





# Radon gas emissions during the 2021 Tajogaite eruption at Cumbre Vieja Volcano (La Palma, Canary Islands)

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#### Introduction

On 19 September 2021, the largest historic eruption of La Palma began, naming the Tajogaite volcano, at the W flank of Cumbre Vieja volcanic ridge. It was active for 85 days, ending on 13 December 2021.

During the eruptive and post-eruptive periods, <sup>222</sup>Rn measurements were carried out across the affected areas to assess the radiological impact of this volcanic episode on La Palma inhabitants.

#### Method

- Eighty CR-39-SSNT (solid state nuclear track) detectors were set up at workplaces and dwellings located mainly in the vicinity of the eruption. Exposure time was ca. 90 days (from September 2021 to January 2022), though only 77 detectors could be retrieved due to the effects of lava flows.
- Two portable RadonScout devices (SARAD GmbH) were used for continuous monitoring (1 h integration time) of radon gas and meteorological variables (air temperature, humidity and barometric pressure). They were installed inside two buildings located 2,5 (*El Arenero*) 5 km (*Visitor Centre*) from the eruptive fissure.









#### **Results – SSNT radon measurements in dwellings**



a) 80% of the CR-39-SSNT radon concentrations were < 300 Bq/m<sup>3</sup> (reference level, Directive 2013/59/Euratom; Royal Decree 1029/2022).

b) Compared to other areas of the island, a large percentage of radon levels (25%) were above 300 Bq/m<sup>3</sup> in the inhabited Aridane valley (>25,000 inhabitants), the area most affected by the volcanic eruption.





### **Results – SSNT radon measurements in dwellings**



At the Aridane valley, <sup>222</sup>Rn levels exhibit a spatial pattern with higher values at shorter distances to the eruptive centre (a, b), in contrast with areas at largest distances (Fuencaliente and Santa Cruz de La Palma) (c).













#### **Results – Effective dose due to <sup>222</sup>Rn contribution**

The effective dose due to the contribution of  $^{222}$ Rn (D<sub>Rn</sub>) was computed by using the equation:

$$D_{Rn}$$
 (mSv/y) =  $C_{Rn} \cdot D \cdot H \cdot F \cdot T$ 

Where:

 $C_{Rn} = {}^{222}$ Rn concentration (Bq/m<sup>3</sup>) D = Dose conversion factor (9 · 10<sup>-6</sup> [mSv · m<sup>3</sup> Bq / h]) H = Occupancy factor (0.5) F = Equilibrium factor (0.4) T = Occupancy time (8760) [h/y]

The **computed effective dose** was 0.3 mSv after 3 months of eruption, which, extrapolated to the annual reference value, provides an estimated effective dose of 0.9 mSv/y. This value is 50% lower than the estimated worldwide annual average dose from natural and artificial radiation sources (2.4 mSv/y) (UNSCEAR 2000). Thus, radon levels did not lead to a significant increase in exposure level to this radioactive gas during the Tajogaite eruption.









#### **Results – Continuous radon monitoring (hourly data)**



Dayssince 19/09/2021





#### **Results – Continuous radon monitoring**

El Arenero



			TER Instituto Energías	Tecnológico y de Renovables	Universidad de La Laguna
El Arenero					
Spearman Corr.	Rn	т	н	Р	
Rn	1				
т	0.02	1			
н	-0.11	-0.79	1		
Р	-0.08	0.89	-0.70	1	

	Coefficients of PC1	Coefficients of PC2
Rn	0.056	0.987
Т	0.597	-0.049
Н	-0.554	-0.083
Р	0.576	-0.125

At the El Arenero site, closer to the volcano, PCA, correlation matrix, and MLR analyses showed no significant correlation between radon and meteorological variables.

	Percentage of					
Eige	envalue	Variance	Cumulative			
1	2.57	64.3	64.3			
2	1.01	25.3	89.6			
3	0.31	7.67	97.2			
4	0.11	2.78	100			

El Arenero (MLR)									
	Intercept	Intercept	T (ºC)	T (ºC)	H (%)	Н (%)	P (mbar)	P (mbar)	Statistics
				Standard		Standard			
	Value	Standard Error	Value	Error	Value	Error	Value	Standard Error	Adj. R-Square
Radon									
(Bq/m³)	22,343.85	3,386.97	13.63	8.55	-19.12	2.542	-22.78	3.79	0.037





#### **Results – Continuous radon monitoring**

Visitor Centre







Visitor centre				
Spearman Corr.	Rn	т	Н	Р
Rn	1			
т	0.16	1		
н	-0.12	-0.62	1	
Р	-0.18	-0.037	-0.08	1

	<b>Coefficients of PC1</b>	Coefficients of PC2
Rn	0.15	0.702
т	0.687	0.046
н	-0.69	0.044
Р	0.15	-0.708

At the Visitor Centre, the same analysis (PCA, correlation matrix, and MLR analyses) showed slightly higher correlation indixes.

	Eigenvalue	Percentage of Variance	Cumulative
1	1.65	41.5	41.5
2	1.17	29.3	70.7
3	0.795	19.9	90.6
4	0.375	9.38	100

Visitor centre (M	ILR)								
	Intercept	Intercept	T (ºC)	T (ºC)	Н (%)	Н (%)	P (mbar)	P (mbar)	Statistics
				Standard		Standard		Standard	
	Value	Standard Error	Value	Error	Value	Error	Value	Error	Adj. R-Square
Radon( Bq/m <sup>3</sup> )	2,457.72	263.01	1.01	0.31	-0.16	0.079	-2.63	0.28	0.04084





0.25

1.00

4.00

16.00

0

20

Period (days)

#### **Results – Continuous radon monitoring**

**CWT Rn** 





# El Arenero

At **El Arenero** site, located 2.5 km from the volcano, wavelet analysis does not show common frecuencies in the frequency domain for radon and meteorogical variables time series.

Interestingly, the radon timefrequency structure changes during the last two weeks of the eruption (weak 0.25 cpd band).





CWT P

Time (days)

40

60



CWT T









#### **Results – Continuous radon monitoring**





**CWTH** 

## Visitor Centre

At the *Visitor Centre*, located 5 km away from the volcano, common frequencies (1 cpd) for radon and air temperature and relative humidity are observed during the first month and the last 2 weeks of the eruption.













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#### **Results – Continuous radon monitoring**



Higher radon levels and anomalous temporal patterns are observed at the monitoring site closer to the volcano (El Arenero):

- 27/09/2021: Short eruptive calm (hours) followed by a reactivation with strong discharge rate increase and phreatomagmatic pulses
- (2) 15-21/10/2021: Relative discharge rate increase
- (3) 9-15/11/2021: Relative discharge rate increase
- (4) 27/11-02/12/2021: Relative discharge rate increase
- (5) 13/12/2021: Short period of higher explosivity (hours) and eruption end











#### Conclusions

- ✓ During the Tajogaite eruption (Cumbre Vieja, La Palma, 2021), a spatial pattern of radon increase with decreasing distance to the volcano was observed.
- ✓ Transient radon bursts, not correlated with meteorological variables, were observed simultaneously to changes in the eruptive activity (relative discharge rate increases, opening of new eruptive fissures, and phreatomagmatic pulses).
- These space-time patterns of radon might be interpreted as associated to permeability changes caused by magma injection and/or to the atmospheric expansion of the volcanic plume.
- ✓ The annual effective dose due to the <sup>222</sup>Rn contribution was 0.9 mSv/y, 50% lower than the estimated worldwide annual average dose from natural and artificial radiation sources (2.4 mSv/y) (UNSCEAR 2000). Thus, the eruption did not lead to a significant increase in the radon exposure level of the population in La Palma island.









#### Acknowledgments

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#### References

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