Radon Emanation from Stainless Steel

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D. Steinberg's group at Drexel have reported on radon emanation from a stainless steel drum. This drum was bought commercially and its inside had been polished to provide a dull shine. They observed a count rate of 1000 counts (radon plus daughters) per hour in their Lucas cell from this 200 liter drum of surface area 2 m^2. They are planning to remeasure this and also test the effect of acid etching the drum's surface.

Assuming a total efficiency (radon collection and counting) of 85%, 1000 counts per hour corresponds to 9412 Rn decays per day since there are three sequential alpha decays. An equivalent number of radon must be emanated from the 2 m^2 to support this decay rate i.e. there are

4706 radon atoms emanated per day per m^2.

Assuming a steel (density 8 gm/cm^3) wall thickness of about 4 mm and all the radon produced in the steel "diffuses" through to the inside of the drum, we obtain an equivalent level of

$$139 \times 10^{-12} \text{ gm U per gram of steel}$$

supporting the emanated radon.

If the steel in reality is of the order of 1×10^{-9} grams U per gram of steel, then the thickness of steel in which all the radon would have to diffuse into the drum is 4 mm $\times$ 139/1000 = 0.6 mm.

Radon also leaves the steel surface by recoiling out. The radon atoms have an initial energy of about 100 keV and a range of 150 Angstroms in steel (according to the Ziegler range program). One-quarter of the recoiling radon in a layer 150 Angstroms thick will leave the steel surface. Hence the equivalent uranium level which would support the radon observed by Steinberg et al is

$$139 \times 10^{-12} \times 4 \times 0.4 \;/\; 150 \times 10^{-8}$$

$= 148 \times 10^{-6}$ gm U per gram of steel in the 150 Angstrom layer.

The microscopic surface of steel is full of peaks and valleys many microns high and deep so that the effective surface area where the radon can recoil from is much larger than the macroscopic geometrical surface area. Additionally we do not know how the radium parent of radon is distributed in the surface layer of steel and the nature and effect the surface oxide layer of steel has on radon emanation. These factors makes the above calculation of the equivalent uranium concentration in the top 150 Angstrom layer of the steel very uncertain.

It is interesting to note that it has been reported there is no apparent correlation between ^{226}Ra concentration in rock from well sites and the ^{222}Rn concentration in the well [1]. It has been stated that this could be due to localized minerals high in uranium, abundance of microfractures in the well and geochemical factors influencing the radon concentration. Also high (higher than expected from an assumed uniform volume distribution of radium and an assumed diffusion rate) Rn emanation rates have been observed from some rocks and soils. Apparantly Ra resides in thin accessory minerals or forms coatings (30 nm to over 1 micron) on the surface of minerals, which is sufficiently thin for a large fraction of the radon to be released [2].

In the SNO detector the area of stainless steel under water is about 1700 m^2. Using the above Drexel radon emanation rate gives

$$8.0 \times 10^6 \text{ radon emanated per day.}$$

This is to be compared to 7000 tonnes of H_2O at 1×10^{-14} gm U per gm water which in secular equilibrium contains 260 radon atoms per tonne or a total of ~~1.8×10^6~~ radon. The radon from stainless steel would not be a problem if the H_2O circulation pattern is radially outward from the acrylic vessel.

At Queen's we have measured the radon from a piece of four inch diameter, 5 feet long stainless steel beampipe. We also have estimated the radon emanation rate of our radon extraction apparatus which is made up of stainless steel Swagelok components. Our results along with the Drexel results and the inferred rate of rádon emanation from an electropolished steel ionization chamber (N.I.S.T. [3]) is shown in the following table.

Radon Emanation Rates from Stainless Steel

	Radon per m^2 per hour
Drexel Univ.	180
Queen's Beampipe	370±100
NIST chamber (1)	60
Queen's Rn board	30±20

There is a range of about a factor of ten in the emanation rate listed in the table from the different steels.

The radon emanation rate from aluminum, glass and the PMT cables is unknown at present. The results on stainless steel suggests that it is crucial to get radon emanation rates on these three materials.

References

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3. R. Colle, J. Hutchinson and M. Unterweger, J. Nat. Instit. Stand. and Tech **95**:155, (1990).