STUDY OF THE INFLUENCING NATURE OF METEOROLOGICAL FACTORS AIR TEMPERATURE AND RELATIVE HUMIDITY ON THE EXHALATION PROCESS OF ^{222}RN/^{220}RN GASES AT MAT FAULT

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Abstract: *In-situ* online data of ^{222}Rn/^{220}Rn gases, air temperature and relative humidity were measured at Mat fault, Mizoram (India) between May, 2018 and October, 2018 with a frequency of once a month. The measurement was carried out using a ZnS(Ag) alpha scintillation based counter named SMARTRnDuo (Model: BARC, India) equipped with capacitor type digital sensor (Model: DHT22/AM2302) for measuring the air temperature and relative humidity. The hourly and day-to-day variation of ^{222}Rn/^{220}Rn gases were correlated with the simultaneously recorded air temperature and relative humidity. The correlation analysis in general shows that ^{222}Rn and ^{220}Rn gases exhibit a negative correlation with air temperature and a positive correlation with relative humidity for the hourly average data. Understanding the influencing nature of meteorological parameters on ^{222}Rn/^{220}Rn exhalation is of vital importance especially in studies where ^{222}Rn/^{220}Rn gases were used as premonitory gases in order to avoid false signal. Hence the authors believe that the present study will serve as baseline data for future study carried out in the region related to ^{222}Rn and ^{220}Rn.

Keywords: ^{222}Rn/^{220}Rn; Mat fault; meteorological factors; correlation

1. Introduction:

In the earth crust, ^{222}Rn and its isotopes are released into the pore space of the soil by the process of *emanation* from the solid matrix containing their parent nuclei. Out of the several isotopes ^{222}Rn ($T_{1/2}$=3.8 days), ^{220}Rn ($T_{1/2}$=55.6 s) and ^{219}Rn ($T_{1/2}$=3.6 s) occur naturally and were from the decay series of ^{238}U, ^{232}Th and ^{235}U, respectively. After emanation, they travel toward the surface mainly by diffusion process and sometimes by advection [1, 2]. The diffusion process of radon gas through the soil was known to be deflected by geophysical phenomena intervening through the region; hence it has been extensively monitored from the past till date in the hope to predict seismic activity [1-9]. Beside geophysical phenomena, meteorological effect is one of the most influencing factors on radon exhalation process and hence must be identified and filtered out to avoid false signal, especially in case where radon data was measured for seismic forecasting. In the present study, an *in-situ* online data of ^{222}Rn, ^{220}Rn, air temperature and relative humidity were generated at Mat fault at the interest of developing a reference database for future studies based in the region especially related to seismic activity. The measurement was carried out between May, 2018 and October, 2018 with a frequency of once a month from a selected 9 grid location formed at one of the most prominent fault in Mizoram, Mat fault (Figure 1).

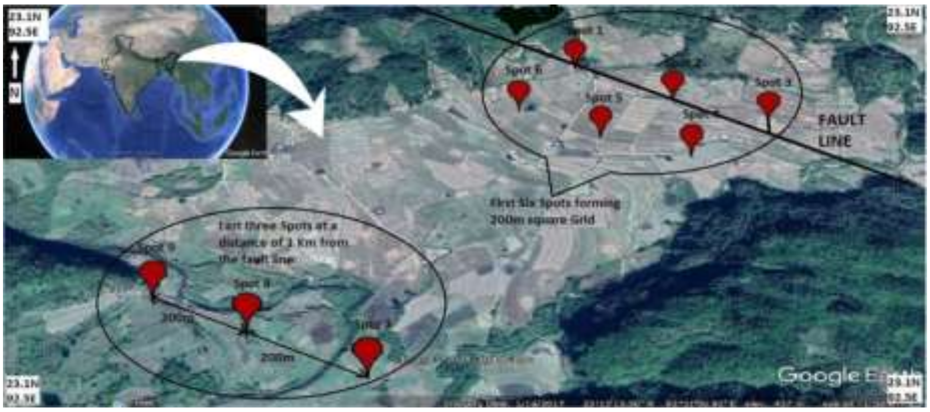

Figure 1: Map of the study area and formation of grid at Mat fault [2].

An indigenously developed and calibrated scintillation counter (Model: *SMARTRnDuo*, BARC, Mumbai, India) was deployed for measuring the radon data and meteorological data. From the analysis, it was observed that the two meteorological factors have a significant influence on the exhalation process of ^{222}Rn and ^{220}Rn gases and their diurnal and day-to-day effect on the two gases were also discussed in detail. According to BIS [10], Northeast India belongs to the highest seismic level (Zone V) and is one of the most seismically active regions of the world. Hence generating data and developing literature to describe the geophysical nature of the region is of vital importance as a natural disaster like an earthquake can harm human being in many ways. The authors hope the present study will serve as baseline data for such studies in the region.

2. Materials and method:

A scintillation counter named SMARTRnDuo equipped with a capacitor type digital sensor (Model: DHT22/AM2302) was deployed for measuring the ^{222}Rn/^{220}Rn data and meteorological data at Mat fault. It was developed and calibrated by Bhabha Atomic Research Centre, Mumbai, India. A rectangular grid of 9 spots (1000 m x 400 m) was formed within the fault line of Mat fault (Figure 1) and recorded the radon and meteorological data at each spot between 5:00 and 17:00 hours of Indian Standard Time (IST) every time the field was visited. An accumulator chamber of 3.1×10^{-5} m^3 was placed at the soil-air interface; the metal-earth interface was secured in such a way that no atmospheric air might be sampled (Figure 2).

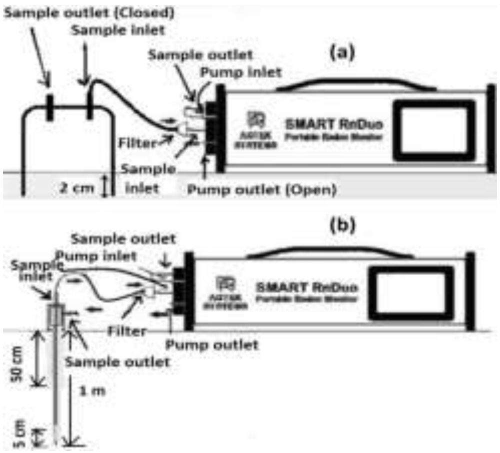

Figure 2: Experimental set-up of the instrument for measurement using (a) accumulator chamber and (b) soil probe.

Now the accumulator chamber was connected with a rubber tube to the SMARTRnDuo and the inbuilt pump draws in the sample gas for 5 minutes through a progeny filter and simultaneously counted alpha particles from ^{222}Rn and ^{220}Rn together. The counting of alpha particles was delayed for 5 minutes to decay out thoron gases ($T_{1/2}$=55.6 s) from the sample gas and then restart counting for the following 5 minutes which attribute the counts of ^{222}Rn and some long-lived alpha particles. The counts of ^{220}Rn gas from the sample were obtained by the difference of the first 5 minutes counts and the last 5 minutes counts. During these 15 minutes cycle, the digital sensor simultaneously records the air temperature and relative humidity of that particular spot. Hence the $^{222}Rn/^{220}Rn$ data were an average of 5 minutes sampling while air temperature and relative humidity were an average of 15 minutes sampling. After 15 minutes the accumulator chamber was replaced by a soil probe of length 1 m to draw sample gas at 5 cm, 50 cm and 1 m depths (Figure 2). A time of 15 minutes was spent at each sampling depth hence a time of 1 hour was required at each spot for acquiring $^{222}Rn/^{220}Rn$ data of the four depths. After assessing $^{222}Rn/^{220}Rn$ data of the four sampling depths at spot 1 it was proceeded to spot 2 and so on till spot 9. The 9 sampling spots were located within a small rectangular area (1000 m x 400 m) of the fault where the geomorphology and topography of the soil and diffusion process of the gases were assumed to be uniformed. Hence shifting of measuring spots within the said area was the same as a station measurement from any spot within the rectangular area. The sampling procedure makes a particular sampling depth resample after every 1 hour and the measurement was completed between 5:00 and 17:00 hours of IST for each field visit. Details of the method adopted and procedure for operating the instrument were already given by Thuamthansanga and group [1-2]. A two tail t-test at 95% confidence interval was performed to check the significance of correlation between any two data.

3. Result and discussion:

A 5 minutes average $^{222}Rn/^{220}Rn$ data and 15 minutes average air temperature and relative humidity data were generated at Mat fault between May, 2018 and October, 2018. The data were generated with 1 hour frequency within 12 hours of each 1 month frequency field visit. The study period comprises the rainy season of the region hence it is a suitable period to study the meteorological influence of $^{222}Rn/^{220}Rn$ exhalation rate especially due to precipitation and humidity. The recorded $^{222}Rn/^{220}Rn$ data and meteorological data were extracted from the instrument and analysed to observe the diurnal and day-to-day variation of the isotope pair with the meteorological data. Details of correlation between the radon and meteorological data are given in Table 1, Table 2 and Figure 3. Table 1 shows details of the correlation between radon and meteorological data's generated with a frequency of 1 hour's between 05:00-17:00 hours of each field visit. From Table 1 the diurnal variation of ^{222}Rn data shows a reverse correlation with air temperature while a positive correlation coefficient with relative humidity at all the four sampling depths (Figure 3, Table 1). But when tested the significance of the correlation, ^{222}Rn data shows no significant correlation with air temperature and humidity at all the four sampling depths (Table 1). Hence the influence of temperature and humidity on the exhalation process of ^{222}Rn was uncertain though it shows a distinctive trend with both the variable.

Table 1: Details of correlation between 5 minutes average $^{222}Rn/^{220}Rn$ data and 15 minutes average air temperature and relative humidity data assessed between 5:00 and 17:00 hours of IST. (Correlation Coefficient=r: Significance (p-value)=Sig.)

Sampling Depth/Variable		**Soil-Air Interface**		**5 cm depth**	
		^{222}Rn	**^{220}Rn**	**^{222}Rn**	**^{220}Rn**
Temperature	**r**	-0.026	-0.345	-0.124	-0.521
	Sig.	0.853	0.011	0.381	7.5E-05
Humidity	**r**	0.183	0.364	0.088	-0.010
	Sig.	0.189	0.007	0.533	0.946
Sampling Depth/Variable		**50 cm depth**		**1 m depth**	
		^{222}Rn	**^{220}Rn**	**^{222}Rn**	**^{220}Rn**
Temperature	**r**	-0.172	-0.466	-0.001	-0.422
	Sig.	0.214	0.0004	0.993	0.001
Humidity	**r**	0.089	0.389	0.069	0.319
	Sig.	0.523	0.004	0.619	0.019
No. of Data points= 54 for each parameters					

Diurnal variation of ^{220}Rn gas, like radon, shows a reverse correlation with air temperature and a positive correlation with humidity at all the sampling depths except at 5 cm depth. At 5 cm depth ^{220}Rn and humidity has a reverse correlation coefficient and the p-value of the correlation indicates that this correlation was insignificant

(Table 1). Considering it as an outlier data the correlation between ^{220}Rn, temperature and humidity was significant in all the other cases. Hence in general it was concluded that humidity enhance thoron exhalation process while air temperature suppress it. The same observation was made by Jaishi and group [11-12] and Thuamthansanga and group [1] at the same fault. At the same time, some authors [13-15] reports expansion of soil-gas radon with increase in air temperature, which enhance radon exhalation rate and hence their direct relationship. To a certain optimum level of moisture content in the soil, it prevents burying of the radon particle in the adjacent soil grain during the emanation process which increases its concentrations in the soil. The optimum level was reported to be 15-20% by weight by Stranden and group [16] and Schumann and group [17].

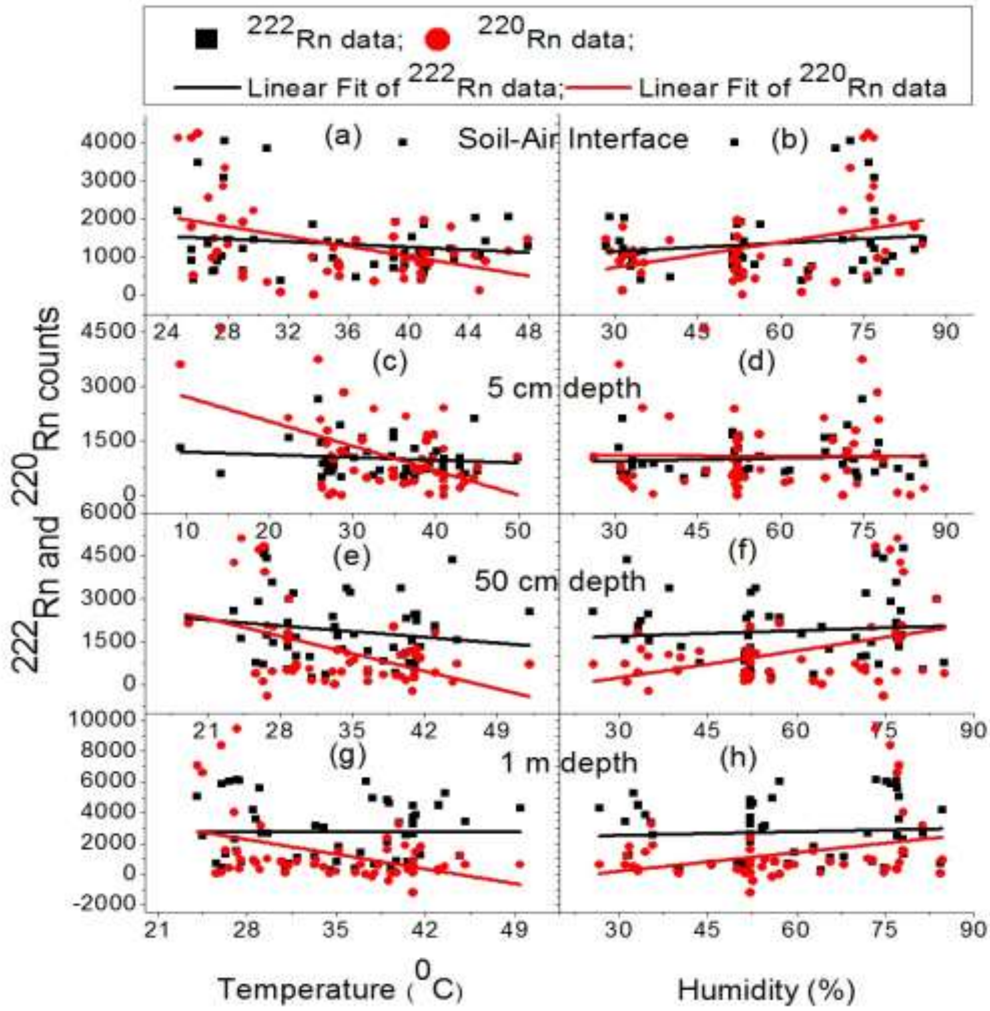

Figure 3: Plot of ^{222}Rn/^{220}Rn versus air temperature and relative humidity at the (a, b) soil-air interface, (c, d) 5 cm, (e, f) 50 cm and (g, h) 1 m depths for data's generated with 1 hours sampling frequency 1 month frequency field visit between May, 2018 and October, 2018.

The hourly recorded ^{222}Rn/^{220}Rn data and meteorological data were average daily and correlated to observe the day-to-day meteorological influence on ^{222}Rn/^{220}Rn exhalation rate. It was observed that at a sampling depth closed to the surface that is at the soil-air interface and 5 cm depth ^{222}Rn data has a positive correlation with air temperature but a negative correlation at the two later sampling depths away from the ground surface (Table 2). The opposite was observed between relative humidity and ^{222}Rn data where negative and positive correlations between the two data's were observed at depths near and away from the ground surface, respectively (Table 2). ^{220}Rn data, on the other hand, maintained its nature of correlation with the two meteorological parameters as that of the diurnal variation that is a reverse and direct correlation with air temperature and relative humidity, respectively (Table 1&2).

Table 2: Correlations of 24 hours average $^{222}Rn/^{220}Rn$, air temperature and relative humidity data.

Sampling Depths	**^{222}Rn**		**^{220}Rn**	
	Temperature	Humidity	Temperature	Humidity
	Correlation Coefficient (r)	Correlation Coefficient (r)	Correlation Coefficient (r)	Correlation Coefficient (r)
Soil-air Interface	0.5	-0.3	-0.7	0.7
5 cm	0.4	-0.2	-0.4	0.3
50 cm	-0.01	0.2	-0.6	0.8
1 m	-0.8	0.7	-0.01	0.0

No. of data points=10 for each parameters

In most studies, in order to show the meteorological influence on radon exhalation rate, average value of both the data's were often taken for more than one day and in some cases even a week or more where a passive sampling method is deployed. The study highlights how one can miss the actual nature, that is, the diurnal variation of radon exhalation under the influence of meteorological factors. It also depicts that the day-to-day variation of radon exhalation rate need not be in the same manner as that of the diurnal variation, that is, the date on which average radon data is high necessarily need not to be the date with low air temperature or high humidity and vice-versa. Determining significance of the correlation was neglected for this portion as the sample size was too small but was included to simply differentiate the trend from the diurnal variation. Hence it was concluded that to observed the real nature of meteorological influence on $^{222}Rn/^{220}Rn$ exhalation rate the sampling frequency must be narrowed down to at least some hours and has been 1 hour in the present study.

4. Conclusion:

The study shows that during rainy season of the region air temperature and relative humidity has reverse and direct correlation with $^{222}Rn/^{220}Rn$ exhalation, respectively. Significant correlation was observed between thoron and the meteorological factors while that of radon was uncertain though a distinct trend was obtained. It also highlights how one could miss the real characteristic influence by a large sampling interval. Though diurnally the meteorological factors might have direct or reverse correlation with the two isotope pair doesn't necessarily mean that their exhalation rate of two different days under the same meteorological condition should be equal. Hence in order to observe the real characteristic nature of meteorological influence on $^{222}Rn/^{220}Rn$ exhalation rate, diurnal variation must be considered rather than day-to-day or more variation. Identifying and filtering of radon fluctuation due to meteorological effect is of vital importance where radon data is monitor for geophysical prospecting to avoid false signal. Hence the authors hope the present study will serve as reference data for future studies carried out in the region especially in a field where radon monitoring is used for forecasting seismic activity.

Acknowledgements:

This work was supported financially by DAE-BRNS, BARC, Mumbai, India [Sanction Order No.:36(4)/14/66/2014-BRNS/36024 Dt.26.02.2016.].

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