Preliminary considerations on the surface contamination

Materials-WG

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1 General aspects

The ^{222}Rn daughters are heavy metals, which easily deposit on surfaces (the so-called plate-out effect). In a simplistic scenario, the Rn daughters produced in the air column above a surface will be deposited on the surface below them. If not supported (by ^{226}Ra/^{222}Rn) the short-lived progenies decay within $\sim$3 hours, but the long-lived ^{210}Pb remains (half-life of 22 y) leading usually to disequilibrium in the decay chain. Therefore one cannot conclude about the activities of the long-lived U daughters (^{226}Ra, ^{210}Pb, ^{210}Po) from the well-established techniques making possible to assay the upper part of the chain, like e.g. high sensitivity radon emanation measurements or U determination via ICP-MS (the same for the Th chain). Moreover, due to the recoil energy a nucleus can get after an alpha decay ($\sim$100 keV), ^{210}Pb may be implemented into a sub-surface layer of the material in question, and can remain as the main residual contamination due to that effect, even after surface treatment (cleaning).

At the same time, ^{222}Rn may penetrate inside the material. As a consequence, in addition to the plate-out effect, it has to be taken into account the decay of all the ^{222}Rn daughters in a sub-surface layer which is not related to the ^{238}U contamination in the material bulk. The effect depends on the material properties and the environmental conditions, and it can be particularly relevant in case of plastics or similar materials. This effect can be sub-dominant with respect to the plate-out (four orders of magnitude in [2]) . On the other hand, the depth of the diffusion (up to several millimeters depending on the material) makes more difficult to remove the contamination given by the ^{222}Rn diffusion with respect to the plate-out.

2 Surface activity estimation

The amount of activity coming from the mentioned effects can be estimated if certain environmental parameters are known. One has to bear in mind that these parameters depend largely on the atmospheric conditions in which the deposits

happen (humidity, temperature, pressure...) and that the ones presented here are only strictly valid for the cases of study, so they have to be taken only as an indication.

From the Bateman equation [1],

$$A_{Po}(t) = N_{Pb}(0)\frac{\lambda_{Po}\lambda_{Pb}}{\lambda_{Po}-\lambda_{Pb}}(e^{-\lambda_{Pb}t} - e^{-\lambda_{Po}t}),$$

one can calculate the activity, known the decay constants of the relevant nuclei in the chain. This equation is valid taking into account that the exposure needs to be short compared to the half-lives involved. With the same assumption, the number of ^{210}Pb deposited in your sample is linear with time and depends on the environment conditions via a deposition rate R_{Pb}:

$$N_{Pb}(t_{exp}) = R_{Pb}t_{exp}.$$

In [2], this deposition rate is calculated to be $R_{Pb} = 249\pm12$ atoms/day/cm^2 for SNOLAB, where the radon activity concentration is 135 Bq/m^3. One day of exposure under this conditions, considering 880 m^2 of acrylic surface, leave 2.2 e9 ^{210}Pb nuclei on its surface. The activity produced by the dust deposition is, in addition to this one, 36 nBq/day/cm^2 leading to an extra number of .

The time of maximum activity can be inferred from the Bateman equation:

$$t_{max}(t_{exp}) = \frac{1}{\lambda_{Po}-\lambda_{Pb}} ln\left[\frac{e^{t_{exp}\lambda_{Po}}-1}{e^{t_{exp}\lambda_{Pb}}-1}\right],$$

and for exposure times in the order of days, the maximum Po activity is 2.3 years after exposure.

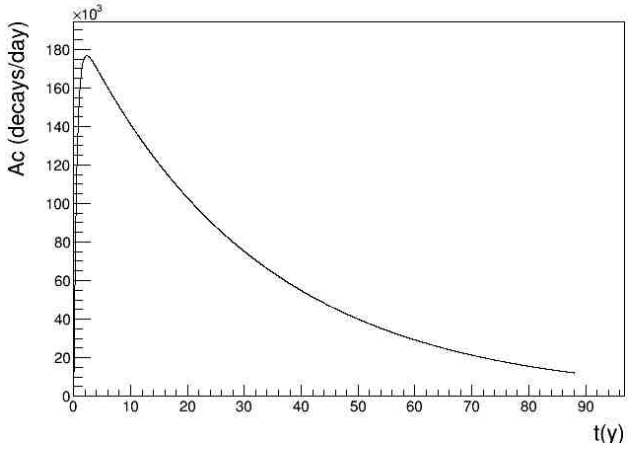

Figure 1: Evolution of ^{210}Po activity as a result of 1 day exposure to Rn.

Considering that the experiment starts 2 years after the exposure and lasts for 5 years,

3 Strategy and preliminary recommendations

In each step, from the production to the assembly phase, surfaces of the material should be protected against deposition of the ^{222}Rn daughters. Surfaces could be covered by protective foils (as the mill does for metal sheets) or the elements could be wrapped in a simple stretch foil (usually clean enough). Wrapping can be combined with storage in ^{222}Rn-free atmosphere (Nitrogen, synthetic air).

In details, the surface cleaning strategy should consider:

Cleaning: Specific surface cleaning protocols have to be prepared depending on the material properties. Tests of various methods could be performed with surfaces exposed to high ^{222}Rn activities for artificial, high contamination. Materials which have been not passed a specific cleaning protocols cannot be used for the assembly of the detector.

Tracing: The history of the exposure of materials to the air have to be carefully known in order to issue specific cleaning protocols.

Storage: The exposure of the material surface to air has to be avoided after the cleaning. Surfaces have to be protected against plate-out and ^{222}Rn diffusion, storing the materials in Rn-free/reduced atmosphere. Storage in one (or more) protective bags have to be foreseen.

Transportation: The transportation of the materials to the detector construction site has to guarantee Rn-free/reduced conditions.

Mounting: In a cleanroom with ^{222}Rn-free/reduced atmosphere (Ateko air)

4 Prevention from Recontamination Protocols

The prevention from the re-contamination during the cleaning process were guaranteed following these points:

1 Manipulation with double gloves (Class 100 clean room gloves + polyethylene gloves see Fig. 2)

2 Manipulation with Alpha Wipe TX1009 tissue 100% continuous filament polyester (Fig. 3)

3 Storage in single polyethylene bags under vacuum (during the intermediate steps of cleaning Fig. 4)

4 Cosmogenic activation limited to 90 days

NB: The vacuum pump for vacuum packaging is a commercial electrical appliance for food storage under vacuum but commissioned with the option oil

and grease free. These appliances are frequently replaced due to the absence of lubrification on mechanic parts. For what concerns the transport between the cleaning plant and the storage plant were adopted these countermeasures:

1 Not air freight

2 Triple plastic bags under vacuum. The packaging is made in a clean room class 1000 and collected inside a plastic box under vacuum too (Fig. 4). Cu transport logistic was organized to minimize the cosmogenic activation

3 Database with bar codes for every component to collect all the cleaning passages before the installation.

Figure 2: Super market PET gloves and class 100 Nitrile gloves.

5 Conclusions

Surface contamination given by Rn and Rn-daughters can be a serious concern for the experiment. Specific protocols have to be identified in order to clean the materials surface. After the cleaning, the exposure of the materials to air has to be avoided and the surfaces have to be protected against plate-out and ^{222}Rn diffusion. Materials have to be stored in Rn-free/reduced atmosphere and the transportation has to guarantee this conditions.

Figure 3: Alphawipe tissue.

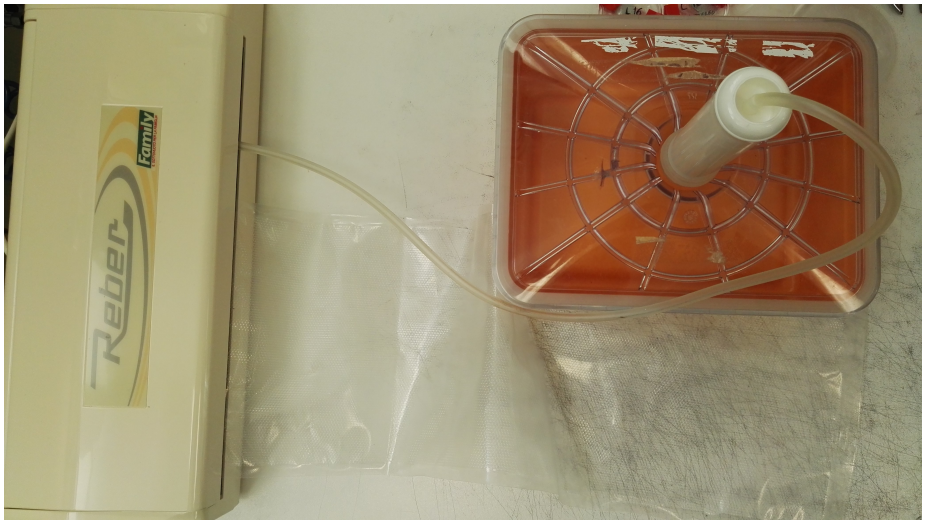

Figure 4: Oil free vacuum pump, plastic bag and plastic box.

References

[1] Harry Bateman. Solution of a system of differential equations occurring in the theory of radioactive transformations. *Proc. Cambridge Phil. Soc., 15.*, pages 423–427, 1920.

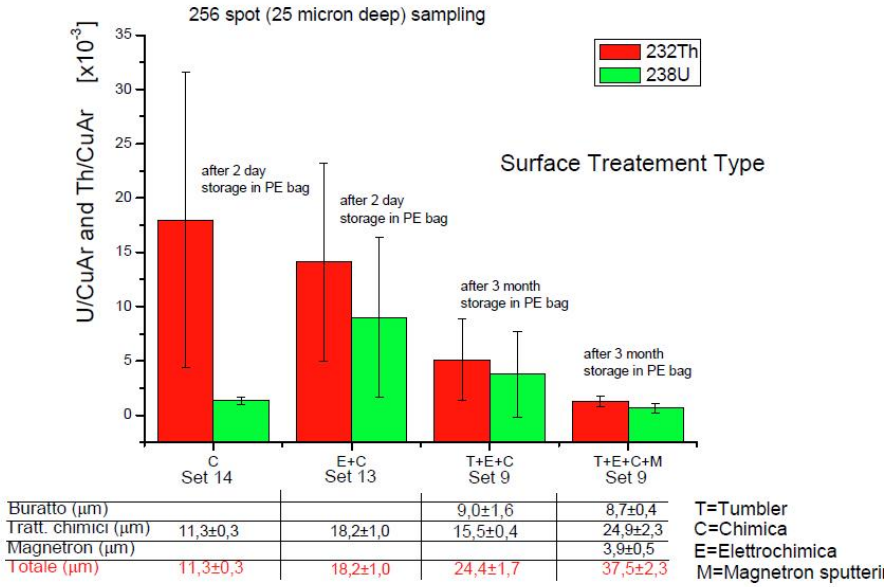

Figura 6.5 Il livello di contaminazione residua mediata sul singolo set. Si vede che il trattamento in plasma è quello che permette di abbassare maggiormente la contaminazione..

Figure 5: Recontamination after the storage in plastic bags under vacuum for different cleaning processes.

[2] Matthew Stein, Dan Bauer, Raymond Bunker, Rob Calkins, Jodi Cooley, Ben Loer, and Silvia Scorza. Radon daughter plate-out measurements at snolab for polyethylene and copper. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 880, 08 2017.