CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

Investigating Radon Exhalation

Parallels between waste-rock dumps and mountain screes

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Acknowledgments

In collaboration with:

DIAMO, s.p., o.z. SUL

National Radiation Protection Institute (SÚRO), v.v.i.

National Institute for Nuclear, Chemical and Biological Protection (SÚJCHBO), v.v.i

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https://geoportal.cuzk.cz/WMS_ORTOFOTO_PUB/WMService.aspx

Photo by **David Strnad**

Introduction
When ventilation can increase Radon Concentration

- Ventilation is an effective way of reducing indoor radon concentration
- Assumption: Low outdoor radon concentration
- In most situations reasonable
- Not in vicinity of strong sources of radon
- Our example: Waste-rock dumps around Příbram*
    - Calm (wind) summer nights
- Focus on area surrounding Shaft 15

Photo by **Alistair MacRobert** on **Unsplash.com**

*L. Thinova; R. Bican; A. Fronka; K. Johnova; J. Solc; J. Vosahlik**; 2017; Radon concentration in the are of waste rock dumps, Brod, CR – Case study; *Radiation Protection Dosimetry;* Volume 177; Issue 1-2; p. 149–154
***L. Thinova et. al.;** 2022; Nové poznatky k sezónnímu chování objemových koncentrací radonu v blízkosti odvalu š. č. 15; Brod u Příbrami; *XLIII. Dni radiačnej ochrany 2022*

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- Example: Waste-rock dumps in Příbram*
  - Calm (wind) summer nights
- Focus on area surrounding shaft № 15
  - Many more dumps aroud příbram (21 total)

View of Shaft 15 from top of the dump, Original photo

*L. Thinova; R. Bican; A. Fronka; K. Johnova; J. Solc; J. Vosahlik; 2017 RADON CONCENTRATION IN THE AREA OF WASTE ROCK DUMPS, BROD, CR—CASE STUDY; *Radiation Protection Dosimetry*, Volume 177, Issue 1-2, p. 149–154

*L. Thinová et. al.; 2022; Nové poznatky k sezónnímu chování objemových koncentrací radonu v blízkosti odvalu š. č. 15, Brod u Příbrami; *XLIII. Dni radiačnej ochrany 2022*

Waste-rock dumps

- Made of loose material
  - High air permeability
- Contain a lot of mass
  - High thermal capacity
- Has a vertical structure
  - Tall structure
  - Eg. dump at shaft № 15 is cca. 90 m tall
- In case of uranium waste-rock
  - Contain left over uranium ore
  - Generates Radon

Photo *Dumps around Příbram* by **ČT24**
https://ct24.ceskatelevize.cz/regiony/2118987-obri-uranove-haldy-u-pribrami-maji-zmizet-likvidace-potrva-desitky-let

Field measurements
High radon concentrations

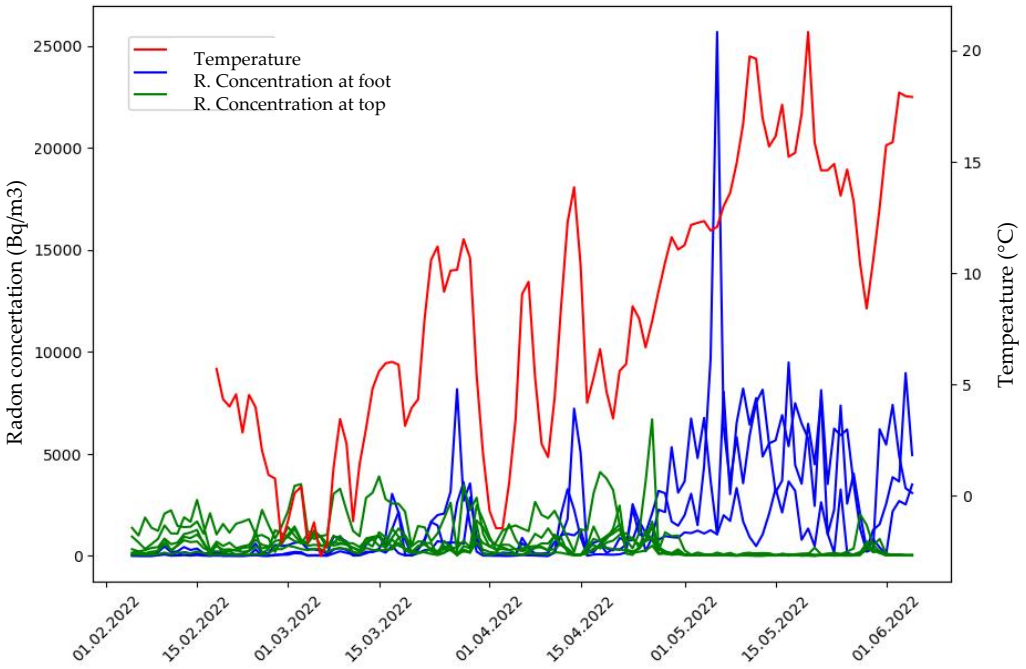
- Showcase of high radon concentration
- Mean R. concentration
  - From 22.8.2023 12:00
  - To 23.8.2023 12:00
- Data collected using TSR4 made by Tesla a.s.

Location	R. Conc (Bq/m^3)	Distence (m)
1	7090	10
2	3470	15
3	880	160
4	1180	195
5	3145	140
6	4980	90
7	3090	85
8	320 (900)[1]	340
9	135	325
11	1830	160

[1]Seen in different interval (18.8. 12:00 – 19.8. 12:00); August

Daily and seasonal variations of radon concentration

- Seasonal variation*
  - Induced by temperature changes?
  - Cold
  - Warm
- Daily variation*
  - Temperature changes?
  - Solar radiation?
- Closer look
  - Short interval
  - Single device



Average **daily** radon concentrations at different places at top of dump and around the foot of the dump (translated from Czech)*

***D., Strnad;** 2023; Analýza a predikce uvolňování radonu z důlních odvalů (Analysis and prediction of radon release from waste rock dumps); *master's thesis;* Czech Technical University

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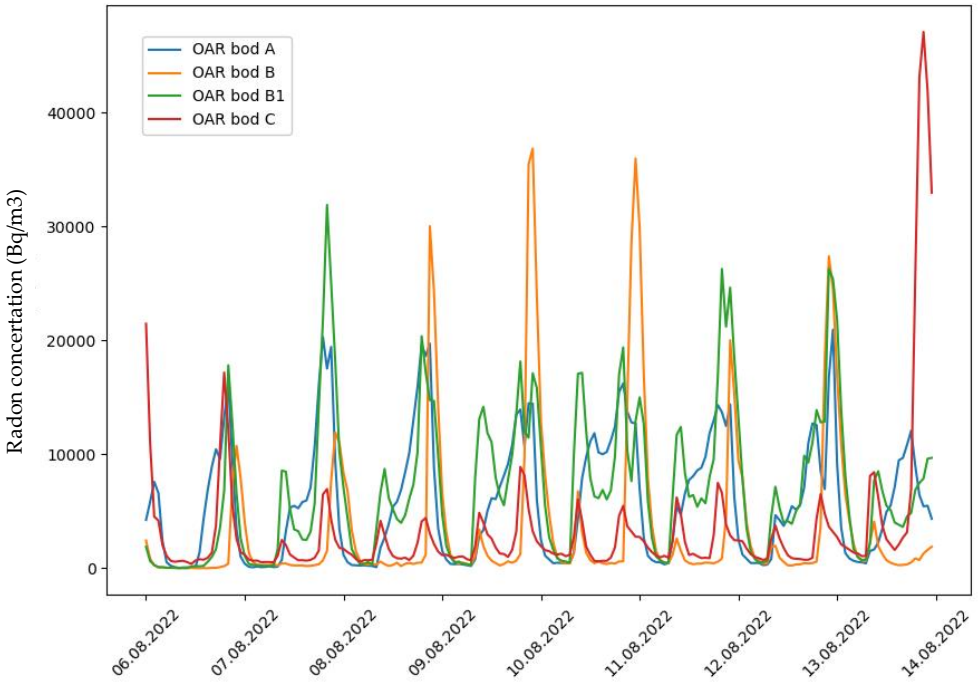

Average **hourly** radon concentrations at different places around the foot of the dump (translated from Czech)*

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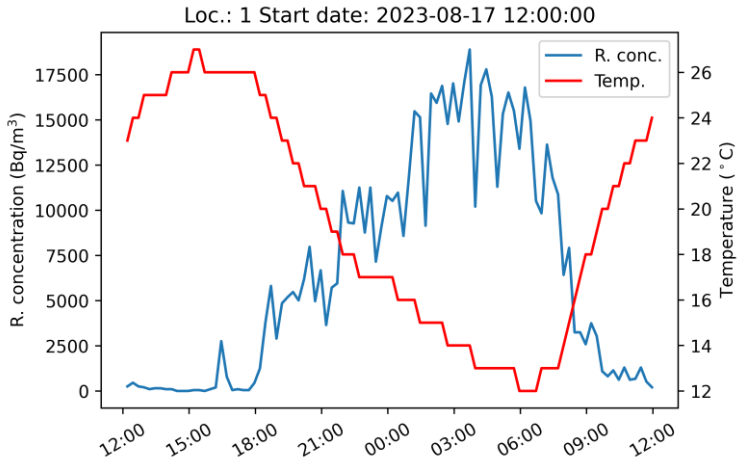

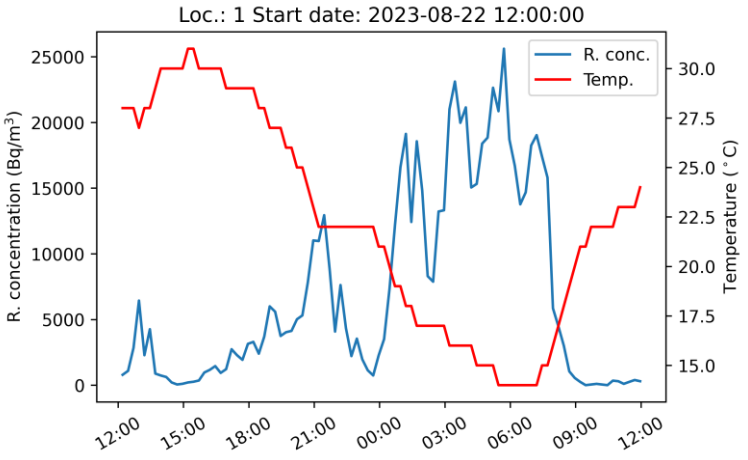

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Places of radon exhalation
Infrared images

- Places where airflow exits the dump can be identified
  - At the foot of the dump (Summer)
  - At the top of the dump (Winter)
- Simple observation
  - Detectable airflow (by hand)
  - Different temperature, High humidity
  - Increased presence of mosses
- Infrared images

Photo (summer) by Václav Štěpán

Photo (winter) by Václav Štěpán

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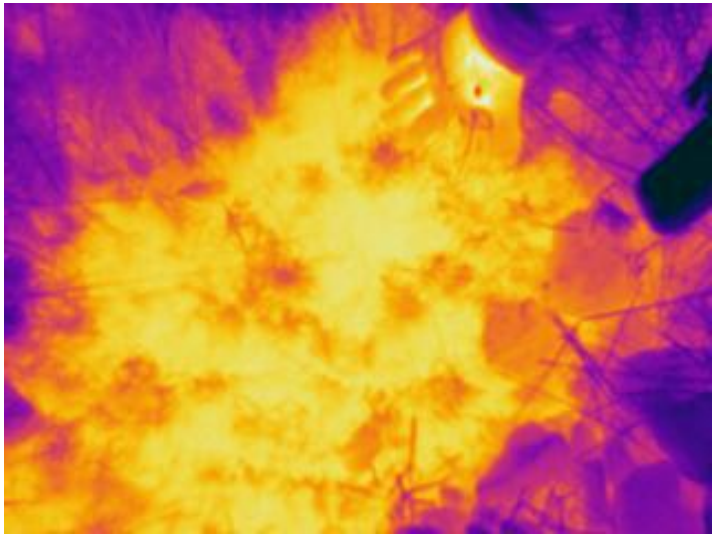
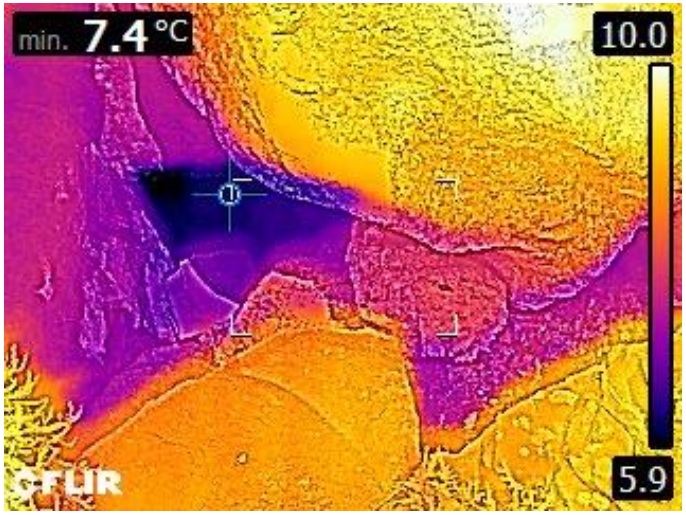
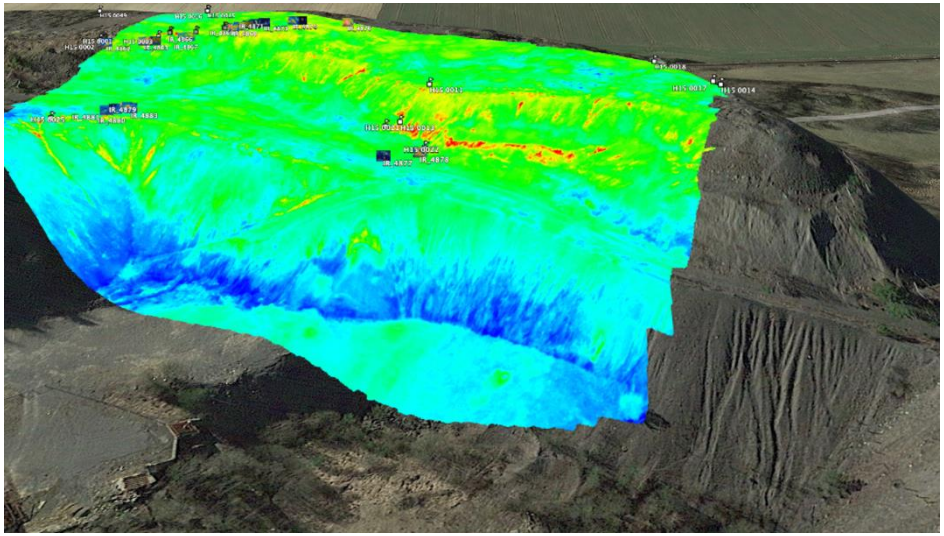


Infrared image; Warm exhaust in winter



Infrared image; cold exhaust in summer



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Explanation
The parallel with screes

- Naturally occurring screes are of similar structure
  - Loose pile of material with high air permeability
  - Significant mass and thermal capacity
  - **An airflow with similar seasonal variation**
- Example in Swiss Alps*
  - Creux-du-Van
  - Dreveneuse
  - Bois des Arlettes
- In cold ventilated areas
  - Microclimates
  - Extrazonal permafrost
  - Boreo-alpine species
  - Dwarfing of trees

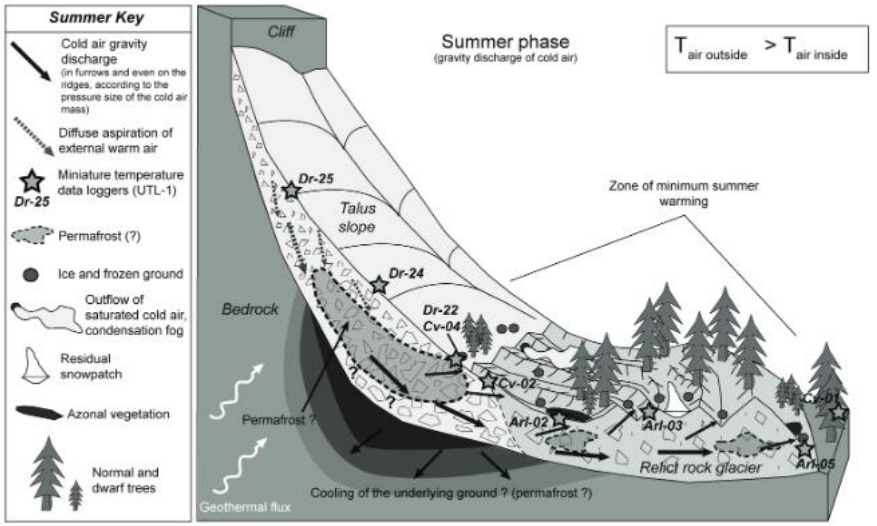

Figure 5. Model of summer descending air circulation (in talus slope / relict rockglacier system). The stars indicate the general position of the dataloggers presented in Figure 2.*

*S., Morard; R., Delaloye; J., Dorthe; 2008; Seasonal thermal regime of mid-latitude ventilated debris accumulation; https://www.researchgate.net/publication/235665719

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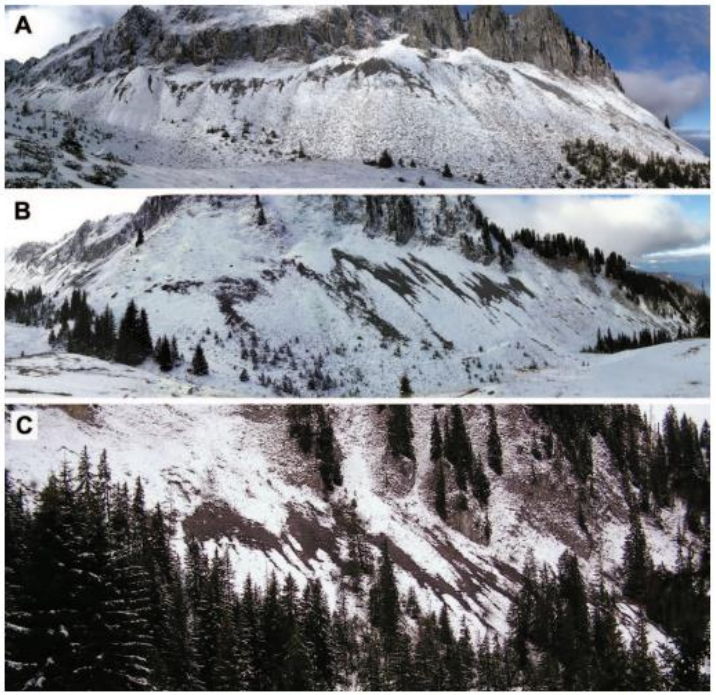

Figure 6.2: Snow melt windows (evidences of warmer air outflows) in the upper part of the talus slopes of the Combe de Dreveneuse. A: Dreveneuse d'en Haut, B: Dreveneuse du Milieu, C: Dreveneuse d'en Bas. Photos: R. Delaloye (November 2004).

J. Noetzli; D. Von der Muhl; 2010; Permafrost 2010: Permafrost in Switzerland 2006/2007 and 2007/2008; *Glaciological Report (Permafrost)*

*__S., Morard; R., Delaloye; J., Dorthe;__ 2008; Seasonal thermal regime of mid-latitude ventilated debris accumulation; https://www.researchgate.net/publication/235665719

Ground surface temperatures Recorded 10-20 cm bellow ground

Type I

Winter exhaust

Type II

Mixed

Type III

Winter intake

Type IV

Summer exhaust

Winter nothing

Type 0

No anomaly

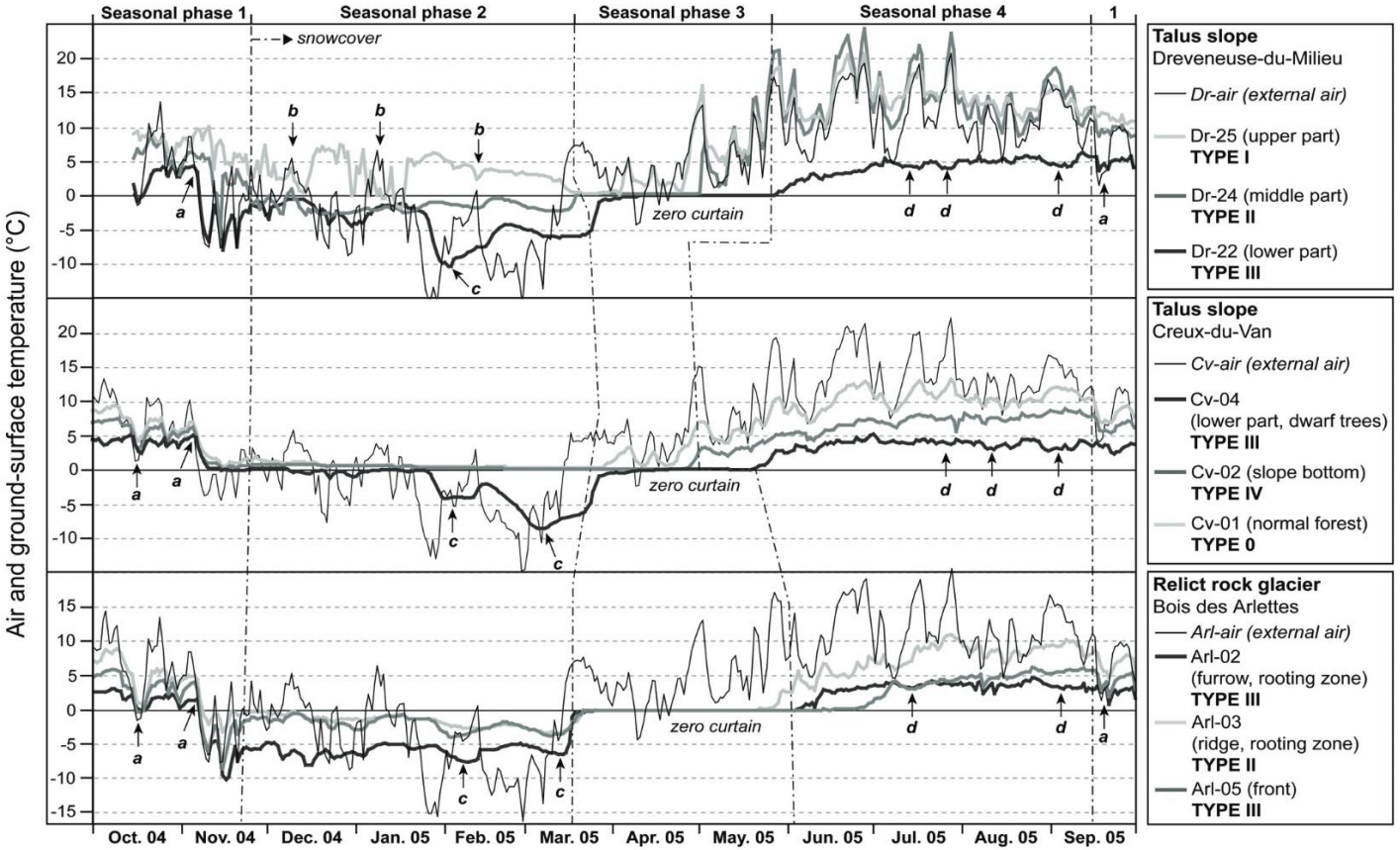

Figure 2. Thermal behaviors of the different parts of a ventilated talus slope – relict rock glacier complex. Data are daily air and ground-surface temperature. Locations of the dataloggers are shown in Figures 4 and 5. Arrows: a) inversion of the air flow direction; b) mild weather events; c) colder ground-surface temperature in January-March 2005; d) coldest ground temperature in summertime.

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Explanation
The chimney/stack effect

- Most significant driving force behind airflow*
  - For both dumps and screes
- Caused by difference in density of cold and warm air

- Two primary regimes
- Warm structure and Cold air
  - Winter
  - Stack effect
- Cold structure and Warm air
  - Summer
  - Reverse stack effect

Photo by **Mike Marrah** on Unsplash.com

***H. Wakonningg**; 1996; Unterkühlte Schutthalden; *Arbeiten aus dem Institut für Geographie der Karl-Franzens Universität Graz*, Issue 33, p. 209-223

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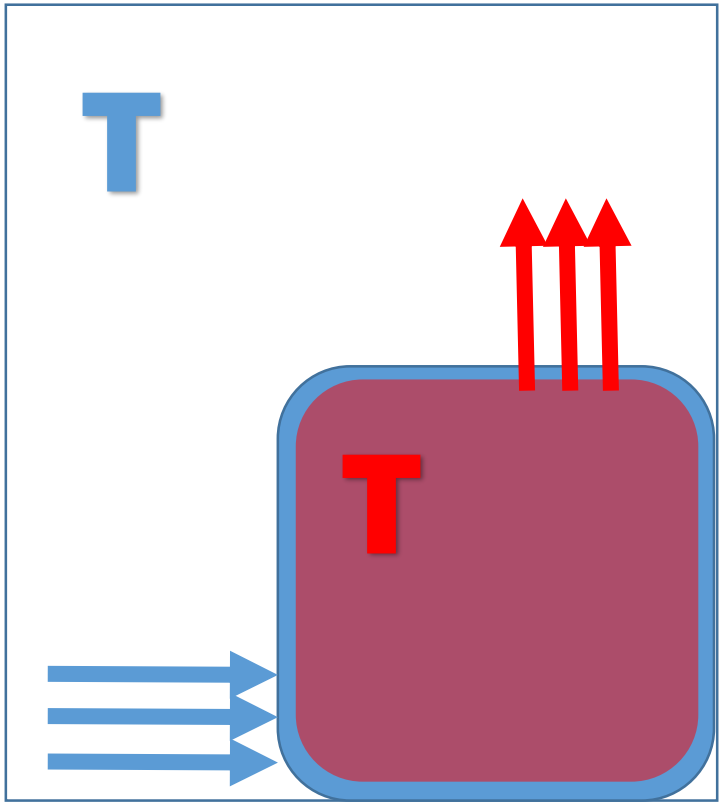

Simple ilustration of stack effect, Original

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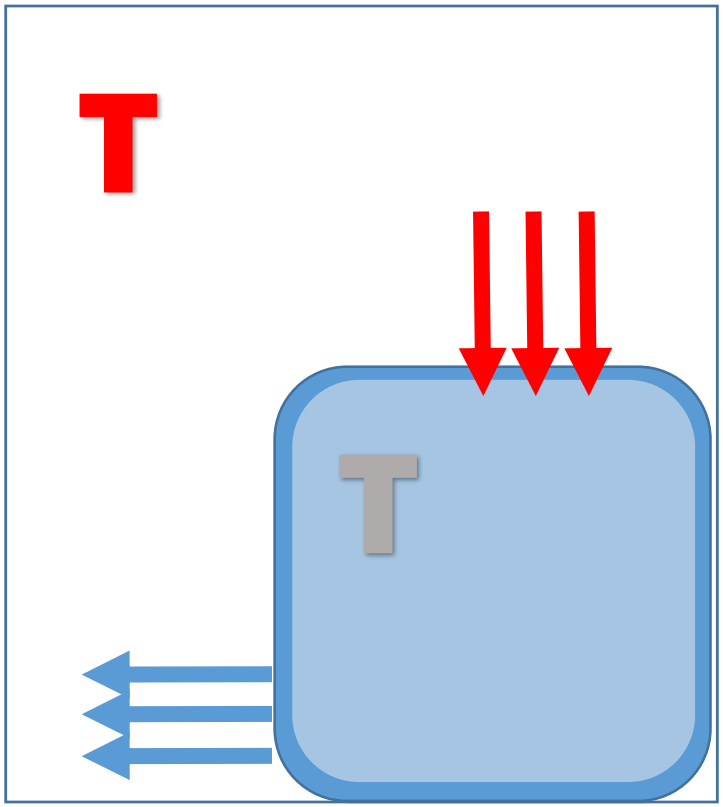

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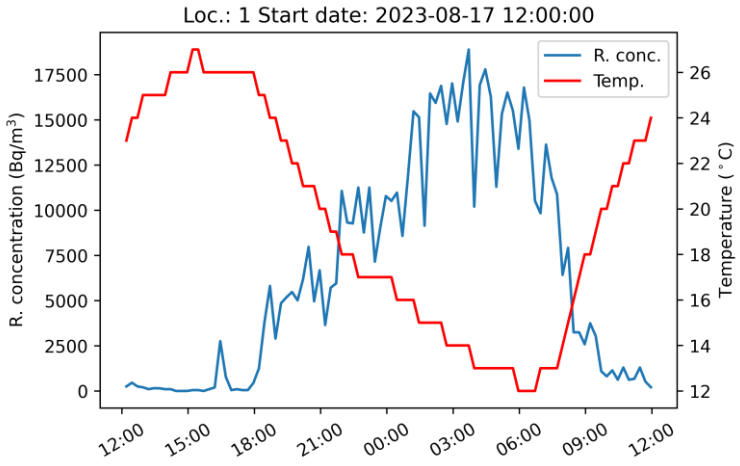
Effect of sunshine on airflow around the dump

- Our theory to explain daily variation
- At night streams of cold air flow far from the dump and keep high radon concentration ‘intact‘
- During the day solar radiation heats the ground which forms upward air currents
- These currents disturb the cold flows
  - Explains near zero concentration during the day
- This leads to quick dissipation of radon concentration



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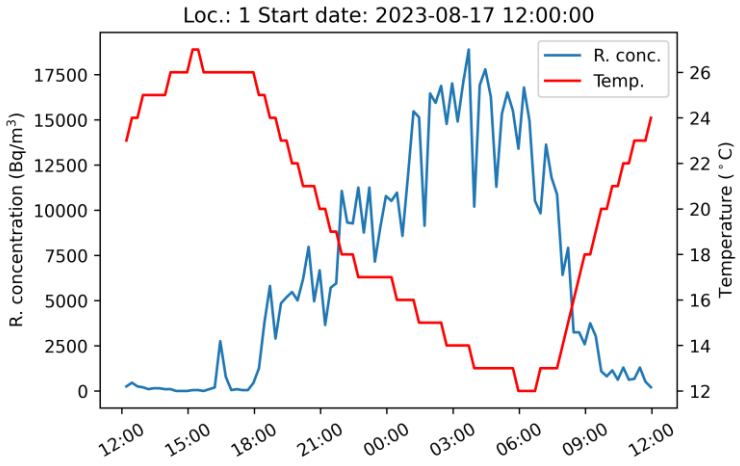

Future plans

- Model the radon exhalation from the dump
  - 3D CFD (detailed) model of the entire dump seams unfeasible
- Split the model into two parts
  - Identify locations of radon exhalation just from surface information
    - Mainly summer, winter is secondary
    - Predict their strength
- Identify a pattern of exhalation
  - Will most likely be function of atmospheric temperature
- Merge the models -> Description of contamination source

Thank you for your attention

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