Determination of turbulent diffusion coefficient using atmospheric radon concentration

E. Yeboah, G. Yakovlev, and A. Telminov

National Research Tomsk Polytechnic University (TPU), National Research Tomsk State University (TSU), Institute of Monitoring of Climatic and Ecological System (IMCES)

TOMSK POLYTECHNIC UNIVERSITY

INTRODUCTION AND MAIN RESULTS

This presentation provides insights related to radon, the turbulent diffusion coefficient, and meteorological and turbulent parameters under three different stratification regimes. Radon concentration showed significant correlation with both turbulent and meteorological parameters. Higher radon activity concentration corresponded with a lower turbulent diffusion coefficient in the atmosphere, and an increase in precipitation resulted in a decrease in radon concentration.

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Introduction

Radon is a natural radioactive gas that can be found in the environment. The soil emits radon, which is then transported into the atmosphere. It has characteristics that make it a suitable atmospheric tracer, and it is used in the study of the transport and distribution of atmospheric masses. It can also be used in the study of the dynamic processes in the atmosphere. Radon is uniformly distributed throughout the atmosphere due to turbulent diffusion.

The turbulence diffusion coefficient determines the ability of a flow to maintain or develop into turbulence. It can also be defined as the ability of the ABL to spread and deposit pollutants. Turbulent diffusion coefficients are critical for studying the movement and distribution of radionuclides, preventing nuclear power plant accidents, and analyzing environmental and human health concerns.

The main objective of this work is to determine the turbulent diffusion coefficient using radon concentration and to study the relation between radon concentration and turbulent parameters.

Fig.1. IMCES Tomsk Region

Methods

The method involves determining the turbulent diffusion coefficient (D_T) in the surface layer of the atmosphere based on the activity concentration of radon. A sonic anemometer (AMK-40) and an Alpharad radiometer were used in the Tomsk region's IMCES to detect radon concentration, meteorological, and turbulent parameters for determining the turbulent diffusion coefficient in the atmosphere. The measurements were conducted at a height of 1 m (z_1) and 22 m (z_2) at a flat area and canyon, respectively. The radiometer was configured to operate in cyclic air sampling mode for continuous measurement of the volumetric activity of radon over a 24-hour period with a time interval of 60 minutes. The turbulence diffusion coefficient in the surface layer of the atmosphere is determined from the formula:

$$D_T = \frac{(z_2 - z_1)^2 \times \lambda_{Rn}}{\left(\ln\frac{A_2}{A_1}\right)^2} - D_m \qquad (1)$$

Where D_m - molecular diffusion coefficient, λ_{Rn} - half-life of radon, A_1 and A_2 - radon activity concentration at z_1 and z_2, respectively.

Fig. 2. Experimental set-up

Results

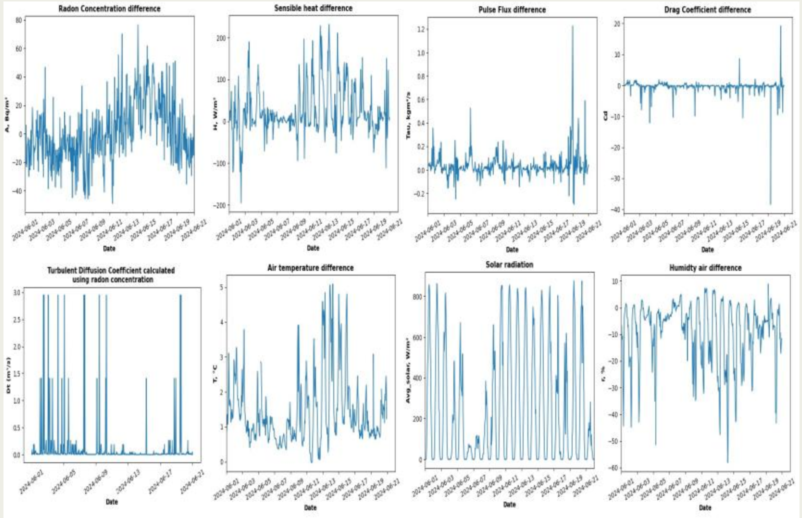

Fig.3. Radon concentration, turbulent parameters and meteorological parameters

Correlation between radon concentration difference, turbulent diffusion coefficient and turbulent parameters									
	Convection stratification			Inversion stratification			Neutral stratification		
	Sensible heat flux	Pulse flux	Drag coefficient	Sensible heat flux	Pulse flux	Drag coefficient	Sensible heat flux	Pulse flux	Drag coefficient
Radon concentration difference	-0.229	0.080	0.066	0.009	0.010	-0.132	-0.227	0.114	0.116
Turbulent diffusion coefficient	-0.152	-0.017	0.085	-0.013	-0.070	-0.024	-0.054	-0.112	0.015

Correlation between radon concentration difference, turbulent diffusion coefficient and meteorological parameters									
	Convection stratification			Inversion stratification			Neutral stratification		
	Temperature	Pressure	Humidity	Temperature	Pressure	Humidity	Temperature	Pressure	Humidity
Radon concentration difference	-0.195	-0.412	-0.146	-0.254	-0.468	0.088	-0.325	-0.334	0.244
Turbulent diffusion coefficient	0.027	-0.160	0.022	0	-0.200	-0.091	-0.004	-0.118	-0.074

Table 1. Correlation coefficient between parameters.

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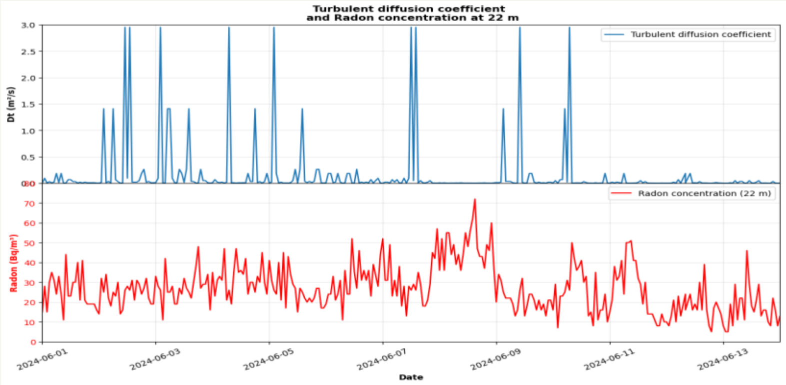

Fig.4. Radon activity concentration measured at 22 m and turbulent diffusion coefficient

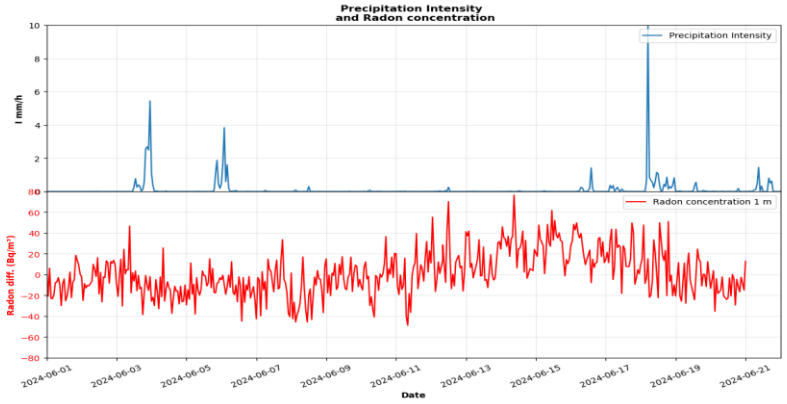

Fig.5. Radon activity concentration difference and precipitation intensity

Discussion

The findings suggest that radon is an effective natural tracer for studying turbulent diffusion coefficients in the atmosphere. The results show the correlation between differences in radon concentration, turbulent diffusion coefficients, turbulent parameters, and meteorological parameters under three different stratification regimes: convective, inversion, and neutral. The influence of atmospheric stratification and confinement is evident because measurements were taken in two environments with contrasting geometries: a deep canyon (22 m) and a flat surface (1 m).

The results showed that radon concentration is strongly influenced by turbulence, stratification, topography, and meteorological parameters. Radon activity varies with turbulence, accumulating during stable conditions and dispersing more rapidly during turbulent conditions. The negative relationship between radon concentration and turbulent diffusion coefficient demonstrates how turbulence enhances the dilution of atmospheric constituents. The influence of precipitation on radon indicates that it must be considered in dispersion studies.

Conclusion

Radon proved to be an effective natural tracer for turbulent diffusion, with its variability controlled by turbulence, stratification, topography, and meteorology. Results from both canyon and open environments showed radon accumulation under stable conditions and dilution during turbulence, with precipitation further modulating its behavior. These findings highlight the use of radon for studying boundary-layer dynamics and pollutant dispersion in contrasting terrains.

Future works

To compare the results of the turbulent diffusion coefficient calculated using radon concentration with that of carbon dioxide.

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