SNOLAB water purification and radon and radium assay techniques

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Overview of water purification plant

• Ultra pure water (UPW) provides shielding for SNOLAB experiments
• Potable water from Vale is treated and purified to remove radioactivity, organic and inorganic impurities
• SNO+ uses large majority of SNOLAB UPW (focus of this talk)
• Other experiments such as DEAP-3600 post treating SNOLAB UPW
Water from Mine

Deaerator
- Removes N2 and O2

Charcoal
- Traps large particles and organic matter
- Removes chlorine

Zeolite softeners
- Remove Ca, Mg

Reverse osmosis (RO)
- Remove insoluble inorganic matter such as salts, some organics, particles with molecular mass higher than 200

UPW supply of SNOLAB
- 300 L/m water circulation
- (130 L/m goes for re-purification)

Process Degasser (PDG)
- Remove N2, O2, Rn

Ion Exchange columns
- Removes Th, Ra, ...

UV 185 nm
- Breaks down organic matter to ionic form

10 tonne level Control tank

Pump

Regasser
- Adds N2

0.1 micron filters

UV 254 nm
- Sterilization

Chillers

Polishing RO

Add EDTA
• Other experiments, such as DEAP-3600, are further away from SNOLAB water plant and performing further treatment
UPW background measurement using ex-situ techniques for SNO+

- $^{232}$Th and $^{238}$U content in UPW needs to be monitored regularly
- $^{224}$Ra and $^{226}$Ra can be measured using **Hydrous titanium oxide technique (HTiO)**
  
  Sufficient to measure Th-chain backgrounds but not U-chain

- $^{222}$Rn ingress from the PMT cables and rock surrounding the cavity causes disequilibrium in $^{238}$U chain

- $^{222}$Rn is measured by using **degassing and trapping radon technique**

- $^{232}$Th and $^{238}$U target levels for SNO+ PSUP are ([10.1103/PhysRevC.72.055502](https://doi.org/10.1103/PhysRevC.72.055502)):

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<tbody>
<tr>
<td>$^{238}$U</td>
<td>2.06 E-13 g/g</td>
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<tr>
<td>$^{232}$Th</td>
<td>5.2 E-14 g/g</td>
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HTiO technique

• The method is described in NIMA 604:531, 2009
• HTiO is an inorganic ion-exchanger, can remove heavy ions ($^{224}$Ra, $^{226}$Ra) from water
• Deposited on to a pair of memtrex filters with Ti coverage of 2.5 g/m$^2$ on surface
• Typically 30 tonnes of UPW passes through HTiO per assay
• In elution stage 15L of 0.1 mol/L HCl passes through the columns
• The elute is then concentrated in preparation for counting
• This final sample was added to Optiphase HiSafe 3 liquid scintillator
• Used beta-alpha coincidence counting system
• Working on finalising the uncertainty on efficiency of the concentration stage
• The minimum detectable concentration during SNO was 4 E-16 g$^{232}$Th/g H$_2$O
$^{210}\text{Pb}$ capability

- SNOLAB Canberra Well detector can measure $^{210}\text{Pb}$ with high precision

- Preliminary work:
  - 66% $^{210}\text{Pb}$ total measurement efficiency
  - Sensitivity of Pb-210 assay technique: $0.4 \pm 0.13 \text{ mBq/m}^3$

Prefill commissioning water sample (D. Chauhan et al, TAUP 2017 poster)
Radon assay

Process Degasser (PDG)
Remove N2, O2, Rn

Ion Exchange columns
Removes Th,Ra,...

UV 185 nm
Breaks down organic matter to ionic form

UPW supply of SNOLAB

300 L/m water circulation (130 L/m goes for re-purification)

Monitor Degasser (MDG)
Flow rate: 19 L/m

Regasser
Adds N2

0.1 micron filters

UV 254 nm Sterilization

Chillers

Polishing RO

Spray nozzles

Gas to Rn collector

View point

Monitor Degasser (MDG)
Radon assay

• The system is described in: NIMA 517:139, 2004
• Rn is extracted by vacuum stripping, then concentrated using a series of cold traps, before being transferred to a Lucas cell
• Typical assays are half an hour (570 L)
• Total radon collection efficiency =77%
Radon counting system

• Using ZnS coated Lucas cells to count decayed alphas

This year SNOLAB purchased 8 new channels with CAEN electronics used for both SNO+ radon assays and SNOLAB radon emanation counting
Rn-assay system’s background

- The background of the system during SNO times was $20^{+9}_{-6}$ Rn atoms/h.
- The background level was seen to be higher during recommissioning for SNO+.
- Mixture of baking the traps and locating leaks in N2 purge system reduced the background.
- The oil vacuum pump was replaced with dry pump.
- Leak discovered in one of the purge lines.
- The current background level is $45^{+13.5}_{-13}$ Rn atoms/h.
Historical assays

Between PSUP and AV

Bottom of cavity
Recent assays

Between PSUP and AV
413±123.9 Rn atoms in 600 L of UPW

Bottom of cavity
1185±355 Rn atoms in 640 L of UPW
Summary and outlook

• Water purification developed by SNO is performing well for SNOLAB experiments and the quality of the water is similar to SNO times.
• HTiO system for SNO+ is being recommissioned and final tests are ongoing.
• Radon assay system for SNO+ is commissioned and regular assays are resumed.
Backup
Water purification (details of components)

• Softeners: two 0.14m³ bottles containing strong base Purolite C100-E cation exchange resin

• Reverse osmosis: Twelve spiral-wound thin film composite (polyamide on polysulfone) membranes

• Ion Exchange: two sets of six bottles containing 0.1m³ of purolite nuclear grate NWR-37 mixed (cation and anion) bed resins