Optimization of Low Level Waste Disposal Policy, Strategies and Techniques – 17201

Kapila Fernando*, Peter Ormai**, Jiri Faltejsek**, Michel Dutzer***, John Shevelan****, Felicia Dragolici***** and Lisa Almkvist******

* Australian Nuclear Science and Technology Organisation (ANSTO)
** International Atomic Energy Agency (IAEA)
*** Agence Nationale Pour la Gestion des Déchets Radioactifs (ANDRA)
**** Low Level Waste Repository Limited (LLWR)
***** Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering IFIN-HH
****** Swedish Nuclear Fuel and Waste Management Co (SKB)

ABSTRACT

The mission of low level radioactive waste disposal facilities is to accept and dispose of waste in compliance with all applicable laws, regulations, license requirements, and social expectations. These facilities need to provide a cost effective disposal service to the waste generators, so that the cost savings could be passed down to business, industry, and ultimately, to the general public. To fulfil this mission, waste disposal facilities need to establish and maintain review and optimization mechanisms to respond to changing circumstances that may impact the long-term safe, cost effective operation of their facilities. Maintaining existing disposal resources available as long as possible, managing increased demand for disposal space as a consequence of growing number of nuclear facilities to be decommissioned, and developing capacity for future needs and uncertainties are some of the key challenges that drive optimization of disposal facilities. While the concept of optimization of low level waste disposal facilities is not new, the framework for holistic optimization of waste disposal facilities, enabling them to provide cost effective, sustainable services to the nuclear industry, as well as maintaining optimized safety and radiation protection systems is a notable gap in the current radioactive waste management body of knowledge. A comprehensive optimization framework is required to support the implementation of safe, effective, and sustainable integrated waste management strategies.

INTRODUCTION

In July 2016, an International Atomic Energy Agency (IAEA) International Low Level Waste Disposal Network (DISPONET) technical meeting was held in Gyeongju, South Korea to collect Member States' input and their experiences in developing robust radioactive waste disposal activities and facilities. The focus of this meeting was Optimization of Low Level Waste Disposal Policy, Strategies, and Techniques. The workshop explored a broad range of opportunities for optimization in waste disposal, that can enhance safety and radiation protection, cost effectiveness, public acceptance, environmental impact, and deliver better value for the stakeholders.

Some of the conclusions of this workshop are presented in this article. It provides an overview of the international framework for optimization of safety and radiation protection, the drivers, objectives, the context and the nature of optimization of waste disposal facilities, giving examples and case studies from several IAEA Member States. This article is also intended to initiate a dialogue on developing a systematic and globally applicable framework for holistic optimization of waste disposal policy, strategies, and techniques.

BACKGROUND

Radioactive waste disposal facilities are a critical part of national infrastructure in countries with current or past nuclear industry activities. The mission of low level radioactive waste disposal facilities is to accept and dispose of waste in compliance with all applicable laws, regulations, license requirements, and social expectations. These facilities need to provide a safe, cost-effective disposal service to waste generators, which in-turn will be able to pass down the efficiencies to their customers – business and industry, ultimately resulting in improvements in the cost and services provided to the general public. The ability to maintain cost effective waste disposal services is underpinned by ongoing review and optimization mechanisms to anticipate and respond to changing circumstances that may impact the long-term safe operation of the facility.

The need for ongoing optimization in safety and radiation protection is a well-established practice in the nuclear industry [1]. However, it can be seen that in the context of waste disposal, the concept of optimization can take a broader perspective. If the ultimate objective is to provide better value to the stakeholders, it can be seen that most elements of the framework of review and optimization of safety and radiation protection could also be applied to the other aspects of a disposal facility. Optimizing of the waste volume in the facility could allow more waste disposal without expanding the facility. Similarly, optimizing the methods and accuracy of waste characterization will lead to more effective use of the uncertainty budget in the radionuclide limits for the facility, which may allow more waste to be disposed of within the envelop of the approved safety case.

Optimization of safety and radiation protection systems in waste disposal facilities is embedded in organizational strategy and culture as a proactive process. In comparison to this, it can be seen that the optimization of non-safety related parameters are perhaps carried out mostly in reaction to external factors, such as operational requirements, technology, and changes in the policy environment. They are yet to achieve the proactivity seen in the optimization of safety and radiation protection. The framework for holistic optimization of waste disposal facilities has not yet been captured systematically in the radioactive waste management body of knowledge.

NEED FOR OPTIMIZATION

Optimization can be defined as the process of finding the best way forward where many different considerations need to be balanced. The most common goals in optimization are maximizing benefits and minimizing costs. Frameworks such as Six Sigma and Lean provide numerous tools and techniques to optimize design, production and operational activities. Various integrated business planning processes approach optimization through the use of these tools as well as streamlining decision making processes, directing the management effort to the areas of highest impact. Project Management methodologies offer tools and techniques to optimize various aspects of projects to achieve on time, within budget delivery of projects, while meeting scope and quality requirements. Although the approach to optimization may be significantly different between industries, optimization always has the end goal of delivering quantifiable changes to products, services, facilities, systems, and business processes to create better value for its stakeholders.

There is significant literature on optimization of safety and radiation protection. It is one of the key principles of radiation protection (Justification, Optimization, and Limitation) recommended by the International Commission on Radiological Protection (ICRP). The definition of optimization of radiation protection is an evolving concept, as can be seen in its use in a series of ICRP documents. The concept is used in ICRP 26 and ICRP 60 [2, 3]. In ICRP 81, the concept of constrained optimization is introduced as a judgement process which should be conducted in a structured, qualitative manner [4]. ICRP 101a develops the concept further by introducing the principle of Best Available Technology (BAT) [5].

The optimization of radiation protection is well documented in IAEA documents. IAEA Safety Fundamentals (SF-1) identifies Optimization of Protection as Safety Principle No. 5, among the ten safety principles [6]. According to 'As Low As Reasonably Achievable' (ALARA) principle, it requires that protection must be optimized to provide the highest level of safety that can reasonably be achieved. It requires judgements about the relative significance of all factors that influence the outcome, including the magnitude and likelihood of radiation exposures as well as economic, social, and environmental factors. It naturally follows that when optimized, the resources devoted to improving safety is commensurate with the magnitude of the risks identified.

The IAEA General Safety Requirements (GSR) Part 3 introduces optimization of safety and protection as 'ensuring that radiation exposures are as low as reasonably achievable (ALARA) in the given circumstances' [1]. The GSR Part 3 describes the optimization of protection and safety for a radioactive waste disposal facility as a judgmental process that is applied to the decisions made in the development of the facility design and in the planning of operations. It identifies the requirement for sound engineering design and technical features to be adopted and the use of sound management principles throughout the development, operation, and closure of waste disposal facilities.

The IAEA Specific Safety Requirement (SSR) 5 addresses the safety of waste disposal [7]. It states that the protection and safety can be considered optimized, provided that:

a) Due attention has been paid to the implications for long term safety of various design options at each step in the development and in the operation of the disposal facility.
b) There is reasonable assurance that the assessed doses and/or risks arising from the generally expected range over the natural evolution of the disposal system do not exceed the relevant constraint.
c) The likelihood of events that might affect the performance of the disposal facility in such a way as to give rise to higher doses or greater risks has been reduced as far as reasonably possible by site selection and evaluation and/or design.

Requirement 11 of the above document addresses the design and development of waste disposal facilities and state that 'the design process must be able to respond to changing requirements and refinements arising from step by step evaluation of the disposal facility'. Collectively, these documents identify the elements of a facility with optimized safety systems, processes, and culture. They present a framework for developing and maintaining them.

THE BROADER CONTEXT OF OPTIMIZATION

It can be seen that the current international guidance on this subject speak exclusively to the optimization of safety and radiation protection. However, these concepts, tools, and techniques can be applied in the wider context of waste disposal policy, strategies and techniques to deliver broader benefits, such as improvements in cost effectiveness, public acceptance, and environmental impact. Some key aspects of such a holistic optimization approach are discussed in the following sections.

Boundary Conditions for Optimization

The mechanism of optimization of waste disposal facilities closely resembles the mathematical optimization processes, comprising *Disposal Facility Variables* and *Boundary Conditions*. In a waste disposal facility, key parameters such as the types of waste accepted to the facility, operating regime, construction cost, operating cost, institutional control period, engineered barriers, and to some extent, the dose constraints (not the limits set by regulators) to workers can be selected to suit the needs of the stakeholders. These can be considered *Disposal Facility Variables* from an optimization perspective, where the values / options selected for one will impact the range of values or options available for the others. Optimization involves taking a holistic perspective of these variables to find the most desirable set of values or options for these parameters.

On the other hand, National Policy and Strategy are overarching boundary conditions which are rarely influenced by the disposal facility. Similarly, disposal facilities may not have influence on factors such as regulatory framework, exposure limits set by regulators, budget allocation, and waste generator requirements. These present some of the requirements within which the facility needs to operate. These are set or defined for the disposal facility and have little or no flexibility. Therefore they can be considered as *Boundary Conditions* from an optimization perspective. Figure 1 shows some popular variables available for optimization of a disposal facility and the key boundary conditions that provide the limits for optimization of such variables.

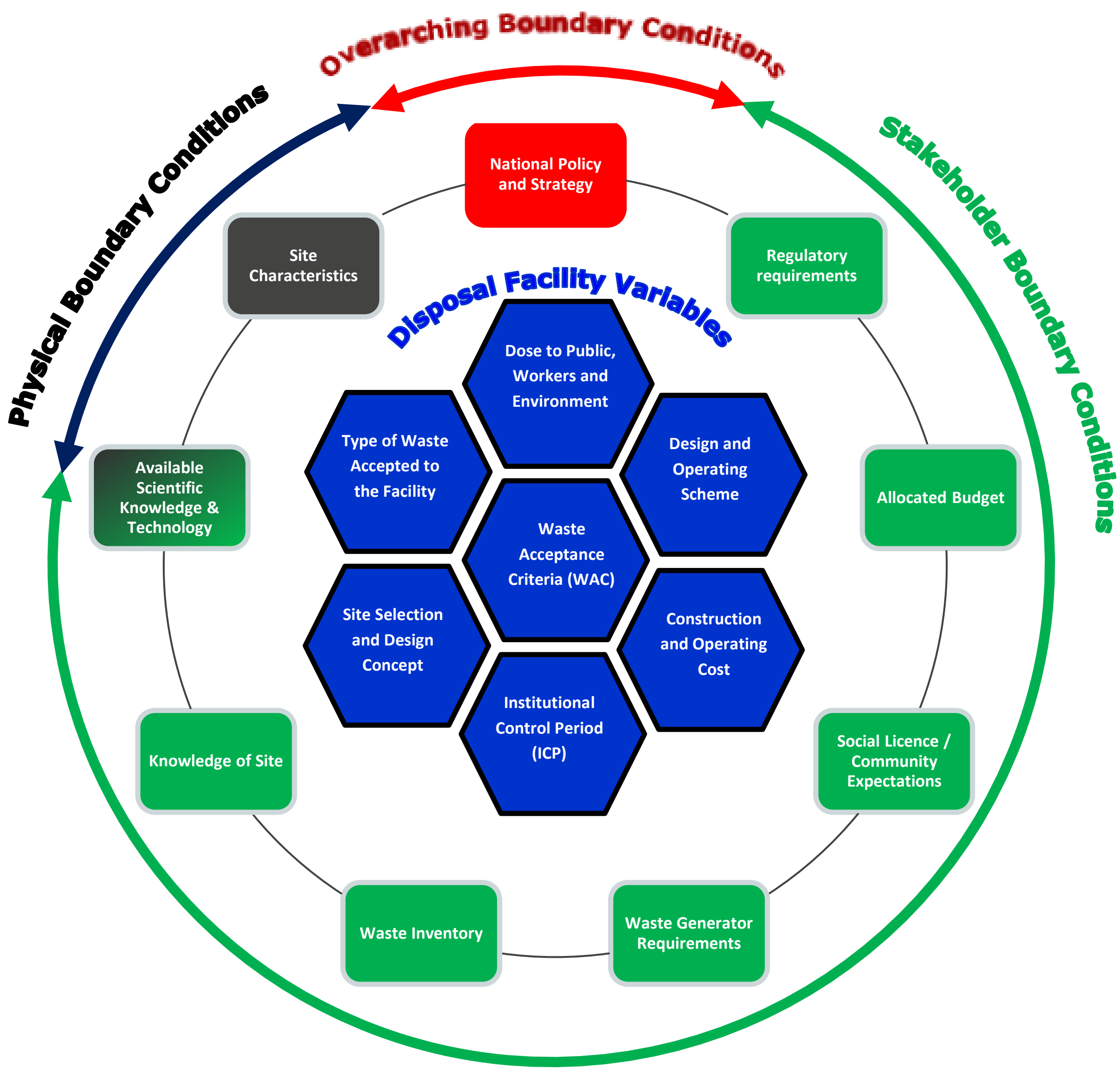

Fig. 1 Key Variables Available for Optimization of a Disposal Facility and Boundary Conditions.

To illustrate this, it can be seen that the countries with relatively small volumes of waste or large inventories of complex legacy waste are better served by a disposal facility that can handle both Low Level Waste (LLW) and some Intermediate Level

Waste (ILW), as they offer significant cost savings over dedicated LLW and ILW disposal facilities. Facilities such as the Deep Geologic Repository (DGR) in Canada are designed for co-disposal of LLW and ILW from Bruce, Pickering and Darlington NPPs, taking advantage of the economy of scale, enhanced safety for LLW disposal, community preferences and reduced predisposal management costs [8]. However in some countries, the national policy and strategy on waste management may limit the optimization options available in this space. As an example, the current national policy on radioactive waste management in Australia calls for the establishment of a LLW disposal facility and an ILW temporary storage facility [9].

For an optimization process to produce a meaningful outcome, the boundary conditions need to be well defined. Nevertheless, it has been frequently observed that some boundary conditions may have significant levels of uncertainties. As an example the costal erosion rate, which has a large uncertainty, is a parameter for assessing the long term exposure scenarios from the Low Level Waste Repository Ltd. (LLWR) facility in the United Kingdom (UK) [10, 11]. As evidenced in that assessment, such uncertainties are typically handled using appropriate numerical methods. The treatment of uncertainties needs to be captured in the assumptions that underpin the optimization.

Iterative Optimization

In can also be seen that the dynamic nature of the boundary conditions make optimization of a disposal facility an iterative process throughout the lifecycle of the facility. Community expectations change over time. The national policy and strategy on waste management can be expected to evolve. The budget allocation to the facility may change periodically. Optimization of waste disposal facilities will remain open-ended as long as the boundary conditions keep evolving and the opportunity to make changes in the facility remain open. Iterative optimization offer opportunities to review the assumptions made during previous cycles and revise the contingencies and buffers built into various scenarios. As such, optimization of a waste disposal facility does not reach completion until the post Institutional Control Period of the facility.

For instance, due to increasing need for disposal of very low level waste at the facility operated by Andra, the design of the cells had to be revised recently to avoid the early closure of the repository. This optimization cycle resulted in a 40% increase in the efficiency of the use of the disposal space (measured in volume of waste disposed per unit surface area of facility footprint). Subject to a change of the license, the capacity of the facility can be changed from 650,000 m^3 to approximately 900,000 m^3 extending the service life of this facility until 2030 [12].

Unique Nature of Disposal Facility Optimization

In the context of a waste disposal facility, optimization is the process of finding the best way forward to fulfil the mission of the facility within the boundary conditions. It can be seen that the boundary conditions such as national policy and strategy on

waste management, social license and community expectations vary between countries, and at times, between regions within the same country.
As such, the set of boundary conditions is unique for each facility. Most waste disposal facility optimization exercises are usually challenges without established precedent.

As an example, to avoid costs and radiation exposure associated with the segmentation of large decommissioning waste items, facilities such as Centre de l ’Aube in France have opted to dispose of large waste components in existing vaults, maintaining the existing design for the facility, with appropriate changes to the Waste Acceptance Criteria (WAC) [13]. Figure 2 shows how the disposal of large components is implemented in the existing vaults at Centre de l ’Aube.

Fig. 2 Disposal of Non-standard Waste Package in Disposal Vaults at Centre de l ’Aube

However, at the Rokkasho LLW Disposal Centre in Japan, which is very similar to the engineering design of the Centre de l ’Aube facility, existing disposal vaults were deemed unsuitable for decommissioning waste. The concern about the increase in radiation exposure to the public during the operational phase caused by skyshine from decommissioning waste items called for a re-design of the disposal vaults.

In order to reduce the exposure to the public in the surrounding area, the design of the disposal vaults were changed from a pit-type vault to a box-culvert-type vault. In these new vaults, waste will be emplaced horizontally by use of a forklift truck, instead of a crane as used in the standard vaults. [14]. A conceptual diagram showing how the proposed box-culvert type cell design could result in a reduction of skyshine exposure is shown in Figure 3. In addition to the reducing the skyshine exposure to members of the public, the box-culvert-type cells allow for all weather operation and more effective use of the vault footprint.

It can be seen that for a very similar problem, the optimized solution differs between facilities due to the differences in boundary conditions. In waste disposal facility optimization, there is rarely a 'one-size-fits-all' solution.

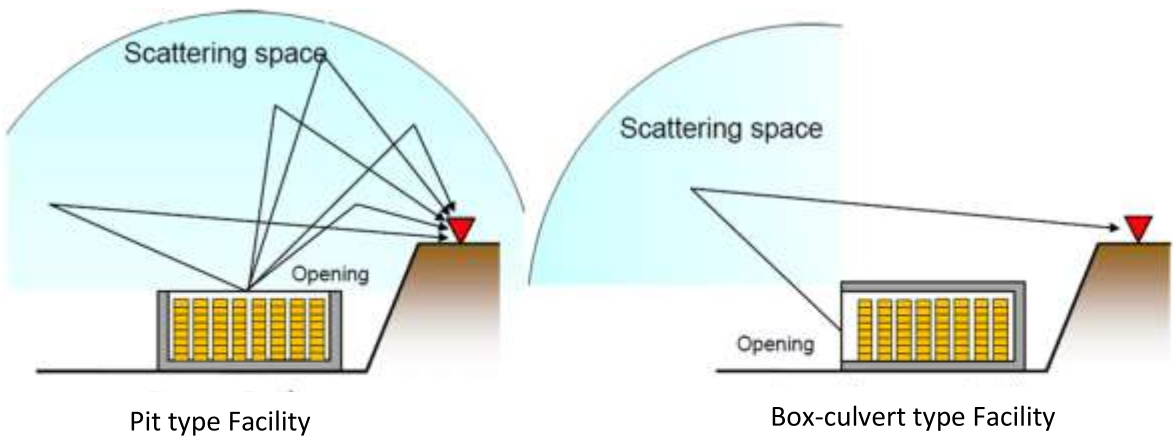

Fig. 3 Optimized Re-design of the Disposal Vaults at the Rokkasho Waste Disposal Centre. Adopted from 'Conceptual study on disposal facility for waste from decommissioning of NPPs' [14].

Transition from Qualitative to Quantitative Optimization

There is a number of decision aiding methods applicable for optimization of waste disposal facilities. While any of these decision aiding methods could be used during the lifecycle of a facility, it can be seen that qualitative optimization methods are predominately used during the early stages. During the latter stages of a disposal facility, quantitative methods become more useful.

The use of a qualitative screening process in Australia to identify waste package specifications during the very early stages of WAC development [15] and the use of Technical, Economic, Commercial, Organizational & Political (TECOP) criteria evaluation method in Sweden to evaluate benefits of disposal of large components instead of size reduction prior to disposal [16] are some examples of qualitative optimization processes used during the early stages of disposal planning. The TECOP method is particularly effective in identifying the most favorable options using high level information in relatively short period of time.

As the disposal concept moves from design and construction to operations, more and more assumptions give way to data and information. Uncertainties are gradually eliminated if not reduced, making quantitative optimization methods more applicable. The recent use of Value Engineering to optimize the available volume at the Hungarian Bátaapáti Radioactive Waste Repository illustrates the use of quantitative methods [17]. Disposal of Low and Intermediate Level Waste (LILW) started at this repository in December 2012. Sometime after commissioning of the disposal facility, the life extension of Hungarian nuclear power plants was confirmed, which resulted in an increase of LILW requiring disposal. After initial studies proved that the characterized sections of the host rock adjacent to existing vaults may not be ideal for new disposal vaults, a systematic optimization program based on Value Engineering was undertaken to make better use of the existing disposal space. This work was driven by the repository operator in close collaboration of the waste generators.

The outcome of this exercise included recommendations to develop alternate treatment and conditioning methods for liquid waste (by waste generators), changes to the disposal overpack design, modification of engineered barrier system inside the disposal chamber and changes to the disposal method of waste packages. As a result of these improvements, the facility was able to identify approximately US$ 48 million (14 billion Hungarian Forint) cost savings, while remaining within the originally approved envelop of safety parameters. The efficiencies of the current and future designs are summarized in Figure 4.

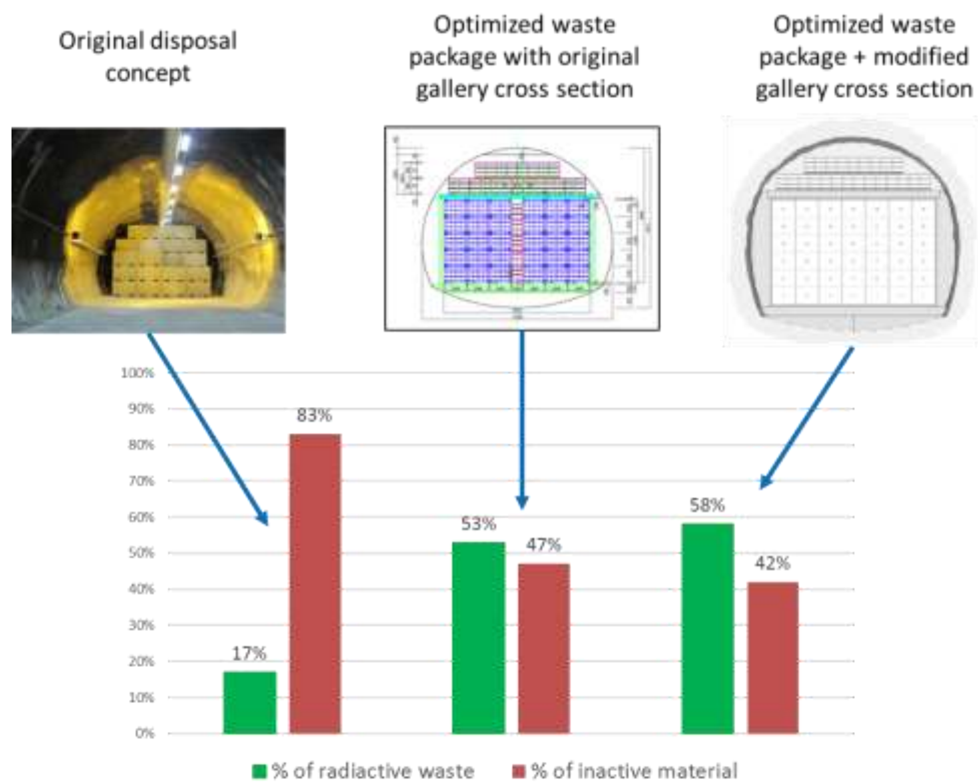

Fig. 4 Current and Proposed Future Optimized Disposal Vault Configurations at the Bátaapáti Radioactive Waste Repository

Integrated with Predisposal Management of Waste

Efforts to optimize disposal must be integrated with the pre-disposal management of waste, and implemented as a part of an integrated waste management strategy. Considering reuse, recycle and energy recovery possibilities, alternative treatment or conditioning methods to get better volume reduction, optimizing waste package design to improve safety and to get better volume efficiency, delay and decay, improving characterization allowing better segregation and clearance, introducing conditional and unconditional clearance for waste and diverting VLLW to dedicated disposal facilities are some examples where optimized disposal solutions involve the consideration or modification of predisposal management strategies. As an example, approximately 50% of the waste initially identified as LLW is cleared for unrestricted disposal following a 2 year delay-decay program at ANSTO, Australia. Most of the examples discussed previously also involve the consideration of predisposal management processes in disposal optimization.

THE OBJECTIVE OF OPTIMIZATION

Optimization is a change process aimed at maximizing the benefits and minimizing the costs, in response to changes in boundary conditions. As can be seen in Figure 1, boundary conditions for waste disposal facility optimization can be broadly classified into three groups: Overarching Boundary Conditions, Physical Boundary Conditions, and Stakeholder Boundary Conditions. Overarching Boundary Conditions are those set by national policy and strategy. These are closely related to the political and social factors. Stakeholder Boundary conditions are those set to meet the needs of the stakeholders of the facility. These boundary conditions evolve constantly and at times difficult to predict. On the other hand, Physical Boundary Conditions are those related to physical reality. They are more stable and predictable. A closer examination of these boundary conditions is presented below to help understand the drivers and objective of optimization.

Drivers for Optimization

As shown in Figure 1, most of the boundary conditions impacting waste disposal facilities are to some extent related to the stakeholders. Changes in regulations, changes in waste generator requirements and changes in the waste inventory for disposal are some examples of such stakeholder driven changes. Since optimization is driven by changes in boundary conditions, which are in-turn a function of stakeholder expectations, it can be argued that optimization of waste disposal facilities are driven by the changes in stakeholder expectations.

The changes in the UK waste disposal landscape in the last two decades is a good example of optimization driven by stakeholder expectations [18]. In 2007, UK Government recognized that the disposal capacity of the LLW repository would not be sufficient to meet future demand, if the existing waste management practice continued.

In response, the Nuclear Decommissioning Authority (NDA) on behalf of the UK Government and devolved administrations, published the 2010 UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry.

The strategy provides a high level framework governing the management of LLW in the UK. The strategy had three themes to guide the optimization of the use of existing waste disposal capacity. These are:

1. Application of the Waste Hierarchy
2. The best use of existing LLW management assets
3. The need for new fit-for-purpose waste management routes.

This strategy has been applied with great success at the LLWR facility, which has allowed the extension of the service life of the existing vaults. One of the most important achievements is the diversion of significant volumes of LLW from the LLW repository, conserving its strategically important but limited capacity. In 2014/15 and 2015/16 over 85% of waste earmarked for disposal was diverted to alternative paths. In parallel to this, alternate treatment routes have been developed to facilitate diversion and the Waste Hierarchy has been used to aid decision making related to waste management.

Optimized Disposal Facilities and Stakeholder Satisfaction

As the primary driver for optimization, the stakeholders continue to seek improvements until their requirements are met. As such, a disposal facility can only be considered 'optimized' when the stakeholders are satisfied. The stakeholder group for a radioactive waste disposal facility is large and diverse. Their level of interest and influence can also be highly variable and their expectations can be complex and inter-related. It is essential that waste disposal facilities are supported by robust stakeholder management strategies to identify the needs & expectations of stakeholders, their level of interest & influence, their communication requirements and external factors that may influence these.

In most cases, stakeholder agreement could be reached through effective engagement, negotiation and by making appropriate changes to disposal facility variables. In such situations, the optimization process and supporting assessments should be clearly documented so that the reasons for adopting specific conditions or approaches instead of the possible alternatives is clear and transparent.

Case studies illustrating the importance of stakeholder engagement in waste disposal facilities can be found in almost every country which has an active nuclear industry. The South Korean experience in locating a host site for waste disposal serves as a good example here. Efforts to locate a host site for all types of radioactive waste (including spent fuel) in South Korea started in mid 1980s [19]. From mid 1980s until 2005, a number of communities were investigated as potential host sites.

Unfortunately, all these attempts were met with overwhelming public opposition and did not proceed beyond the site selection phase. Following these unsuccessful attempts, the strategy for site selection was revised.

With the improved understanding of public risk perception, a decision was made to remove disposition of spent fuel from the mission of the proposed facility. Legislation on various incentives were passed in 2005, including relocating the head office of Korea Hydro & Nuclear Power (KHNP) to the host region, a new proton accelerator industry, and over US$300 million in benefits to the community.

Furthermore, the views of the local communities were given recognition through referendums and transparency in policymaking. With these changes in stakeholder engagement and legislation in place, four additional sites were identified as potential candidates for a LILW disposal facility and local referendums were held to test the community support. Not surprisingly, each of the four host communities supported the proposal with a very convincing 'yes' vote of over 2/3 majority. The facility was finally awarded to the Gyeungju community which had the highest support with the 89.5% yes vote.

As can be seen in the above case study, while the stakeholder requirements are not met, optimization remains open ended. Optimization reaches its logical end point when stakeholder requirements are met.

CONCLUSIONS

Recent global developments have put more emphasis on optimization of radioactive waste management, including disposal. The optimization of safety and radiation protection in the nuclear industry is supported by a number of processes and internationally accepted guides. Most elements of optimization of safety and radiation protection could be applied to optimizing aspects of a disposal facility not directly related to safety. The primary driver for optimization of waste disposal facilities is the satisfaction of stakeholders. Optimization can enhance safety and radiation protection, cost effectiveness, public acceptance, and environmental impact, delivering better value to the stakeholders.

The mechanism of optimization of waste disposal facilities closely resembles the mathematical optimization processes, comprising system variables and boundary conditions. It has been noticed that optimization will remain open-ended as long as the boundary conditions keep evolving and the opportunity to make changes in disposal facilities remain open. The set of boundary conditions for waste disposal facilities is unique for each facility, making most optimization exercises challenges without established precedent. In waste disposal facility optimization, there is rarely a 'one-size-fits-all' solution.

International experience shows that qualitative optimization methods are predominately used during the early stages, while in the latter stages of disposal facilities, quantitative methods become more useful. Furthermore, the optimization of disposal must be performed by considering all phases of waste management, taking into account processing, storage, and transport. Disposal optimization needs to be integrated with the pre-disposal management of waste, and implemented as a part of an integrated waste management strategy. All available variables need to be used to achieve an overall optimization of the waste disposal facility.

It is essential that waste disposal facilities are supported by robust stakeholder management strategies to identify the needs and expectations of stakeholders, their level of interest and influence, and their communication requirements.

In most cases, stakeholder agreement can be reached through effective engagement and negotiation, and by making appropriate adjustment of disposal facility variables.

The availability of a globally accepted framework for holistic optimization of waste disposal, including non-safety related parameters is a notable gap in the current radioactive waste management body of knowledge. A comprehensive optimization framework is required to support the implementation of safe, effective, and sustainable integrated waste management strategies.

REFERENCES

1. Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - General Safety Requirements Part 3, IAEA, 2004.
2. Recommendations of the ICRP. ICRP Publication 26. Ann. ICRP 1 (3), ICRP, 1977.
3. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Ann. ICRP 21 (1-3), ICRP, 1991.
4. Radiation protection recommendations as applied to the disposal of long-lived solid radioactive waste. ICRP Publication 81. Ann. ICRP 28 (4), ICRP, 1998.
5. Assessing Dose of the Representative Person for the Purpose of the Radiation Protection of the Public. ICRP Publication 101a. Ann. ICRP 36 (3), ICRP, 2006.
6. IAEA Safety Standards Series No. SF-1, Safety Fundamentals, IAEA, 2006.
7. IAEA Safety Standards Series No. SSR-5, Disposal of radioactive waste, IAEA, 2011.
8. Deep Geologic Repository for Low and Intermediate Level Radioactive Wastes, Project Description, Report Number: 00216-REP-07722.07-00001, OPG, 2005. Accessed 2 December 2016: http://www.opg.com/generating-power/nuclear/nuclear-waste-management/Deep-Geologic-Repository/Pages/Project-Development.aspx
9. Australian National Radioactive Waste Management Facility Website, Accessed 05 January 2017: http://radioactivewaste.gov.au/radioactive-waste/kinds-radioactive-waste/waste-we-will-manage
10. The 2011 Environmental Safety Case: Site Evolution, LWR/ESC/R(11)10023, LLWR, May 2011.

11. The 2011 Environmental Safety Case: Assessment of Long-term Radiological Impacts, LLWR/ESC/R(11)10028, LLWR, May 2011.
12. Torres, P., Cahen, B., Dutzer, M., The Cires Facility in Morvilliers: from a VLL Waste Disposal Facility to the Development of Industrial Activities , WM2015 Conference, March 15-19, 2015, Phoenix, Arizona, USA
13. From producers' needs to final disposal solution, CSA : Low and intermediate level short lived waste disposal, IAEA DISPONET, Cape Town – South Africa November 24-28, ANDRA, 2014.
14. Hamanaka, T., Conceptual study on disposal facility for waste from decommissioning of NPPs, , Japan Nuclear Fuels Limited, Technical Meeting of the International Low Level Waste Disposal Network (DISPONET) Optimization of Low Level Waste Disposal Policy, Strategies and Techniques, July 2016, Gyeongju, the Republic of Korea.
15. Fernando, K., Qualitative Waste Package Optimisation During Early Stages of Disposal Faculty Development, Australian Nuclear Science and Technology Organization, Technical Meeting of the International Low Level Waste Disposal Network (DISPONET) Optimization of Low Level Waste Disposal Policy, Strategies and Techniques, July 2016, Gyeongju, the Republic of Korea.
16. Almkvist, L., Optimization of LILW in Sweden, Waste and Decommissioning Swedish Nuclear Fuel and Waste management Co, IAEA Technical Meeting of the International Low Level Waste Disposal Network (DISPONET) Optimization of Low Level Waste Disposal Policy, Strategies and Techniques, July 2016, Gyeongju, the Republic of Korea.
17. Baksay, A., Nős, B., and Ormai, P., Optimizing LILW disposal in Hungary, IAEA Technical Meeting of the International Low Level Waste Disposal Network (DISPONET) Optimization of Low Level Waste Disposal Policy, Strategies and Techniques, July 2016, Gyeongju, the Republic of Korea.
18. Shevelan, J., UK LLW disposal strategy and LLWR Optimisation, IAEA Technical Meeting of the International Low Level Waste Disposal Network (DISPONET) Optimization of Low Level Waste Disposal Policy, Strategies and Techniques, July 2016, Gyeongju, the Republic of Korea.
19. Lee, S-H., Experience with Construction of the First Disposal Facility for Radioactive Waste, KORAD, IAEA Technical Meeting of the International Low Level Waste Disposal Network (DISPONET) Optimization of Low Level Waste Disposal Policy, Strategies and Techniques, July 2016, Gyeongju, the Republic of Korea.

ACKNOWLEDGEMENTS

The technical meeting held in Gyeongju, South Korea was organized by the IAEA DISPONET network and made possible due to the generous support by the host, Korea Radioactive Waste Agency (KORAD). The authors wish to express their utmost gratitude to the IAEA and KORAD for organizing and hosting this workshop.

The authors are indebted to all participants for their contribution including Babilas, E. (Lithuania), Bondar, O. (Ukraine), Bosselaers, R. (Belgium), Hamanaka, T. (Japan), Konopaskova, S. (Czech), Lee, S-H. (Republic of South Korea), Lordello, R. (Brasil), Maleki, A. (Iran), Miguez, R. (France), Mushroof, M. (Pakistan), Nos, B. (Hungary), Palmerio, J. J. (Argentina), Park, J.B. (Republic of South Korea), Sarkar, S. (Australia), Tatrik, I. (Estonia), Tkachenko, A. (Russia) and Wahab, Y (Malaysia).