Influence of Decontamination

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ABSTRACT

This paper describes the influence of several decontamination techniques on the decommissioning of nuclear facilities. There are different kinds of decontamination methods like mechanical and chemical processes. The techniques specified, and their potential to change measured characteristics like the isotope vector of the contamination is demonstrated. It is common for all these processes, that the contamination is removed from the surface. Slightly adhered nuclides can be removed more effectively than strongly sticking nuclides. Usually a mixture of these nuclides forms the contamination. Problematically any kind of decontamination will influence the nuclide distribution and the isotope vector. On the one hand it is helpful to know the nuclide distribution and the isotope vector for the radiological characterization of the nuclear facility and on the other hand this information will be changed in the decontamination process. This is important especially for free release procedures, radiation protection and waste management. Some questions on the need of decontamination have been discussed.

Just like any other industrial plants, nuclear plants reach the end of their service life after their respective operating time. This depends on technical as well as economic marginal conditions, but also legal obligations may lead to decommissioning. But the main difference to other industrial plants is to keep in mind, the case of nuclear plants, this material is radioactively contaminated. Therefore it is recommendable to dismantle the used plants under radiological and safety aspects after operation.

For a smooth course of the decommissioning work, it is necessary to plan logistics and waste management. Contrary to the operation, much larger quantities of waste will accrue during the decommissioning process. In order to guarantee a respective throughput and avoid pile-ups and a stoppage of work, a quick handling of the accruing quantities of waste is necessary. This planning aspect also includes the assessment of the waste volumes to be expected. There is to be weighted the largest-possible part that can be released against the fastest-possible throughput of the waste quantities.

The contamination of materials is the result of different physical and chemical processes. For example the contamination of pipes includes a thin strongly adhesive layer on the inner surface and an airborne, easily removable deposit on the outer surface. In concrete structures there is a penetration in the range of centimetres and possibly more. This is mostly water carried contamination from leakages or cleaning up.

The amount of contamination on a surface depends on the type of base material, the surface roughness, corrosion, the properties of the contaminating medium like water, steam or air and physical or

chemical changes like water/steam transitions. Also the kind of contamination based on these properties: slightly adhered (smearable) or strongly sticking (fixed).

Decontamination is defined as the removal of contamination from the surface with different methods. The objectives are:

- to decrease radiation exposure,
- to decrease the amount of radioactive waste,
- to clean up the site after decommissioning.

Therefore it is necessary for the planning of the dismantling to know about the amount of contamination or activation of radioactive materials, to decide the need of decontamination and the kind of decontamination to reach the proposed mass-flow. The proposed mass distribution between radioactive waste and material for clearance could be fulfilled by the portion of decontamination as well as the limits for radiation exposure. Early radiological characterization like shown in Fig. 1 aided this process.

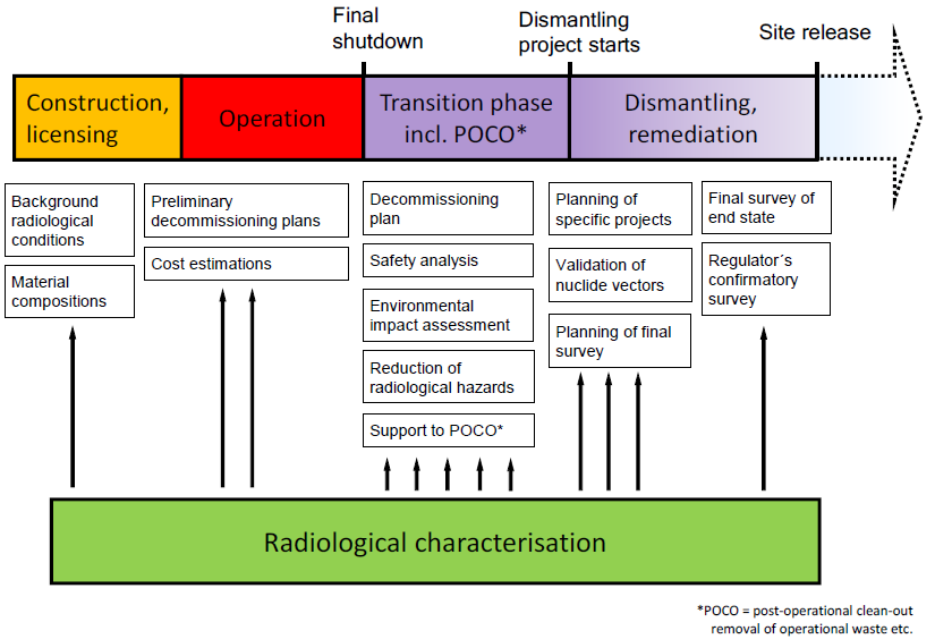

Figure 1: Radiological Characterization during different stages of plant lifetime according to the Final Report of TG RCD (Phase 1) [1]

The radiological characterization of a nuclear facility which shall be decommissioned should start as early as possible after the final shutdown. At that time the generation of radioactive nuclides stops and the situation will mostly change by decay. The radiological characterization is necessary for the estimation of the mass flows in the waste management and for the radiation protection of workers. In both cases it is necessary to know the nuclide distribution and the isotope vector. Difficulties in the estimation of the isotope vector result from direct radiation, activated materials as well as from highly contaminated areas. In these areas and even in areas which are less contaminated but lead to a higher collective dose during measurement, a decontamination process is recommended. In this process contamination is taken from the surface to collect it which could lead to smaller amounts of

radioactive waste, decreased dose rate, better handling properties and higher amount of material for clearance.

There are different kinds of decontamination methods like mechanical and chemical processes [2, 3]. They are originally developed to support maintenance works in nuclear facilities but for decommissioning works an increasing to Full System Decontamination is observed. During the selecting and planning of the decontamination process several criteria and site specific conditions had to be considered. This covered such points as operational history, nature of contamination, distribution of contamination, quantities of secondary waste and its treatment, the disposition of decontaminated materials and time and money. To figure out these points the early radiological characterization could give answers to the planning group.

The following pictures show examples of decontamination processes:

Figure 2: Decontamination by washing, ultrasonic bath, sandblasting, melting

It is common for all these processes, that the contamination is removed from the surface. The structure of the contamination has substantial influence on the success of the decontamination. Slightly adhered nuclides can be removed with simple methods more effective than strongly sticking nuclides. Usually mixtures of these nuclides form the contamination.

So in the case of washing only slightly adhered nuclides will be removed, ultrasonic bathes also remove part of the strongly sticking nuclides. This decontamination method especially would be used in any case to prevent spreading of contamination.

The sand blasting (also ice blasting: dry ice from carbon dioxide) could remove strongly sticking nuclides up to oxide layers on the surface. Blasting methods are used to remove paint layers and contamination layers in order to arrange the material for clearance but have the disadvantage that a part of the contamination could be hammered into the basic material.

Mechanical processes like milling remove not only contamination but also a part of the surface. In this case the contamination is reduced to zero but there is no information left about the isotope vector, which is necessary for clearance measurements. This decontamination method has a very good decontamination effect but is only useful in smaller parts.

Chemical decontamination in electrolytic bathes up to Full System Decontaminations (FSD) can remove oxide layers, but recombination of some kinds of nuclides with the surface occurs. After the treatment only deeply penetrating nuclides are still measurable. This method has the advantage that there is no influence from geometrical forms so the inner surface of components and whole systems

could be decontaminated easily. Another advantage is that in the case of FSD there is a possibility to go in operation after decontamination, working ahead in lower dose rates.

Melting process is also a kind of decontamination because some nuclides like Cesium and other heavy weight nuclides like uranium switch to the slag dust or fume. Elements like Nickel or Cobalt stay in the metal. This method is applicable to contaminated metal and also for low activated materials. For low activated metal it is necessary to have a good radiological characterization from measurement and calculation. If the activation is too high this process fails and the formed ingots must be added, after treatment, to the radioactive waste. If the residual activation/contamination is between recycling level and "waste level" such material could be used again in the nuclear field e.g. to build waste containers or be stored for a calculated term in order to decay before recycling.

All decontamination methods remove contamination from materials and concentrate it in the secondary Waste. Even this waste, especially when it was generated in different processes like divers kind of washing with chemical agents, had to be characterized to know the amount of radioactivity, the isotope vector and the chemical composition to classify it for the repository.

The Full System Decontamination after shutdown and removal of the fuel elements is a suitable method to clean the systems and reduce the dose rate in the systems as well as in the rooms. That is an advantage for later dismantling, when a lot of hours of work are needed to disassemble the loops and even smaller pipes. The collective dose decreases clearly. Therefore a FSD is recommended shortly after final shut down, especially in older facilities. The range and the principle of the Full System Decontamination with external devices like pumps, filters and ion exchange resins are shown in Fig. 3 and Fig. 4.

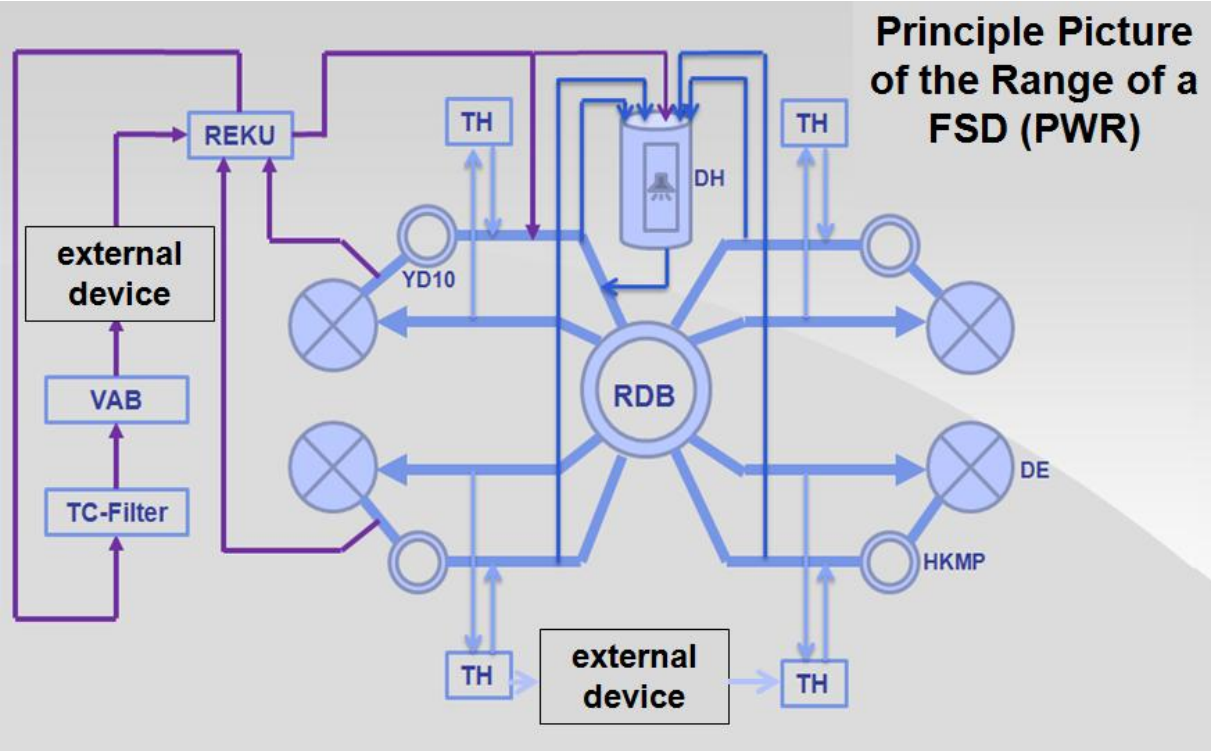

Figure 3: Range of a Full System Decontamination (PWR)

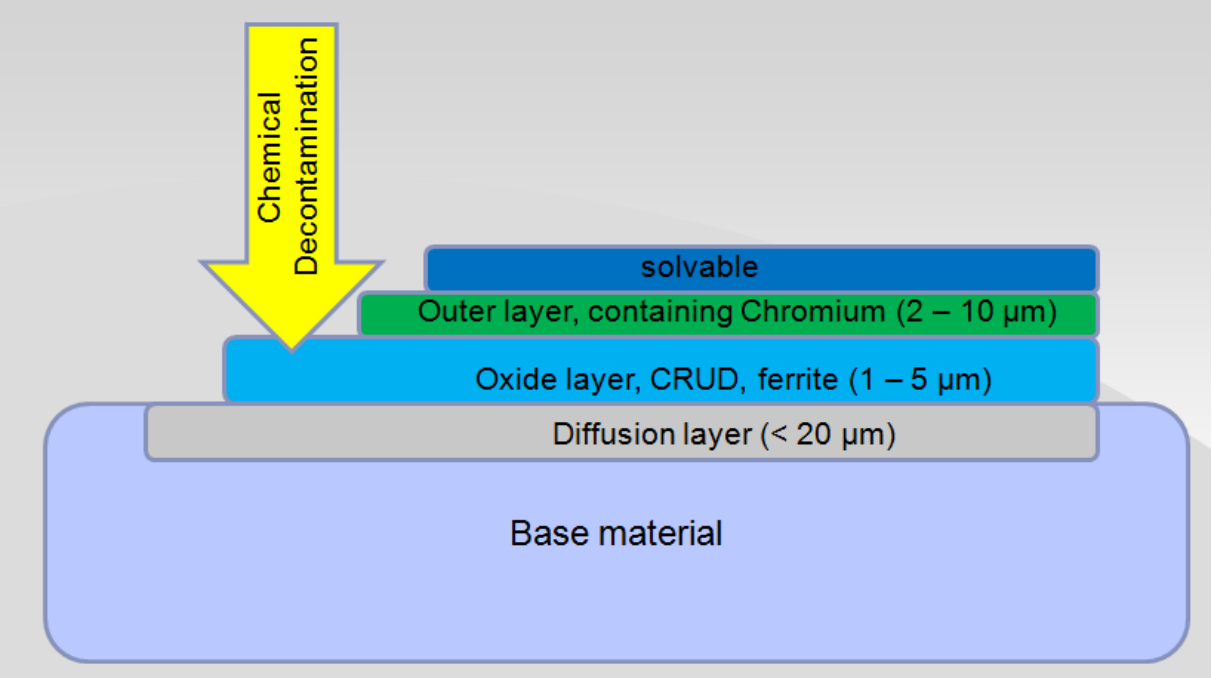

Figure 4: Principle of a chemical decontamination like a FSD (PWR oxide layers)

Figure 5: The result of a chemical decontamination FSD is shown here, final shutdown occurred after more than 30 years of operation

Decontamination of concrete mostly involves removing some millimeters of the surface (shaving). Washing is the first step if the surface is coated by a decontamination layer. But if there are cracks in the decontamination layer or in the concrete, water carrying contamination will penetrate the concrete

in different depths according to the radionuclide transport rates. In this case radiological characterization has the task to determine the penetration depth, the existence of different nuclides in different depth and the isotope vector. It is difficult for the characterization, with regards to the possibility to bring up new layers of paint or even concrete before decontaminating the surface.

It is problematic when any kind of decontamination will influence the nuclide distribution and the isotope vector. Here are some examples [2]:

- washing: some nuclides adhere more than others, there are differences between water solvable and non water solvable nuclides, displacement in the relationship between alpha-nuclides and beta-nuclides
- chemical decontamination: different ability for solution for different nuclides, heavy nuclides need chemicals with chelating agents before they will be removed, high potential for recontamination of the surface, displacement in the relationship between alpha-nuclides and beta-nuclides
- physical decontamination: if the whole surface is removed, no nuclides will remain

The effort of a decontamination process is measured by the decontamination factor (DF):

DF = surface activity before decontamination / surface activity after decontamination.

In particular chemical decontamination could reach a high DF but has the potential of selectively reducing the amount of certain elements [1]. This leads on from the influence on the estimation coefficient for less easily measurable nuclides or the ratio of alpha-/beta-nuclides where the percentage of alpha emitting nuclides increases. This illustrates the dilemma: on the one hand it is helpful to know the nuclide distribution and the isotope vector for the radiological characterization of the nuclear facility at an early point in time and on the other hand this information will be changed in the decontamination process. This is important especially for clearance procedures and radiation protection. That is a reason why in some decommissioning projects mechanical decontamination techniques are used which tends to affect all contamination layers rather equally (like milling).

The isotope vector for the description of radioactive waste could be measured and established before decontamination because a calculated approach based on the original data and the decontamination factor is exact enough for this description. The calculation of the reduction by the decontamination factor is necessary to avoid unneeded high activities in the repository.

In the case of radiation protection the limits for the concentration of radioactive nuclides in the ambient air mostly will be measured by monitors who are sensitive to beta radiation. With proper estimation coefficients it could also be used to recognize the alpha radiation in the ambient air for the workers. This helps to realize the limits for intake of alpha radiation and to seize measures to prevent the workers from too high an intake. This works on a relationship of beta / alpha radiation to detect the limits. If such a relationship is shifted by removing more beta active nuclides than alpha active nuclides the basis for the radiation protection for working in the ambient air is detracted. The result is that the radiation protection for the workers has to be done with other equipment like breathers.

Also in the case of clearance the amount of contamination and the isotope vector are measured at an earlier time before decontamination. If the amount of contamination is too high to match the clearance

levels, the material will be sent to the decontamination. But in these cases the material is dismantled and cut into large pieces so mechanical decontamination is appropriate. This decontamination removes all protective coatings or paint, mostly using a blasting method. After decontamination it is assumed that there is no change in the isotope vector. In return for this assumption an additional measurement step for a homogenous distribution of the contamination is made and the original isotope vector which is estimated before decontamination is used.

Decontamination will always produce secondary waste which has to fulfill the acceptance criteria of a repository. This is sometimes not so easy if organic or hazardous substances are used. Another question is the availability of waste removal paths. There is no necessity to decontaminate below clearance levels without the possibility to make further use of the decontaminated stuff. All these considerations must be taken into account in every single case. In great projects like a FSD, which costs a lot of money and effort, it is necessary to assess the benefit, especially if a longer time after the shut down has elapsed.

In summary, it is necessary to have a concept for the radiological characterization which includes the facilities history and the waste management concepts goals. Assuming the risks of the possible and different shifts in the isotope vector, a suitable decontamination method has to be chosen. The benefits of decontamination are clear: lower dose rate for the dismantling work, more material matches the clearance levels, radioactive waste will be reduced. The problems which may occur out of the decontamination could be solved in a proper way by respecting the different frame conditions for the goal for the radiological characterization e.g. a smooth dismantling process, description of waste, matching the clearance levels and a good radiation protection [2, 3].

References

[1] OECD NEA Radioactive Waste Management NEA/RWM/WPDD(2013)2, September 2013

[2] EC-CND Coordination Network on Decommissioning; Dismantling Techniques, Decontamination Techniques, Dissemination of Best Practice, Experience and Know-How; Final Report, 2009

[3] J. Kaulard, B. Brendebach, E. Strub; Strahlenschutzaspekte gängiger Abbau- und Dekontaminationstechniken, GRS-270, ISBN 978-3-939355-46-5, Dezember 2010