a pluviometer to monitored in the last two years (2019 and 2020), the intensity and spectrum of the x and gamma radiation, the intensity of radon gas and rainfall. The same measurement location was used for the three parameters. The intensity and time variation of radon gas in the region depends on rain, dry weather and the sunstroke of the place. With dry weather and sudden arrival of intense rains, the intensity of gamma rays undergoes intense and rapid variation. The maximum intensity of radon gas per hour recorded in this region did not exceed 80 Bq / m3. Maximum intensity of gamma radiation per minute did not exceed 45000 counts /min. The intensity of the highest rainfall per minute was 3.5 mm. These values are related to the period from 2019 to the end of 2020. As each year has a different rainfall regime at all times, it appears that the presence of radon gas and the intensities of gamma radiation in that energy interval will also be different. It can be noticed in the integrated measurements of x and gamma radiation that there is a variation day / night, in intensity per minute when there is intense rain and other small variations due

to other phenomena. This fact can be better visualized when choosing the region of the graph to be studied with a zoom in the curve in the chosen time.

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