ADVANCED DECOMMISSIONING COSTING CALCULATION TOOLS FOR PILOT VIENNA TRIGA MARK-II RESEARCH REACTOR

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ABSTRACT:

The paper presents a recent study of the Institute of Nuclear and Physical Engineering at FEI STU Bratislava, company DECOM, a.s. Trnava and the Vienna University of Technology, Atominstitute Vienna, Austria on decommissioning cost calculation of research reactors.

The key purpose of the study is to compare decommissioning costing code CERREX (Cost Estimation for Research Reactors in Excel) with the advanced – new generation calculation methodology applied in eOMEGA_RR code. CERREX code was developed in line with the IAEA recommendations for decommissioning costing of research facilities and fully implements ISDC (International Structure for Decommissioning Costing of Nuclear Installations) - the standardised costing platform. In comparison with CERREX, usually applied in the preliminary costing, the code eOMEGA_RR incorporates the unique tool for the simulation of the material and radioactivity flow during decommissioning process (e.g. decontamination, dismantling and waste management). This advanced approach enables to carry out the decommissioning planning and costing more effectively. Moreover, the user-friendly interface helps to perform wide range of sensitivity analyses.

The object of model cost calculations and benchmarking has become the TRIGA Mark II research reactor in Vienna. The whole process is covered by four step-by-step procedures to be implemented. At first, facility inventory database including physical and radiological parameters (e.g. activation levels, nuclide vectors, limits and conditions) was developed. At second, advanced decommissioning costing cases using CERREX and eOMEGA_RR code were created. Subsequently, several sensitivity analyses to estimate the impact of changing input parameters on calculated results were performed. Finally, the costing results obtained from both cost calculation codes are compared and discussed.

1 Introduction

An important aspect of decommissioning costing of nuclear facilities, including research reactors, is the harmonization of decommissioning costs in order to be able to compare them and to develop a uniform approach to decommissioning costing. This requirement lead to the establishment of a common platform for the identification of decommissioning activities and presentation of the results of decommissioning cost estimation projects – A Proposed Standardised List of Items for Costing Purposes in the Decommissioning of Nuclear Installations, issued jointly by the IAEA, the Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) and the European Commission (EC) in

1999 [1]. The structure was upgraded by the same organizations in 2012 as the International Structure for Decommissioning Costing (ISDC) of Nuclear Installations [2]. Since then, ISDC has become IAEA standardised costing platform for decommissioning of nuclear facilities.

In order to support the decommissioning cost estimation for research reactors as a part of decommissioning planning process, the calculation code CERREX [2] was developed within the IAEA projects. CERREX code is developed in line with the IAEA recommendations for decommissioning costing [3] and fully implements the ISDC structure and costing methodology. The main purpose of CERREX code is the performance of the preliminary cost estimations for research reactors.

However, in parallel to CERREX code, there are many national decommissioning costing codes used worldwide. Decommissioning cost calculation code eOMEGA_RR represents a version of the code eOMEGA developed by Slovak experts as a new generation costing tool for research reactors. The code eOMEGA_RR is based on internet platform, fully implementing ISDC structure and has incorporated a unique tool for simulation the material and radioactivity flow in the decommissioning process.

2 Methodology

For the purposes of demonstrating the eOMEGA_RR calculation methodology and functionalities, the model decommissioning costing case was developed and compared with CERREX costing case results. As a model case, the TRIGA Mark II reactor in Atominstitute at the University of Technology in Vienna (ATI) was selected. This research reactor is under operation since 1962 with thermal power output of 250 kW. The model ATI costing case calculation methodology consisted of the following step-by-step procedures to be implemented:

1. Inventory database development including physical & radiological parameters.
2. Advanced decommissioning costing cases created using CERREX and eOMEGA_RR code.
3. Sensitivity analyses performed in eOMEGA_RR code.
4. Benchmarking of costing results obtained from both codes.

2.1 ATI inventory database

At first, it was necessary to collect inventory data on ATI TRIGA Mark II research reactor. For that purpose an inventory database template in Excel was used corresponding to ISDC approach, including building–floor–room hierarchical structure data of the facility and detailed equipment inventory parameters. Equipment parameters covered the following type of data:

- Identification data – equipment designation and name, allocation within the facility structure and technological system, relevant ISDC number.
- Physical inventory data – mass, inner/outer surface, bulk volume, CERREX category of equipment and dominant material.
- Hazardous inventory data – hazardous material and possible hazardous waste .
- Radiological inventory data – internal/external contamination, activation, relevant dose rate and corresponding radionuclide vector for each radiological parameter with relevant reference date.
- Calculation data – calculation of radioactivities for user defined calculation date and preliminary determination of resulting waste streams based on the relevant radiological limits from Austrian legislative requirements.
- Supporting data sheets – list of technological systems, CERREX inventory categories, radionuclide vectors and their compositions, dominant materials, list of ISDC items, relevant research reactor hazardous materials and waste and radiological limits for all corresponding radioactive waste streams (exempt waste, conditionally released metals, conditionally released other materials than metals, long-term storage waste).

The collected inventory data represent the results of mutual cooperation between ATI colleagues and colleagues from the Institute of Nuclear and Physical Engineering of STU. Material inventory represents 532 t of mainly massive concrete reactor shielding structures of reactors. The total radiological inventory of 2.11 E+13 Bq estimated at the end of operation, in Fig.1, is formed by activated reactor components only. Contamination of systems and components was not considered, since the activity was below the clearance levels.

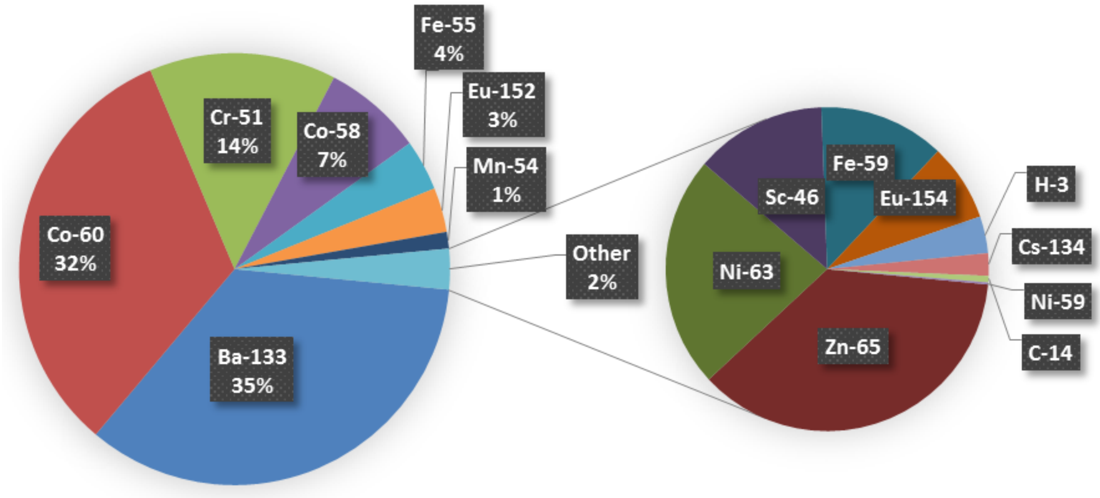

Fig 1 Radionuclide composition of ATI activation inventory

2.2 ATI CERREX model costing case development

The immediate dismantling is considered to be a basic calculation option for ATI model calculation case. The inventory database was implemented to the CERREX code and a model costing case was developed by definition of the following set of parameters:

- General calculation parameters e.g. labour rates for basic professions.
- Input parameters for inventory dependent activities e.g. dismantling, decontamination, waste management activities (unit factors, waste distribution coefficients, work difficulty factors) for relevant ISDC items.
- Input parameters for period dependent activities and collateral costs e.g. management of project, maintenance, surveillance, procurement, taxes (duration, workgroup composition, expenses, investments).

2.3 ATI eOMEGA_RR pilot costing case development

The presented ATI costing case is the pilot demonstration of the eOMEGA_RR code. In order to perform the cost calculation and comparison with CERREX code there had been used the same input data. The calculation algorithm applied in the eOMEGA_RR code (as well as in the CERREX) is based on the ISDC calculation methodology i.e.:

- Costs are calculated for each cost category i.e. labour costs, investments, expenses and contingency.
- Unit factors approach together with work-difficulty factors are applied for the calculation of output decommissioning parameters for inventory dependent activities.
- Duration of the activity together with the work group composition and definition of fixed and period dependent expenses or investments are the basis for the calculation of decommissioning parameters for period dependent activities and collateral costs.

Calculation of waste quantities in the eOMEGA_RR code are performed by using the unique system simulating the material and radioactivity flow in the decommissioning process, which is the major difference in comparison with CERREX code. This tool allows linking physical and nuclide resolved radiological characteristics (radioactive decay of individual nuclides is taken into account) of each material item, it means that every parameter of material item is traceable from dismantling (demolition) up to release to the environment or disposal in radioactive waste repository.

3 Results

After development of ATI CERREX costing case it was possible to obtain calculated manpower and total costs according to the ISDC structure (labour costs, investments costs, expenses and contingency), see Fig 2.

® CERREX-D_Cost Estimation for Research Reactors in Excel; IAEA project DACCORD			ISDC Level 1 data of the costing case				Currency	EUR
Case:		ATI TRIGA reactor costing case	Retrieval of calculated data into ISDC Level 1 format					
Reactor:		ATI TRIGA reactor; > 1MW incl.	*Total calculated data*		*Calculated ISDC cost categories*			
Operation:		Standard Operation	Workforce	Costs	Labour costs	Investment	Expences	Contingency
Version: AM		© International Atomic Energy Agency	[man.h]	[EUR]	[EUR]	[EUR]	[EUR]	[EUR]
A	ISDC No.	**ISDC Name**	151 360	13 725 020	7 868 233	944 536	2 918 942	1 993 308
	01	Pre-decommissioning actions	7 020	561 975	386 438	0	92 288	83 250
	02	Facility shutdown activities	2 925	250 350	132 188	0	76 438	41 725
	03	Additional activities for safe enclosure or entombment	0	0	0	0	0	0
	04	Dismantling activities within the controlled area	33 880	3 885 037	1 916 611	769 536	374 917	823 974
	05	Waste processing, storage and disposal	15 285	2 505 958	764 248	150 000	1 174 050	417 660
	06	Site infrastructure and operation	31 500	1 945 800	1 361 250	25 000	339 750	219 800
	07	Conventional dismantling and demolition and site restoration	0	0	0	0	0	0
	08	Project management, engineering and support	60 750	4 365 900	3 307 500	0	661 500	396 900
	09	Research and development	0	0	0	0	0	0
	10	Fuel and nuclear material	0	0	0	0	0	0
	11	Miscellaneous expenditures	0	210 000	0	0	200 000	10 000

Fig 2 ATI CERREX model costing case results

ATI eOMEGA_RR costing case results are documented by Table 1 with relevant calculated workforce and costs in ISDC structure and Table 2 with calculated quantities of waste streams from decommissioning process.

ISDC No.	Name of ISDC item	Workforce (manhour)	Total costs (kEUR)	Labour costs (kEUR)	Investments (kEUR)	Expenses (kEUR)	Contingency (kEUR)
	Total	**157 000**	**13 446.9**	**7 590.6**	**940.7**	**2 986.0**	**1 929.5**
01	Pre-decommissioning actions	7 000	562.0	386.4	0	92.3	83.3
02	Facility shutdown activities	2 900	250.4	132.2	0	76.4	41.7
04	Dismantling activities within the controlled area	37 700	3 692.5	1 693.8	765.7	458.6	774.4
05	Waste processing, storage and disposal	17 100	2 420.3	709.4	150.0	1 157.5	403.4
06	Site infrastructure and operation	31 500	1 945.9	1 361.3	25.0	339.8	219.8
08	Project management, engineering and support	60 800	4 365.9	3 307.5	0	661.5	396.9
11	Miscellaneous expenditures	0	209.9	0	0	199.9	10.0

Table 1 ATI eOMEGA_RR model costing case calculated workforce and costs

Type of material	Quantity	Unit	Activity [Bq]
Material released to environment (unconditionally)	473.26	t	1.82E+05
Material released to environment (conditionally)	1.37	t	1.59E+06
Radioactive waste	57.29	t	1.38E+13

Table 2 ATI eOMEGA_RR model costing case calculated quantities of waste streams

4 Sensitivity analyses

The main objective of sensitivity analyses was to identify and analyse the impact of input uncertainties on the resulting costs, workforce and waste quantities from decommissioning process. In the case of ATI calculation case, the following sensitivity analyses were performed in eOMEGA_RR code:

1. Effect of deferred dismantling – 50 years safe enclosure.
2. Higher level of activation – 10 times.
3. Extended duration of the project – 1 year extension.

The effect of deferred dismantling confirmed reduction of waste management costs due to radioactive decay of nuclides and reclassification of materials to lower radioactive waste categories. On the other hand, additional significant operational costs are needed for site operation, security, taxes and insurances during safe enclosure period. As a result for ATI model costing case, total calculated costs for deferred dismantling are 15% higher than for immediate option.

The impact of 10-times higher activation level for reactor components with the unchanged radionuclide vectors and considered Austrian relevant waste limits is represented by slight increase of radioactive waste quantities. Therefore the total calculated costs are 1% higher in comparison with the basic costing case with initial activation level.

The extended duration for the project causes an increase of labour costs mainly and subsequently an increase of total calculated costs representing 10%.

5 Benchmarking of eOMEGA_RR with CERREX

Since the same input inventory database and input calculation parameters as close as possible were used during CERREX as well as eOMEGA_RR case development, it was possible to benchmark the results of ATI costing cases, see Table 3.

ISDC No.	ISDC item	CERREX code		eOMEGA_RR code	
		Workforce (manhours)	Costs (€)	Workforce (manhours)	Costs (€)
01	Pre-decommissioning actions	7 020	561 975	7 020	561 975
02	Facility shutdown activities	2 925	250 350	2 925	250 350
03	Additional activities for safe enclosure or entombment	0	0	0	0
04	Dismantling activities within the controlled area	33 880	3 885 037	37 673	3 692 520
05	Waste processing, storage and disposal	15 285	2 505 958	17 094	2 420 306
06	Site infrastructure and operation	31 500	1 945 800	31 500	1 945 902
07	Conventional dismantling and demolition and site restoration	0	0	0	0
08	Project management, engineering and support	60 750	4 365 900	60 750	4 365 900
09	Research and development	0	0	0	0
10	Fuel and nuclear material	0	0	0	0
11	Miscellaneous expenditures	0	210 000	0	209 885
	Total	**151 360**	**13 725 020**	**156 962**	**13 446 838**

Table 3 Comparison of results calculated by CERREX and eOMEGA_RR codes ATI

The difference between the total costs calculated by CERREX and eOMEGA_RR is about 2% which represents a very good correlation between both decommissioning costing codes. The main reasons for the differences for inventory dependent activities (ISDC 04, 05) are different considerations for working groups, different ways for calculation parameters of remote dismantling, different ways for application of work difficulty factors and different algorithm for calculation of waste and material quantities in both codes.

6 Conclusions

The new generation decommissioning costing code eOMEGA_RR was developed with the aim to improve features of CERREX code used for preliminary cost estimates of research reactors. Within the collaboration of STU in Bratislava with the Atominstitute of Austrian University in Vienna, the pilot demonstration of the code was successfully performed for the operating TRIGA Mark II reactor. For the purpose of benchmarking, ATI model costing cases using CERREX as well as eOMEGA_RR code were developed. Both codes have fully implemented ISDC structure and methodology and meet the actual international requirements, trends and best practices in the decommissioning costing. However, there are several advantages of eOMEGA_RR vs. CERREX code, such as: more detailed cost calculations of inventory dependent activities, automatic sorting of material due to incorporated unique tool for simulation the material and radioactivity flow, sensitivity analysis tool allowing to compare automatically multiple costing cases, modern user-friendly environment and online access. These features might help to next applications of eOMEGA_RR code in the future for other research facilities.

References

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[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Financial Aspects of Decommissioning, IAEA TECDOC 1476, IAEA, Vienna (2005.)