MODELLING OF NUCLEAR POWER PLANTS DECOMMISSIONING TASKS – ISSUES AND THEIR SOLUTION

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1. Introduction

The crucial task within the decommissioning process is the optimisation of radiation protection. This requires the knowledge or prediction of the dose rates. However, in the many cases, the parameters regarding the source term (i.e. the nuclide composition as well as the activity content) are unknown or hard to estimate.

To overcome this issue, the following approaches can be applied:

- Development of the methodology which allows quick recalculation of the results after the radiological parameters are particularised.
- Application of the conservative approach – to ensure that the results will not be underestimated.

The necessary prerequisite of the application of these approaches is the detailed analysis of the studied issue. The paper shows this process on the example of final disposal of secondary waste arising from the decontamination of steam generator.

2. Problem description

During the operation of nuclear power plants (NPP) the technological equipment of primary circuit becomes contaminated. The contamination process is a combination of many factors, e.g. physical and chemical properties of coolant and of metallic surface as well as the history of the operation [1] -[2] Thus the estimation of contamination level becomes very difficult.

This fact causes other issues during planning and optimisation of radiation protection during tasks regarding the final disposal of radioactive waste. In many decommissioning projects, the pre-dismantling decontamination is applied. This can significantly reduce the dose rates in the vicinity of the contaminated components (e.g. steam generator) especially when immediate dismantling is carried out. On the other hand, the decontamination process generates secondary radioactive waste which has to be treated, conditioned, stored and/or disposed in a repository. It is obvious that within the complex analysis of exposure during dismantling process and final disposal of resulting radioactive waste also secondary waste has to be considered.

Currently there are several finished full system decontamination projects applied on western type of pressurised water reactors in the Europe or in the US(e.g.[3] [7]). However, the following issues can be identified:

- Some of the documents provide general information only, or
- the documents provide the overall data only, i.e. the total amount of secondary waste from the decontamination of the whole primary circuit (and not of the individual components).

From the total amount of secondary waste no information regarding the waste originating from an individual component (e.g. steam generator) can be obtained. This is because the distribution of contamination is non-homogeneous and thus the secondary waste generator strongly varies case by case [8] [9] . Moreover, the more detailed data are often a subject of a trade secret.

2.1 Final disposal of secondary waste in the Slovak Republic

Based on the activity and nuclide composition, secondary radioactive waste from pre-dismantling decontamination of steam generator used in NPP V1 in Jaslovské Bohunice can be considered as low-level waste (in accordance with the waste classification in[10]). This waste class is disposed in National Radioactive Waste Repository (NRWR) in Mochovce in fibre-concrete containers (FCC). This container is a cube with outer dimension of 1.7 m, and 10 cm thick walls [11] . The secondary waste from the decontamination of SGs consists of the different parts which can be treated and conditioned as follows:

- **Spent ion exchange resins** used for the purification of decontamination solutions. They are incorporated into so-called SIAL matrix (**SI**licon and **AL**uminium) which is then disposed in 200 l drums [12] . These drums are subsequently put into FCCs.
- **Water and solutions** used for flushing.They can be evaporated and the concentrate is (depending on its activity and nuclide composition) mixed with cement matrix. This active grout is then poured into the FCC (with drums and solid waste) to fill its volume.
- **Solid waste –** metallic particles (iron oxides). They can be put into 200 l drums and supercompacted and disposed in FCCs.

3. Calculation models

The assessment of radiation impact on the workers from the perspective of external exposure requires the application of specialised calculation tools. In this analysis, the computer code VISIPLAN 3D ALARA was used. This code was developed in Belgian company SCK-CEN and was applied in many projects regarding the decommissioning of NPPs (e.g. in [13] [15] where the steam generator dismantling process was studied in the detail).

3.1 Model 1 - Disposal of super-compacted heat exchange tubes and secondary waste in FCC

The activity of heat exchange tubes of SG can be reduced depending on the nuclide composition and the effectiveness of the decontamination (decontamination factor). After super-compaction of drums with fragmented heat exchange tubes the amount of radioactive waste in each FCC can be enhanced (according to the activity and nuclide limit). In the model, each considered die-casting has a height of 50 cm and a mass of 350 kg (density of 2.74 g/cm^3). Thus 8 die-castings can be disposed together with active cement grout (water and solutions used for flushing)in 1 FCC – Fig. 1:

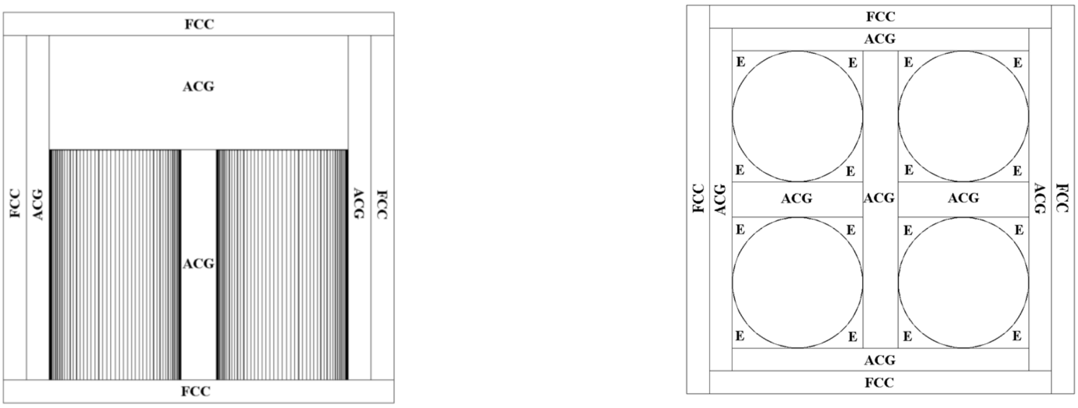

Fig.1: *Reference model of FCC with die-castings and active cement grout. Left: side view, right: upper view. Legend:* ***ACG*** *– active cement grout (density 1.73 g/cm^3),* ***E*** *– empty space (air),* ***FCC*** *– walls of fibre-concrete container (density 2.70 g/cm^3).*

As can be seen from Fig. 1 there are some empty spaces which does not reflect the real case. Therefore it can be expected that this model will lead to slightly conservative results because of the self-shielding effect of cement grout (compared with air gaps). Despite this it can be stated that this model is very close to the reality and is therefore considered as a reference model. On the other hand, its modelling is quite complicated especially when different situations are studied (e.g. transport and final disposal in NRWR in Mochovce). Moreover, the amount and the geometric dimensions of die-castings (height) can vary. From this reason, the simplified model was created consisting only of fibre-concrete and active cement grout filling all the inner volume – Fig. 2:

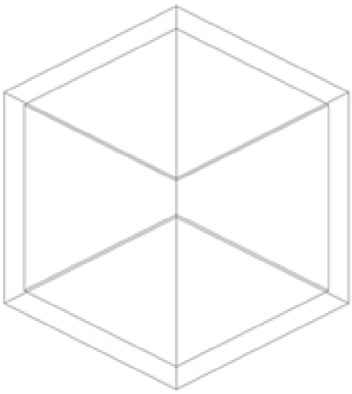

Fig.2: *Simplified model of FCC and active cement grout.*

This simplified model will lead to conservative results since the self-shielding effect of die-castings (iron) is excluded.

3.2 Model 2 - Disposal of spent ion exchange resins and other secondary waste in FCC

The modelling of FCC with drums with SIAL matrix (modelled as concrete with the density of 1.5 g/cm^3) and active cement grout is similar as in the case of Model 1. Since these drums must not be super-compacted, a maximum of 7 drums can be disposed in 1 fibre concrete container – Fig. 3:

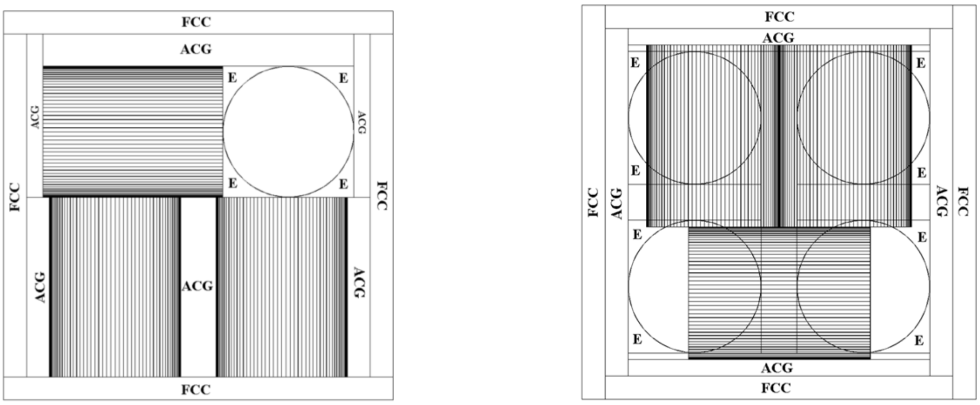

Fig.3: *Reference model of FCC with conditioned spent ion exchange resins and active cement grout. Left: side view, right: upper view. Legend:* ***ACG*** *– active cement grout (density 1.73 g/cm^3),* ***E*** *– empty space,* ***FCC*** *– walls of fibre-concrete container (density 2.70 g/cm^3).*

It is necessary to emphasize that the configuration depicted in Fig. 3 depends on the activity content and nuclide composition. If the total activity of nuclides (within 7 drums) would exceed the acceptance limit, the lower number of drums could be disposed in 1 FCC. This situation was also studied, the considered configuration is similar as Fig. 1.

The model depicted in Fig 3 is considered as reference model (despite some empty spaces) and its modelling is quite complicated (as well as in the case of Model 1). Therefore the same simplification was carried out– Fig. 2.

4. Results

In all the models, the dose rates in 18 points on the top, in the middle and at the bottom side of FCC were calculated (distances 0 cm, 10 cm, 30 cm, 50 cm, 100 cm and 500 cm from the surface). The source term is in the all cases the same – 1 Bq/g of ^{60}Co. After the calculation of the dose rates in the reference models, the density of the cement grout in the simplified models was changed in order to compensate the self-shielding effect. The results comparison is in Tab. 1:

Tab. 1.*Comparison of the results.*

Average dose rate [mSv/h]			
Model 1		**Model 2**	
Reference model	**Simplified model (1.73 g/cm^3)**	**Reference model**	**Simplified model (1.25 g/cm^3)**
4.40×10^{-5}	4.95×10^{-5}	4.34×10^{-5}	4.68×10^{-5}

5. Conclusion

The results in Tab. 1 show that the application of the simplified model leads to conservative results (the deviation in the case of Model 1 is 11%, in the case of Model 2 is 7.8%). However these results still can be less conservative depending on the density of active cement grout. The aim of the paper was to demonstrate the issues originating from the analyses of external exposures during different tasks of the decommissioning of NPPs. Within these analyses the application of simplified models is necessary. Despite these simplifications the relevant results can be obtained.

Acknowledgement

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