

Assessment of gamma radiation, environmental variables, and potential health correlations in tropical climates

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ABSTRACT

The months of October 2019 until the end of January 2020 were very rainy in São Jose dos Campos (23°12'S, 45°52'W) tropical Brazilian region. In the period from 10/14/2019 to 01/27/2020, the counting of gamma rays, neutrons and rainfall intensity in a tower at 25 meters high was monitored at every one-minute interval. This tower is located in a free area without electromagnetic interference from man on the site. The average rate of gamma radiation count between (0.2-10.0) MeV was 39000 counts / min. The average neutron count observed was 2 neutrons / min, between 25 eV to 10.0 MeV. The amount of net rainfall in the period was 461(mm) with variations in dry weather, fine, moderate and heavy rainfall throughout the monitored interval time. It can be seen in these measurements that the intense rains correlate very well with variations in the gamma rays and delayed of 4 to 5 days with the measured neutron intensities. This work gives possible explanations about this correlation based in in same site of rainfalls, gamma and neutron observations.

Keywords: neutron, gamma rays and rainfall measurements.

I. INTRODUCTION

At the ground level interface of the Earth's surface, ionizing radiation it is composed mainly of gamma ray, soil telluric radiation, primary and secondary cosmic ray radiation [1]. However, it is difficult to separate over time the intensity of the ionizing radiation emanating from each component as the energies overlap. The telluric radiation is given by ^{238}U , ^{235}U , ^{40}K and ^{232}Th disintegration's series that are constant for each region. The gamma ray and neutrons coming from radon gas arriving through the ^{238}U in Earth's crust disintegration to ^{226}Ra and ^{222}Rn reaching the stables isotopes ^{214}Pb , ^{214}Po and ^{214}Bi . Radioactive elements such as Uranium, Thorium and Potassium are found in almost all types of rocks, sands, soils and water [2]. The Radium ^{226}Ra and its decay products are responsible for a major fraction of the dose of internal emissions received by humans. ^{226}Ra has a half-life of 1,600 years, and decays to Radon ^{222}Rn , which has a half-life of 3.82 days. The decay of ^{222}Rn is followed by successive disintegration of short half-life alpha, beta and gamma ray emitters. After decay stages, the radioactive chain ends with stable lead ^{206}Pb . The alpha particles coming from radon gas in interaction with elements of ground level and can produce neutrons. With regard to soils and rocks, the ^{226}Ra is present in virtually all soils and rocks in varying amounts. Areas with high levels of background radiation found in some soils are due to geological conditions and geochemical effects and cause increased terrestrial ionizing radiation. Researches in the world, and specifically in Brazil, show these conditions. Several studies report variations throughout the day of radon concentrations. Maximum concentrations are observed in the first hours of the day and the lowest values are found late near afternoon, when concentrations are about one third of morning values [3]. The same profile is observed with the gamma ray intensity variation in the tropics region. However, it is likely that variations in concentrations in localities of gamma ray intensity are dependent on local meteorological parameters (rain, wind, pressure, temperature and cloudiness) in the gamma ray detector site [4]. Electrical discharges in low atmosphere of the region also can contribute with production of low energy gamma ray and neutrons near ground level according lightning see Figure 1 and Figure 2.



Fig. 1: Geographical location of Sao Jose dos Campos.

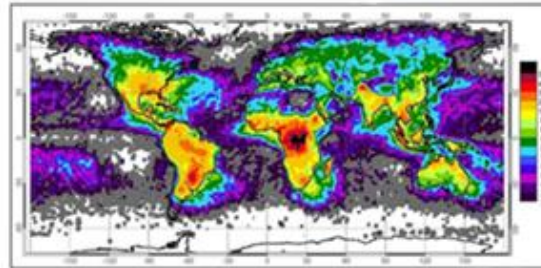


Fig.2: Frequency of lightning strikes per km² per year. The frequency of lightning strikes at São José dos Campos is about 20-40 strikes /km²-year.

II. METHOD & MATERIAL

To monitor the gamma radiation in energy interval 200 keV to 10.0 MeV, it has been used a portable system detector composed of Sodium Iodide scintillator activated with Thallium NaI(Tl). This crystal (3" x 3") inches (diameter and height) placed in a thin cylinder of aluminum foil and coupled with a PM (photomultiplier) with source power circuit settled in 1500 VDC and with data acquisition system provided by the company (Aware Electronics-Inc., USA)[5]. Detector and associated electronics of gamma ray were previously calibrated in ITA (Technological Institute of Aeronautics) laboratory using radioactive sources (Cs- 137) and (Co-60) in terms of energy from emitted photons 662 keV and 1,17 MeV, 1,33 MeV respectively [6]. The data acquisition in terms of gamma radiation and intensity of rainfall was performed using 1-minute time interval between each measurement. This detail contributes to verify possible correlations between variation of rain intensity, and local ionizing gamma radiation.

The Ludlum Model 2531 tube Neutron Detector is designed for detection of thermal and fast neutrons (0.025 eV to 10 MeV) [7]. The neutrons are detected, not directly, but through nuclear reactions, which result in energetically charged particles such as alpha particles. In many instances, intense fields of gamma rays are also found with neutrons. Therefore, it is important to choose a method of neutron detection with the ability to discriminate against these gamma rays in the detection process. The most common reaction used in neutron detection today is: $(n+{}^3\text{He}\rightarrow{}^3\text{H}+{}^1\text{H} + 0.764 \text{ MeV})$ where both the proton H and the ${}^3\text{H}$ are detected by gas-filled ${}^3\text{He}$ the Ludlum Model 2531 tube. The helium-3 (${}^3\text{He}$), which fills the gas proportional tube of the detector, with 1500 VDC and sensitivity: 100 cpm/mrem/hr using the neutron source of (${}^{241}\text{AmBe}$ fast neutrons) [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. The data acquisition in terms of ionizing radiation and intensity of rainfall was performed using 1-minute time interval between each measurement [9].

Using these three tools properly calibrated for the measurements of gamma rays, neutrons and rainfall intensity, he was placed in the tower at 25 meters high for simultaneous monitoring see Figure 3.



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)

III. RESULTS AND DISCUSSIONS

During the period from 10/14/2019 to 01/27/2020, 8 peaks of gamma radiation are observed, as shown in Figure 4. However, in Figure 5, the measurements of rainfall intensity show 5 peaks indicating heavy rains. Therefore, it is admitted that not only heavy rains cause an increase in the observed gamma radiation. Figure 6 shows the neutron monitoring observed every minute. The intensity during each day varies very related to weather. After 4 to 5 days of intense rain there is a significant increase in neutrons in the region. This fact can be explained by the increase of hydrogen atoms of water in the earth close to the detector that through the reaction (protons / alpha) produce neutrons. That kind of cosmogenic neutrons produced from cosmic radiation in the Earth's atmosphere or surface is very well studied today [10].

With the soil on the wet surface conditions, the back scattering neutrons increase at the measurement site. In times of heavy rain with very humid soil, there was always an increase in neutron counts caused by interactions of cosmic rays. Also in times of dry and very hot weather, the measurements obtained show a variation and increase in neutrons, but now originated by the exhalation of radon gas from the earth's surface. Radon gas produces alpha particles that interact with the soil and produce neutrons in this energy range. For this reason, the neutron monitoring graphic is very variable in this period studied here see Figure 5.

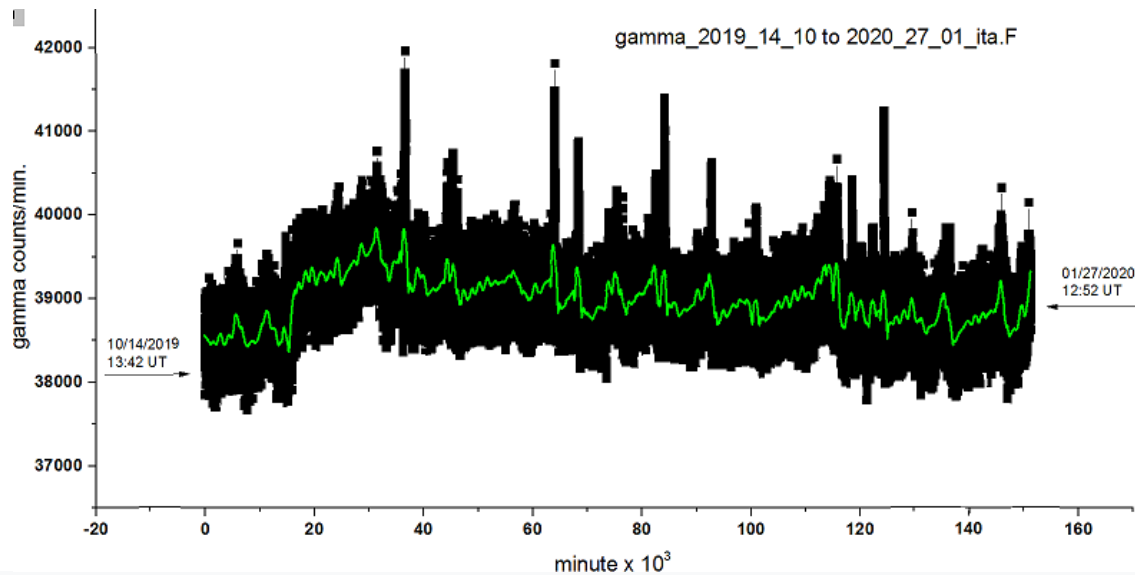


Fig. 4 -Measures every minute of gamma radiation intensity between 10/14/2019 and 01/27/2020 showing 8 peaks of radiation increase.

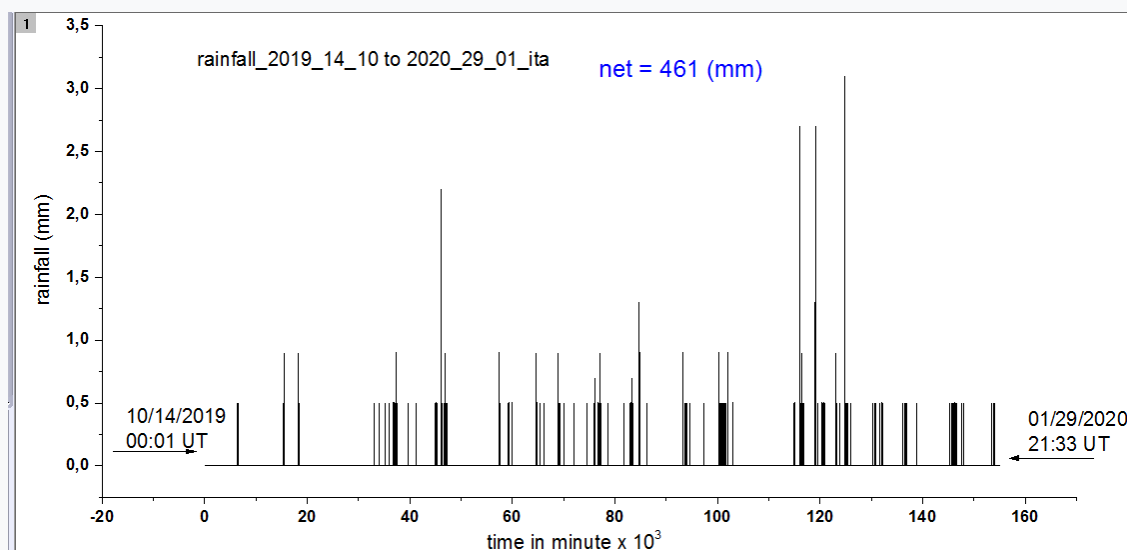


Fig. 5 – Measures of rainfalls each minutes during 10/14/2019 to 01/27/2020.

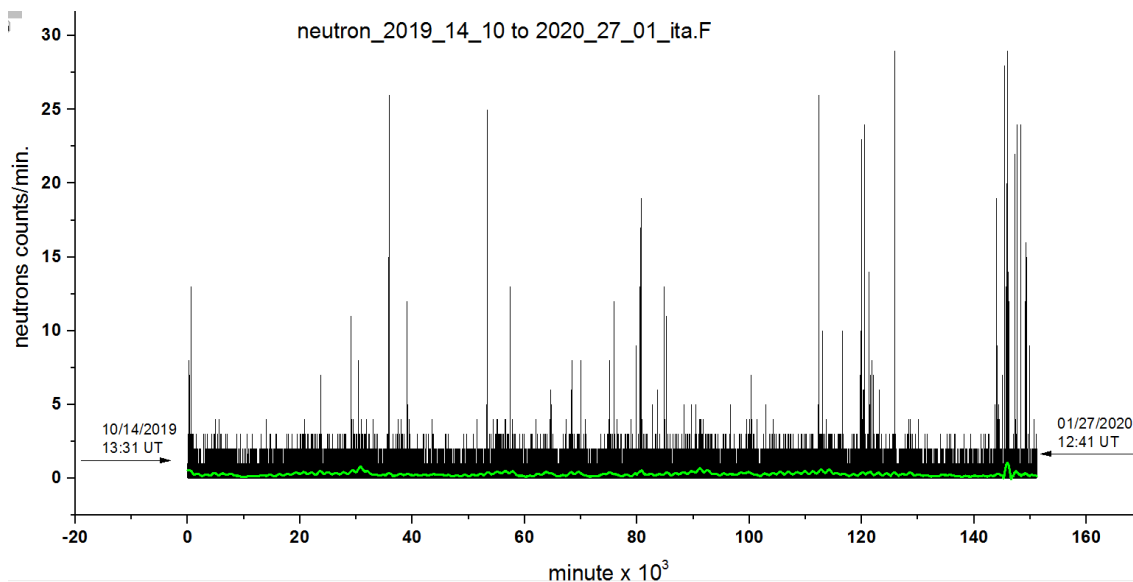


Fig. 6 - Detection and monitoring of thermal and fast neutrons (0.025 eV to 10 MeV) during the period of 10/14/2019 to 01/27/2020. Green line represents 1-day variation

Figures 4, 5, 6 show a good correlation between rainfall intensities and intensities of gamma rays during monitoring time. In the case of neutron and rainfall measurements, the correlation is good but there is also a delay of a few days as clearly seen at the end of the monitoring curve in the Figure 6.

IV. CONCLUSION

Variations in the intensities of gamma rays, neutrons and rains were monitored between 10/14/2019 to 1/27/2020 in tropical regions with only 1 minute intervals between each measurement. These measures show a good correlation between rain and gamma radiation due to the presence of radon gas in heavy rains. The correlation between rain and neutrons is due to the wet soil coming from rain and the phenomenon of neutron back scattering via cosmic rays. Also in the case of neutrons in dry times is due to exhalation of radon gas that increases the production of neutrons via interaction of alpha particles with elements of the Earth surface.

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