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Monitoring of radon gas during 2020 year in São José dos Campos, tropical region of Brazil

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Abstract
During the period from January 27 to November 13, 2020, on the ITA campus in the São José dos Campos tropical region of Brazil, the intensity of radon gas close to the Earth's surface was continuously measured every hour. In January, February, March, and April with 1900 hours measured due to the rainfall regime, the average intensity was ~ 15 Bq / m3. From 1900 hours to 5900 hours due to hot sun and very dry surface, the average intensity was ~ 30 Bq / m3. Between 5900 to 6900 hours measured also due to dry weather and very little rainfall in the region, the average measured radon gas returned to ~ 15 Bq / m3. An identical detector was placed at the same time in a tower 25 meters above the ground and the results were practically the same. These measures identified that the radon gas depends on the surface of the dry or wet earth and the intensity of the sunstroke at the location. With a lot of rain, the Earth remains very wet and there is almost no exhalation of radon gas. However, when heavy and fast rains arrive, there is an increase in the instantaneous radon gas due to the washing of this gas in the air molecules suspended in the lower local atmosphere.

I. INTRODUCTION

In the ground level interface of the Earth's atmosphere, ionizing radiation is mainly over time the intensity of ionizing radiation of each component including particles and photons coming from the local atmosphere as the energies overlap. The telluric radiation is constituted by ^{238}U, ^{235}U, ^{40}K, ^{232}Th decay products, and it is constant in each specific region [1]. Radon gas ^{222}Rn is measured by isotopes ^{214}Pb, ^{214}Po, and ^{214}Bi originating from the uranium decay in the earth's crust [2]. The primary cosmic radiation consisting mainly of high-energy galactic and extragalactic protons and those coming from regions that interact with the Earth's atmosphere produces the EAS (Extensive Air Showers) [3]. The intensity of this radiation is maximal at altitudes between (13 -17) km call (Pfotzer maximum). In the tropics forming secondary cosmic rays flux in muonics, 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 at ground level mostly formed by cosmic rays and (α, n) reactions with surface earth's elements. These radiations can cause health problems for the crew and passengers of civil and military aviation and are more intense present at the beginning of the stratosphere at (13 – 17) km. However, this component contributes less to radiation concentration on the Earth's surface. Another possible natural ionizing radiation source in the lower atmosphere of the Earth is produced by electrical discharges between clouds-earth ground; clouds-clouds and earth ground-clouds. X-rays, gamma rays, neutrons, and beta particles are produced of the lightning cone [4]. Other ionizing radiation sources are those used in industry, medical or dental clinics, and hospitals, but these radiations are mostly controlled in specific and small areas. Radon gas is formed on the Earth's surface by the disintegration of Uranium-238, which in 1600 days falls on Radio-226 and after 3.8 days falls on Radionio-222 emitting alpha particles [5]. So one of the best and easiest ways to measure radon gas intensity in a location is to measure alpha particles of energies known per unit of time in that open space, see table 1 below.

b	Isotope	**^{222}Rn** → ^{218}Po → ^{214}Po → ^{210}Po → ^{206}Pb				
	α-particle energy, MeV	5.5	6.0	7.69	5.3	Stable

II. METHOD & MATERIAL

Radon gas RD 200

The radon gas detector is a portable ionization chamber as shown in Figure 1. 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 [6].

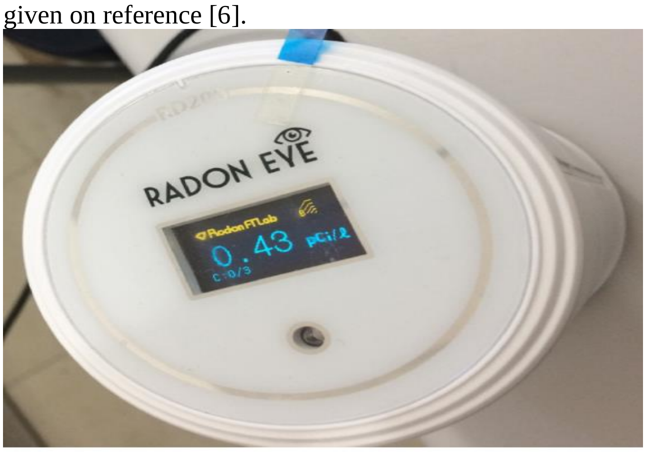

Fig 1 – Top view of Radon Eye RD200 ionization chamber used for monitoring radon gas [6]

In Figure 2 we present variations that occurred in the measurements of the ITA made on 13/11/2020. These measures are shown here giving insight into how easy the RD200 is operated about obtaining, storing, and manipulating data. Figure 1 above is shown the Radon Eye RD200 measuring on a table in an 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. Utilizing iTunes software installed on an iPhone, you get the data that is already plotted on the screen of the iPhone as indicated by Figure 2. A maximum time of measurements for the Radon Eye RD200 can be considered up to one year in hourly sequence as shown in Figure 2 obtained in ITA via IPhone on 13/11/2020. For periods longer than one year, both the acquisition data and download of measures are very slow in time.

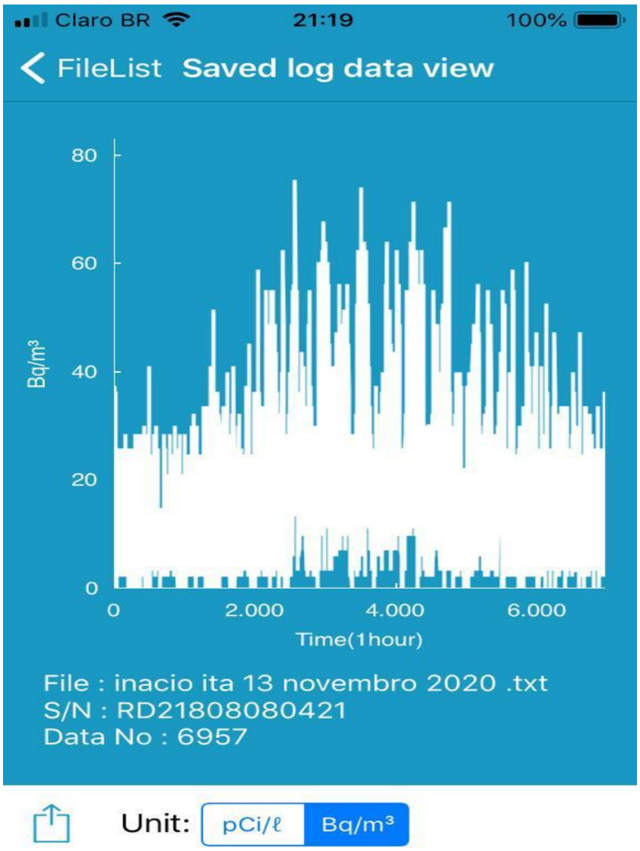

Fig. 2 – Monitoring of 7000-hour series observed by Radon Eye RD200 in ITA using (Bq/m^3) unit, (author).

The same data can be shown in (pCi/l) in a proper smartphone using the FTLab application software. To make clearer that variation in the time it is possible to use the software ORIGIN 2015 and make the graph of all periods of measurements.

III. Results and Discussions

The year 2020 was very rainy between January and March and quite dry and sunny from April to October. From October to the end of November the rained period coming against. This dynamic can be seen in the graph in Figure 2 above. In Figure 3, we plot this graph with the Origin -15 software with hourly values and with a smoothing of 7000 points. See that it reflects very well the rainy region and those dry and sunny days.

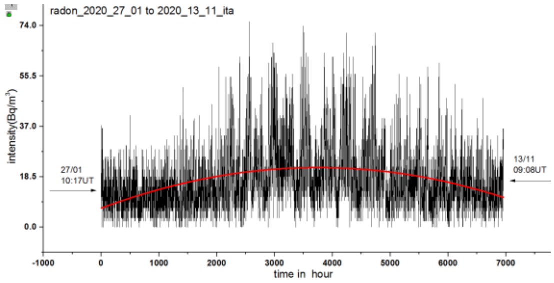

Fig. 3 – The counts/hour of radon gas during the period of January 27 to November 13, 2020. The Redline corresponds to 7000 smoothed points measured in the ITA campus, (author).

During exactly that same time interval, another identical Radon-Eye RD200 detector was placed on top of a 25-meter high tower. This tower is approximately 300 meters distant from ITA. Figure 4 below shows this monitoring. Note that the change between the two identical detectors was minimal as shown in figure 5.

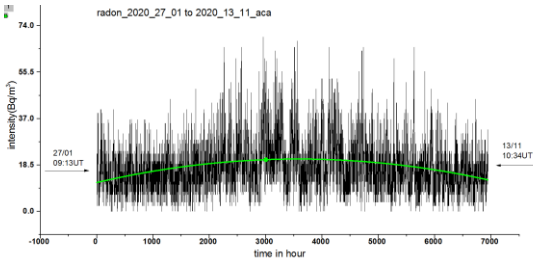

Fig. 4 - The counts/hour of radon gas during the period of January 27 to November 13, 2020. The green line corresponds to 7000 smoothed points measured on the ACA campus, (author).

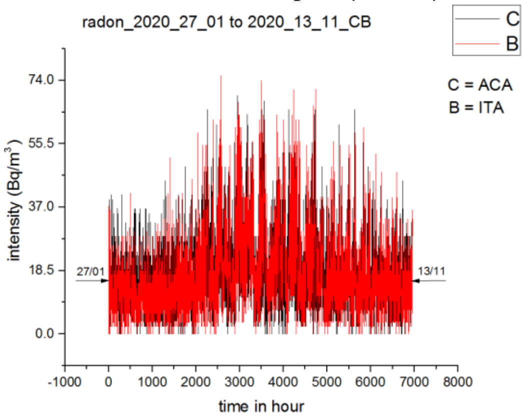

Fig. 5 - Radon gas measurements carried out from 27/01 to 11/13 of 2020 on the soil of ITA(red) and at 25 meters in height at the ACA(dark) tower, (author).

It can be noted that from the beginning of the counts until ~ 1900 hours of measurements, the detector located in the tower has values slightly higher than the ground. In the period from 2900 hours to 4900 hours, this procedure is reversed, that is, the soil detector counts more than from above. Between 4900 to 7000 corresponding to

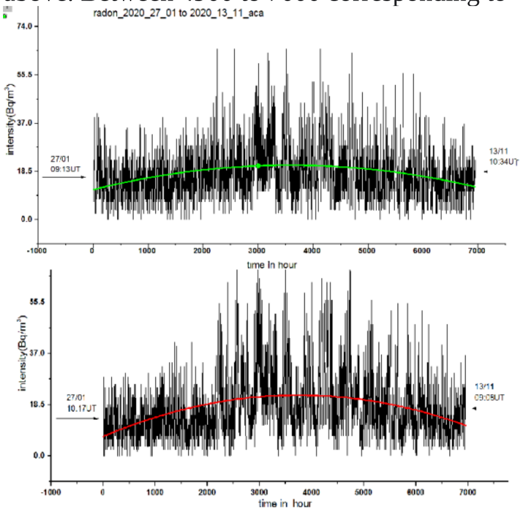

Fig. 6 – Comparison between the intensity of the tower detector 25 meters above the ground (green) and on the ground of the ITA below (red line).

the rainy season, the two detectors count the same values. In general, on sunny days and dry soil during the day, there is a high intensity of radon gas and at night this intensity is reduced. This daily cycle can be seen here in the tropical region of Brazil. See a region from figure 3 between 5900 to 6900 hours from the beginning of the measurements that show this visible (day/night) cycle. Figure 7 shows the measurements made between 5900 to 7000 hours obtained in figure 3, zooming in on this interval with the red curve being a smoothing of the points every hour for 12 hours.

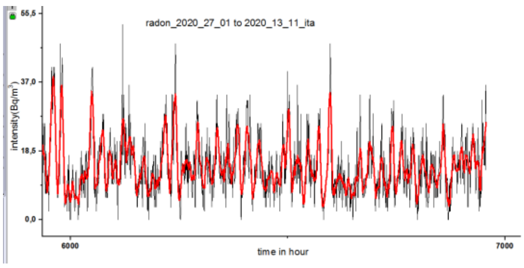

Fig. 7 - Gas radon measurements black line between 6000 to 7000 hours hourly and red with 12-hour smoothing showing (day/night) cycle, (author).

Figure 7 shows the (day/night) cycle of the variation of radon gas in the region. There is always a maximum and a minimum corresponding to 12 o'clock on a sunny day and midnight. Note that the maximum peak values also vary depending on the weather as they are reflecting the local weather conditions. In Figure 8, the measurements per day are also shown for the two detectors.

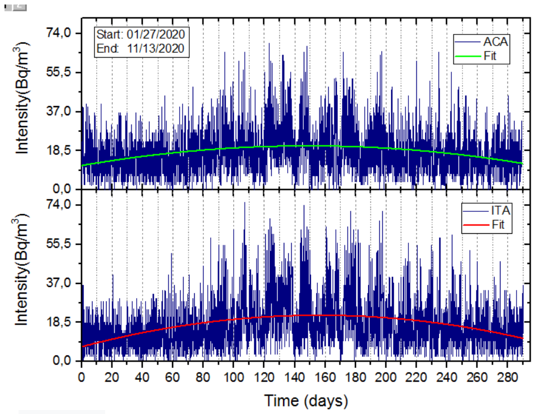

Fig. 8 - Comparison between the intensity of radon in tower detector 25 meters above the ground (green) and on the ground of the ITA below (red line) during 290 days in 2020.

Doing the smoothing in 290 days as shown in figure 8, it is evident that in the dry period and with a lot of sunstrokes there is a visible increase in the radon gas in the region.

IV. Conclusion

The average hourly radon gas intensity was monitored for an extended period of 7000 hours continuously at two locations close to 300 meters on the ITA campus in São Jose dos Campos, SP, Brazil. It was observed that the average values of the measurements were, the intensities varied between (30-70) Bq / m^3 while in the rainy and cloudy period the variation was of (05-30) Bq / m^3. These measures showed the reality of the region because with humid or wet soil there is less exhalation of radon gas from the soil. It was also observed that with dry soil and rapid and intense rains there was an increase in radon gas due to the washing of radon gas suspended in the air in the lower atmosphere.

V. Acknowledgements

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