Radon Emanation Measurement in the Utility Room at SNO Underground Laboratory

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Introduction

Of the several options to mitigate the radon interference in the water systems, elimination of radon in air, or reducing its concentration in air to an acceptable level, has its appeal from several points of view. In order to pursue this option radon levels were mapped[1] at the SNO laboratory site at INCO Creighton mine with the sampling cylinder method using the mobile electrostatic chamber (ESC) detecting system available at the underground laboratory. From the measured on site radon levels typical values were deduced for design variables[2] to mitigate the radon problem. The effect of leakage of air through the entrance doors into the utility room was taken into account[3] in order to calculate the radon emanation rate from the walls of the utility room.

In order to set the requirements for providing radon-free air to the utility room the calculated radon emanation rate must be verified by actual measurement. Sealing the utility room from the outside radon loaded air, and measuring the activity inside the room during the sealed period is considered to be the direct way of doing this verification.

The results from the first experiment to measure the effective emanation rate of radon from the walls of the sealed utility room are reported below.

Description of the utility room

The utility room provides an ideal location in the underground laboratory to measure the radon emanation rate from the walls from several points of view.

The source term from radon emanation is maximized in this location from a large enclosed surface area (about 16800 sft), while the leakage of air through the openings into the room is minimized because five sides of the room are solid rock and the remaining side is a partition wall separating the room from the rest of the underground laboratory.

Ventilation system in the room consisted of: Air handling unit (AHU) #1 which recirculates, filters and cools room air; some of the fresh clean air provided by AHU #5 is introduced into the room as make up air in AHU #1; and an exhaust fan (EF #5) removes up to 1000 cfm of air from the room. Under normal operating conditions the inlet and exhaust air flow rates through the ducts are such that there is always a small negative pressure in the room with respect to the pressure outside so that air always flows into the room via leakage paths.

The exhaust duct from the room, and the in-coming fresh air stream from the air handling unit (AHU) #5 can easily be blocked completely to isolate the room from external radon loaded air, while the AHU #1 is still kept running to provide the air conditioning in the room to maintain the temperature, humidity, and the air particulate cleanliness at operating values.

The openings into the room for water and electrical connections are bunched together in a few locations which can be sealed effectively to minimize the ingress of air into the room from the outside via this path way. The entry ways into the room through the two large double doors offer a high quality seal to reduce the ingress of air to an insignificant level.

Details of the sealing of the utility room

The experiment was conducted from July 18-24, 1996 towards the end of a month long shut-down period in the operations of the Creighton mine during the month of July 1996. The shut-down period was particularly quiet due to the elimination of blasting for mining operations which affect the ventilation in the mine even though the over all ventilation in the mine was redued to about 60% of the normal level[4].

All openings to the utility room were stuffed with foam insulation where needed, covered with 3 mil plastic sheet, and sealed with duct tape. The openings into the room bringing in ventilation ducts, pipes and electrical connections were sealed on July 18th, the day before the room was sealed totally. There were the regular morning and afternoon shifts using the room on this day.

The louvers in the fresh air in-take duct of AHU # 1 were found to be closed on July 18th. They were on automatic pneumatic control with the control solenoid energized. This implied that most of the fresh air was entering the room through the entrance doors and other leakage paths rather than through the supply duct.

The final sealing of the room started on July 19th through the later half of the morning shift. The exhaust fan EF-05 was shut down at 1 pm. The fresh air inlet duct was plugged with a plastic covered foam insulation and sealed securely with duct tape. Then the exhaust port was blocked off with a suitable piece of cardboard, and covered with a 3 mil plastic sheet and sealed with duct tape. The plastic sheet was also used to cover and seal both sides of the ventilation grills in the door ways to the room.

After the regular morning shift the room was totally sealed on July 19th at 2 pm by closing the doors shut and sealing all the cracks in the door frames with duct tape.

The seal was broken at 8 am on July 22. The entrance doors on the lower level were kept open for about an hour afterwards, and then closed. The fresh air inlet duct from AHU#5 was unplugged and the access port closed. The exhaust fan was turned on after removing the seals blocking it. The exhaust flow was measured to be 800 cfm with an anemometer available in the laboratory.

Experimental Measurements

The controls, monitors and alarms (CMA) system was used to keep a continuous record of temperature, humidity, and absolute pressure during the duration of the experiment.

The AHU #1 in the utility room was kept running normally with an air recirculation rate of 13,000 cfm.

Radon concentrations in the air were determined before, during, and after the sealing of the utility room by three methods.

The sampling cylinder method[1] with the ESC was used to determine radon concentrations at some time before the seal, at the end of the seal, and several times one day after the room was reopened. About eight litres of air was sampled each time, transferred into the ESC, and spectral data were recorded two times for 1000 seconds each. The gross counts under the peak at 6 MeV in the second count each time was taken to be proportional to the radon concentration in room air.

The continuous air sampling method[5] with the ESC was used to determine radon levels from the evening of July 18th for two days, and eight hours after the room was reopened. After setting up the ESC, air was sampled continuously near the 10 ton tank area about 6' above floor level at a rate of about 0.3 lpm through a drying column using a suction pump. Spectral data were recorded continuously for 1800 s each time automatically. The gross counts under the peak at 6 MeV in each spectrum was taken to be proportional to the radon concentration in room air.

The activated charcoal canister method with a commercial service provider[6] was used between July 18th and July 24th. The canisters were exposed to room air for fixed periods, and returned to the service provider at the end of each period for analysis.

One canister was exposed to room air before the room was sealed for about 24 hours from July18th 1:08 pm to 19th 1:20 pm in the 10 ton tank area about four feet above floor level. Two other canisters were exposed from July 19th 2 pm to July 22nd 8 am for about 66 hours, one in the 10 ton tank area as before, and the other on top of a desk in the D_2O area. Two more canisters were exposed from July 22nd 1:40 pm to July 24th 1:45 pm for about 48 hours in the same locations as during the sealed period.

Results and discussion

The temperature, humidity, and pressure values were constant to better than 5% during the duration of the experiment.

The sampling cylinder method and the continuous sampling method readily provide measurement of relative radon concentrations in the air. These relative values may be converted to absolute values by normalizing to an ambient radon concentration[7] of 3 pCi/l for air in the utility room from measurements with Lucas cells.

The activated charcoal canister data gave absolute values for radon concentrations. Results are summarized in the table below.

The combined ESC data and the charcoal canister data seem to be agreeing with each other qualitatively to indicate that the activity level went up during the period the utility room was sealed relative to the period before or after. Within experimental errors they also seem to indicate that the factor by which the activity went up is about 3.

Table of results from ESC and charcoal canister measurements of radon levels in the utility room before, during and after the room was sealed to measure the effective radon emanation from the walls.

counting period	sampling cylinder	continuous sampling	charcoal canister pCi / l	
	(relative values only)		10 TT Area	D_2O Area
Average few weeks before	1			
July18-19		2	8.8	
July19-22	3*	increasing slowly	11.8	12.4
July22		1		
July23	1			
July22-24	1 - 1.5**		4.7	4.8

*sampled at the time of reopening the room at 8 am on July22

**Activated Charcoal filters in the water systems were being unloaded for servicing during the morning shift between 8 Am and 2 pm on July 24

However, there seems to be some disagreement with the absolute values reported by the charcoal canister method and the nominal value of 3 pCi/l assumed for the average ambient radon level in the utility room. In this context, a value reported by Norman[8] of about 2 pCi/l by charcoal canister method should also be taken into account before any conclusions can be drawn about systematic errors. On the other hand, the disagreement may only be due to the elevated levels of radon in the mine during the shut-down period due to changes in mine ventilation and the fact that the two charcoal canisters were monitoring the two-day period immediately following the end of shut-down of the mining operations.

The over all ventilation in the mine was found to be reduced to 500k cfm from the normal operating level of 1,100k cfm of air[4]. The exhaust volume through the #11 uprise on the 6800 level was also reduced from a normal 55,000 cfm to 41,400 cfm. The normal fresh air supply to the 6800 level through the #9 shaft was 86,600 cfm which was reduced to 43,000 cfm. This change in ventilation during the shut-down period may be responsible for the elevated levels of radon during the day before the utility room was sealed, as well as during the first two days after the end of the shut-down period as indicated by the charcoal canister monitors.

Assuming that the ambient radon activity during normal operations is 3 pCi/l in the utility room, and that it is the sum of two components consisting of an emanating source from the walls of the room and the transported source brought-in by the fresh air through the ventilation system one can deduce that the emanation source is between 5% and 15% of the total activity as visualized by Bonvin[9] to explain the observed increase during the seal period. See Appendix 1 for other scenarios considered by Bonvin.

On the other hand, if the emanation source is only 1% of the total activity during normal operations, then the activity must decrease marginally during the seal period as reported earlier[3]. Since a significant increase was recorded by all the three methods of detection during the sealed period it is unlikely that the emanation source in the utility room is lower than 5% of the total activity.

At the same time it is also not possible that the emanation source is greater than 15% of the total activity during normal operations as can be seen from the table of values reported by Bonvin.

For an average value of 10% for the emanation term in the total ambient radon activity it can also be shown that the present ventilation system will achieve a radon level of 0.1 pCi/l with a radon-free air supply of 1000 cfm to the room.

Appendix 1

Question: What are the activities supported by each of two sources?

Model: 700 cfm incoming air to the utility room. Turn-around time: 2 hours= 0.022 half-life of Rn to decay during these two hours

Rn total activity during standard operations = 3 pCi/l from two main sources: 1. brought in from the mine by the ventilation system, and 2. emanating from the utility room walls.

Measurement proposed by Jagam: Seal-off the Utility room over a week-end (=2.75 days) and measure the Rn activity after the seal period.

Seal time of 2.75 d corresponds to 0.72 ^{222}Rn half-lives. 60% of Rn present at t=0 will still be present, whereas the build-up activity from Rn emanating from the walls will be around 40% of the saturation activity.

Scenario 1:	90% of Rn from ventilation	10% of Rn from walls	Total Activity
before seal	2.7 pCi/l	0.3 pCi/l	3 pCi/l
after 2.75 d	1.6 pCi/l	8.0 pCi/l	9.6 pCi/l

Scenario 2:	75% of Rn from ventilation	25% of Rn from walls	Total Activity
before seal	2.2 pCi/l	0.8 pCi/l	3 pCi/l
after 2.75 d	1.3 pCi/l	20. pCi/l	21.3 pCi/l

Scenario 3:	50% of Rn from ventilation	50% of Rn from walls	Total Activity
before seal	1.5 pCi/l	1.5 pCi/l	3 pCi/l
after 2.75 d	0.9 pCi/l	40 pCi/l	41. pCi/l

Scenario 4:	99% of Rn from ventilation	1% of Rn from walls	Total Activity
Before seal	3.0 pCi/l	0.03 pCi/l	3 pCi/l
after 2.75d1	1.8 pCi/l	0.8 pCi/l	2.6 pCi/l

Conclusion : With a counting system that is quite able to quickly measure activities around or larger than 1 pCi/l, one should have NO PROBLEM to differentiate between the different scenarios, assuming that the various assumptions are correct and that an adequate seal of the Utility Room is achievable.

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