T2.2-P7

Measurement of Ar-37 backgrounds at the Nevada National Security Site

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A series of measurements have been undertaken on the Nevada National Security Site as part of a large scale subsurface gas migration experiment. Shallow samples have been collected and analyzed for Ar-37, which is expected to be present in shallow soil gas as a result of natural production. As part of the gas migration experiment Ar-37 and Xe-127 were also injected deep underground into the test cavity made by a previous underground nuclear explosion (UNE) and measurements are being made to track the migration of the injected gases. The initial Ar-37 results at both shallow and deeper depths have been obscured by an interfering radiometric signature which has been determined to be Ar-39 produced during the nuclear explosive test and is still present.

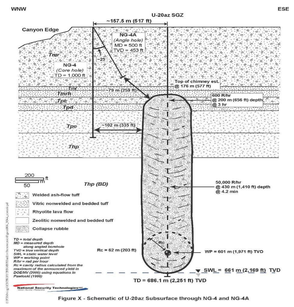
Goals and Objectives

- Determine how radioisotopes from an UNE transport though the subsurface to the surface
- Measure and understand the effect of backgrounds from a previous nuclear explosive test
- Understand the fate and transport of radioactive and stable tracers
- Refine subsurface transport models to reflect experimental conditions and measurements

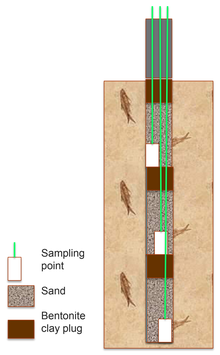
Approach

- Use radioactive and stable tracers injected into UNE U20az cavity/chimneys and sample gases from deep and shallow bore holes
  - Chemical tracers (CF_2Br_2, SF_6, and C_8F_{16})
  - Radiotracers Ar-37 and Xe-127
- Have six deep boreholes (> 150 m), and two shallow (10 m) bore holes located around the site for collection
- Each bore hole has 3-6 sample depths
- Collect 1-5 liter samples to measure stable tracer concentration over time
- Collect 2,000 liters samples to measure Ar-37 and Xe-127 tracer concentration over time

U20az Testbed



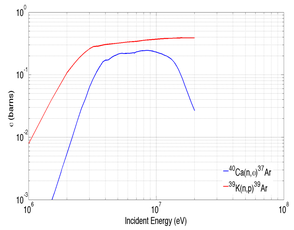
- Drill back hole into base of chimney ~600 m below ground surface
- Six deep holes, five angled

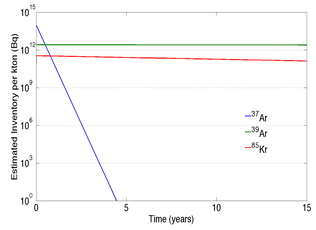


- Two shallow holes (10m)
- Completion of boreholes into three sampling zones

Methods

Production of Ar-37 and Ar-39

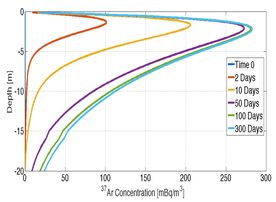




- Charts showing neutron cross-section for the production of Ar-37 from calcium and Ar-39 from potassium in the soil or rock surrounding an UNE
- Models predict measureable Ar-37 from reaction

  (n +Ca-40)→ (α + Ar-37)
- Models predict measureable Ar-39 from reaction

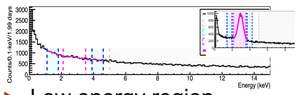
  (n +K-39)→ (p + Ar-39)
- Krypton-85 is a high yield fission product from the UNE.
- Half-life differences (Ar-37 $t_{1/2}$ = 35 days, Ar-39 $t_{1/2}$ = 269 years, Kr-85 $t_{1/2}$ = 10.9 years) lead to larger concentrations of Ar-39 then Ar-37 after 2 years



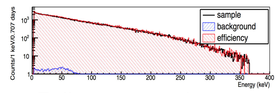
- Argon-37 is produced naturally at shallow depths by way of cosmogenically produced neutrons
- Chart shows Ar-37 concentrations over time for typical concentrations of Ca

Measurement of Ar-37 and Ar-39

- Measurement of Ar-37 was done using an internal proportional counter to detect weak 2.2 keV Auger electron decay
- Measurement of Ar-39 was present and it emits a 569-keV beta particle that is in interference with the low energy Auger electron of Ar-37.



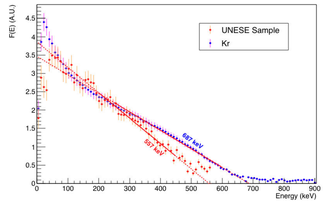
- Low energy region showing location of Ar-37 2.2 keV peak
- Inset shows a strong Ar-37 peak



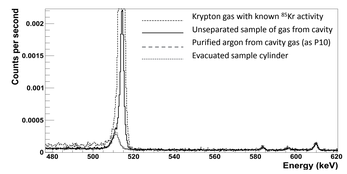
- Full energy region showing Ar-39 beta distribution

Verifying Ar-39 Interference

- Krypton-85 also has a beta energy distribution and long half-life that is difficult to differentiate from Ar-39 without careful measurement
- Two independent measurements were made
  - Using a plastic scintillation cell to measure both Kr-85 (blue symbols) and a processed U20az cavity sample (red symbols) the beta endpoint energy was determined for each



  - An additional gamma-spec measurement was made using both an unseparated air sample from the U20az cavity and the processed sample.
  - Argon gas processing of the U20az samples reduced the Kr-85 by a factor greater than 10,000



Ar-39 Concentrations

Sample ID	Sample Description	^{39}Ar Specific Activity (mBq/SCM) whole-air equivalent
FP005a	NG-6, Shallow, 3/14/2016	40,400 ± 360.0
FP006a	NG-6, Mid, 3/14/2016	48,900 ± 420.0
FP007a	NG-6, Deep, 3/15/2016	36,600 ± 388.0
FP010	U20az, Casing, 5/18/2016	99,900 ± 789.0
FP011	U20az, Chimney, 5/18/2016	952,700 ± 7,720

Argon-39 has been measured in all of the samples taken at U20az. Table above shows the large concentrations found in a small set of samples taken.

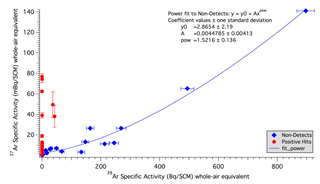
Results

Sample ID	Sample Description	Bkg Elevation Factor over atm. air	Bkg Count Rate (cpd) in the 5-15 keV ROI	Constrained Fit Analysis of ^{37}Ar on Exponential Bkg (mBq/SCM)
FP005	NG-6, Shallow, 3/14/16	860x	22,276.2	31.2 +/- 10.6
FP006	NG-6, Mid, 3/14/16	1,020x	26,433.2	43.6 +/- 11.6
FP007	NG-6, Deep, 3/15/16	676x	17,502.2	20.3 +/- 14.8

- Argon-37 concentrations have been measured for one of the shallow wells prior to injection of Ar-37 and Xe-137
- Results are consistent with naturally occurring Ar-37 concentrations in soil, large error bars indicate the presence of Ar-39 interference

Discussion

- Argon-39 has been measured in all of the samples taken at U20az and is likely to be detected at all UNE sites if Ar-37 is measured
- The Ar-39 represents a significant interference for Ar-37 measurements at naturally occurring backgrounds and for UNEs after ~ 2 years
- Argon sampling systems for onsite inspections will need to be able to handle potentially large Ar-39 concentrations



- Plot showing the effect of Ar-39 concentrations on the minimum detectable concentration of Ar-37

Acknowledgment

The authors wish to acknowledge to the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development, the Underground Nuclear Explosion Signatures Experiment working group, and an interdisciplinary group of scientists and engineers from Pacific Northwest and Lawrence Livermore National Laboratories and Nevada Security Technology. This work was performed by Pacific Northwest National Laboratory under award number DE-AC52-06NA25946.

PNNL-SA-126375

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