Refurbishment of the tritium laboratories at SCK•CEN

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Abstract

The tritium laboratories at SCK•CEN were commissioned in 1975 for a maximum tritium inventory of 37 TBq tritium. With an aim to improve the infrastructure, the capabilities and the safety, SCK•CEN's general management has decided to refurbish the laboratories. A new ventilation system, including a stack and gloveboxes equipped with a detritiation installation, will allow a higher tritium inventory limit of 0.37 PBq. This paper discusses the ongoing refurbishment of the two neighbouring SCK•CEN tritium laboratories. Currently one laboratory has been denuclearised whilst the other is still in operation and a number of conclusions can already be drawn.

The Belgian authority and nuclear control agency only accepted a tritium free release limit based on removable surface tritium contamination of less than 4 Bq/dm². This rigorously low limit made the free release of the laboratory's equipment extra labour intensive. A reasonable free release limit of 250 Bq/dm² would have led to fewer disposals of materials as nuclear waste and less generation of secondary nuclear waste. Nevertheless we succeeded in denuclearising most of the equipment, waste and infrastructure without the personnel having received measurable doses of tritium. It has been estimated that if the free released metals were disposed to a nuclear melting facility 22% of the costs could have been saved, but free release might be more socially acceptable.

Keywords: ***Tritium, laboratory, decommission, denuclearise, free release limit, nuclear waste, detritiation***

1 Introduction

The tritium laboratories at SCK•CEN were commissioned in 1975 for a maximum tritium inventory of 37 TBq (1000 Ci) tritium. Major tritium research for both fission and fusion has been executed.

The tritium laboratory consists of 2 adjacent rooms. The lab refurbishment is necessary to improve the infrastructure, the capabilities and the safety. The refurbishment will not increase the surface of the laboratories. A technical storey on the building is necessary to house a new ventilation system including a stack, which will allow a higher tritium inventory of 370 TBq (10000 Ci).

It was opted to refurbish one room whilst keeping the other in operation. Despite the increased complexity of the refurbishment project, it was more important for SCK•CEN to ensure ongoing tritium research capabilities.

2 Decommissioning a tritium laboratory

The initial step in the project was to clear the room that had to be refurbished. As much equipment as possible was moved into the other laboratory room whilst another part was stored in a warehouse (nuclear zone). The furniture, fume hoods, gloveboxes and process cells will not be reused. The total weight of metal from the process cells and gloveboxes was estimated to be 5 ton. Since free released metal can be sold for recycling and there is a

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cost to dispose contaminated metal, free releasing was the desired option. A strategy had to be worked out to free release or dispose these items.

2.1 Disposal / free release strategy.

The general strategy is depicted in fig. 1. The first step in this process is to clean the items. Subsequently the removable surface activity is measured and compared with the free release limit (FRL). If the items are below FRL they can either be recycled or disposed as non radioactive waste. In the case that an item is not below the FRL, again two options are open: either further decontaminate it and try to get it below the FRL or dispose of it as radioactive waste.

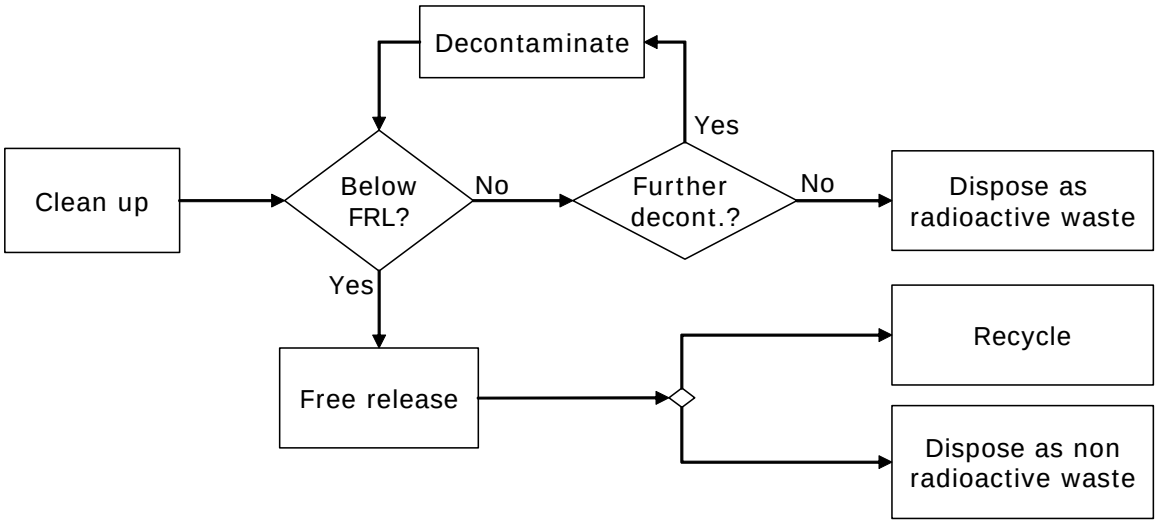

fig. 1: Disposal/free release strategy

2.2 Tritium free release limits

The FRL is the key point in the strategy above. The lower the FRL, the more difficult and costly decontamination will become.

2.2.1 Usableness of the existing Belgian free release limit

The tritium free release limit for solid radioactive waste products in Belgium is 100 Bq/g [1]. This legal FRL is not practical in our case for several reasons:

- A limit expressed per weight material averages the tritium contamination at the surface with the tritium in the bulk. Despite tritium can migrate into substance, most of the tritium contamination in solid construction materials that were contaminated at room temperature by tritiated liquid spills or by tritiated gasses is concentrated in or at the surface layers. Incorporated tritium contamination is more an issue for materials in which tritium would be generated due to activation or materials in which tritiated species can penetrate easily.
- Due to the low energy level (β-radiation, E_{max} = 18.7 keV) the radiation emitted by tritium incorporated in the bulk of a material has no effect on the environment. In this perspective it becomes clear that, especially in the case of surface contaminated materials, the tritium surface contamination [Bq/dm²] is a better safety criterion than the average tritium content of a material [Bq/g]. [2]
- Another, practical, reason to prefer surface contamination based tritium free release limits for solid materials is that non-destructive measurement techniques can be used. The low energy level of tritium radiation prevents 'incorporated' tritium measurement with non destructive techniques.

2.2.2 Surface contamination based tritium free release limits

The above arguments for a tritium FRL based on surface contamination are valid for the equipment and furniture that were present in our lab. In order to convince the Belgian nuclear control agency and the Belgian authorities to accept release of our materials based on surface contamination measurements a small survey for surface based tritium FRLs was done.

There can be found two classes of tritium surface contamination limits in the literature: the limits based on the total tritium surface contamination and the limits based on the removable tritium surface contamination. An overview of surface contamination limits found in literature is given in Table 1.

Table 1: Overview of different tritium surface contamination limits

Issuer **Description**	**Limit [Bq/dm²]**
CEA	
Derived fixed tritium surface contamination limit [3]	200.000.000
Derived removable tritium surface contamination limit [3]	2.000.000
European commission	
Tritium clearance criterion for direct reuse of recycled metals from nuclear installations. [4]	1.000.000
Tritium specific clearance level for building reuse or demolition [5]	1.000.000
U.S. Department of energy	
Total tritium contamination limit for release of materials [6]	16.667
Removable tritium contamination limit as interim guideline for safe storage of tritium contaminated materials [2]	167
SCK•CEN	
Total tritium contamination limit [7]	2500
Removable tritium contamination limit [7]	250

The removable tritium surface contamination is usually determined by taking a smear from the surface and by measuring the activity using liquid scintillation counting. One methodology has been to calculate the total surface contamination from a number of successive removable tritium measurements on the same spot [8]; but usually the total contamination is estimated by multiplying the removable contamination by a factor. At SCK•CEN this factor is 10 [7]. There have been built tritium surface activity monitors. These devices are open window ionisation chambers [9] or proportional counters [10] with a detection limit in the order of magnitude of 100 Bq/dm², but no such working device was available at SCK•CEN. There have also been built experimental avalanche photodiodes to measure the total tritium surface contamination [11] but they are not widely available yet [12]. The smear method requires only a liquid scintillation monitor which was available. Therefore a removable tritium surface contamination based limit would be preferred.

An application was made to the Belgian Federal Nuclear Control Agency and the Belgian Authorities to introduce an exceptional free release limit of 250 Bq/dm² removable tritium for surface contaminated material. Although all parties agreed that the removable tritium contamination was a valid criterion for free release there was no will to treat tritium as an exceptional low radiotoxic element. As a result we were forced to use an interpretation of the international transport regulations [13] for beta- gamma emitters as a free release limit. The materials from the tritium lab could be free released when the measured removable surface contamination was less than 4 Bq/dm².

3 Dismantling and decontamination

3.1 Probably non-contaminated equipment

Items like closets, tables and furniture that were not suspected to have been exposed to medium or highly tritiated species were cleaned and checked for residual tritium contamination. The items that did not meet the free release criterion were disposed off as nuclear waste although the removable tritium surface contaminations were

not higher than 30 Bq/dm². This was justified because of the limited volume, complex shape or composition and lack of recycle value.

3.2 Probably contaminated equipment

The probably contaminated items in the laboratory were the glovebox, the hood, the process cell and the ventilation shafts. These items were mostly composed of painted carbon steel and represented a large volume.

The biggest challenge in our attempt to free release as much of these materials as possible were the process cells. With the 2.8 tons of painted metal they formed the largest amount of materials in which the highest volume of tritiated compounds was processed. The highest tritium concentrations were handled in the glovebox, but the volume and duration of processing tritiated species was less than in the process cell. The weight and volume of the glovebox was only a fraction of the process cell.

Five litres of organic tritiated waste with a concentration of 100 GBq/L was spilled in the process cell. Due to a leak in the cell a small amount got on the floor underneath the cell. Within days after the incident (Jan/2002) the spilled organic liquid was cleaned up. Apparently this did not prevent the tritium from penetrating the paint layer on the metal.

More than three years after the clean up, the total tritium contamination in the paint layer at the spot of the incident reached 47000 Bq/dm². A total tritium contamination of 2600 Bq/dm² was measured in the metal layer that was in contact with the paint. Underneath this first layer of metal, the maximum measured removable tritium contamination was 3.96 Bq/dm².

Based on these measurements it was proposed to scour off the paint and a thin metal layer to decontaminate the walls and the bottom of the process cell. A final wash with water would remove remaining shavings containing tritium. The ceiling of the process cell only needed to be thoroughly washed to be decontaminated.

Other likely contaminated items from the laboratory were the hood, the glovebox and the ventilation shafts. All this equipment was handled in a similar way as the process cells. The removable tritium contamination from those parts that could not meet the free release criterion was not higher than 100 Bq/dm². These parts were either disposed of as radioactive waste or sent to a melting facility for metals from the nuclear industry.

The size and complexity of the glovebox design made it difficult to decontaminate it properly. It was disposed of as radioactive waste.

3.3 Wall, floor and roof covering

After removing all the equipment, the floor, walls and ceiling had to be checked for tritium contamination before the room could be declared as denuclearised.

The tiled concrete floor was covered with sealed linoleum. The linoleum from under the process cell, the fume hood and the glovebox were disposed of as nuclear waste.

The rest of the floor covering did not pose a problem. During the decommissioning phase this part was washed regularly and a sample of the wash water was analysed. The maximum measured removable tritium concentration during the decontamination period was 64 Bq/cm². After the final cleanup the linoleum could be free released and disposed as regular waste

After the linoleum, the remaining materials on the floor, wall and ceiling were tiles and concrete on the floor and chalk on the ceiling and walls. These materials were free released against the classical free release limit of 100 Bq/g. There were two main reasons for using this limit for these materials: firstly the structure of these materials would enable penetration of tritiated species, so surface contamination would become a less relevant measure. Secondly a destructive tritium determination on samples of these materials could easily be done.

A sampling scheme with more sampling points in the neighbourhood of the process cells, the fume hood and the glovebox was made up. Finally 10 m³ rubble from the floor and walls could be free released against the 100 Bq/g free release limit.

3.4 Material balance

Table 2 below summarizes, per class, the amounts that have been free released, disposed or recycled versus the amounts of generated secondary waste to free release the materials. Nor the amount of tritiated water or air that were discharged are reported in this table as they could not be separated from discharges from the ongoing experimental work in the other room. There is no report of exceeding the tritium discharge limits during the decontamination. The relatively high amounts secondary waste generated during the decontamination of the 'probably contaminated equipment' is in proportion to the efforts that have been made to decontaminate these materials. Especially the decontamination of the process cells required a lot of resources.

Table 2: Overview of free released / recycled and disposed material during dismantling tritium lab equipment

	Probably not contaminated equipment		**Probably contaminated equipment**		**Floor, wall and ceiling**	
Free released material	917	kg	4061	kg	10	m³
Metal to nuclear melting facility			307	kg		
Disposed radioactive waste	252	kg	880	kg	446	kg
Additional secondary radioactive waste						
Compressible waste	7	kg	131	kg	6	kg
Scintillation liquid	10	L	20	L	3	L
Air filters			48	kg		

3.5 Dose received by decontamination workers.

A number of measures were taken to protect the personnel that performed the decontamination. During the work in the process cells the personnel wore PEDI suits. These suits are constantly inflated by a relatively high flow rate of breathing air that prevents the worker from inhaling airborne tritium. A number of other more classic personnel protective equipment like gloves, clothing and dust masks were used for less critical areas in the lab. The ventilation and the tritium air monitoring system of the room were kept operational as long as possible.

Tritium dose monitoring was another aspect of the protection of the personnel. The energy from tritium radiation is too low to be monitored by the TLD or EPD dosimeters used at SCK•CEN. Since tritium presents a certain risk when incorporated by inhalation, ingestion or penetration through the skin, the received tritium dose is calculated based on the tritium concentration found in urine. During decommissioning the workers had to regularly deliver urine samples, but it was impossible to calculate the received tritium dose because the tritium concentrations in their urine samples were always below the detection limit.

4 Cost balance – an opportunity to do better next time?

We opted to free release as much of the material as possible. The cost for melting the unreleased metal parts at a nuclear melting facility turned out to be only 25% of the cost of disposing them as nuclear waste. This led to the idea to compare the costs of the free release strategy versus the cost for disposing all metal to the nuclear melting facility. The results are shown in Table 3.

The melting facility strategy would be less labour intensive. It was estimated that 40% of the manhours in 2005 (or 31% of the total manhours) were spent on removing the paint and getting the metal from the process cells below the free release limit, compared to a couple successive washes to take away the worst contamination. There would be some savings by generating less nuclear waste. On the other hand the cost for disposing the metals at the nuclear melting facility would increase. The pure financial balance indicates that there could have been a cost reduction of 64000 EUR, or 22% of the total decommissioning cost, by melting the metals instead of free releasing them, but free release might be socially more accepted. A decision on the decommissioning strategy for the second room of the tritium lab, containing similar equipment, still needs to be made.

Table 3: Cost estimation of tritium lab decommissioning for two different strategies for metal disposal

Entry	Decontamination and free release metal	Nuclear metal melting facility
Manhours	213 000 EUR	146 000 EUR
Materials	13 000 EUR	13 000 EUR
Radioactive waste	64 000 EUR	48 000 EUR
Nuclear metal melting facility	2 000 EUR	21 000 EUR
Total	**292 000 EUR**	**228 000 EUR**

5 Conclusions

One of the two laboratory rooms has been denuclearised and reinstallation activities are currently taking place. The rigorously low limit made the free release of the laboratory's equipment extra labour intensive. If a reasonable free release limit in the range of 250 Bq/dm² could have been applied, less materials should have to be disposed as radioactive waste and less secondary waste would have been generated. Nevertheless, we succeeded in denuclearising most of the equipment, waste and infrastructure without the personnel having received measurable doses of tritium. It has been estimated that disposing the metals to a nuclear melting facility could have saved 22% on the costs, but free release might be socially more accepted.

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