SnT 2019
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Measurement of radioargon and radioxenon in soil gas

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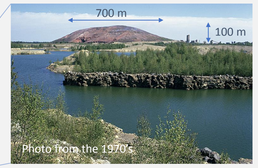
T2.4-P40

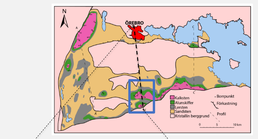
Among the most important indicators for a under ground nuclear explosion during an on-site inspection (OSI) are the radioactive xenon isotopes ^{131m}Xe, ^{133}Xe and ^{133m}Xe and the radioactive argon isotope ^{37}Ar. In the assessment of a detection of these nuclides it is important to have knowledge about the levels that can be expected due to the natural background. In order to contribute to an understanding of possible detection of radioactivity in the ground, sub soil sampling has been carried out on in the area of Kvarntorp, Sweden, a location with known elevated uranium content. More than 40 samples for xenon analysis has been collected from ten different sites and ^{133}Xe was detected in 17 samples (ranging from 2 to 95 mBq/m^3). ^{37}Ar was detected in all ten samples sent to laboratory for argon analysis.

The Kvarntorp area and sampling locations



The Kvarntorp pile, a relic from the oil shale industry (1942-1966)

Sampling at the foot of the Kvarntorp (KVA) oil shale pile



Andersson et al., 1985: The Scandinavium Alum Shales. *Sveriges Geologiska Undersökning (SGU) Ca 56*, 1-49

Sampling sites are located both on the Kvarntorp shale pile as well in areas not affected by the oil industry. The area is selected due to the relatively high uranium content in the upper layer of the ground.

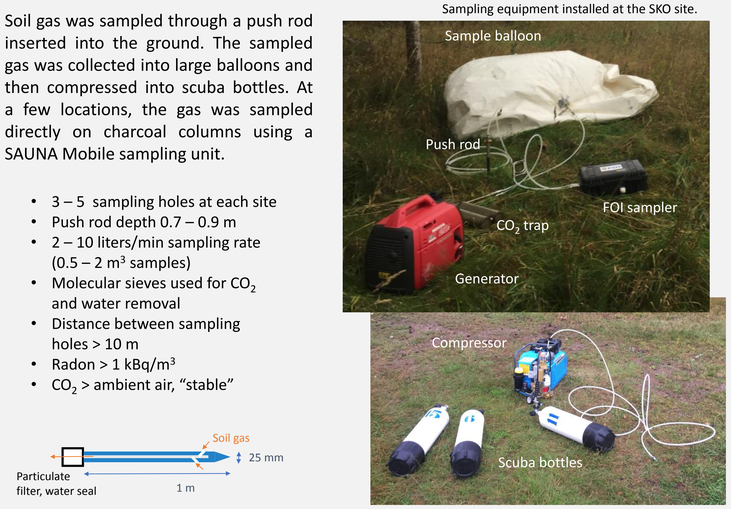
Objectives:

- Build capacity, test and develop methods and equipment
- Study the natural background of radioxenon and radioargon
- Collect data for modeling and better understanding of transport mechanisms of gases in the soil

Soil gas sampling

Soil gas was sampled through a push rod inserted into the ground. The sampled gas was collected into large balloons and then compressed into scuba bottles. At a few locations, the gas was sampled directly on charcoal columns using a SAUNA Mobile sampling unit.

- 3 – 5 sampling holes at each site
- Push rod depth 0.7 – 0.9 m
- 2 – 10 liters/min sampling rate (0.5 – 2 m^3 samples)
- Molecular sieves used for CO_2 and water removal
- Distance between sampling holes > 10 m
- Radon > 1 kBq/m^3
- CO_2 > ambient air, "stable"



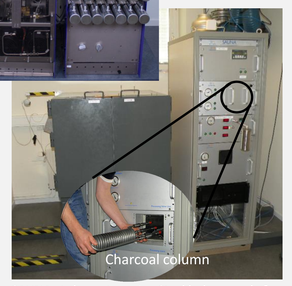
Schematic drawing of the push rod used for sampling

Sampling equipment installed at the SKO site.

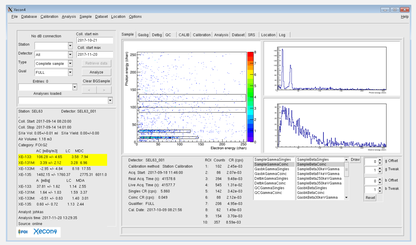
Equipment for transferring the sampled gas to the laboratory

Analysis of soil gas samples

A SAUNA Field system* similar to the system used for processing the samples in the lab



SAUNA Lab system in Stockholm used for quantifying the amount of radioxenon in the sub soil samples. Also showing the insertion of a transport column (charcoal) used for direct sampling in the field.



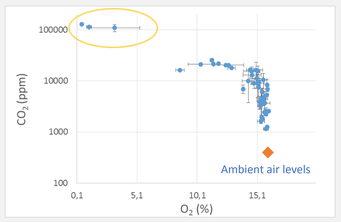
Example of analysis of a sample using Xecon4

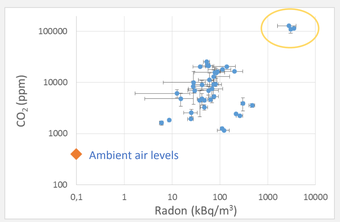
The sub soil gas samples were processed at the xenon laboratory in Stockholm. Additional molecular sieve traps were used in the laboratory to further reduce the CO_2 and water concentrations prior to processing the gas in the SAUNA Field system. Some samples where also merged in the laboratory to increase the sensitivity.

During the purification process, a portion of the gas (100-150 liters) were extracted and sent for argon analysis to the University of Bern (10 samples).

* See poster T3.2-P5

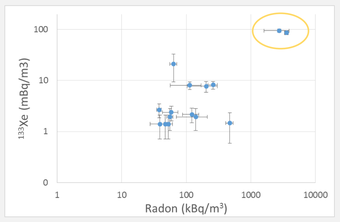
Subsoil gas compositon





Large variations in gas composition were found between different sites but also during the sampling process.

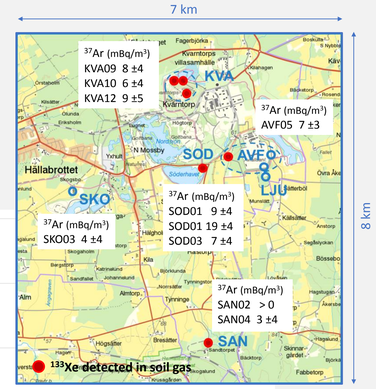
- CO_2 levels between 1000 ppm and 13% were measured
- O_2 levels between 16% and 1% were measured
- Radon concentration between 6 kBq/m^3 and 3900 kBq/m^3

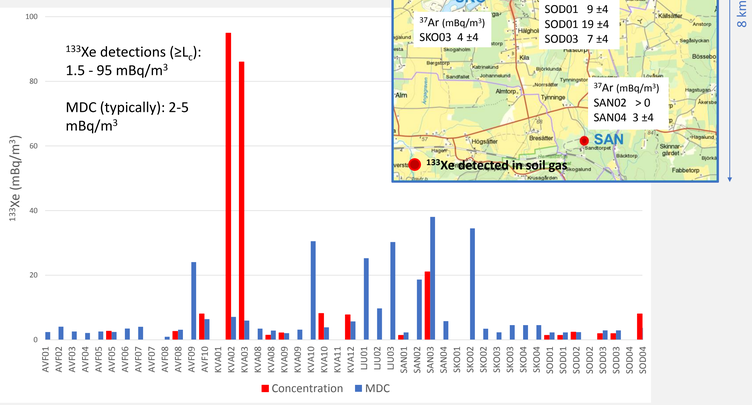


These samples were collected on top of the oil shale pile there the conditions are quite different compared to the non-industrial area (elevated pressure and temperature in the ground).

Results of analysis

The radioxenon isotope ^{133}Xe was detected in 17 of 47 samples and ^{37}Ar was detected in all the argon samples. The detections were made both within the post-industrial area of Kvarntorp oil shale pile as well in areas not affected by the oil mining operations.



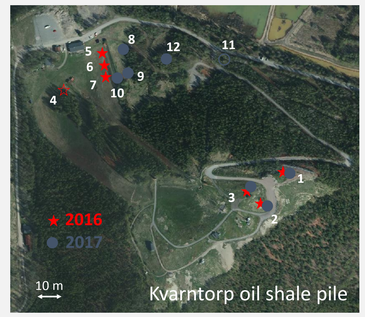


Comparision with previous measurements

	Type	Year	CO_2 %	O_2 %	Rn kBq/m^3	^{133}Xe mBq/m^3	^{37}Ar mBq/m^3
1	Rod	2016	13	2	2400	(57 ±17)	-
	Rod	2017	11	3	3400	n/a	-
2	Rod	2016	12	1	2400	116 ±18	36 ±4
	Rod	2017	13	0.4	2500	95 ±7	-
3	Tarp	2016	6	10	930	72 ±19	12 ±3
	Rod	2017	11	1	3600	86 ±8	-
5	Rod	2016	0.2	18	150	20 ±2	6 ±2
6	Rod	2016	0.1	18	210	23 ±4	7 ±1
7	Tarp	2016	0.05	18	26	<5	-
8	Rod	2017	0.35	15	300	1.5 ±1	-
9	Rod	2017	0.12	16	100	2 ±1	8 ±4
10	Rod	2017	0.24	16	250	8 ±1	6 ±4
12	Rod	2017	1.6	14	240	8 ±2	9 ±5

Rod: Sampling using a rod pushed approximately 1 m into the ground.
Tarp: Sampling underneath a 20 m^2 surface covered with a tarp.

The measurements from 2016 are described in: Kastlander et al., Journal of Environmental Radioactivity 197 (2019) 62–66



At this site samples were collected both in 2016 and 2017. The sampling site consists of a 100 m high hill of 40 million m^3 of oil shale residues. The ground contains up to a few hundreds of ppm uranium, a waste product from 24 years of oil extraction. Due to the high temperature processes used and ongoing oxidation in the pile, still 50 years after closure, the temperature reaches up to 700 °C below the surface.

For more details see for example Sjöberg & Karlsson, Minerals Engineering 75 (2015) 100–109, and references wherein

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO