SOIL GAS MONITORING
CARST MEETING
APRIL 25, 2017
RADON – A DANGER FOR THE HEALTH
RADON ENTRY WAYS

A. Cracks in Concrete slabs
B. Spaces between brick veneer that rest on uncapped hollow brick foundations
C. Cracks and pores in concrete blocks
D. Floor – wall joints
E. Exposed soil as in sump pump areas
F. Drain tile to sump
G. Mortar joints
H. Loose pipe penetrations
I. Open top block walls
J. Rock walls
K. Water
Emanation is the process by which radon is transported from a solid to a gas or liquid medium. Only a fraction of the radon atoms so created is able to emanate from the mineral grains and enter the void space, filled either by gas or water. From here, radon moves further by **diffusion** and, for longer distances, by **advection** dissolved either in water or in carrier gases.

This transportation of radon throughout soil is primarily accomplished through **alpha recoil** and the mechanical flow of air and water throughout the soil.

- Alpha recoil is defined as the process by which an atom (radon) recoils in the opposite direction from the path of particle ejection following the radioactive decay of its parent atom.
Radon emanation (Flux rate) to air depends mainly on Ra-226Ra concentration and mineral grain size, its transport in the earth is governed by geophysical and geochemical parameters

- Soil Porosity
- Meteorological factors;
  - moisture, humidity, atmospheric pressure

The radium content of surface soils in the Canada is in the range 10-100 Bq/kg.

Soil is the dominant source of radon.
TYPICAL Rn CONCENTRATIONS

- Wide measuring range:
- 2 Bq/m³ – 10 MBq/m³, e.g. low outdoor air concentration up to very high concentrations like in mines or in soil gas
LIMITING FACTORS

The Radon-222 gas flux rate out of the soil into a house are:

a.) its half-life of 3.8 days
b.) the geochemical composition and geophysical properties of the soil under and around the house
c.) the type of the building foundation
d.) the construction techniques implemented
e.) the level above the ground
f.) the dimensions of the rooms
g.) the ventilation rate
h.) meteorological and seasonal parameters
i.) living and working conditions
From various research studies, we know:

Average reported flux rate from undisturbed soil into the atmosphere are 0.015-0.048 Bq m²/s for ²²²Rn.

A typical radon entry rate into a single-family dwelling of 10-15 kBq h⁻¹ can be accounted for by weather-induced pressure-driven flow through moderately to highly permeable soils.

The soil-gas radon concentration may vary, often very greatly, over a small distance.

Occurrence of inhomogeneity often indicates the presence of faults or tectonic zones.
Easy-to-use soil gas measuring probe for sampling as well as for continuous monitoring of radon in soil gas

- Sampling and continuous monitoring
- Robust and reliable set-up for long-term use
- Field-proven sampling method and protocol
Radon in soil gas – Sampling method Rn222 – Rn220 discrimination

Sampling method, developed in cooperation with GGD Leipzig:
1. Driving the drilling rod into the soil. Tearing back the drilling rod for ca. 5 cm
2. Inserting the capillary probe and pressing out the closing rivet
3. Connecting the tube and the Aquastop filter
4. Sampling with connected AlphaGUARD in Radon/Thoron discrimination mode (1 or 2 l/min)
Continuous radon in soil gas monitoring system for permanent operation at a remote location in the open air

Measurements incl. wind speed data are managed by AlphaGUARD and are read out by the headquarter via cellular phone network (GSM modem)

The station includes:
- 1 AlphaGUARD PQ2000PRO
- 1 Soil gas probe
- 1 Wind speed sensor
- 1 DataGATE (former version of COM Server)
- 1 GSM Modem
BUILDING SITE SAMPLE MEASUREMENTS

To ensure reliability of the results, it is required to make at minimum of 15 soil-gas sample measurements for averaged concentrated value for an quarter acre building site.

The minimum sampling depth of 1 meter at the foundation level of building represents a relatively compromise between the reduction of weather effects and the practicability of the field conditions.

Other parameters, including vertical and horizontal changes in soil and rock profile, should also be taken into consideration.

The backfill in various construction can vary widely and needs to be considered to ensure measurements are not in backfill areas.
Determination of Radon exhalation (flux) rate from soil was measured using the Exhalation Box (EB) and the same AlphaGuard monitor and pump.

The air was circulated in the closed circuit for about 90 min and the concentration of radon accumulated in EB was recorded.

The barometric pressure and temperature should be recorded during testing.
SOIL PERMEABILITY MEASUREMENT

PERMEABILITY DETERMINATION becomes the challenge since more issues are connected with this determination of soil permeability. The factors influencing the permeability (soil moisture, density, porosity) need to be taken into consideration and reviewed for several samples to describe the heterogeneous geological environment.

Soil permeability - The pressure difference between soil air and open air (1P) and flow rate (Q) are measured by the AlphaGuard system.

The soil permeability is calculated using a modified equation of Fick’s law of diffusion (Janik, 2005):

\[ k_{soil} = \mu \cdot Q \cdot W \cdot 1P, \]

(k_{soil} is soil permeability (m²), \( \mu \) is dynamic viscosity of air (Pa s), W is depth parameter of the soil-gas probe (m), Q is soil gas flow rate (m³/min), and 1P is pressure difference measured (Pa) (Zunic et al., 2006))
RADON RISK CLASSIFICATION

The classification developed uses a correlation between the radon concentration in soil gas and the associated soil permeability.

This Radon risk classification of foundation soils provides a base for additional study and correlation to potential indoor radon levels to base preventative measures of radon infiltration within the building.

The results of radon risk classification should allow to choose an optimal building technology based on three categories of risk is semi-quantitative.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>RADON CONCENTRATION IN THE SOIL GAS (kBq·m⁻³)</th>
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<tbody>
<tr>
<td></td>
<td>soil permeability</td>
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<tr>
<td>low</td>
<td>low</td>
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<tr>
<td>medium</td>
<td>medium</td>
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<tr>
<td>high</td>
<td>high</td>
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<tr>
<td>low risk area</td>
<td>&lt; 30</td>
</tr>
<tr>
<td>medium risk area</td>
<td>30 - 100</td>
</tr>
<tr>
<td>high risk area</td>
<td>&gt; 100</td>
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</tbody>
</table>
In addition a recently developed model simulates transport of radon through unsaturated soil and compares calculated soil radon activities against field-measured values.

This model adds consideration of air temperature changes and air flow driven by barometric pressure change to the other soil variables currently used.

Sensitivity analysis and simulated results have clearly demonstrated the relative importance of barometric pressure change, rainfall events, changes in water content, gas advection, and radon source term in radon transport process.

Comparison between measured and simulated soil radon activities showed that models can provide realistic estimates of long-term radon activity concentration in the soil profile.
Radon Assessment in New Homes

In new homes typically are not required to meet specified radon levels prior to sale.

- The practical applicability of radon soil gas survey results, to define a single parameter (radon availability or flux) for characterizing of the radon potential within a building site. The correlation of potential indoor radon levels to design the preventative mitigation measures of radon infiltration within the building.

- The results allow builder to choose an optimal building technology, and mitigation of the intrusion of Radon into of home during construction.
CONCLUSIONS

Knowing the Radon Soil Gas activity concentration – measured at sufficient depth to building grade – provides key information in designing radon reduction methods for an energy efficient home.

Providing a methodology to measure the associated correlation between Soli Gas concentration and potential flux rate of Radon gas released.
BERTIN INSTRUMENTS: THE COMPREHENSIVE SOLUTION FOR RADON MEASUREMENT SOLUTIONS

Continuous Innovation

- More than 40 years of experience in Radon
- 1000+ AlphaGuards operating worldwide
- In more than 40 countries

Prestigious customer references
- National Research Council
- EPA
- Health Canada

Made in Germany

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References

- Bertin Soil Gas Measurement Instruction  Dr Schubert  2001
- Bertin AlphaGuard Training program.
- Bertin Applications Document;  RADON IN SOIL GAS – SAMPLING METHOD RN222 – RN220 DISCRIMINATION
- Univ of Minn website  http://enhs.umn.edu/hazards/hazardssite/radon/radonfate.html
- Modeling of radon transport in unsaturated soil;  Chen and Thomas;  JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 100, NO. B8, PAGES 15,517-15,525, AUGUST 10, 1995