Measurement of radioargon and radioxenon in soil gas

Among the most important indicators for a UNE during an 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 these occurrences, sub soil sampling has been carried out on the oil shale ash waste pile in Kvarntorp, Sweden, a location with known elevated uranium content.

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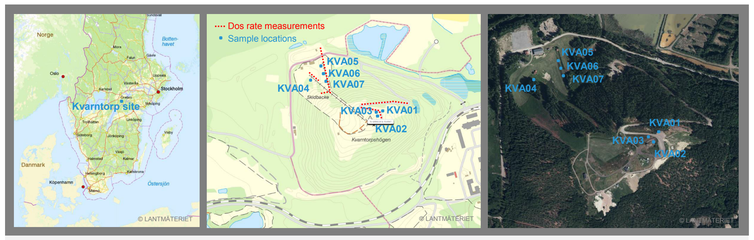
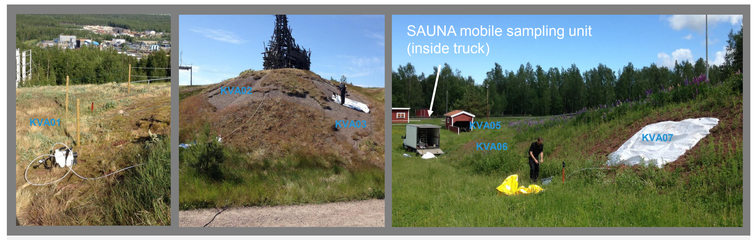


The Kvarntorp site

At this site, a 100 m high hill of 40 million m^3 of shale residues containing up to a few hundreds of ppm uranium as a waste product from 24 years of oil extraction can be found. Due to the high temperature process and ongoing oxidation in the pile, still 50 years after closure, the temperature reaches up to 700 °C below the surface*. The dose rate in the area is varying between 0.1 and 1.5 µSv/h.

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



Sampling locations

Sampling was carried out at six out of seven scouted locations within the Kvarntorp site, at one location no indication of increased radon levels were found. The locations (KVA01-KVA03) were selected on the top of the pile, where an increased surface temperature was noted as well as venting of sub soils gases and water vapor. Four locations (KVA04-KVA07) were selected at the foot of the pile, where no evaluated temperature or outgassing were observed.

Soil gas sampling

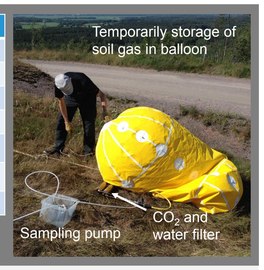
Soil gas was sampled either by inserting a push rod into the ground or covering the ground with a tarp. For radioxenon analysis the sampled gas was collected into large balloons and then compressed into scuba bottles. At two locations, the gas was sampled directly on active charcoal traps using a SAUNA mobile sampling unit. At four of the locations, direct samples, approximately 150 liters, were collected into bags and shipped to University of Bern for radioargon analysis.

Sample	Type	Dose rate (µSv/h)	Radon (kBq/m^3)	CO_2 (%)	O_2 (%)	Volume (m^3)	CO_2 Filter	Xe-133 (mBq/m^3)	Ar-37 (mBq/m^3)
KVA01	push rod mobile	0.5	2370 ±340 [a]	13 ±1 [a]	2	0.82 [b]	Yes	57 ± 17 [c]	Not sampled
KVA02	push rod balloon	1.0	2380 ±1090 [a]	12 ±1 [a]	1	0.42 [b]	Yes	116 ± 18 [c]	36 ±4
KVA03	tarp balloon	1.1	930 ±360 [a]	5.6 ±0.9 [a]	10	2.2 [b]	Yes	72 ± 19 [c]	12 ±3
KVA04	No sampling	0.5	< 1	0.08	18	-	-	-	-
KVA05	push rod mobile	1.3	150 ±70 [a]	0.17 ±0.003 [a]	18	1.5 [b]	Yes	20 ± 2 [c]	6 ±2
KVA06	push rod balloon	1.1	210 ±90 [a]	0.11 ±0.006 [a]	18	0.94 [b]	No	23 ± 4 [c]	7 ±1
KVA07	tarp balloon	1.2	26 ±16 [a]	0.05 ±0.02 [a]	18	1.0 [b]	No	< 5 [c]	Not sampled

[a] The uncertainty is estimated by the spread in the measured quantity

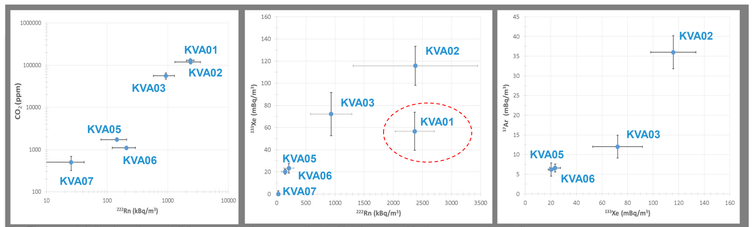
[b] The sample volume is referring to the measured volume after the CO_2 and water filters, hence the volume is smaller than the actual soil gas volume extracted from the ground.

[c] The xenon activity concentrations are air equivalent, calculated from the stable xenon volume using 87 ppm stable xenon in air.



Analysis of soil gas samples

Filters (molecular sieves) were used, during xenon sample collection, in the field, in order to reduce the water and the carbon dioxide concentration, as high content of these components interfere destructively with the purification process and absorption efficiency. The analyses of the xenon samples were made using the SAUNA lab system in Stockholm and the argon samples analyses were carried out by the University of Bern.



- The uncertainties in radon and CO_2 concentrations are estimated by the spread in the measured quantity
- The xenon activity concentrations are air equivalent, calculated from the stable xenon volume using 87 ppm stable xenon in air.
- The xenon concentration for data point KVA1 has been included for completness, however, a system malfunction may have effected the results

Results

The evaluated levels of CO_2 and radon are clear indications that soil gas has successfully been sampled. The very high radon concentrations are due to the specific nature of the site. The measured xenon concentrations are in agreement with estimations based on the uranium content of the pile. The ^{37}Ar levels are typical for shallow alluvium. The lack of enrichment is the result of the domination of cosmogenic production at shallow depth. The apparent correlation between ^{37}Ar and ^{133}Xe could be caused by mixing of fresh atmospheric air with soil gas.

Conclusion

For the first time a comparison of measured ^{133}Xe and ^{37}Ar activity concentrations in soil gas was possible. The ^{37}Ar levels were found to be within normal soil gas ranges, while the ^{133}Xe activities were highly enriched compared to the atmospheric and normal subsurface background due to the nature of the sampling site.

The ^{133}Xe values observed in this study demonstrates the concentration levels that can be found in a area with highly elevated uranium content in the ground. However, further measurements are needed to establish a better understanding of the expected concentrations and the correlation with other measurable parameters such as CO_2 and radon.

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