

Abstract

Radon (^{222}Rn) is a naturally occurring radioactive noble gas produced in the decay series of uranium (^{238}U), which is ubiquitously present in rocks, soils and some building materials. Radon from soil is being continuously released into the atmosphere. It can also accumulate in enclosed spaces, where it can pose a significant health risk upon inhalation. With a half-life of 3.8 days, ^{222}Rn undergoes further radioactive decay through a series of short- and long-lived progeny. Beyond its radiological significance, outdoor radon and its progeny serve as effective environmental tracers.

This dissertation presents a comprehensive, multi-year study of outdoor radon dynamics in Bratislava, Slovakia, with a focus on its temporal variability, environmental influences, and radon potential as a tracer of environmental process. The study spans six years (2018-2023) of continuous radon measurements using a scintillation detector, and three years (2020-2022) of short-lived progeny measurements collected via alpha spectrometry. Low average radon concentrations ($5.6 \pm 3.9 \text{ Bq}\cdot\text{m}^{-3}$) were detected in the atmosphere of Bratislava during the monitored period, which is significantly lower than the global average of $10 \text{ Bq}\cdot\text{m}^{-3}$.

Diurnal cycles of outdoor radon showed maximum concentrations in the early morning and minimum concentrations in the afternoon, while seasonal trends showed the lowest concentrations in April and the highest in November. These patterns are governed by changes in boundary layer height (BLH) and radon flux dynamics. Conventional regression and machine learning models were both applied to hourly data to identify the dominant environmental drivers of radon variability. The machine learning models significantly outperformed the traditional approaches, consistently identifying BLH as the dominant predictor of outdoor radon concentration and precipitation as the least influential factor.

Further analysis of the interactions between radon progeny, particulate matter (PM), meteorological variables, and BLH demonstrated a strong, non-linear relationship between radon progeny and PM, suggesting enhanced attachment under polluted conditions.

A box model incorporating outdoor radon concentration and radon flux was used to estimate the mixing layer height. The estimated mixing layer height effectively captures diurnal and seasonal boundary-layer dynamics, despite some limitations due to low radon concentration measurements and uncertainties in the radon flux data.

Furthermore, the mean aerosol residence time was derived from activity ratios of $^{210}\text{Pb}/^{222}\text{Rn}$, $^{210}\text{Pb}/^{214}\text{Pb}$, and $^{210}\text{Pb}/^{214}\text{Bi}$, averaging 3.15 days (ranging from 0.35–6.73 days), which is consistent with findings in the existing literature.

Overall, this work underscores the importance of long-term outdoor radon monitoring for both atmospheric research and public health. It demonstrates that radon and its progeny are effective, low-cost tracers of atmospheric mixing and aerosol dynamics.