PRELIMINARY ANALYSIS OF CLEARANCE AND RECYCLING OPTIONS FOR METALS FROM DECOMMISSIONING IN SLOVAKIA

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Abstract

Nowadays, decommissioning process of two NPPs in Slovakia (V1 NPP – standard operation, A1 NPP – shut down after an accident) takes place. Therefore, identification of potential waste streams, modification and the optimization of waste management system is one of the top priorities in the next few years. Moreover, implementation of new IAEA Basic Safety Standards (via Council directive 2013/59/EURATOM) into Slovak legislation will result into stricter clearance levels for several radionuclides of concern. This may lead to decrease of amount of materials that may be free released into the environment and may have impact on overall costs of decommissioning. Taking into account current situation in Slovakia, possibilities for waste management optimisation via concepts of clearance, recycling and reuse of materials should be deeply analysed.

Method for the overall assessment including safety and economical aspects was developed within research project called CONRELMAT devoted to derivation of clearance levels and evaluation of possible scenarios for reuse and recycling of decommissioning materials both within and outside of nuclear sector. Applied method follows international recommendations related to the basic safety principles and implements the lessons learned from numerous decommissioning costing calculation cases including simulation of material flow.

Objective of the paper is to discuss the possibilities for optimization of metal waste management and to present preliminary comparison of various scenarios related to the metal clearance and recycling within nuclear industry. Based on calculations performed within the CONRELMAT project, some of mentioned metal reuse and recycling scenarios are feasible and may save financial resources as well as disposal capacity.

Keywords: Decommissioning, Clearance, Conditional Clearance, Recycling, Waste Management.

1. Introduction

Process of NPPs decommissioning is connected with generation of significant volumes of various materials. Majority of them are non-contaminated, however some of them may be hazardous as well (e.g. chemicals, asbestos, oil products, etc.). During decommissioning of NPP, significant quantities of materials with various levels of radionuclides concentration arise as well. All of these materials should be managed appropriately keeping in mind safety principles, legislative requirements, lessons learned and other relevant factors.

Nowadays, optimization of waste management is highly discussed issue worldwide. The main topic is to identify the optimal waste stream, waste management technique or technology, which ensures required level of safety, while other factors, such as optimisation of costs or effectiveness of disposal capacity use, are taking into account as well.

In Slovakia, decommissioning of two NPPs (V1 NPP – NPP with standard operation, A1 NPP – shut down after an accident) takes place. Therefore, identification of potential waste streams, modification and the optimization of waste management system is crucial in the next few years. Since A1 NPP and V1 NPP are completely different NPP type (A1 NPP is prototype, gas cooled, heavy water moderated reactor with natural uranium fuel; V1 NPP is standard VVER 440 type of reactor), the waste streams differ a lot. Moreover, A1 NPP was shut down after an accident. The accident itself as well as post-accident issues have significant impact on higher level of contamination with fission products and transuranic elements and generation of non-standard waste types.

Moreover, implementation of new IAEA Basic Safety Standards (via Council directive 2013/59/EURATOM) into Slovak legislation will result into stricter clearance levels for several radionuclides of concern. Based on the Council Directive, new clearance level shall be implemented by February 2018.

All these factors give rise to the necessity for deeper analysis of options for waste management optimisation. One of possibilities of optimisation for materials with very low level activity concentration is application of concepts of clearance, recycling and reuse for materials with higher intrinsic value – metals. There exist internationally accepted guidelines issued by IAEA or European Commission [1][2][3][4], documents published by regulatory bodies – e.g. US NRC [5] or nuclear industry code of practice [6].

Recommendations, requirements (e.g. dose criteria) and lessons learned from aforementioned documents were applied in research project CONRELMAT supported by Slovak Government. The following chapters are devoted to brief description of this scientific project, presentation of main results as well as discussion on possibility for metal recycling within nuclear industry. Moreover, preliminary analyses regarding financial aspects of selected scenarios are included as well.

2. Proposal for development of clearance and recycling scenarios for metals

As it was mentioned above, paper is devoted to describe and present preliminary analysis of clearance and recycling options for metals from decommissioning in Slovakia. The first step in analysis is to gather all relevant input parameters and boundary conditions related to particular scenarios/options. The process of development of selected scenario from safety and financial point of view is briefly described in the following subchapters.

2.1 Safety aspects – methods applied in the CONRELMAT project

Project CONRELMAT was devoted to the conditional clearance of metals and concrete rubble from decommissioning of NPP. Several scenarios for conditional clearance and subsequent reuse of materials for industrial purposes with long-term fixation of materials (50 – 100 years) were selected and analysed. The basic difference between CONRELMAT project and above mentioned international guidelines for clearance lies in fact, that CONRELMAT tried to focus on more specific scenarios, i.e. clearance or recycling of materials for specific/restricted purpose. Particular scenarios analysed in CONRELMAT were carefully chosen following the basic radiation protection principles:

- Exposure time – industrial applications were chosen, where lower exposure time during theirs operation is expected (e.g. motorway tunnel or bridge; electricity transmission towers);
- Distance – scenarios, which inherently ensures greater distance from source (bridges, tunnel, transmission towers);
- Shielding – scenarios, where source is shielded by concrete layers (e.g. reinforcement in bridges and tunnel, robust ferroconcrete structures).

Overview of logical steps within project is depicted on Figure 1 below.

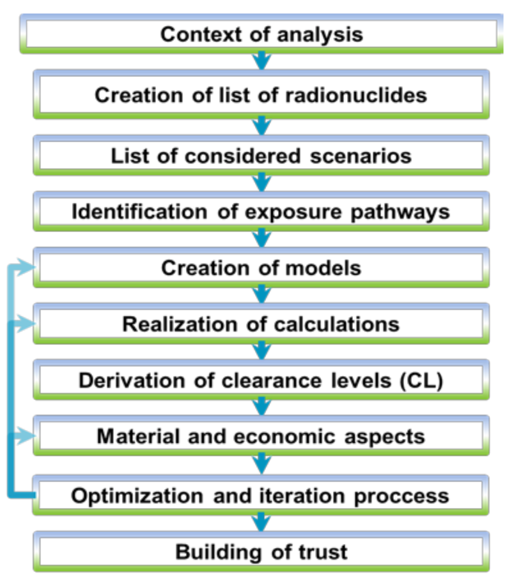

Figure 1 Overview of logical steps for development of scenarios within the CONRELMAT project

Another significant aspect that was taken into account, was the long-term fixation of materials at one place (e.g. several decades in case of motorway tunnels or bridges), i.e. significant decrease of the concentration of short-lived nuclides in the material by the natural radioactive decay.

First of all, radionuclides of concern had to be identified. This was done using radiological characterization data from mentioned two Slovak NPPs in decommissioning phase. Then the list of several scenarios was created considering mainly clearance and reuse of metals for industrial purposes such as motorway bridge or tunnel construction (metals reused in form of reinforcement mesh), transmission towers, ferro-concrete constructions or recycling of metals within nuclear sector. Clearance of concrete rubble was analysed as well via road construction scenario (it was considered to use concrete rubble within road base under the carriageway). The next step was to identify all relevant exposure pathways in particular scenario both form short-term and long-term perspective. Based on the input parameters and boundary conditions, models were created using tools like VISIPLAN 3D ALARA, MicroShield or GoldSim. Following the applied dose criteria based on safety principles, results from the dose assessment and internationally accepted guidelines, the clearance levels valid for each scenario were derived [7].

2.2 Material flow and related financial aspects

Using the robust decommissioning database and derived clearance levels, it was possible to determine the amount of clearable materials valid for particular scenario. Costing calculation tool OMEGA was used for this purpose. OMEGA code were developed in DECOM company and are widely used for decommissioning costing purposes related to final or preliminary decommissioning plan for nuclear installations in Slovakia and abroad (e.g. Hungary or Romania).

Currently new version of OMEGA code called eOMEGA is deployed. International Structure for Decommissioning (ISDC) jointly recommended by IAEA, NEA/OECD and European Commission [8] is fully implemented in these codes. New eOMEGA code utilizes the lessons learned from OMEGA code development and use. Idea is to merge the ISDC itself, costing methodologies based on the ISDC, recent trends in decommissioning costing and funding along with principles of transparency, modern software design and user-friendliness into one compact and flexible working package [9].

Moreover, both codes incorporates unique feature for simulation of material and radioactivity flow, which enables to track particular material piece and its physical and radiological characteristics through whole decommissioning and related waste management process.

Thanks to this feature it is possible to analyse clearance and recycling scenarios from waste management perspective, in particular, it is possible to determine quantities of materials that may be cleared and/or recycled or on the other hand that have to be disposed of at appropriate repository (see Figure 2).

Utilizing investment and operational costs, unit factors and manpower needed for waste management, it is possible to estimate the overall waste management costs (including disposal) and compare various scenarios from financial perspective.

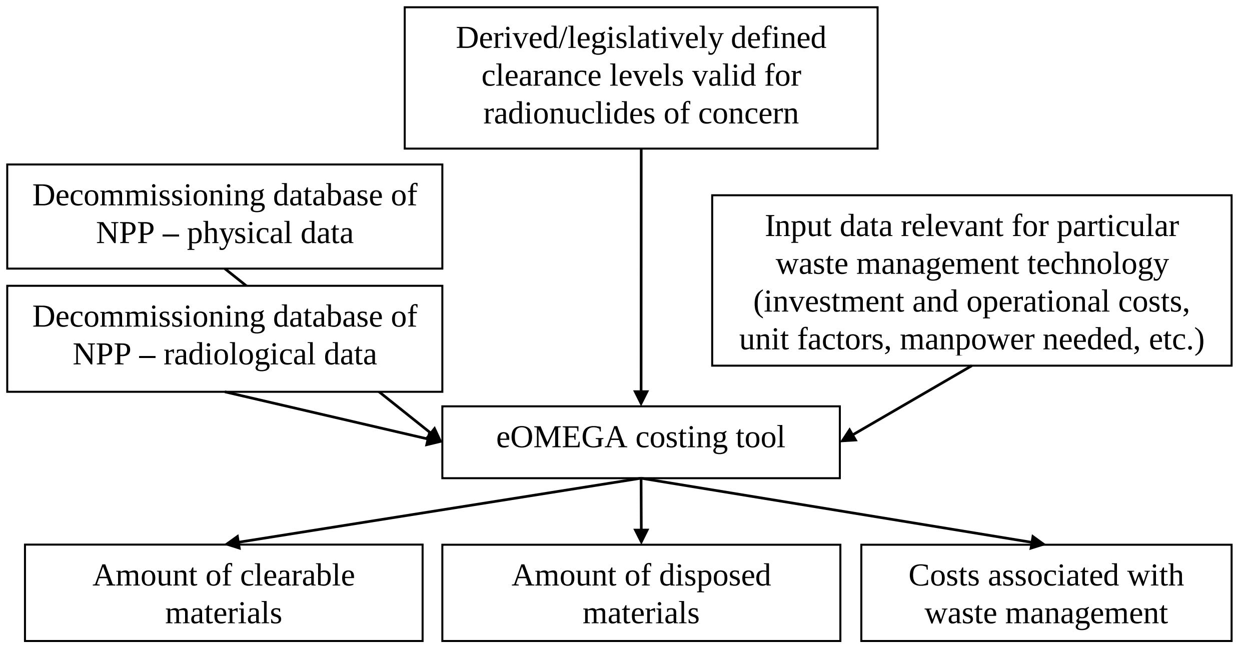

Figure 2 Principal scheme of material flow and costing feature implemented in eOMEGA tool

3. Results from preliminary analysis

It should be mentioned that below stated preliminary results are country specific, since set of specific clearance levels, Slovak waste management system, as well as costs – related parameters was taken into account. However, method applied is universal and can be used for different country and waste management systems as well (in case of availability of all necessary input parameters).

3.1 Derived clearance levels

Table 1 below depicts the comparison of derived clearance levels valid for following scenarios:

- Clearance concept following new clearance levels (new IAEA Basic Safety Standards),
- Clearance concept following current clearance levels defined in Slovak legislation,
- Conditional/restricted clearance scenario – derived specific clearance levels within project CONRELMAT for reuse of material outside of nuclear sector,
- Recycling of metals within nuclear sector – preliminary estimation of possible options.

Table 1 Summary of clearance levels valid for considered scenarios

Radionuclides of concern	Clearance levels (Bq/g)			Recycling levels (Bq/g)
	IAEA – new BSS	Current legislation in Slovakia	Scientific project CONRELMAT - conditional clearance	Recycling of metals within nuclear industry
^{55}Fe	1 000	300	18 300 000	18 300 000
^{59}Ni	100	300	557 000	5 570 000
^{60}Co	0.1	0.3	2.4	24
^{63}Ni	100	3 000	1 470 000	14 700 000
^{90}Sr	1	3	144	144
^{93}Mo	10	30	34 400	344 000
^{135}Cs	100	30	248	248
^{137}Cs	0.1	0.3	2.1	2.1
^{151}Sm	1 000	300	10 800	10 800
^{239}Pu	0.1	0.3	1	1
^{241}Pu	10	30	54	54
^{241}Am	0.1	0.3	1.2	1.2

Clearance levels from CONRELMAT project are valid for motorway tunnel scenario, in which dose criterion 50 μSv was taken into account. Application of melting technology to transform the metal into reinforced bars and mesh was considered. Radionuclide distribution occurs during melting process. This fact has significant impact on clearance level for radionuclides such as ^{137}Cs that are distributed almost entirely into the dust. Therefore, limiting activity for ^{137}Cs is melting process within controlled area (despite the fact that 20 mSv dose criterion was applied for professional workers) resulting into lower clearance level for ^{137}Cs than value valid for ^{60}Co.

Recycling levels was derived based on results from CONRELMAT project. Considering the fact that melting process within controlled area of NPP was identified as the limiting activity for several radionuclides, recycling levels for these radionuclides (e.g. ^{90}Sr, ^{137}Cs, or ^{241}Am) are the same as clearance levels relevant for CONRELMAT project.

Since materials remain within nuclear industry, 6 mSv dose criterion (non-professional workers) was considered. However, it should be noted, that conservative approach is taken into account, i.e. increase by factor of 10 was applied for recycling levels relevant for the rest of radionuclides (e.g. ^{59}Ni, ^{60}Co, or ^{93}Mo).

Based on the results, safety assessment performed on the case by case basis, which is relevant strictly for particular scenario of restricted reuse/recycling may lead to the significantly different clearance values. However, as it was mentioned above, this is preliminary analysis and further investigations, modelling and calculations should be performed.

3.2 Waste management costs and saving of disposal capacity

Scenarios (i.e. impact of different clearance or recycling levels) stated in previous chapter were analysed from costing and material flow perspective as well. The following boundary conditions were applied for metal that breaching the legislatively defined clearance limits, i.e. cannot be cleared directly into the environment:

- Decontamination with factor of 10 was considered for carbon steel and with factor of 100 for stainless steel materials;
- Melting technology is applied for all metal materials (in case that melting leads to clearance).

Each scenario was applied for the model calculation database of NPPs containing the flowing system and components:

- A1 NPP – systems and components of primary circuit excluding reactor and the most contaminated steam generators,
- V1 NPP – system and components of controlled area excluding reactor and its internals.

The following figures describe waste management costs (including disposal) and material flow comparison between reference scenario (current state in Slovakia) and remaining 4 analysed scenarios.

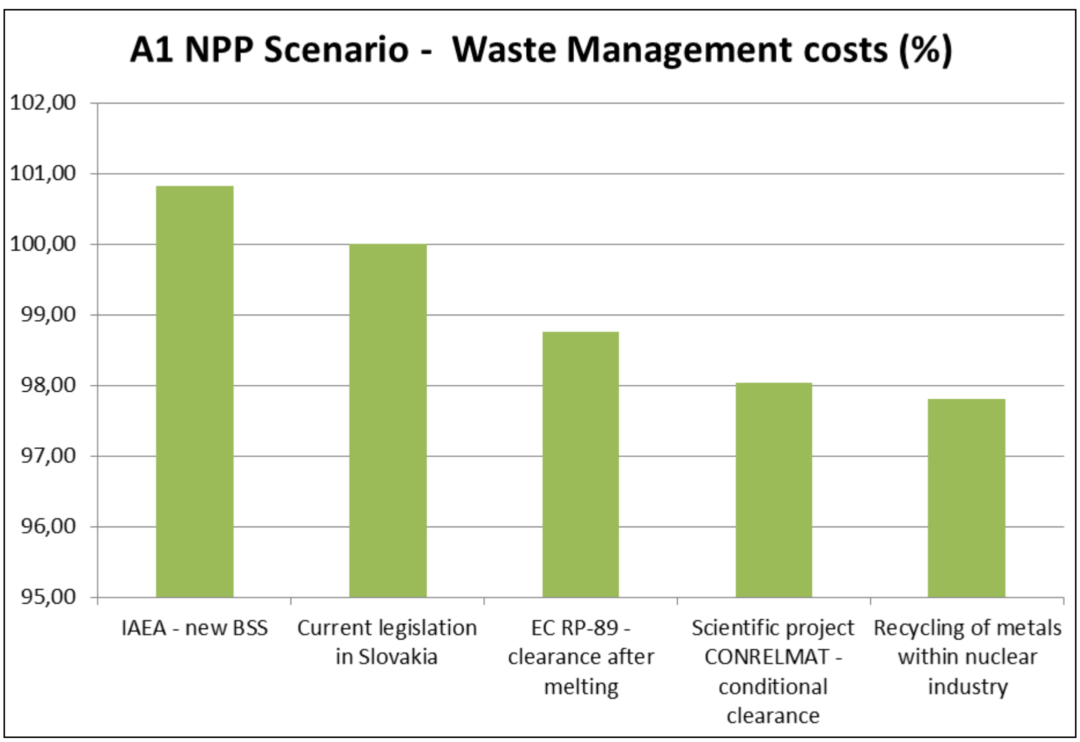

Figure 3 Comparison of scenarios for A1 NPP from waste management costing perspective (100 % is represented by the reference scenario - Current legislation in Slovakia)

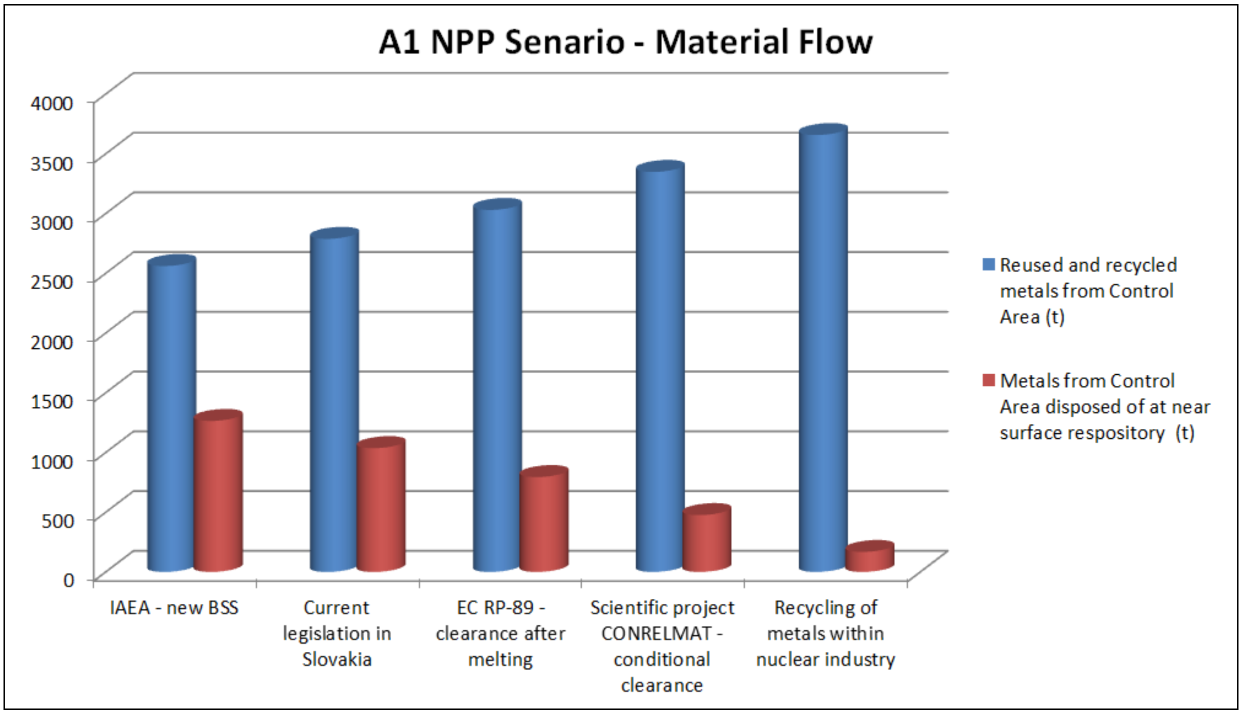

Figure 4 Comparison of scenarios for A1 NPP from material flow perspective

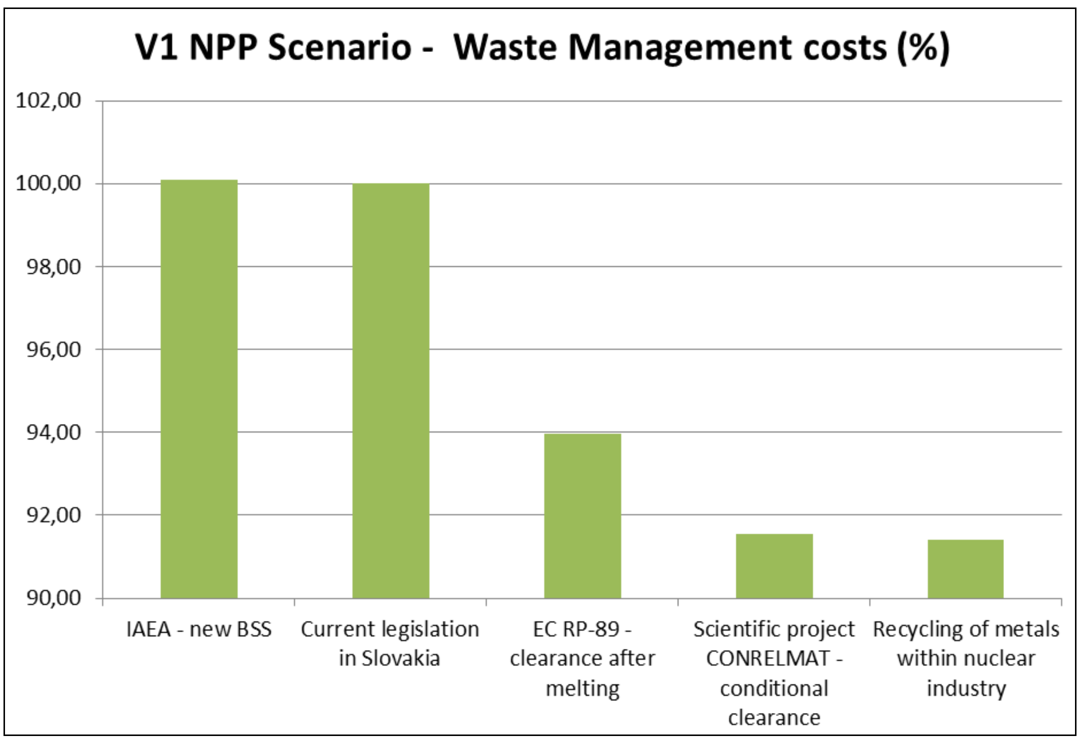

Figure 5 Comparison of scenarios for V1 NPP from waste management costing perspective (100 % is represented by the reference scenario - Current legislation in Slovakia)

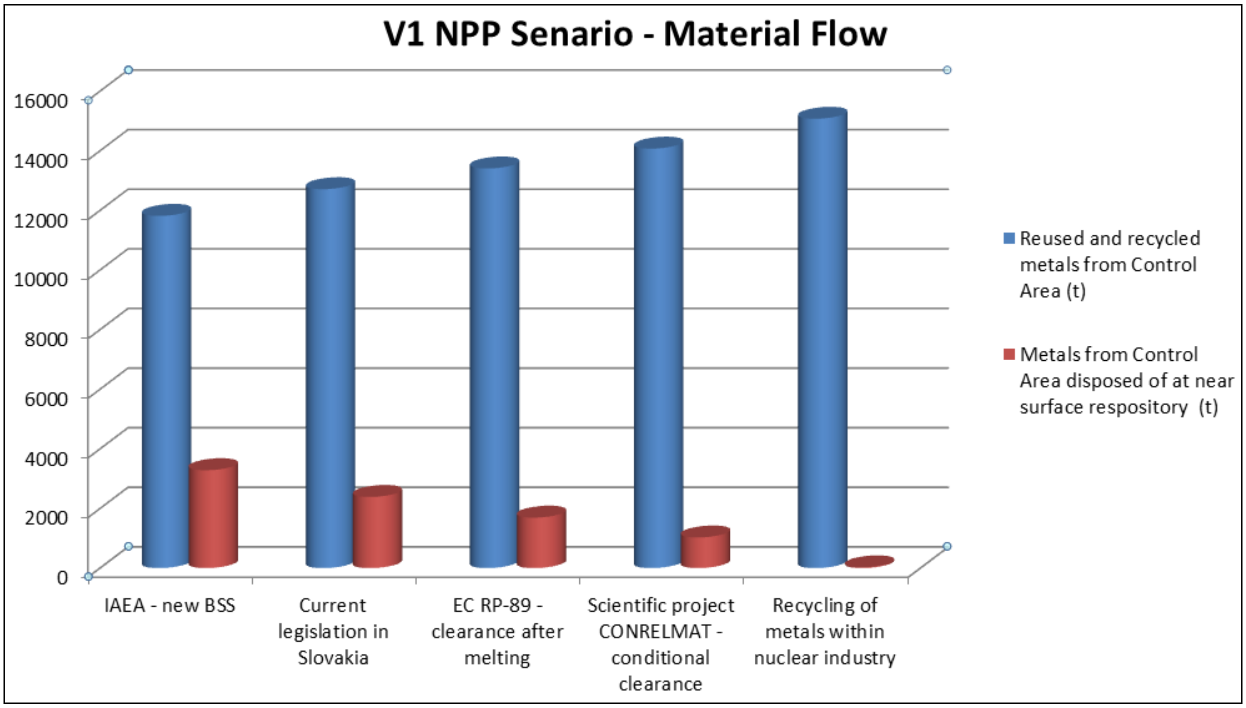

Figure 6 Comparison of scenarios for V1 NPP from waste management costing perspective

Based on the results, certain cost saving within waste management including disposal process (up to 3 % in case of A1 NPP scenario and up to 8.5 % in case of V1 NPP scenario) may be achieved, despite the fact that melting technology with relatively high investment and operational cost is used (comparing to the high-force compactor technology usually used for metal waste that has to be disposed of at near surface repository).

Comparing the "recycling/reuse" concept with the "dispose/buy new" concept, the waste management cost seems to be lower in case of recycling/reuse concept. However, costs of metal products manufacture may be slightly higher than cost of new product (e.g. reinforcement mesh) based on the following considerations:

- Unit cost factor for manufacturing of metal components in small scale facility located within nuclear site is definitely higher than in large scale commercial facility;
- In case of commercial facility, there are no costs of radiation protection measures that should be in place in case of production facility dealing with slightly radioactive materials.
- Lower or no transportation costs (small scale facility is located within nuclear site) and no cost for buying new raw material or metal scrap may partially compensate the aforementioned drawbacks;

Further analyses including detailed feasibility studies for particular scenarios taking into account detailed costs and amount of clearable/recyclable metals are inevitable in order to select optimal scenario for radioactive metals management.

Significant difference may be found in the amount of metals that meets particular clearance levels and may be reused or recycled for certain purpose. Approximately 1 000 tonnes of metals from decommissioning of primary circuit of A1 NPP (excluding reactor and the most contaminated steam generators) and 3 000 tonnes of metals from decommissioning of systems and components of controlled area of V1 NPP excluding reactor and its internals may be recycled within nuclear industry.

4. Conclusion

Preliminary results indicate that both concept of clearance with subsequent reuse of materials for specific purpose and recycling of metal materials within nuclear industry are feasible and may lead to save significant disposal capacity.

However, it is necessary to bear in mind stakeholder involvement, especially in case of conditional clearance of metals. On the other hand, the concept of recycling of radioactive metals within nuclear industry may be more acceptable by the public and other stakeholders involved. Moreover, nuclear industry may save additional financial resources using the recycling scenario – metals with very low level concentration of radionuclide may be utilized instead of acquiring new "clean material".

Typical examples of metal recycling options may be as follows:

- metal material would be rather a shielding than a source (e.g. shielding blocks, mobile shielding walls, drums or containers for waste containing higher amount of radioactivity);
- radioactivity of recycled metals is very low comparing to the other sources in the vicinity (e.g. steal lining of rooms, tanks for liquid radioactive waste);
- metal material would be shielded, used as a reinforcement, i.e. it would be long-term fixed inside of robust structure (e.g. reinforcement bars, or mesh used in construction of larger structures – e.g. disposal vaults or other robust ferroconcrete structures).

Since performed analysis is at conceptual stage, no detailed results as well as validation data are available yet. Therefore, further detailed analysis of potential for clearance of metals with reuse in industrial applications and in particular recycling scenarios of metals within nuclear industry along with detailed identification and assessment of possible recycle scenarios including associated input parameter and boundary conditions are highly desirable.

Acknowledgement

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5. References

[1] International Atomic Energy Agency, Application of the concepts of exclusion, exemption and clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna, 2004.

[2] International Atomic Energy Agency, Derivation of activity concentration values for exclusion, exemption and clearance, IAEA Safety Report Series No.SRS-44, IAEA, Vienna, 2005.

[3] International Atomic Energy Agency, Managing low radioactivity material from the decommissioning of nuclear facilities, IAEA Technical Report Series No. 462, IAEA, Vienna, 2008.

[4] European Commission, Recommended Radiological Protection Criteria for the Recycling of Metals from the Dismantling of Nuclear Installations, Radiation Protection 89, EC, Luxembourg, 1998.

[5] U.S. Nuclear Regulatory Commission, Radiological Assessments for Clearance of Materials from Nuclear Facilities, NUREG – 1640, 2003.

[6] Clearance and Radiological Sentencing: Principles, Processes and Practices for Use by the Nuclear Industry, A Nuclear Industry Code of Practice, Issue 2, December 2012.

[7] T. Hrncir, M. Panik, F. Ondra, V. Necas, “The impact of radioactive steel recycling on the public and professionals”, J. Hazard. Mater. Vol. 254–255, 2013, pp. 98–106.

[8] Nuclear Energy Agency, International Structure for Decommissioning Costing (ISDC) of Nuclear Installations, NEA/OECD, 2012.

[9] V. Daniska, M. Zachar, T. Hrncir, F. Ondra, D. Daniska, P. Zubcak, “ISDC universal costing platfrom eOMEGA based on internet technologies”, Decommissioning of Nuclear Installations: Strategies, Practices and Challenges, NEA/OECD International Conference, Moscow, Russian Federation, 9-11 November, 2015.