GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

OUTDOOR GAMMA, NEUTRONS, RADON GAS AND RAINFALLS MEASUREMENTS DURING 2018 IN SÃO JOSÉ DOS CAMPOS, BRAZIL REGION

Inacio M. Martin
Technological Aeronautics Institute – ITA – São José dos Campos – Brazil

ABSTRACT
During the year 2018 the intensity and its variation in time of gamma, neutrons, and rainfallswere monitored, everyminute the presence of the radon gas in two distinct points and close in 2 kilometers away which other in São José dos Campos, Brazil. One point was 25 meters high (ACA tower) and the other 3 meters high (ITA laboratory). Two identical RadonEye RD200 (ionization chamber) detectors were used, calibrated in the construction company itself in the number of hourly counts in pico Curie/liter (pCi/l) or Bequerel/cubic meters (Bq / m3). These measurements indicate that there is always a day/night variation in the intensity of the local radon gas. With dry and hot periods there is a more increase in radon gas intensity. Intense rains and short period of time there is also increased presence of the radon gas in that place. Fine and continuous rains decrease the presence of radon gas present. Comparisons between radon gas intensities per hour,gamma, neutron and rainfalls at the same time interval were observed.

I. INTRODUCTION

The interest of monitoring the radon gas of a region as a function of time lies in the fact that it is a tracer of the local tropospheric air movement. The local radon gas is also attributed the highest number of deaths observed in each year as shown in figure 1 below (Radon-related lung cancer deaths compared to other select cancers).

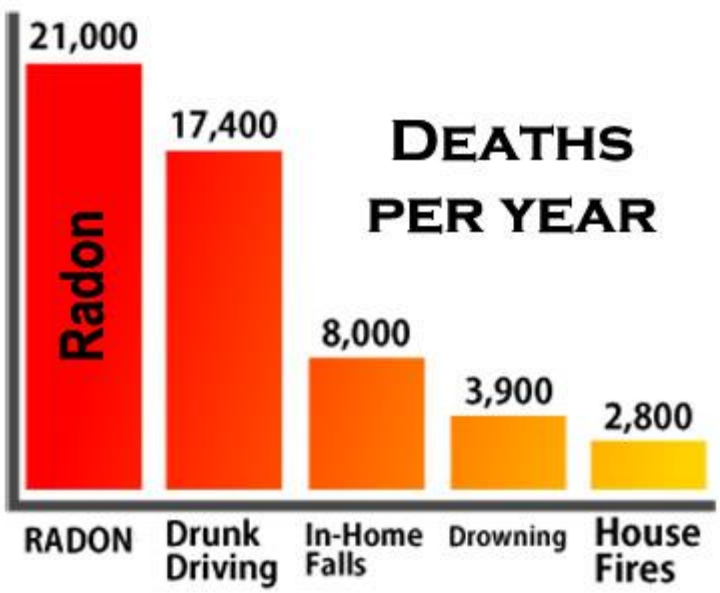

Fig. 1 - Number of deaths per year caused by radon gas compared to other causes credit Ref.1 (https://www.epa.gov/radon/health-risk-radon).

Radon is a natural gas formed by disintegration of Radium ^{226}Raan element coming from the Uranium ^{238}U decay series. Emanating naturally from the Earth crust and accumulating in indoor/outdoor environments in near ground level atevery place. From ^{226}Ra decay in 3,82 day the radon gas^{222}Rn appeared emitting alpha particles of energy E_α = 5,49 MeV and others non-gaseous daughter products Polonium, Bismuth (^{218}Po ,^{214}Po and ^{214}Bi) that produces near 50% of equivalent dose of natural ionizing radiation near earth surfaces.In the ground level interface of the earth's atmosphere, ionizing radiation is mainly resulting from radon gas, the telluric radiation from the ground of earth and the primary and secondary cosmic radiation produced in low atmosphere interface [2]. However, it is difficult to separate over time the intensity of ionizing radiation of each component including particles and photons coming to São José dos Campos, as the energies overlap. The telluric radiation is constituted by ^{238}U, ^{235}U, ^{40}K, ^{232}Th series decay products, and it is constant in each specific region [3]. Isotopes ^{214}Pb, ^{214}Po and ^{214}Bi originating from the uranium decay in the earth's crust [4] measure radon gas ^{226}Ra and ^{222}Rn. The primary cosmic radiation consisting mainly of high energy galactic and extragalactic protons and those coming from regions which interacts with the earth's atmosphere produces the EAS (Extensive Air Showers) [5]. The intensity of this radiation is maximal at altitudes between 13 km and 17 km,call (Pfotzer maximum) in the tropics forming secondary cosmic rays flux with muonic, hadronic and electromagnetic components that propagate to the earth's surface in the same region. The low energy neutrons up to 10, 0 MeV present in ground level mostly coming by cosmic rays with (α, n) reactions with surface earth's elements. These radiations cause health problems for the populations on Earth surface and crew more passengers of civil and military aviation. Another possible natural ionizing radiation source in the lower atmosphere of the earth is by electrical discharges between clouds-earth ground; clouds-clouds and earth ground-clouds. X-rays, gamma rays, neutrons and beta particles are produced all the way of the lightning cone [6,7].Other ionizing radiation sources are those in industry, medical or dental clinics and hospitals, but these radiations are mostly controlled in specific and small areas.

II. MATERIALS AND METHODS

Fig. 2– Aerial and ground view of the tower ACA and his environmental field region, GPS coordinates: São José dos Campos, SP, Brazil (23° 12'45" S, 45° 52'00" W).

Figure 2 shows the location where the measurements of the radon gas, gamma, neutron and rainfalls that were carried out below and above the tower of 25 meters of altitude. This place is free from any local human interference.

Radon gas

The radon gas detector is a portable ionization chamber as shown in Figure 3. It is powered with 110 or 220 V. It can measure hourly counts between 0.00 and 10000.00. These counts can be transformed into (pCi/l) or by (Bq/m³) directly by the FTLab application software coming jointly with the detector to acquire the data in Android Smart appliances. This application can generate files on each download and can be saved in .txt. All instructions are given on reference [8].

Fig 3 – Top view of Radon Eye RD200 ionization chamber used for monitoring radon gas [8]

See Figures 4 and 5 for the format of the variations that occurred in the measurements of the ITA made on 12/5/2018. These measures are shown here giving insight into how easy the RD200 is operated about obtaining, storing and manipulating data.

In Figure 3 above is shown the RadonEye RD200 measuring on a table in open space in ITA. The view count of 0.43 (pCi / l) represents the value at the last hour that the ionization chamber made measurements. By means of an ITunes software installed on an IPhone you get the data that is already plotted on the screen of the IPhone as indicated by Figures 4 and 5. A maximum time of measurements for the Radon Eye RD200 can be considered up to six months in hourly sequence as shown in Figure 4 obtained in ITA via IPhone on 12/05/2018. For periods longer than 6 months, both the acquisition data and download of measures are very slow in time.

ISSN 2348 – 8034
Impact Factor- 5.070

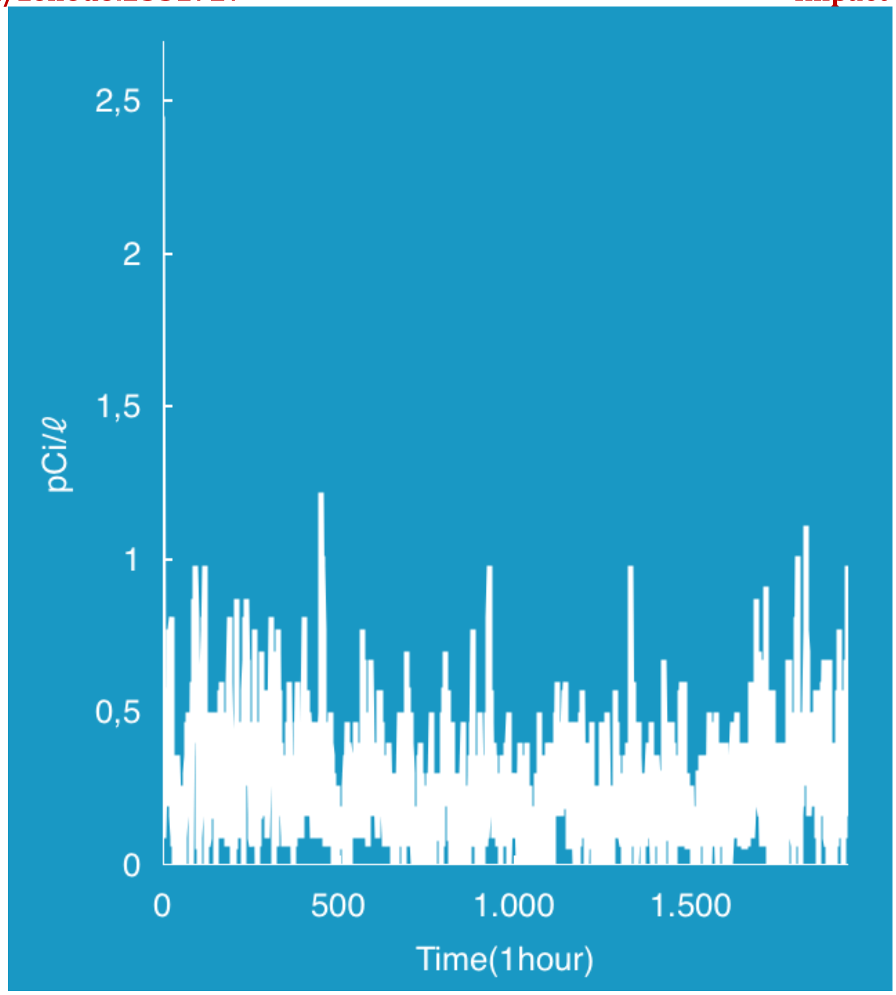

Fig. 4 – Monitoring of 1943-hour series from Radon Eye RD200 in ITA using (pCi/l) unit.

Gamma detector

To monitor the gamma radiation in interval between 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 1700 VDC and with data acquisition system provided by the company (Aware Electronics-Inc., USA).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 [9]. 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 gamma radiation.

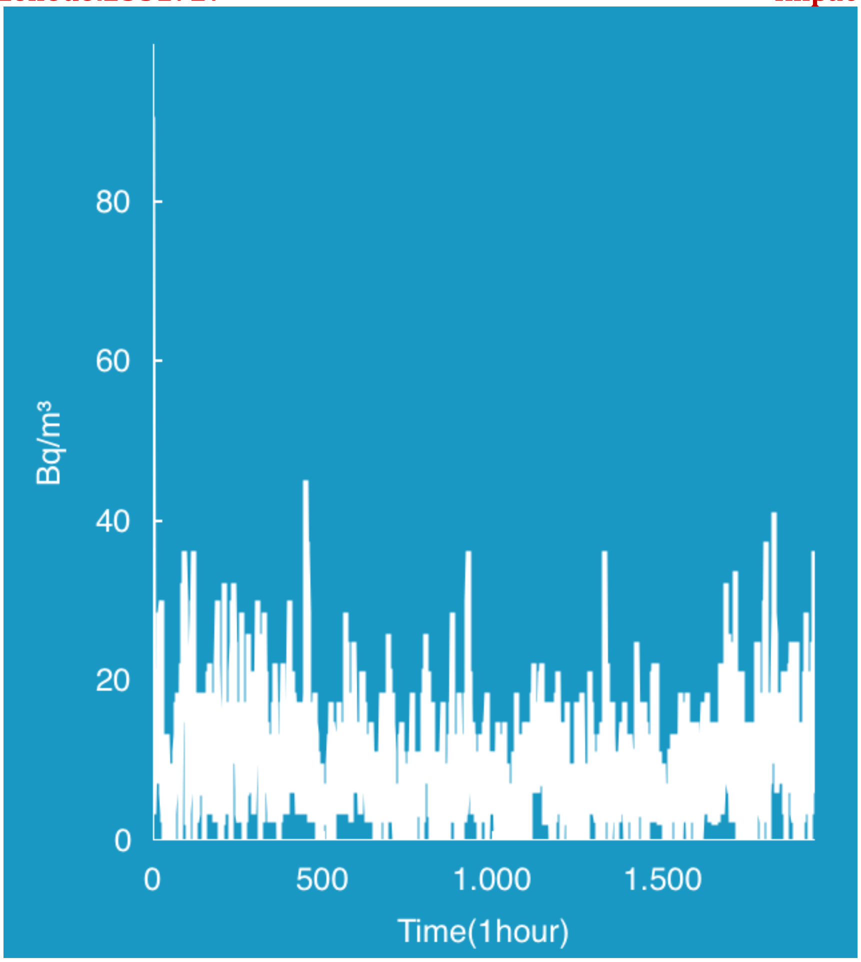

Fig. 5 – Monitoring of 1943-hour series from Radon Eye RD200 in ITA using (Bq/m³) unit.

Neutron detector

A standard He^3Helium detector (Ludlum® tube model 25311 of 250 *cm²* area, pressure 3800 *Torr*, operating voltage, 1750 *V*), was used for thesemeasurements. Neutron registration efficiency of such detector tube is inversely proportional to neutron energy, reaching about 80% for thermal neutrons [10]. The detector was calibrated in aexperimental instrumentation laboratory, using a neutron source of (Am-Be)-Americium-Beryllium.

The analog signals are converted into digital signals by a built-in circuit (PMI-30) that also powers the He-3 tube and can vary the voltage from 1200 to 2000 VDC, where the technical details are on the American company website (Aware Electronics Inc. - USA) [11].

III. RESULTS AND DISCUSSIONS

Throughout 2018 the presence of radon gas close to the ground (ITA) and 25 meters high in the Tower (ACA) was measured. Figure 6 shows the measurements performed between April 24 and May 28, 2018. During this period, the maximum peak of radon gas reached 2.0 pCi / l and an average of 0.5 pCi / l. It was also clearly observed the 24 hours smoothed evidence of day / night changes in the presence of the radon gas.

ISSN 2348 – 8034
Impact Factor- 5.070

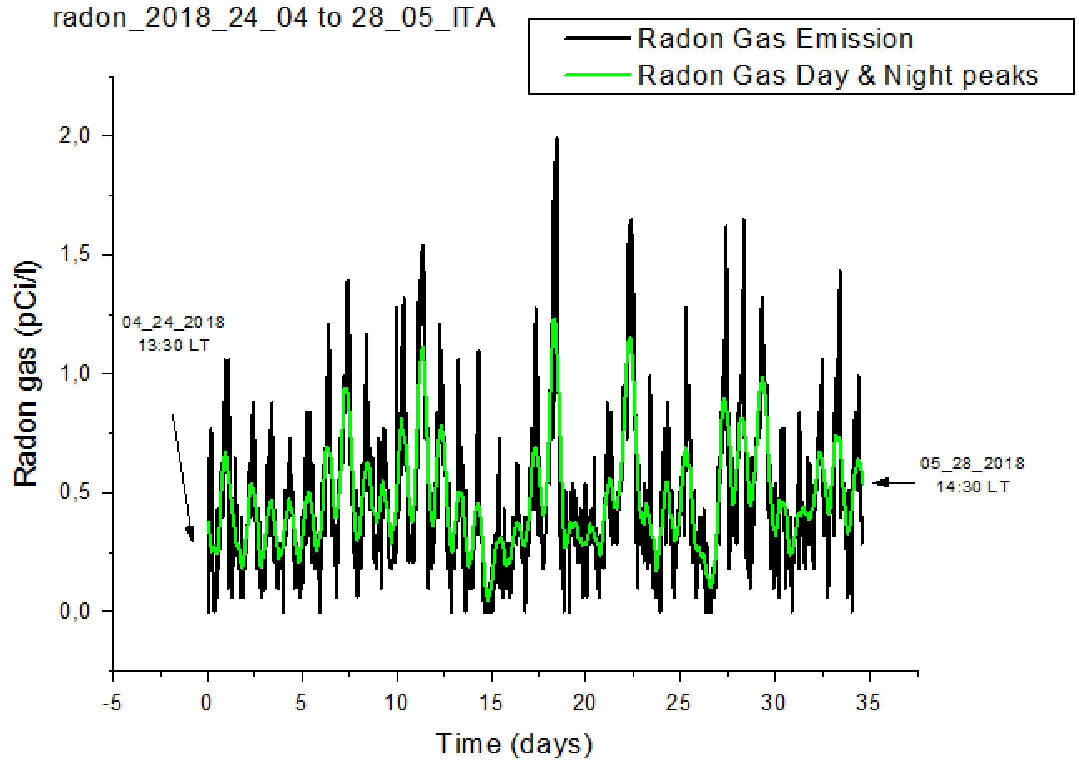

Fig. 6 – Radon gas measured in ITA during 04/24/2018 to 05/28/2018 with green line showing smoothed curve of one day.

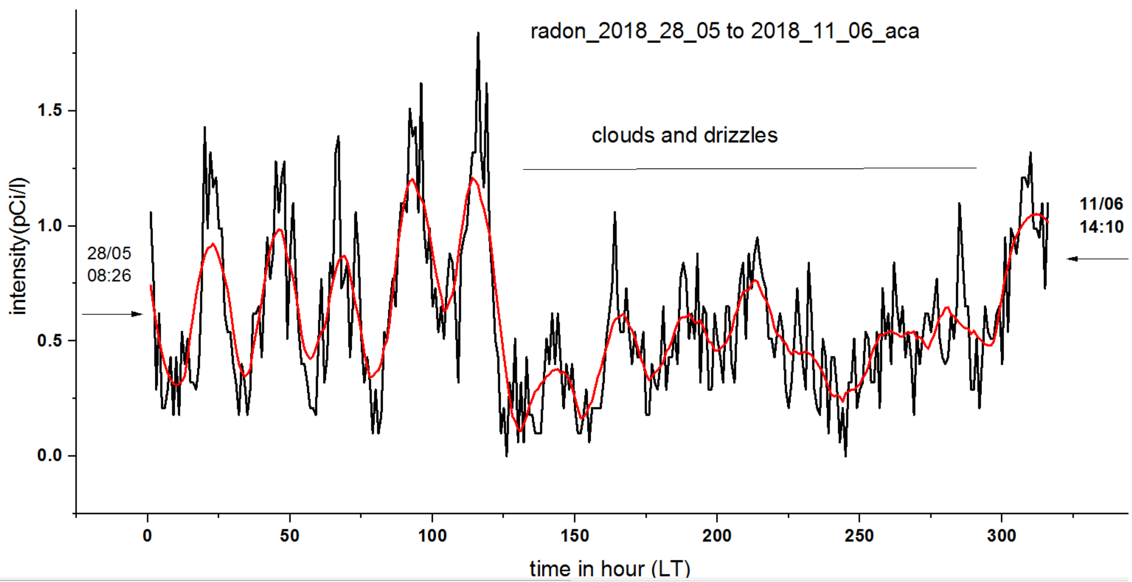

Fig. 7 - Observation of intensity variation in radon gas emanating from the soil in the period 28/05 to 11/06, 2018. The red line show smoothed curve of 24 hours.

It can be observed in Figure 7 that there was an appreciable change in the intensity of radon gas during the period of rains and drizzles in the region of São José dos Campos. This phenomenon is much more remarquable in the measurements made at 25 meters of altitude (ACA).

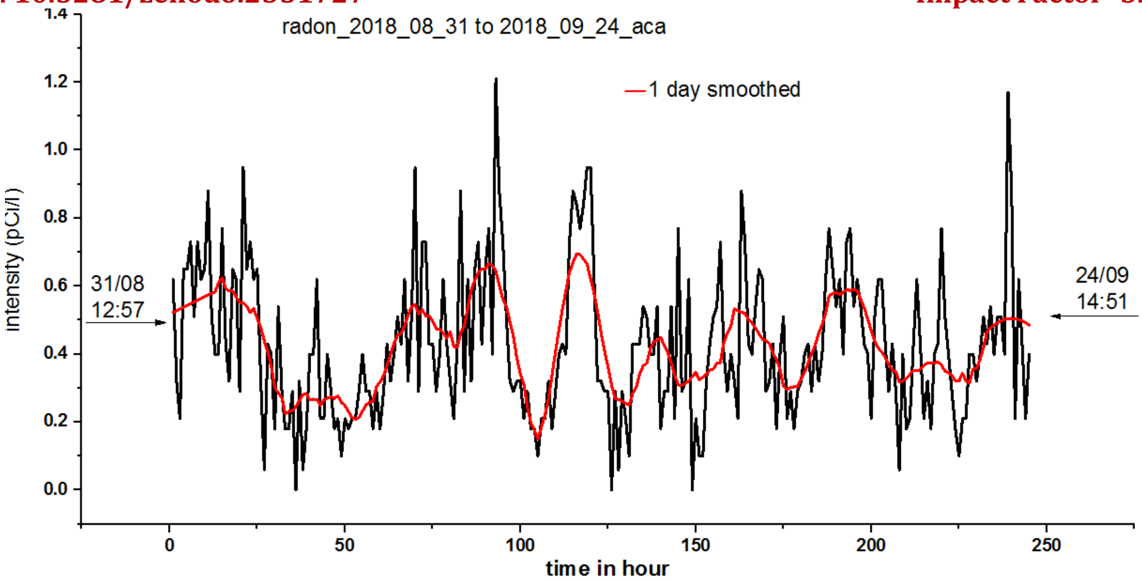

Fig. 8 - Radon gas measurements from 31/08 to 24/09/2018

In the months of August and September 2018 with very few rainfalls and clear ceilings the intensity of radon gas varies less than normal days. Even the day / night variation as indicated by the smoothed red curve of one day (in Figure 8), does not show very clear variation.In the months of October, November and December of 2018 the rains have been more frequent in the region. Between the end of September and the end of November 2018 the sky remained very cloudy in the region. However, in the beginning of December until 2019/02/01the weather was very hot, great insolation and heavy rains during this period. These meteorological phenomena were perceived as shown in Figure 9, in the measurements of radon gas intensity [12].

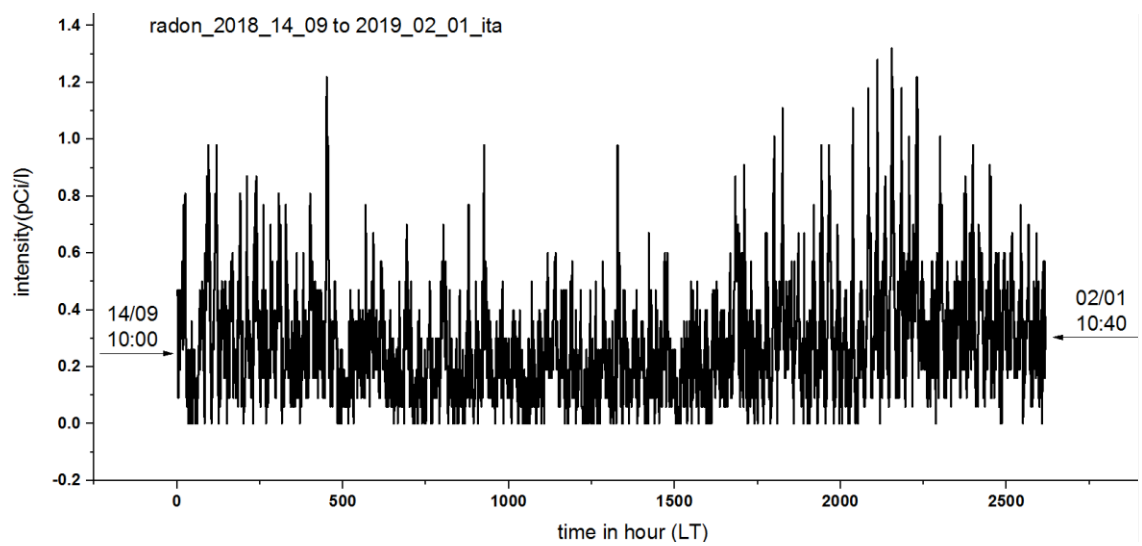

Fig. 9 – Radon gas measurements near ground level (ITA) during 14/09 to 02/01 in 2018 and 2019.

It is noted by comparing the two curved monitoring profiles of Figures 9 and 10, they have approximately the same intensities between 0.2 to 0.6 pCi /l (mean value).

However, in the 25-meter altitude (ACA) the variation profile is more regular then near ground level as a function of time due to shear winds influence on local atmosphere.

ISSN 2348 – 8034
Impact Factor- 5.070

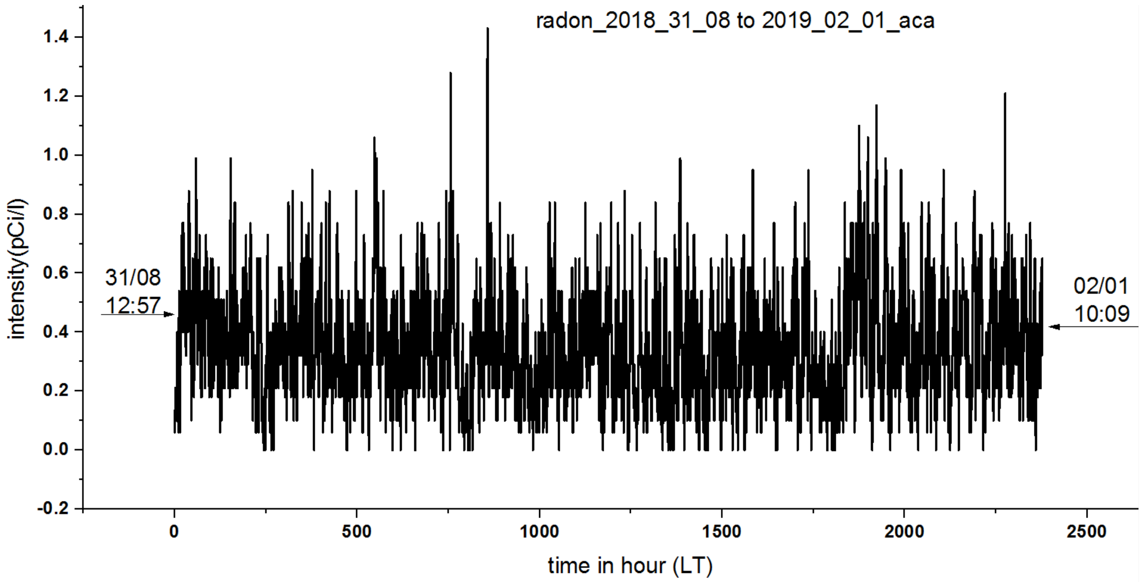

Fig. 10 – Radon gas measurements at 25 meters high level (ACA) during 31/08 to 02/01 in 2018 and 2019.

Gamma ray and neutrons measurements was made only at ACA Tower. In Figure 11 it is showed gamma counts/minute in function of time during 20-22 January 2018.

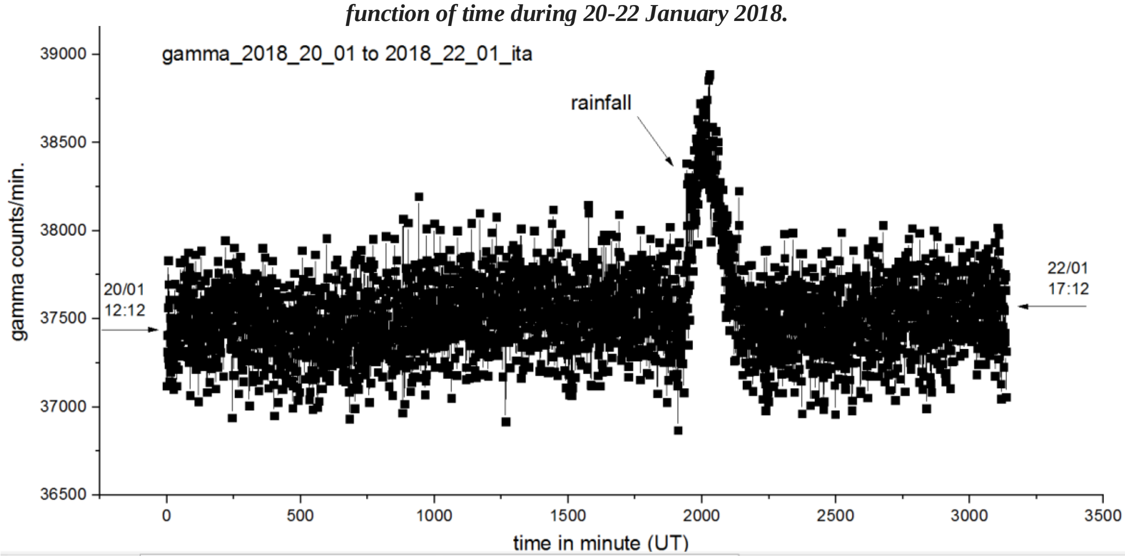

Fig. 11 – Rainfall and increasing effect in low energy gamma ray during 20-22 January 2018.

During all period of monitoring gamma ray showing in Figure12 only one interval of rainfalls occurred near ~ 140000 minute after beginning, with increasing in gamma rays intensity counts.

ISSN 2348 – 8034
Impact Factor- 5.070

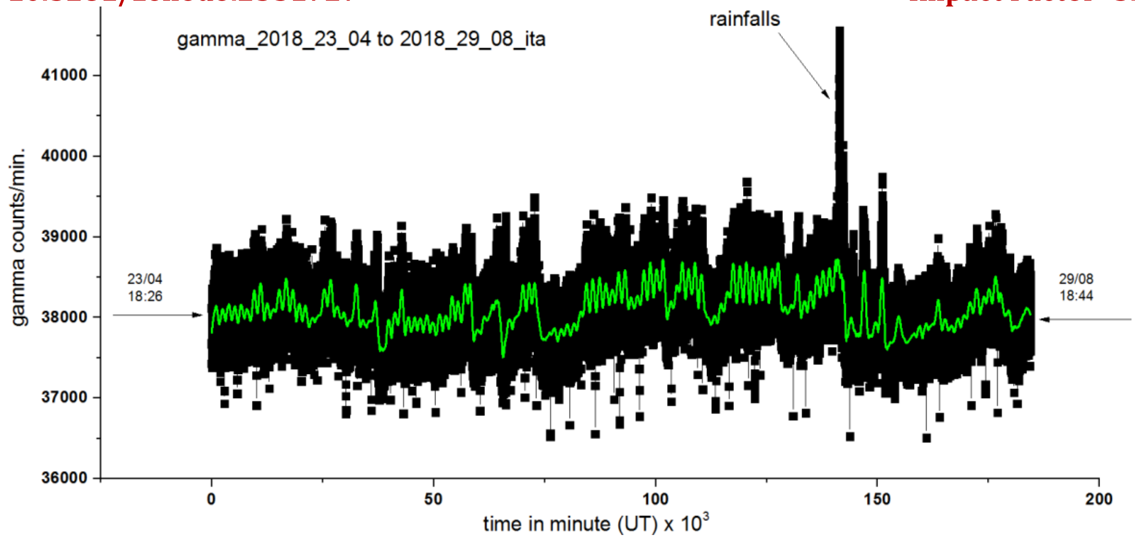

Fig. 12 – Long dryer period without rain and effect in increasing low energy gamma rays intensities during rainfalls time.

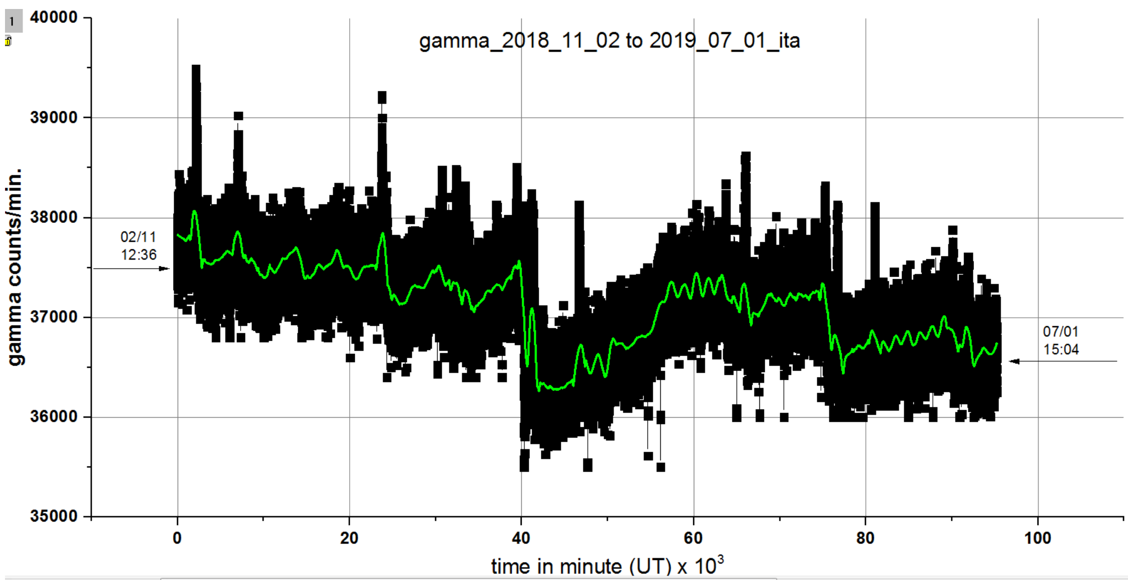

Fig. 13 – Rainfalls and effects in low energy gamma ray measurements duringNovember, December 2018and January 2019.

Heavy and frequent rains cause important variations in the intensity of gamma radiation at the site as seen in the measurements carried out between November 2018 to January 2019 see Figure 13 above.However, it is difficult to quantify the exact correlation between the intensity of rainfall in the soil and the exact intensity increase of gamma ray radiation due to this phenomenon.

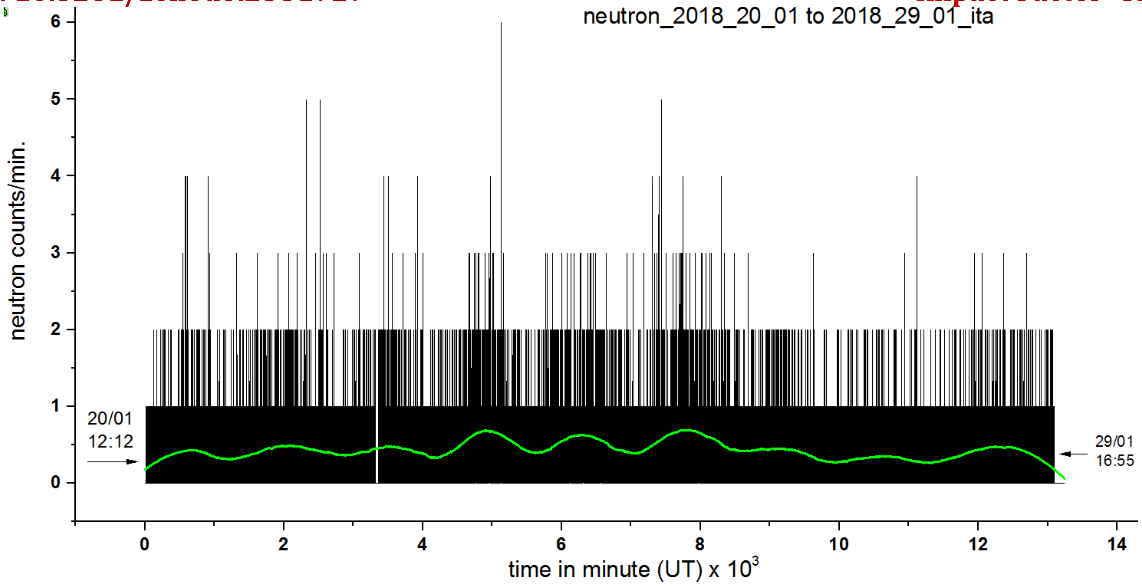

Fig.14Monitoring of neutrons in the ACA tower from January 20 to 29, 2018.

As shown in Figure 11 in the month of January 2018 there was only one weak rain on January 20-22. The presence of this rain was not sufficient in intensity (mm/min.) to increase the presence of neutrons as shown in Figure 14 above due to rainfall effect.

In Figure 15, neutron monitoring is observed during the period from 02/11 to 14/12 of 2018, where there were continued and moderate rains leaving the soil wetter. This is seen in the monitoring of neutrons according to the variation of intensities in counts per minute seen in these curve. However, in Figure 16 it is shown the monitoring of neutron intensities between 17/12 of 2018 to 07/01 of 2019. With intense rains observed during this period the neutron intensities also underwent intense variations.

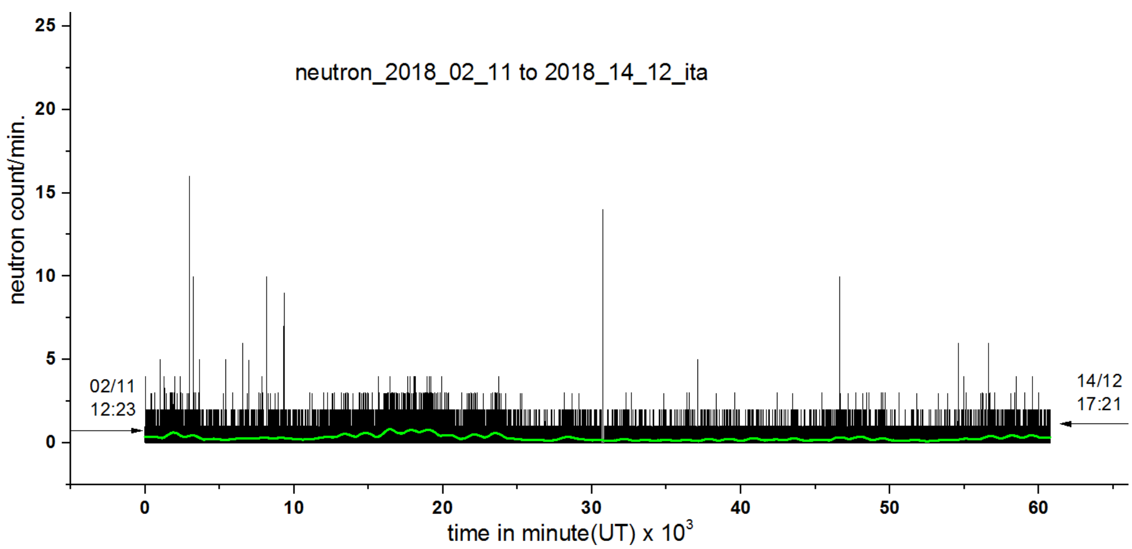

Fig. 15 - Intensity variations of neutron count/min. from 02/11 to 14/12, 2018.

As can be seen in Figures 15 and 16 the measured neutron intensity was higher with intense rainfall in December 2018 and early January 2019. With the surface of the Earth at the well-soaked site there is greater neutron production in this energy range.

This procedure occurs due to the reaction of neutron production through alpha particles with hydrogen contained in the local surface water.

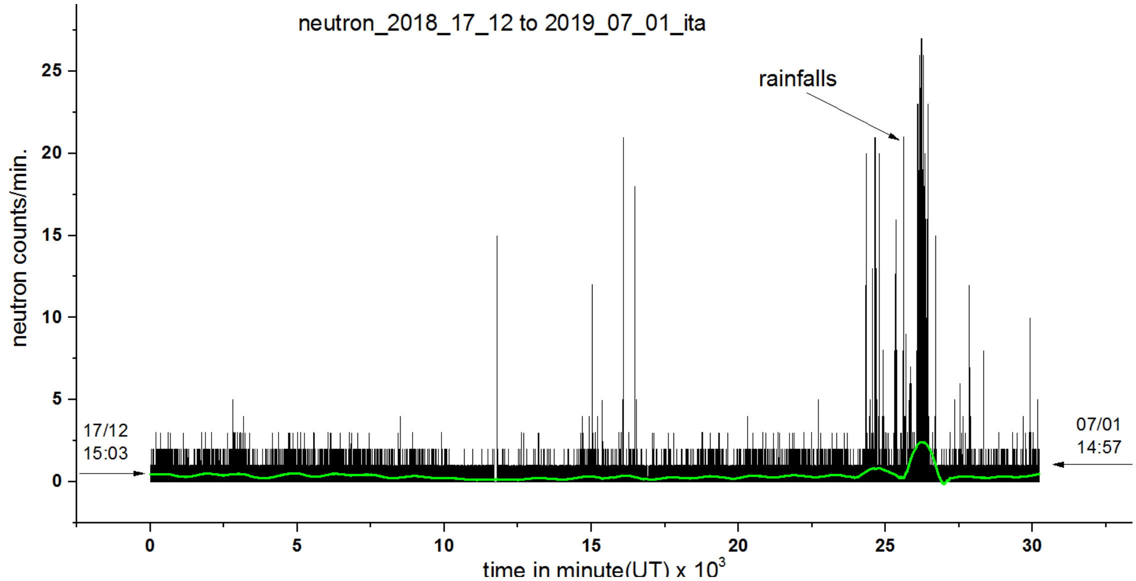

Fig. 16 –Low energy neutrons observed during 17/12, 2018 and 07/01, 2019.

During the month of December 2018, due to the greater intensity of heat (32°C) and higher rainfall intensity in the region, there is a tendency to increase the intensity of radon gas. It is noted in Figures 9 and 10 that in the month of December 2018 due to frequent rains and even intense sun every day an increase in radon gas intensity appeared.

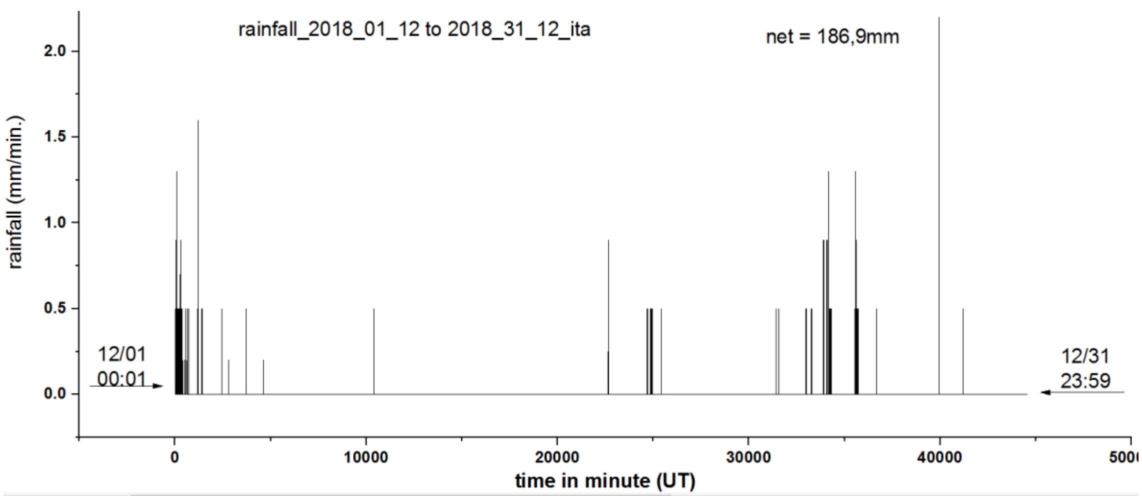

Fig. 17 - Heavy rain that occurred between 01 and 31 December 2018 at the ACA Tower site.

During the entire radon gas measurement period in 2018, the RD200 RadonEye detector described in (Materials and Methods), was used. Both on the surface of the Earth and in the Tower at a height of 25 meters, the monitoring every hour was perfect indicating variations (day / night), and (dry/wet)weather period.

IV. CONCLUSIONS

Throughout 2018 and early 2019, uninterrupted monitoring was performed at both ITA and ACA sites. Next to the soil (ITA) the measurements show better indices of variations of this gas regarding dry weather and wet weather. The day / night variation and the presence of heavy rains and drizzles also clearly affected the presence of radon gas in the region. The same type of variation happens in 25 meters of altitude (ACA) but with less sharpness and intensity of the gas. It is suggested that the presence of shear winds at the height of 25 meters provokes this interference of intensity of local radon gas. However, during all year 2018 the intensity was always below 100 Bq / m^3 as shown by the measurements made in this region.

The intensity of gamma rays and neutrons in the energy interval up to 10.0 MeV was also monitored in 2018 and early 2019. There is a very visible correlation during rains and the increase of both radiations.

V. ACKNOWLEDGEMENTS

Thanks to CNPq (National Counsel of Technological and Scientific Development) and CAPES (Coordination for the Improvement of Higher Education Personnel) by the fellowships grants support to the group's researchers and the ITA Division of Fundamental Sciences for supporting this research. Thanks also to INCT-FNA-ITA to support this research at ITA.

REFERENCES

1. *EPA- https://www.epa.gov/radon/health-risk-radonaccessed in january 2019.*
2. *Magalhães MH1, Amaral EC, Sachett I, Rochedo ER, Radon-222 in Brazil: an outline of indoor and outdoor measurements. Journal of Environmental Radioactivity. (2003), vol. 67, serie 2, pg 131-143.*
3. *Da Silva, A. A. R. and Yoshimura, E.M. Radon and progeny in the city of São Paulo—Brazil, Radiation Measurements 40(2) 678-681, (2005)DOI 10.1016/j.radmeas.2005.06.034.*
4. *TameshigeTsukuda- Radon-gas monitoring by gamma-ray measurements on the ground for detecting crustal activity changes – Bull. Eartq.Research Institute, University of Tokyo, vol (83), (2008), pg. 227-241, Japan.*
5. *Grieder, P.K.F., 2010 – Extensive Air Showers, Book Springer Verlag, Berlin, Heidelberg, Germany.*
6. *N. A. Bui Van, I. M. Martin and A. Turtelli Jr. – Measurements of natural radioactivity at different atmospheric depths. Revista Geofísica, IPGH, numero 28, enero-junio 1988, México.*
7. *Martin, I. M, Measurementsof natural radioactivity in Poços de Caldas, Brazil, Revista Ciência e Cultura, 34(8), 1065, 1982, Brazil.*
8. *RD200 RadonEye - https://www.amazon.com/Radon-Detector-Home-Owner-Plus/dp/B07864XVBH accessed in January 2019.*
9. *Matheus Carlos Silva1, Douglas Carlos Vilela1, Victor G. Migoto1, Marcelo P. Gomes1, Inácio M. Martin1 and Silvério J. Germano1, Ionizing radiation measurements using low cost instruments for teaching in college or high-school in Brazil published to Physics Education, may 2017 see http://iopscience.iop.org/journal/0031-9120.*
10. *Yajima, K., Yasuda, H., Takada, M., Sato, T., Goka, T., Matsumoto, H., Nakamura, T. 2010. "Measurements of Cosmic-Ray Neutron Energy Spectra from Thermal to 15 MeV with Bonner Ball Neutron Detector in Aircraft." Journal of Nuclear Science and Technology 47 (1): 31–39.*
11. *Boardman, B. J.: User's Page. 2015. Aware Electronic Corp. https://www.aw-el.com/Accessed in 07 September 2018.*
12. *Inacio M. Martin, Anatoli A. Gusev and Franklin A. Silva; " Dynamics of Radon Gas Near Ground Level in São José dos Campos Region During April-May 2018" Global Journal of Engineering Science and Researches, Vol. 5 pag. 117-120, DOI: 10.5281/zenodo.1288483, June 13, 2018.*