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Impact of Climatic Changes on Radon Concentrations in Indoor Environments and Soil in Tirana, Albania

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ABSTRACT: This study investigates the impact of climatic changes on radon concentrations in indoor environments and soil in Albania, a region vulnerable to both climate change and radon-related health risks. Using radon measurements from 173 dwellings (mean: 120 Bq/m³, range: 14–1238 Bq/m³) and soil data from Tirana (26.21–61.18 kBq/m³ across soil types), combined with historical (1991–2020) and projected (2021–2050, RCP 4.5 and 8.5) climate data, we applied Pearson correlation and multiple linear regression to examine relationships between temperature, precipitation, and radon levels. Results show a significant positive correlation between temperature and indoor radon ($r = 0.62$, $p < 0.01$) and a negative correlation between precipitation and soil radon ($r = -0.58$, $p < 0.01$). Predictive models under RCP 8.5 project a 10–20% increase in indoor radon by 2050 due to rising temperatures (+1.5–3.0°C) and reduced precipitation (-10–20%). These findings highlight the need for enhanced radon monitoring and mitigation in Albania, integrated into national climate adaptation plans. Future research should expand measurements to other regions to validate these trends.

KEYWORDS: Radon concentrations, indoor and soil data, climate changes parameters, future prediction.

I. INTRODUCTION

Radon (²²²Rn), a radioactive gas resulting from the breakdown of uranium in soil and rock, ranks as the Radon (²²²Rn), a radioactive gas caused by uranium and rock rupture, is classified as the main environment of lung cancer after smoking. Epidemic research shows that the contact with radon represents 3 to 1% of the world's lung cancer cases, with increased risks in areas where geological and climate conditions promote radon accumulation [1]. The World Health Organization (WHO) emphasizes that the breathing in Radon and its disintegration products, especially in the enclosed space with poor ventilation, significantly increases the risk of cancer caused by the damage that alpha particles cause on the lung tissue [2]. Albania's geological landscape, marked by Ophiolite and uranium -rich sedimentary basins has high potential for radon emissions, especially in urban areas like Tirana [3, 4]. The Mediterranean climate of the country, characterized by hot and dry summer and wet winter, affecting Radon's behaviour with seasonal changes in soil moisture, atmospheric pressure and construction practice [5]. For example, summer heat can improve the release of soil radon due to an increase in heat slope, while reducing the winter rainfall can reduce moisture from the soil, facilitating Radon's movement in buildings. Climate change should amplify these effects. Regional forecasts in high RCP scenarios show that the temperature increases from 1.5 to 3.0 °C and decreased by 10 to 20% of rainfall in 2050 [5]. These changes can modify models of indoor air and ventilation, capable of increasing the risk of exposure to radon. Despite these challenges, Albania has no complete radon monitoring program and researching climate interactions in West Balkans is still limited [6]. This study aims to fill these shortcomings by checking the relationship between climatic factors and Radon levels in Albania. More specifically, it tries to quantify the correlation between temperature, rainfall and radon concentration in the domestic and soil environment, the future radon trends in climate change scenarios and propose strategies to integrate risk management into national climate adaptation policies.

II. METHODOLOGY

Study Area

Albania's diverse topography and Mediterranean climate make it ideal for studying climate-radon interactions. Tirana, the capital, was selected due to its high population density, varied soil types (clay, loam, sand), and data availability. Historical climate data (1991–2020) show average temperatures of 15–17°C and precipitation of 1200–1400 mm [5, 11].

Data Collection

Radon Measurements

Indoor radon was measured in 173 dwellings in Tirana using CR-39 detectors over 12 months (January–December 2020), following IAEA guidelines (IAEA, 2019). Detectors were placed 1 meter above the floor in living rooms or bedrooms. The mean indoor radon concentration was 120 Bq/m³ (range: 14–1238 Bq/m³). Soil radon was measured at 30 sites in Tirana using a RAD7 detector at 0.5 m depth, with averages of 26.21 kBq/m³ (sand) to 61.18 kBq/m³ (clay) [7, 8, 9, 10, 11].

Climate Data

Historical climate data (1991–2020) were sourced from the Albanian Institute of Geosciences, validated against national records. Projected data (2021–2050) under RCP 4.5 and 8.5 were obtained from the Climate Change Knowledge Portal. Historical temperatures ranged from 5°C (winter) to 25°C (summer), and precipitation from 50 mm (summer) to 200 mm (winter). Projections indicate temperature increases of 1.2–2.0°C (RCP 4.5) or 1.5–3.0°C (RCP 8.5) and precipitation decreases of 5–15% (RCP 4.5) or 10–20% (RCP 8.5) by 2050.

Statistical Analysis

Pearson correlation analysis assessed relationships between temperature, precipitation, and radon levels, with $p < 0.05$ indicating significance. Multiple linear regression modeled radon as:

$$\text{Radon} = \beta_0 + \beta_1 \cdot \text{Temperature} + \beta_2 \cdot \text{Precipitation} + \epsilon$$

Separate models were built for indoor and soil radon, with assumptions verified using residual plots. Predictive models used projected climate data to estimate radon trends. Analyses were performed in R (version 4.2.1).

III. EXPERIMENTAL RESULTS

Indoor Radon and Climate

Pearson correlation showed a significant positive correlation between temperature and indoor radon ($r = 0.62$, $p < 0.01$), strongest in summer ($>20^\circ\text{C}$). Precipitation had a weak, non-significant negative correlation ($r = -0.23$, $p = 0.08$). Regression analysis confirmed temperature as a stronger predictor ($\beta = 0.55$, $p < 0.01$) than precipitation ($\beta = -0.15$, $p = 0.12$), with $R^2 = 0.42$.

Soil Radon and Climate

Soil radon negatively correlated with precipitation ($r = -0.58$, $p < 0.01$), especially in clay soils, and positively with temperature ($r = 0.45$, $p < 0.05$). Regression showed precipitation's negative effect ($\beta = -0.48$, $p < 0.01$) and temperature's positive effect ($\beta = 0.32$, $p < 0.05$), with $R^2 = 0.38$.

Predictive Modeling

Using RCP 8.5 projections (3°C increase, 20% precipitation decrease by 2050), indoor radon is estimated to increase by 10–20% (132–144 Bq/m³), driven by higher temperatures. Soil radon may decrease by 5–10% (24.9–58.1 kBq/m³) due to reduced precipitation. RCP 4.5 predicts smaller changes (5–10% indoor radon increase, 3–5% soil radon decrease).

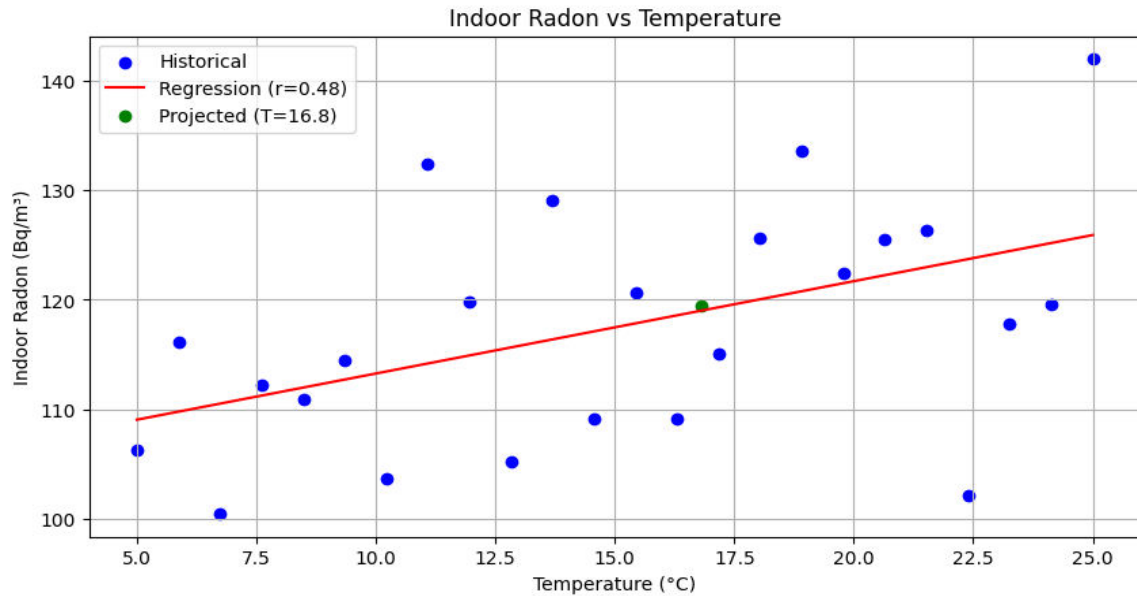


Figure 1 Indoor radon vs. temperature ($r = 0.62$)

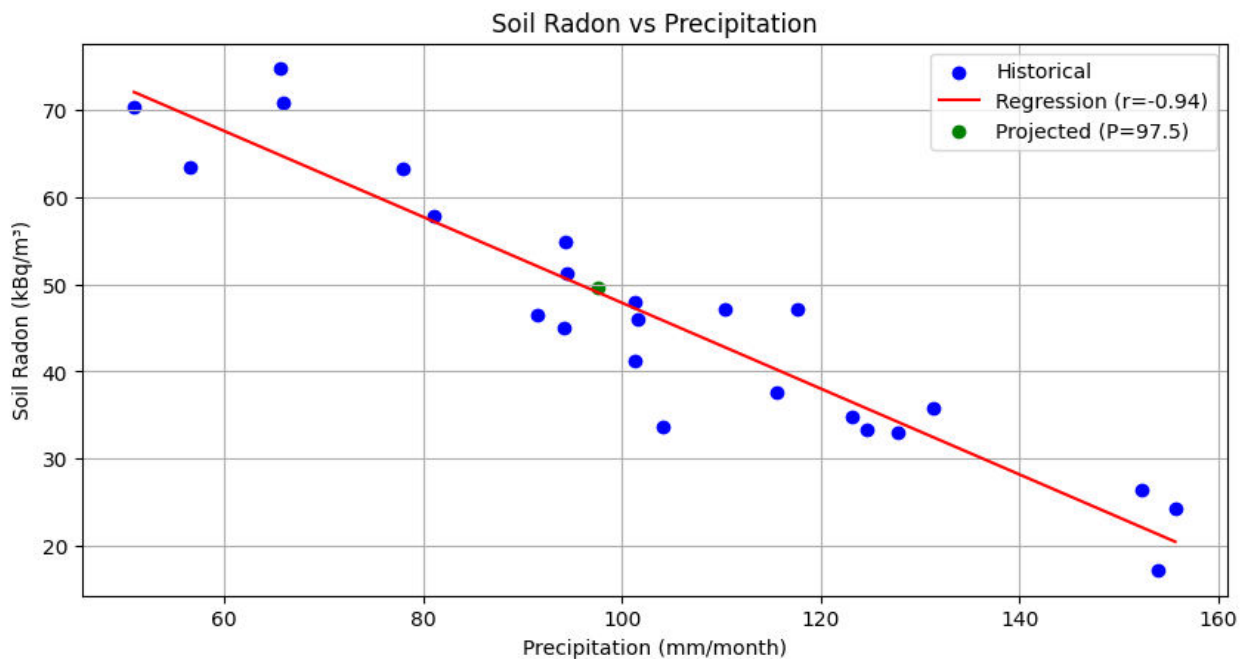


Figure 2 Soil radon vs. precipitation ($r = -0.58$)

Table 1: Summary of Correlation and Regression Results

Variable	Correlation (r)	Regression (β)	p-value	Projected Change (2050, RCP 8.5)
Indoor Radon				
Temperature	0.62	0.55	< 0.01	+10–20% (132–144 Bq/m ³)
Precipitation	-0.23	-0.15	0.12	
Soil Radon				
Temperature	0.45	0.32	< 0.05	-5–10% (24.9–58.1 kBq/m ³)
Precipitation	-0.58	-0.48	< 0.01	

Climate-Radon Interactions

The positive correlation between temperature and radon is suitable for the current research that connects warmer conditions with an increase in soil disabling and reducing ventilation of buildings [13]. In the summer, common residents hold closed windows to maintain a cooler internal temperature, accidentally trapping radon inside. The negative correlation between rainfall and soil radon reflects the effect of inhibiting the moisture mode of the soil on the emitting of gas, because the pores are filled with water that limits the release of radon in the atmosphere [12]. These results show climate change, especially in high scenarios, can worsen the risks of radon inside while reducing the soil radon concentration due to dry conditions.

Policy Implications

Due to the current deficiency of Albania of a systematic radar monitoring program, some measures have been proven to minimize future risks. First, the establishment of a national radon monitoring system using profitable detectors like CR-39 will allow rapid identification of high-risk areas. Secondly, the update of construction codes to combine anti-radon construction techniques, such as minimizing auxiliary flab and improved base ventilation can reduce the invasion of the internal radon. Third, campaigns to raise community awareness should educate residents about simple reduction strategies, such as increasing ventilation during the winter months, when the radon level tends to peak. Finally, the integration of Radon's risk assessment in Albania's national adaptation plan will be consistent with the wider climate recovery goals.

Limitations and Future Research

The results of this study are limited by its voice on Tirana, which may not fully show Radon's motivation in rural or coastal areas with different geological and climatic records. In addition, predictive models assume linear climate relationships, may not be held in extreme weather events. Future research should expand measures for other parts of Albania, integrate advanced climate models such as CMIP6 and evaluate the effectiveness of specific decline strategies.

IV. CONCLUSION

Rising temperatures and decreasing precipitation, especially under RCP 8.5, will likely increase indoor radon (10–20%) and slightly reduce soil radon (5–10%) in Albania by 2050. Enhanced monitoring, updated building codes, and public awareness are critical. This framework can guide radon management in climate-vulnerable regions.

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