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RADIOACTIVE WASTE MANAGEMENT NATIONAL PROGRAMMATIC PERSPECTIVES

National Programmatic Perspectives / ID 300

TOWARD A NEW GLOBAL STANDARD: CANADA'S OUTLOOK FOR THE FUTURE OF RADIOACTIVE WASTE MANAGEMENT

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Radioactive waste is a global challenge with a global solution. We all must work together towards implementing our respective plans and ensuring that deep geological repositories go from being best practice, to accepted practice, to commonplace, around the world. Canada, like nations around the world, has benefitted from nuclear power generation for more than six decades. However, like all those countries, we must now implement a safe, long-term solution for used nu- clear fuel. Implementing that solution is our job at the Nuclear Waste Management Organization (NWMO), a non-profit organization created in 2002 by the Canadian government. In 2007, the federal government selected Adaptive Phased Management as Canada's plan for used nuclear fuel. Canada's plan will see used nuclear fuel managed in a purpose-built deep geological repository – a series of naturally occurring and engineered barriers which, working in concert, can safely manage used nuclear fuel while protecting both people and the environment over the very long-term. We are not alone in pursuing this option. We are both building upon and contributing to work underway in other countries as well as helping to lead the way for those who are following in our footsteps. Ongoing collaboration with international counterparts is essential for all of radioactive waste management organizations. Sharing information, conducting joint research, learning from shared experiences and lending supportive voices will ensure we can all reach our collective goals. Canada's Plan is approaching a critical juncture. The site selection process that the NWMO initiated in 2010 is drawing to a close. Initially, 22 communities stepped forward to learn more about this project and explore their potential to host it. By 2023, the NWMO plans to have selected a single, preferred site. Canada's Plan will only proceed with interested communities, First Nation and Métis communities, and surrounding municipalities, working together to implement it. The NWMO is proud of its progress to date and is monitoring other nations as they advance the implementation of their projects. In 2020, the NWMO also received a new responsibility: we were asked by the Minister of Natural Re- sources Canada to lead a separate and parallel engagement process with Canadians and Indigenous people to inform the development of a comprehensive integrated radioactive waste management strategy. This is part of the Government of Canada's Radioactive Waste Policy Review and leverages the NWMO's 20 years of recognized expertise in engaging Canadians and Indigenous people on plans for the safe long-term management of used nuclear fuel

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SPENT FUEL, DISUSED SOURCES AND RADIOACTIVE WASTE MANAGEMENT STRATEGY IN ARGENTINA

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The management of spent fuel, disused sources and radioactive waste in Argentina is accomplished within a legal framework including the National Constitution, the Joint Convention, two National Laws and a National Decree. In 1998 the National Law Nr. 25018 appointed the National Atomic Energy Commission as the enforcement authority by establishing the National Radioactive Waste Management Program. The National Program was assigned the responsibility for issuing and updating every three years a Strategic Plan to be sent through the official channels for approval by the National Parliament. The last update of the plan, the Collaborative Strategic Plan (CSP), was jointly composed by the staff of the National Program, issued in December 2020 and sent for review and approval in January 2021. The CSP reviews the Mission and Vision Statements. The former expresses the reason for the National Program, it is a lasting statement of its purpose and allows guidance for establishing objectives, formulating strategies and carrying out tasks in a coherent and organized manner by highlighting the need for sustainability as follows: “Accomplish the effective management of spent fuel, disused sources and radioactive waste from the nuclear activities performed in Argentina to ensure people and environmental protection at present time and in the future”. The latter indicates where the National Program is heading and allows to focus the efforts towards a defined direction as follows: “Safely confine radioactive waste in repositories”. The CSP also sets up organizational values for guiding the decisions, actions and behaviors. Furthermore, this CSP pinpoints the external factors impacting on the organizational environment within the radioactive waste management must be developed. A comprehensive set of references related to the institutional development of radioactive waste management, focusing on political, economical, social, technological, environmental and legal constraints was studied. Interested parties were evaluated based on their degree of interest and their power as opinion leaders for shaping specific strategic communication actions. Afterwards, the strategies were developed by means of SWOT analysis. Once the strategies were ordered according to the public sector perspectives for the construction of the Balanced Scorecard, the metrics (indicator formula), goal (expected numerical value) and means (resources) were determined for each defined objective. The CSP also points out National Program activities contributing to Sustainable Development Goals highlighting goals 7. Grow Affordable and Clean Energy, 9. Increase Industry, Innovation, and Infrastructure, 13. Organize Climate Action and 17. Build Partnerships for the Goals among others.

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IMPLEMENTATION OF DEEP GEOLOGICAL REPOSITORY PROGRAMME IN LITHUANIA

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Fulfilling the obligations set out in Protocol 4 of the Treaty of Accession to the European Union, i.e. the final shutdown of the Ignalina Nuclear Power Plant (INPP) and its decommissioning, Lithuania finally shut down the first INPP Unit on 31 December 2004, and the second INPP Unit - on 31 December 2009. Spent nuclear fuel referred to highly radioactive waste will be transported to special storage facilities at INPP in special containers by 2022, and other long-lived radioactive waste - by 2038. Upon expiry of the design term for the safe operation of containers and storage facilities for high- level radioactive waste (in 2050 and 2067, respectively), one should get ready for the final disposal of high-level radioactive waste and long-lived radioactive waste. Since 2019, INPP is the institution responsible for the implementation of the DGR Project. Based on the implementation of the DGR Programmes of the more advanced countries, a preliminary schedule for the implementation of Lithuanian Project of DGR for radioactive waste repository has been prepared. The preliminary schedule includes for the following stages:

Initial studies, including planning, site selection for the DGR and underground laboratory, geophysical and geological investigations and other activities, prior to the approval of the site for construction of the DGR and underground laboratory will be performed in 2020–2047. Other key stages of the DGR Project: design of the DGR- 2048-2057; construction of the DGR - 2058- 2067; operation of the DGR - 2068-2074; closure of the DGR - 2075-2079; time period after the closure of the DGR - from 2080. Planning and site selection for the investigation borehole are currently in progress (2019-2024). The initial studies are focused on screening of all potentially prospective geological formations as host formations. Negative screening of Lithuanian territory has been performed, i.e. preliminary unsuitable regions have been identified in accordance with the established boundary conditions, including: water body protection zones; protected areas; areas of mineral deposits; cities; sites referred to the European Ecological Network Natura 2000, etc. After eliminating the regions according to the above-mentioned criteria, 110 potential regions have been identified in all geological formations selected as a potential formations for the DGR (Crystalline basement, Cambrian clay, Permian evaporates and Low Triassic clay). Total area of potential regions is 5.632 km2.

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PLANS AND PROGRESS IN ESTABLISHING THE AUSTRALIAN NATIONAL RADIOACTIVE WASTE MANAGEMENT FACILITY

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The paper describes progress to date in siting a RWM facility for management of Australian radioactive waste. The project will secure and support the ongoing production of nuclear medicines and diagnostics in Australia, of great importance to health services, through up to date management of existing and future wastes. The Australian Radioactive Waste Agency (ARWA) was established in July 2020 to: manage Australia's radioactive waste in line with domestic and international regulations; deliver and operate Australia's National Radioactive Waste Management Facility (NRWMF); facilitate communication between government, industry, stakeholders and local communities; and centralize best practice and knowledge about radioactive waste management, including developing a disposal pathway for intermediate level waste. ARWA is undertaking a process to select a suitable site for the NRWMF from voluntary land nominations. The process is specified out in Australian Commonwealth Law and includes assessment of technical suitability and community acceptability. LLW disposal operations are planned for 100 years and ILW storage for a number of decades whilst an ILW disposal pathway is developed. Development of concept designs and work on a safety strategy/ safety case to support environmental and radiological regulatory authorizations is underway.

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RADIOACTIVE WASTE MANAGEMENT IN TURKEY

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Studies in the field of nuclear energy and radiation applications in Turkey started to be carried out in a more coordinated manner with the establishment of the Atomic Energy Commission in 1956. In this context, nuclear research and education centers established in Istanbul and Ankara have made significant contributions to the studies in this field. From 1982 to 2018, TAEA (Turkish Atomic Energy Authority) has jointly carried out nuclear regulatory functions and R&D operations in nuclear energy and radiation applications. In 1989, Radioactive Waste Management Facility was commissioned to meet the needs of the processing, and storage of radioactive wastes resulting from various applications in Turkey at Istanbul Çekmece Campus (former Çekmece Nuclear Research and Training Center). The Radioactive Waste Management Facility serves as the only licensed radioactive waste facility in Turkey. After 2018, according to Presidential Decree No 702, TAEA's duties have been redefined, regulatory duties have been separated from TAEA and the Nuclear Regulatory Authority (NDK) has been established to perform these duties. In line with the new institutional structure, TAEA has been assigned to the task of carrying out the R&D, radioactive waste disposal and capacity building development for Turkey to benefit from nuclear energy and radiation applications. With a new regulation made on 28 March 2020, all of TAEA's authority and power were delegated to Turkey Energy, Nuclear and Mining Research Authority (TENMAK). According to Decree Law No 702, radioactive wastes to be generated as a result of the activities carried out in the sovereignty of the Republic of Turkey shall be disposed by TENMAK. TENMAK shall prepare Draft National Radioactive Waste Management Plan which is a basis for determining national radioactive waste management policy and strategy covering all radioactive wastes resulting from activities and spent fuel in the Republic of Turkey under this Executive Order by the end of December in the years which end with zero (0) and five (5) and submit it to the Ministry of Energy and Natural Resources (MENR) for approval. In line with this Law, First National Radioactive Waste Management Plan was approved by the Minister on December 2020. The plan sets out the necessary strategies, activities and technical solutions required for the management of radioactive wastes and spent fuels, decommissioning of nuclear and radiation facilities and other related works such as cost and financing.

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AN INTEGRATED APPROACH TO WASTE MANAGEMENT

How the UK is integrating radioactive waste management to deliver enhanced waste management services, a stronger workforce, more sustainable supply chain and better value for money for the UK Taxpayer

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Developing a UK approach to integrated waste management will combine, capability, capacity, and skills to develop national waste solutions deliver better innovation and services in waste management, generating future value and operating in a more efficient way. It will ensure an effective thread between policy, strategy, and implementation to support programme acceleration for the NDA and provide lower cost waste solutions. This is the opportunity for NDA to design a more agile waste management system and organisation, with single culture and set of business priorities designed for its future mission. Key advantages of this approach include:

- Centralised capability and knowledge management, which will be more efficient and effective
- Financial savings from lack of duplication and rationalisation of management both internally and with waste producers
- A sustainable waste infrastructure and transport system
- Increased buying power for NDA estate for waste services
- Increased productivity and efficiency for waste services
- Improved methods for scheduling infrastructure availability
- A stronger UK Supply Chain in the decommissioning sector
- Driving the required change in waste management behaviour and culture

The paper describes the key drivers for change and plans for its implementation and highlights external factors contributing to the pace of change.

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DEVELOPMENT OF A COMPREHENSIVE NUCLEAR WASTE MANAGEMENT PROGRAM IN A SMALL-INVENTORY STATE

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Norway had a total of four research reactors in operation from the 1951 to 2019. All have now been taken out of operation, and plans for decommissioning are being developed. To enable de- commissioning, a new infrastructure for management of radioactive waste must be developed. That infrastructure must comprise all classes of radioactive waste, including 16.5 tons of spent research reactor fuel. It must also describe the entire range of activities covered by a waste management strategy: from generation, treatment, and transport of waste to storage and disposal. Few facilities with the required capabilities, capacities, and remaining lifetime exist in Norway. Therefore, practically all types of facilities for management of radioactive waste must be at least considered and, in many cases, built. The spent fuel has a variety of properties. 10 tons consist of metallic uranium in aluminum cladding, which is chemically unstable when in contact with water or air. This makes storage and disposal more challenging than for modern commercial fuel, which is made up of chemically stable uranium oxide. For this reason, different options for pre-disposal treatment are being considered. In addition to pre-disposal treatment of spent fuel, a facility for pre-disposal management of low- and intermediate level waste is being planned, along with storage and disposal facilities for both spent fuel and low- and intermediate level waste. The latter will be generated during decommissioning of the research reactors and supporting facilities and arises from non-nuclear activities. The program may include the establishment of a combined national facility for disposal of all classes of radioactive waste. For spent fuel or high-level waste from pre-disposal treatment, two alternative disposal concepts are being developed: Mined repositories and deep borehole disposal. Despite the relatively small amounts of radioactive waste to be managed, Norway will need to develop solutions for the same waste types as many states with commercial power plants. Therefore many of the same questions must be answered, such as how to select the site for a disposal facility and how to collaborate with other nations in the pursuit of safe and sustainable solutions.

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RADIOACTIVE WASTE MANAGEMENT AT THE ANGRA 1 AND ANGRA 2 NUCLEAR POWER PLANTS AND FUTURE PERSPECTIVES

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The Angra Nuclear Power Plant has two PWR plants in operation (Angra 1 and Angra 2) and one PWR plant under construction. There are five initial deposits of low and medium levels waste on the plant. Three deposits are installed in the Waste Management Center (WMC), one deposit is located inside the UKA building in Angra 2 and one deposit was built to receive two steam generators and a reactor vessel cover from Angra 1. The steam generators were changed in 2009 and the reactor vessel cover was changed in 2013. In Angra Power Plant there are about 8300 low/medium waste packages stored in that Deposits. Angra 1 has storage capacity until 2028 and Angra 2 has storage capacity until 2033. Brazil plans to build a repository until 2024. Candidate sites are already being evaluated and that repository will receive wastes from all parts of the country. This project is very important for Angra 1, Angra 2 and Angra 3 Power Plants.Angra 1 and Angra 2 produce the following waste: Resins, Filters, Compressible Waste, Non Compressible Waste and Concentrate. Angra 1 use cement to incorporate Resins and Concentrates in liners of 1000 liters, use cement to imobilize filters in 200 liters drums. Angra 2 use betume to incorporate resins and concentrates, use betume to imobilize filters in 200 liters drums. Both, Angra 1 and Angra 2, use cement to imobilize the non compressible wastes in 1200 liters boxes. Angra 3 will use the direct drum drying process for resins and concentrates.

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PRACTICAL GUIDANCE DEALING WITH THE CHALLENGES RELATED TO SAFETY OF RADIOACTIVE WASTE MANAGEMENT: EGYPTIAN APPROACH

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The general principles of managing radioactive waste in a safe manner have been set out in the Safety Fundamentals publication entitled Fundamental Safety Principles. The present document is concerned with the application of these principles to the management of radioactive waste prior to disposal in Egypt. Predisposal management of radioactive waste, as the term is used in this document, covers all the steps in the management of radioactive waste from its generation up to disposal, including processing (pretreatment, treatment and conditioning), storage and transport. According to the Egyptian Law that regulates the nuclear and radiological activities in Egypt, the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA) will prepare the regulations and guidelines that may be called the Egyptian safety requirements for the disposal of radioactive waste. This paper focus into the main point that should be considered during preparation of safety guides for safe management of radioactive waste in Egypt. These safety guides are based on the following documents, Law no.7 for the year 2010 “Egyptian Law that regulates the Nuclear and radiological activities” and its executive regulations, Law no 4 for the year 1994 (Environmental law) and its executive regulations, IAEA GSR part 5 “Predisposal of radioactive waste management” 2009, IAEA Safety Guide No. WS-G-2.3 “regulatory control of radioactive discharges to the environment” 2000, IAEA safety standards series No. WS-G-2.5 “Predisposal Management of Low and Intermediate Level Radioactive Waste”, IAEA Radioactive waste management glossary 2003, Ministerial decree no. 202 for the year 2008 (limits of discharge), Radioactive waste management regulations produced from the users of radioactive materials, Egyptian gazette no.152 for the year 1999.

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NATIONAL STRATEGY AND PLANNING FOR THE SAFE AND SUSTAINABLE MANAGEMENT OF RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL

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Nuclear technology applications have been on the increase in Nigeria. The use of radioactive mate- rials in the fields of research, medicine, industry, agriculture, commerce, education and defense; as well as the extraction, processing and combustion of raw materials containing naturally occurring radioactive materials are among the most prominent. Other emerging activities include the development of nuclear reactors for research and electricity generation purposes. These activities generate radioactive wastes, which contain materials that emit ionizing radiation, and have been recognized as a potential hazard to human health and the environment since the beginning of the 20th century. The safe management of these radioactive wastes is therefore, essential for the protection of human health and the environment, in the present and future. The National Radioactive Waste Management Policy expresses the intent of Government to manage radioactive waste and spent nuclear fuel in a safe, secure and sustainable manner to safeguard public health and the environment. To achieve this, a set of strategies need to be developed for the management of radioactive waste arising. The general viewpoint is that the management of radioactive waste involves the reduction to as low as practicable and justifiable, the associated risks through appropriate processing, containment and eventual disposal of processed waste. The most preferred approach in the management of radioactive waste shall be ‘delay- decay’, ‘dilute-disperse’ and to concentrate the waste and contain the radionuclides in it by means of a waste matrix and waste container followed by disposal in an appropriate disposal facility designed to provide adequate isolation from the immediate environment. While our Policy describes intent, the Strategy describes the “how to” and provides the framework for how Radioactive Waste Management will be performed in the country. It also provides for process development and identifies competencies needed and how they will be provided. It elaborates waste management methods for all waste types and prescribes use for communicating with the public and governmental authorities. Among those, in terms of safety, security and environmental protection, one of the main requirements imposed by the Government of Nigeria to all waste generators, is to manage radioactive waste in a manner that protects human health and the environment, now and in the future. The financial requirements for the implementation of the strategic plan for safe, secure and sustainable management of radioactive waste and spent nuclear fuel shall come from the Radioactive Waste Management Fund.

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CHALLENGES OF NEWCOMERS IN DEVELOPMENT OF RADIOACTIVE WASTE MANAGEMENT

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Today, nuclear power produces about 10% of the world's electricity, accounting for around one third of all low carbon electricity. Thirty countries operate nuclear power plants, including several that are planning to expand their nuclear fleet. Another 30 or so countries are considering or embarking on new nuclear power programmes as they regard nuclear power as a clean and reliable source of electricity generation, which can make a significant contribution to their economic development and to mitigating climate change. Launching a new nuclear power programme is a major undertaking. It should be based upon a commitment to use nuclear power for peaceful purposes in a safe, secure and sustainable manner. It requires a sustainable national infrastructure that provides governmental and institutional, legal, regulatory, managerial, technological, human resource, industrial and stakeholder support through- out the life cycle of the nuclear power programme. The adherence to international legal instruments, adoption of internationally accepted standards to ensure high levels of nuclear safety, security and safeguards is also essential in establishing a responsible programme. Experience suggests that a nu- clear power programme involves 10–15 years of preparatory work and a commitment of at least 100 years. It is the sovereign decision of each country whether to include nuclear power in a national energy mix. However, when countries proceed with this option, the IAEA supports them through a variety of activities and services to do so safely, securely and sustainably. Newcomer nuclear countries copes with many special aspects which are not envisaged in energy programme. May be the most helpful way of overcoming them is sharing of experience and bilateral cooperation of other countries. As a case study, the lessons learned during the IPA (Instrument for Pre-Accession Assistance) EU Project "Assistance for development of legislative and organizational framework for management of spent nuclear fuel and radioactive waste generated in Turkey".

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ON EXPEDIENCE AND SAFETY OF HIGH-LEVEL RADIOACTIVE WASTE BOREHOLE DISPOSAL

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Disposal of high-level radioactive waste (HLW) into boreholes to various depths from tenths of meters up to several (3-5) km was considered as an addition to the HLW shaft disposal in many countries, including Russia, UK, and US. Given the high cost of geological disposal, the benefits of borehole disposal are enormous. For example, the placing spent nuclear fuel in deep boreholes can ensure the safety of the disposal and also significantly reduce the waste disposal costs. A promising version of this disposal facility is the concept of long horizontal drillholes repositories (HDR) with depth of 1-2 km. In their main provisions the deep horizontal drillhole disposal projects repeat the concept of vertical borehole disposal. The main difference is the effective use of insulating properties of the surrounding environment and its constituent rocks such as clays and salts which are anhydrous media with the ability to self-heal cracks due to their plasticity. Moreover, the concept of disposal in HDR brings together the technologies of borehole and mined repositories using the advantages of both, and therefore deserves an expert discussion at international level. The HDR allows using effectively at smaller expenses the depths of up to 1 km which can provide necessary insulating capacity not worse than that provided by greater depths of several km. Indeed, the multi-layered structure of the relevant sedimentary cover with a thickness of 500-1000 m above the HDR will be a reliable shield against vertical migration of groundwater from the waste placement horizon. Notable that the HDR can utilise branching horizontal drillholes aiming to increase the total volume of disposal while keeping the disposal costs unchanged. Modern technologies enable drilling of horizontally oriented drillholes very quickly. There are numerous examples of successful horizontal drillings such as the Odoptu field well OR-11 (Sakhalin Island, Russia) of total length 11,475 m with the horizontal section of the wellbore of 11,475 m, which was completed in just two months in 2011. We believe that the HDR is a promising option for countries owning thick horizons of plastic rocks in seismically safe areas, the Russian Federation being an example of. The presence of specific waste e.g. spent nuclear fuel or disused sealed radioactive sources which require geological disposal and are suitable for the emplacement in HDR is another condition for including the drillhole technology in the national strategy for radioactive waste management.

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REGULATORY FRAMEWORK FOR RADIOACTIVE WASTE MANAGEMENT IN MYANMAR

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Establishing a national legal and regulatory framework within which radioactive waste management activities can be planned and safely carried out is important for any country related to production or use of radioactive material. In Myanmar, the legislative and statutory framework for radiation aspects is provided primarily through the Atomic Energy Law (1998) and assigned regulatory du- ties to the Division of Atomic Energy (DAE). Myanmar imports radioisotopes to use in many areas and until recently, the radioactive waste resulted mainly from the use of radioisotopes in medicine, industry and research. At the present time, all spent radioisotopes and disused sealed radioactive sources are sent back to the country of origin but return of the older sources to the supplier is not possible where the supplier is not known or is no longer in business. Although the Atomic Energy Law encompasses radiation safety, it needs to explicitly state radioactive waste. Therefore for more effective regulatory functions for nuclear and radiation safety, security and safeguards with international standards and guidelines and also to have specific criteria for regulating the activities related with radioactive waste management, the existing law needs to repeal with the new one. Now the new “Nuclear Law” (Draft) is submitted to the Parliament and waiting for the Governmental approval. Key priorities for radioactive waste management are included in it and makes clear that waste management are prohibited unless an appropriate authorization has been granted by the regulatory body. A system of regulatory inspection, documentation and reporting for radioactive waste management activities can also be established. Before getting approval of the Nuclear law (Draft) from the Government, Standard Operating Procedure (SOP) for radioactive waste management is being written by the Regulatory Body (DAE). Major considerations in it are protection of individuals, society people and the environment, minimization of waste, and safety of facilities. Now DAE is also preparing to issue Orders and Directives to improve national nuclear and radiation safety infrastructure, including those for managing radioactive waste. All these advancements in radioactive waste management regulatory framework are made to bring it in line with the IAEA safety requirements and recommendations. By doing these, the legal framework for radioactive waste management in Myanmar will be developed and become successful implementation.

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RADIOACTIVE WASTE MANAGEMENT APPROACHES IN PAKISTAN – LEGAL FRAMEWORK, POLICIES AND STRATEGIES

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In Pakistan, radioactive waste is mainly generated from operation of Nuclear Power Plants (NPPs) and research reactors, being operated by Pakistan Atomic Energy Commission (PAEC). Disused Sealed Radioactive Sources (DSRS) are also being collected from application of radioisotopes in medical, agriculture, research and industry. It is anticipated that in future, radioactive waste generation will increase manifold by addition of more NPPs, nuclear applications and decommissioning of nuclear facilities. An independent governmental regulatory body, Pakistan Nuclear Regulatory Authority (PNRA), was established under the PNRA ordinance 2001 by the President of Islamic Re- public of Pakistan. One of the functions of PNRA is to ensure safety of public and protection of environment from harmful effects of radiations. In this regard, PNRA issued “Regulations on Radioactive Waste Management – PAK/915” in July 2005, which was revised in April 2019. Moreover, for safe and sustainable management of radioactive waste, “National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel” has been issued in August 2018 by the Government. This policy sets the goals, requirements and responsibilities of different stake- holders. For sustainable management of radioactive waste, decommissioning and spent nuclear fuel, availability of funds is ensured by the national policy. For implementation of this policy, PAEC has devised three strategies: (i) National Strategy for Safe Management of Radioactive Waste including Disused Sealed Radioactive Sources, (ii) National Strategy for Safe Decommissioning of Nuclear Facilities and (iii) National Strategy for Safe Management of Spent Nuclear Fuel. These strategies guide the ways for achieving the policy goals and requirements within the national legal framework. The strategies are being implemented and practiced in the country. This paper describes key approaches for implementation of regulations, national policy and strategy for safe management of radioactive waste.

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DEVELOPMENT OF SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT STRATEGY FOR THE PROPOSED NUCLEAR ENERGY PROGRAM IN THE PHILIPPINES

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The Integrated Nuclear Infrastructure Review (INIR) Phase 1 mission that was conducted by IAEA in December 2018 concluded that the Philippines is committed to implement a systematic approach in developing its nuclear power strategy and the associated relevant nuclear infrastructure. One key result of the INIR mission is the creation of the Nuclear Energy Program-Inter Agency Committee (NEP-IAC) through Executive Order 116 series of 2020. The NEP-IAC was tasked to perform a com- prehensive study to evaluate the viability of introducing nuclear power in the Philippines and to formulate a national strategy to address nuclear infrastructure gaps and issues. Following the IAEA milestone approach, the NEP-IAC included the evaluation of gaps and issues specific for the Nuclear Fuel Cycle (NFC) and Radioactive Waste Management (RWM) infrastructures. To this end, the NEP-IAC performed assessment of existing radioactive waste facilities, radioactive waste inventory, as well as forecasting of waste generation for two scenarios: Operation of (1) Generation 2 Pressurized Water Reactor (PWR) and (2) Small Modular Reactor (SMR) with 12 modules. Relevant local laws as well as international standards, treaties, and conventions were also reviewed to ensure that the assessment is performed based on international best practices in the implementation of a Nuclear Power Program. To systematically determine the appropriate strategy for management of radioactive waste and spent fuel in the Philippine context, the strategies described in the IAEA NES No. NW-T-1.1.24 was re- viewed. A rating guide was developed with ten relevant criteria identified. This rating guide was used in performing a preliminary option analysis for different spent fuel and radioactive waste management strategies. Initial results indicate that the preferred option for the Philippines is to establish a national storage and disposal facility as its back-end strategy for spent fuel and radioactive waste. This was included as part of the recommendations in the proposed nuclear energy program in the Philippines.

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CREATION OF THE FINAL SYSTEM FOR THE ISOLATION OF RADIOACTIVE WASTE IN THE RUSSIAN FEDERATION

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FSUE "National operator for radioactive waste management" was established by the Government of the Russia Federation and determined as the only organization responsible for the final disposal of Radioactive Waste (RW), as well as for creating a unified system and implementation of state policy in the field of RW management. The mission of the company is to solve the issue of safe final isolation of RW and prevent its contact with biosphere throughout radiation activity. In 2018, preparation work began on creating an underground research laboratory (URL) near the city of Zheleznogorsk, Krasnoyarsk Region, for studying the possibility of final disposal of highly active long-lived waste. Should the study be successful, the URL will be transformed into first Russian Deep Geological Repository (DGR) of highly active Radwaste. This presentation will cover, not only the Russian DRG program including site selection process, but will also describe the Creation of the system of final isolation (disposal) of radioactive waste in the Russian Federation, it’s legal framework and the establishment of the National operator for radioactive waste management. National classification of Radioactive Waste will be described as well. The presentation will cover national program on the disposal of interim and low radioactive waste and its progress. The presentation will also provide information on the research and scientific experiments planed for the underground research laboratory. Possible options for the future development of the facility will be described. Information on the international cooperation of the National Operator as well as participation in international organizations and initiatives will be also provided. The final part of the presentation will describe the work with local authorities and community in order to raise public awareness.

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SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT IN THE HTGR FUEL CYCLE - POLISH PERSPECTIVE

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Gas-cooled high temperature reactors (HTGRs) are efficient power generating and supply high temperature process heat applicable in many industrial processes. They are the Gen IV reactors that are considered as safe and believed to be dominate in the future market. Spherical graphite coated fuel elements (60mm outer diameter; 50mm inner diameter) contain about 8300 triple-coated UO2 particles of 0.92mm in diameter. Recently, it was confirmed that no fuel damage would occur even in the case of a beyond design basis accident such as multiple losses of reactor shutdown functions. Using of the HTGR technology for supporting Polish industry has been recently considered in Poland. It is planned that HTGR will start operation by 2033.The activate of a new reactor must be preceded by complex analysis and answer a number of problems related to the safety of its operation. So, it will be necessary to find proper management methods of the radioactive waste and spent fuel and obtain all necessary permissions for the expected HTGR to operate. Institute of Nuclear Chemistry and Technology is involved in development the procedures that will be proper for the HTR waste management in Poland.Main results of the studies, both the literature analysis and the experiments carried out in the INCT, will be presented.

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SOLID RADIOACTIVE WASTE MANAGEMENT OF ATOMIC ENERGY CENTRE DHAKA, BANGLADESH AND ITS IMPLICATION TO WORKER & PUBLIC SAFETY

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Radioactive substances are being widely used in medicine, industry, agriculture, education & re- search and other fields in Bangladesh. The usage of radioactive substances is increasing day by day with the socio-economic development of the country. The Bangladesh Atomic Energy Regulatory Act 2012 (Chapter V, vide 38) & Nuclear Safety and Radiation Control Rules-1997 (vide 87) mentioned that radioactive materials to be managed from waste generation in such a way that minimize the effects of ionizing radiation on radiation worker, public and the environment. The aim of radioactive waste management is to protect the people and the environment now and future, without imposing an unnecessary burden on future generations. Atomic Energy Centre Dhaka (AECD) was established in 1963. At that time, AECD had the only solid radioactive wastes management facility in Bangladesh. Different types of low activity solid radioactive wastes were kept in the special concrete holes of a large room (L-shape) of the AECD. High activity solid radioactive wastes were buried at the shallow land in the special concrete structures of a large room (L-shape) of the AECD. The number of special concrete holes in the L-shape room is 20. The height of the special concrete wall is 85 cm and depth of the each hole is 64 cm. The special concrete walls act as shielding materials for solid radioactive wastes, which is required for minimizing the radiation hazard to the public and the environment. Continuous indoor radiation monitoring of AECD campus is being performed using the Thermoluminescent Dosimeter (TLD) in order to ensure the safety of the public and the environment from unnecessary radiation hazard (if any) releasing from the solid radioactive wastes of the AECD. Real-time radiation monitoring is also being performed using digital portable radiation mon- itoring devices at indoor & outdoor locations of AECD for detection of any unusual situation arising from the radioactive wastes. The maximum mean dose rate and the estimated maximum mean annual effective dose in the solid radioactive wastes room were found to be 11.024 ± 3.317 μSv/hr and 17.123 ± 5.453 mSv, respectively at 10 cm distance from the special concrete walls. The estimated mean annual effective dose to the public due to the solid radioactive wastes at AECD was 0.415 ± 0.021 mSv, which is lower than the annual dose limit (1 mSv) prescribed by the Nuclear Safety and Radiation Control Rules-1997 of Bangladesh as well as recommended by the ICRP.

National Programmatic Perspectives / ID 70

MOROCCAN EXPERIENCE ON RADIOACTIVE WASTE MANAGEMENT

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The Kingdom of Morocco became a Member State of the IAEA in 1957 and signed and ratified the most important international instruments, under the IAEA auspices, such as the Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management. In accordance with the provisions of Article 30, each Contracting Party shall submit a national report to each review meeting of Contracting Parties. This report shall address the measures taken to implement each of the obligations of the Convention. For each Contracting Party, the report shall also address its: (i) spent fuel management policy; (ii) spent fuel management practices; (iii) radioactive waste management policy; (iv) radioactive waste management practices; (v) criteria used to define and categorize radioactive waste. In addition to that, the national report shall contain namely an inventory of spent fuel and radioactive waste that is subject to this Convention. The paper aims to give an overview of the measures undertaken by the kingdom of Morocco to address the above joint convention requirements such as the adoption and implementation of national policy and strategy of radioactive waste and spent fuel management, as well as and the planned activities to improve safety of radioactive waste management.

National Programmatic Perspectives / ID 71

RADIOACTIVE WASTE MANAGEMENT AND REGULATION UNDER THE NEW NUCLEAR ENERGY FOR PEACE ACT, THAILAND

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The separation of the former government organization, Office of Atomic Energy for Peace (OAEP), in 2007 into Office of Atoms for Peace (OAP) and Thailand Institute of Nuclear Technology (TINT) resulted in the transfer of all radioactive waste management (RWM) tasks, responsibilities, and personnel to TINT. Since then OAP has lacked both knowledgeable personnel in radioactive waste supervision and comprehensive laws to regulate RWM and related activities. For over 10 years, OAP has put much effort, human resources, and budget in pushing forward the reform of the late nuclear act (Atomic Energy for Peace Act 1961), and finally, the new nuclear law (Nuclear Energy for Peace Act) was enacted in 2016, enabling a more solid RWM regulatory framework. OAP also focuses on enhancing new generation staff members to become experienced radiological safety inspectors and implementing the law in the operation of TINT and other licensees. Under the 2016 Act and its 2019 amendment, OAP has issued four ministerial regulations regarding the permission of import/export of radioactive waste, RWM, discharge of radioactive waste, and RWM license or license substitute. Besides, OAP has released four Office Announcements regarding RWM Reports, methods for data collection and monitoring of radioactive waste emissions, evaluation of radiation exposure from radioactive waste to be use to regulate the radiation safety of RWM processing, and radiation safety standards for radioactive waste. OAP examines TINT's RWM through WAC documents, RW Inventory, and orderliness of radioactive waste storage facilities, radiation measuring instrument and environmental impact assessment, occupational dose record, radiation protection, and the security of RW. TINT is the only RWM technical service provider in Thailand at present. Currently, there are 2,522 of disused sealed radioactive sources declared as RW with 5,140,705 mCi. TINT also stores the conditioned waste in waste drums occupying 75.22% of storage area. All sources and conditioned waste are stored in four storage facilities in three provinces, namely Chatuchak District in Bangkok, Khlong Ha District in Pathum Thani Province, and Ongkharak District in Nakhon Nayok Province. In addition, the study of decontamination of Cs-137 contaminated waste is currently needed to re- duce its large volume 700-ton of Cs-137 contaminated metal dust. The stored facility is under construction, thus OAP urgently needs to issue regulations related to the new RWM service and makespreparation for siting and construction assessment and inspection, issues related to safety and security of RWM facility as well as RW processing inspection.

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CONTROL OF RADIOACTIVE DISCHARGES FROM MULTI-UNIT NUCLEAR POWER PLANTS SITE THROUGH DOSE CONSTRAINT IN PAKISTAN

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Radioactive discharges from nuclear power plants (NPPs) in Pakistan are being regulated by Pakistan Nuclear Regulatory Authority (PNRA) under the national Regulations on Radioactive Waste Management (PAK/915). The requirements for radioactive discharges are set considering recommendations of International Commission on Radiological Protection (ICRP) and subsequent IAEA Safety Standards. ICRP publication 60 introduced the concept of dose constraint for the optimization of radiation protection measures for the pertinent source which has been reinforced in the 2007 recommendations i.e. ICRP Publication 103. Thus IAEA issued GSR Part 3 to take into account these recommendations. As a result, PNRA also set requirements for the establishment of dose constraint (DC) in PAK/915 by the licensee and determine discharge limit as a tool for the optimization of measures to protect the members of the public instead of specifying a numeric values for DC in the regulations. The NPPs in Pakistan are already applying dose standards for the evaluation of the effects of radiation and radioactive effluents on the environment during licensing for the construction and operation of an NPP which are USNRC regulations 10 CFR Part 50 Appendix I pertaining to radioactive effluents and 40 CFR 190 Subpart B pertaining to environment. These regulations take into account a maxi- mum of three reactors at single site. Whereas the number of reactors at single site is increasing in Pakistan and currently four (04) NPPs are operational at a site and another is planned in near future. Thus to ensure the compliance with regulatory requirements and analyze the impact of radioactive effluents to the environment from a multiunit site, the licensee was asked to establish a DC value and determine discharge limits accordingly with the approval of regulator and considering international practices. This paper will cover PNRA experience of revising/updating regulatory framework for radioactive discharges in the light of IAEA GSR Part 3 and establishment of acceptable and appropriate dose constraint for members of the public taking into account the operation of multi-unit nuclear reactors at a single site in Pakistan.

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STUDY ON THE RADIOACTIVE BURNABLE WASTE MANAGEMENT OF NUCLEAR MEDICINE FACILITIES IN INDONESIA: CASE OF SARDJITO HOSPITAL'S WASTE

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The utilization of radionuclides in medical fields will produce radioactive waste, one of which is burnable solid waste, such as paper, clothing, tissue, injections, glassware, metal fragments, etc. According to the regulations of the head of Indonesia Nuclear Energy Regulatory Agency (BAPE- TEN) number 8 2016, there are six steps of radioactive waste management in Indonesia which are collecting, grouping, treating, transporting, storing, and disposing. By the government regulations, radioactive waste treatment, including medical radioactive waste, must be conducted only by the National Nuclear Energy Agency of Indonesia (BATAN). This paper described our observation of the management of medical radioactive burnable waste from the nuclear medicine facility of Sardjito Hospital Yogyakarta. The waste amount in a month was compared to the incinerator capacity of the Radioactive Waste Technology Center of BATAN in Serpong, which is dedicated to handle such waste. The medical radioactive burnable waste, especially the medical personnel's clothing, is categorized as activated waste having very low activity and very short half-life (several hours). The burnable waste collected by the hospital is 2.7 kg per day that will be 13.5 kg in a week. Every month, the hospital has to send 54 kg the waste to BATAN to be burnt using their 50 kg/hour incinerator. The Radioactive Waste Technology Centre of BATAN has been establishing and operating since 1988. Due to the center's long experience and the fact that burnable waste is very low activity and half-life, the safety aspect of waste management from nuclear medicine facilities in Indonesia is reliable. The activated waste does not contain radioactive material, and hence there is no need for extraordinary security measures.

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ASSESSMENT OF THE CURRENT STATE OF DISUSED SEALED RADIOACTIVE SOURCES MANAGEMENT OPTIONS FROM DIFFERENT APPLICATIONS IN ETHIOPIA

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The purpose of this study is to assess the current state of Disused Sealed Radioactive Sources (DSRS) from different applications management options in Ethiopia. The study will provide picture of the benefits and challenges of the use of radiological and nuclear technology, challenges on radioactive waste management and challenges on the environment and suggest solutions to alleviate the challenge on RWM in Ethiopia. Radioactive waste management, safety and Environmental issues from the applications of nuclear and radiological technologies test even the developed countries. Ethiopia lacks the requisite technology, skilled personnel, financial stamina and the necessary infrastructures to manage and dispose radioactive waste generated from nuclear technologies from different applications sustainably. The current state of application of Nuclear and Radiological Technology and the challenges due in the country will be assessed. Perspectives and challenges of the use of nuclear technology will be realized and rule on in a balanced manner only in a comparative perspective to addresses the challenges of the use of nuclear technology. Published studies and results on challenges and benefits of using radiological and nuclear technology will be surveyed to put radiological and nuclear technology in a broad perspective. To identify and characterize the radioactive waste stored in the Central Radioactive Waste Processing and Storage Facility idenTIFINDER and survey meters will be used. To be comprehensive and to assure completeness or to reflect all sources of information on the challenges and benefits of radiological and nuclear technology; literature's will be selected according to criteria related to consistency of the research objectives and will be prioritized the most recent studies. The study will cover key aspects of radiological and nuclear technologies that Ethiopia is using, related to economic and radioactive waste management dimensions that are considered relevant for policy making. The study focuses on qualitative and quantitative information available.

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ANALYSIS OF INDONESIAN REGULATORY INFRASTRUCTURE FOR RADIOACTIVE WASTE MANAGEMENT AND ITS IMPLEMENTATION

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Radioactive materials and ionization radiation generators have been used broadly in Indonesia for various purposes. These activities may generate radioactive wastes that should be managed carefully. Moreover, there are also many other industrial activities, such as mining and oil and gas industries, that may produce residues that contain radioactive materials. Considering all those activities and the waste that could be generated, the Indonesian Nuclear Energy Regulatory Agency (BAPETEN) has established a national regulatory infrastructure to manage the radioactive waste in Indonesia. The highest-level regulation is Act No. 10 in 1997 on Nuclear Energy recognized the risk of radioactive wastes and the obligation to manage them properly to protect workers, the public, and the environment. The act assigned the National Nuclear Energy Agency to conduct national radioactive waste management. Moreover, in 2002, the government enacted the government regulation on radioactive waste management, which contains more detailed requirements on radioactive waste management. However, in 2013, this government regulation was revised to be aligned with the latest standard and updated with the newest situation of practices in Indonesia. Some other regulations on radioactive waste treatment for low level and intermediate-level waste and clearance level were also established in the level of BAPETEN Chairman Regulations. This paper analyses how the regulations regarding radioactive waste management in Indonesia compare to the IAEA standards and some issues on its implementation. Based on this analysis is concluded that some of the implementation issues occurred because of a lack of infrastructure and human resources. The misunderstanding due to the ambiguity of the provisions in the regulations is also found to be one of the reasons for the implementation issues.

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RADIOLOGICAL CLEANING OF RUBBLE CONTAMINATED WITH RA-226; IMPORTANT MILESTONE IN THE DOMINICAN REPUBLIC

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The Dominican Republic, as in most of the countries of the world, since the middle of the 20th century, various nuclear techniques have been used in industry, medicine, research and other branches of socio-economic endeavors. These activities based on the use of radioactive materials generate waste in gaseous, liquid or solid form, the management of which requires treatment depending on its characteristics. This presentation will present the lessons learned from an event that occurred in an oncology hospital in the country in 1989, which occurred accidentally when trying to cut with a scissors a tandem arrangement formed by 4 sources of Ra-226, the salt of Radius from one of the sources, consequently contaminating the entire work area. Those contaminated materials and supplies were buried in the hospital parking lot.30 years later, an important milestone is achieved for the country: The rubble was removed be- cause the emanation of Rn-222, which is the son of Radio, was detected; They were transferred to the national center for the management of radioactive waste and disused sources for storage. The implementation of protocols and procedures for physical security and radiological protection was achieved. In addition, a chapter on radiation protection and physical security was integrated into the COE Emergency Operation Center, among others.

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U.S. NUCLEAR REGULATORY COMMISSION APPROACH TO VERY LOW-LEVEL RADIOACTIVE WASTE

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The U.S. regulatory framework for low-level radioactive waste (LLRW) does not differentiate low-activity (LAW) or very low-level waste (VLLW) as its own category of waste. The U.S. Nuclear Regulatory Commission (NRC), in Title 10 of the Code of Federal Regulations Part 61 (10 CFR Part 61), "Licensing Requirements for Land Disposal of Radioactive Waste," provides licensing procedures, performance objectives, and technical requirements for the issuance of licenses for the land disposal of LLRW. This waste is divided into four categories based on its potential risk and need for isolation. Class A is the lowest category of LLRW and poses the least risk. A large percentage of the Class A LLRW contains very low radionuclide concentrations and does not pose a significant health and safety risk. The NRC conducted a VLLW scoping study to identify possible options to improve and strengthen the NRC's regulatory framework for the disposal of the anticipated large volumes of VLLW associated with the decommissioning of nuclear power plants (NPPs) and material sites, as well as waste that might be generated by a radiological event. This VLLW scoping study considered disposal of waste, as defined by 10 CFR Part 61, as the isolation, by emplacement in a land disposal facility, of radioactive wastes from the biosphere. As such, the scoping study did not address non-burial disposal, for example, disposition pathways including unrestricted release, clearance, reuse, or recycle of materials. As part of the VLLW scoping study, the NRC also evaluated regulatory options that would define the conditions under which VLLW could be disposed of in Resource Conservation and Recovery Act (RCRA) hazardous waste facilities regulated by the U.S. Environmental Protection Agency (EPA) and States. The VLLW scoping study considered divergent stakeholder comments; lessons learned from previous initiatives; and best practices of other countries with respect to VLLW disposal. The NRC also engaged other government agencies to discuss regulatory options for VLLW. This paper identifies the options considered by the NRC to improve regulatory waste management strategy, initiatives to manage the lower end of Class A waste, experience from the International community, public stakeholder involvement, and a literature review. It examines previous endeavors and discusses the regulatory challenges that arose from these reviews. The staff concluded that it would continue to operate under the existing framework. The staff found that licensees have adequate flexibility with the current disposal options from a safety perspective.

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MULTICRITERIAL SITE ASSESMENT OF POTENTIAL DEEP GEOLOGICAL REPOSITORY SITES IN CZECH REPUBLIC: INTEGRATION OF SAFETY, TECHNICAL FEASIBILITY AND ENVIRONMENTAL APPROACH

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Radioactive waste disposal in the Czech Republic is managed by the government organisation SURAO. Significant progress was achieved in 2020 with respect to the development of the deep geological repository, which in the Czech Republic will be constructed in a suitable crystalline rock mass around 500 metres below the earth's surface; the commencement of operation of the DGR is planned for 2065. The current DGR development phase is devoted principally to the determination of the optimum disposal concept and the selection of the most suitable site. In the period 2014-2019 a total of 9 candidate sites were investigated in detail from the technical, safety and environmental points of view and, in 2020, the sites were assessed with the aim of reducing their number to four. For the purposes of reducing the number of potential sites and the determination of the relatively most suitable sites (reduction in the number to four recommended sites), both criteria that exclude the location of the DGR at a specific site (exclusion legislation criteria) and criteria that can be used to distinguish relatively more suitable sites (comparative, so-called key criteria) were identified. The key criteria were further divided into so-called indicators (partial characteristics for each criterion). In total, the assessment team considered the nine potential sites in terms of 26 exclusion criteria and 13 key (comparison) criteria further divided into 38 indicators. Via a range of calculations, the assessment process revealed a group of four relatively more suitable sites. The assessment was conducted by SURAO experts and was supervised by the so-called Expert Advisory Group which was an independent body comprising senior technical experts nominated by the various stakeholders, including the affected local communities. In addition, representatives from the regulatory authority, the public and other experts attended the meetings of the Group as observers. Following the technical assessment and final approval by the expert group, the result was reviewed by the Ministry of Industry and Trade and finally submitted to the government, which approved the SURAO proposal in December 2020. The government also instructed SURAO to update the National Policy so as to reflect changes in the time schedule concerning the development of the DGR in the Czech Republic. In addition, special legislation aimed at enhancing public involvement in the deep geological repository programme is currently being discussed and prepared for implementation by the government.

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RADIOACTIVE WASTE MANAGEMENT EDUCATION IN THAILAND

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A study on radioactive waste management (RWM) in Thailand was initiated at the same time that the country started its first nuclear power generation program in 1966. The study was formally incorporated into an undergraduate engineering course in 1982 and a graduate course in 1992. The course topics included radioactivity, radiation effects on living things, dose limit, nature of radioactive wastes, origin of radioactive wastes generation, various characteristics, forms and quantity of radioactive wastes, storage and transportation of radioactive materials, radioactive waste treatment technologies, regulation of RWM in the nation and in various countries, and storage and disposal technology of radioactive wastes. Over the past ten years, several short courses have also been de- livered to enhance the knowledge on RWM for personnel of the industrial sectors, especially the Electricity Generating Authority of Thailand to prepare them in the case that Thailand decides to go nuclear in the future. The teaching and research experiences in RWM will be shared and presented in the conference.

National Programmatic Perspectives / ID 130

MANAGEMENT OF THE CONCRETE AND CAST IRON WASTE RESULTED FROM THE DECOMMISSIONING OF THE VVR-S NUCLEAR RESEARCH REACTOR BLOCK FROM IFIN-HH

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The paper describes the radiological characterization methodology and the management of the concrete and cast iron waste from the VVR-S nuclear research reactor owned by Horia Hubulei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH) resulted during the decommissioning process. A large part of the concrete, about 406 t was measured and treated for free released. The radioactive concrete, about 115 t, was conditioned by mixing with cement paste in 220 L packages, characterized by gamma-ray spectrometry and then transported for disposal to the National Radioactive Waste Repository (DNDR) from Baita-Bihor. 60Co, 152Eu, 154Eu, 155Eu radionuclides were the main radionuclides identified in the packages. 137Cs was also identified due to some contamination occurred during the reactor operation period. The total amount of 64 t of cast iron was managed as follows: 25 t were disposed, 16 t were free released and about 23 t are stored for conditioned and disposal. 60Co and 137Cs were identified in the samples measured. The decommissioning process of the reactor block was planned and realized taking into consideration all measurements and requirements related to characterization and free release of materials.

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THE SEARCH FOR A GEOLOGICAL REPOSITORY SITE IN GERMANY – ITS UNIQUE FEATURES AND THE SAFETY CASE

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Based on a broad political consensus following the 2011 reactor accident in Fukushima, and consequent a policy decision of 2002, Germany opted to abandon nuclear power generation by the end of 2022. The decision gave a strong impulse to the pursuit of geological disposal as the best approach to safe long-term management of high-level waste in Germany. To guide the repository siting process, the Act on the Search for and Selection of a Site for a Disposal Facility for High-Level Radioactive Waste (or the Site Selection Act for short) was adopted in July 2013. As its overriding goal, the 2017 amendment of the act sets out to find a repository site offering the best-possible safety based on a participatory, science-based, transparent, self-questioning and learning process. The Site Selection Act, alongside its subordinate ordinances published in 2020, constitutes the foundation for the repository siting process in Germany. This legislation defines the logic, structure and detailed requirements on the site selection process, thus exerting strong influence on the time schedule. Resulting from the legal framework are some unique features of the German repository siting process. Among these, the necessity to transparently inter-compare sites located within distinct host- rock types (rock salt, claystone and crystalline rock) constitutes an unprecedented and extraordinary challenge. According to international consensus repository safety should be demonstrated by means of the so called safety case. The safety case can be seen as a formal compilation of evidence, analyses and arguments demonstrating repository safety. IAEA and NEA-OECD guidelines discuss in detail the components, structure and presentation of the safety case. Although not legally binding on Ger- many, these recommendations are accepted as best-practice world-wide. In this contribution we discuss the site selection process in Germany in view of international recommendations regarding the structure and development of a safety case for a geological repository. In particular, we draw parallels between the requirements on preliminary safety analyses during site selection stipulated by the German legislation and those coming from international recommendations for the safety case. Special attention is given to the unique features characterising the German search for a site offering the best-possible safety.

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THE JOINT EFFORT JOURNEY TO FINDING A DEEP GEOLOGICAL REPOSITORY FOR GERMAN HIGH-LEVEL WASTE (INTERNATIONAL EXPERIENCES AND REGULATORY FRAMEWORK CONCERNING THE SCIENCE-BASED SITE SELECTION PROCESS IN GERMANY)

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In 1962, the first German commercial nuclear reactor was connected to the grid, raising hopes and fostering aspirations to transform the mostly coal-dominated electricity supply into one based on nuclear power generation. However, the field of nuclear has since its inception been a highly controversial issue. As a result of debates and societal pressure, 40 years later (in 2002), the German federal legislator passed the policy decision to phase out nuclear power in Germany. This decision was affirmed in 2011 after the accident in Fukushima Daiichi by establishing reactor-focused shut- down dates. The last commercial nuclear reactor will hence shut down by December 31, 2022. When the last reactor goes off the grid, Germany's nuclear power plants will have produced approximately 27,000 cubic meters of HLW, that have to be disposed of safely. A deep geological repository for final disposal is the internationally recognized solution to this challenge. While significant technical and scientific knowledge on geological disposal has in the meantime been gained, up to date no repository site for HLW has been found in Germany. Previous attempts to find a safe repository site in Germany have proven unsuccessful and were discussed controversially in society. Learning from the mistakes of the past and international experiences, in 2013 a broad legislative consensus decided in favor of the current site selection process – a conceptual restart following strict rules laid down by the so-called Site Selection Act, being enhanced by the results of a commission of experts in 2017. The present Site Selection Act consists of detailed provisions concerning the three-phase site selection process. Through these, the frame for an innovative comparative process based on geological criteria is set by the law. It is accompanied by novel means and formats of participation and guided by leading principles to be "participatory, science-based, transparent, self-questioning and learning". As a result of the process, the site with the best possible safety will be found and laid down in law. The legislative site determination will be followed by a regular licencing process for the repository. This paper intends to outline the characteristics of the German process in comparison to other waste management programmes and site selection processes. Special emphasis will be given to a comparison to Canada, Switzerland and Finland.

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RESEARCH IN TERMS OF THE GERMAN SITE SELECTION PROCEDURE - THE REGULATOR'S COMMITMENT TO INTERDISCIPLINARITY

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With the Site Selection Act, Germany has committed itself to the goal of identifying the site with the best possible safety for a final waste repository in a participatory, knowledge-based, transparent,self-reflective manner, and in the sense of a learning process. This means breaking new ground in many areas, be it with regard to novel participation elements, the self-learning procedure, its scientific monitoring and performing a complex comparison and ranking process of potential sites. The German authority BASE (Federal Office for the Safety of Nuclear Waste Management/Bundesamt für die Sicherheit der nuklearen Entsorgung) is taking up this challenge with its own interdisciplinary research department. The aim is to build up methodological and technical expertise which fits the special needs of a regulator for assuring the safety of Germany's nuclear legacy. The task involves, e.g., to identify and work on safety issues together with other stakeholders, to scientifically reflect the site selection process and iteratively feedback learnings into the process, to contribute to (inter)national scientific and public debates as well as to participation processes. The concentration of research activities for this scope involves natural, engineering as well as social sciences and holds both opportunities and challenges for a regulatory body.

National Programmatic Perspectives / ID 185

DUTCH LEGACY WASTE PROJECT. AN OVERVIEW FROM THE REGULATOR

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The status and function of the High Flux Reactor (HFR, located in Petten, north of the Netherlands) evolved, since it started operating in 1961, from a versatile material and fuel test reactor for research and industrial purposes to a major isotopes production facility. The radioactive waste resulting from 40 years of research and experiments, was stored in waste containers in a temporary storage facility on-site. At the initiative of the Dutch government in 1982, the national waste management organisation (COVRA) was established and temporarily based in Petten. In the 90's, COVRA was appointed by the government as the only collection and storage facility for radioactive waste, meaning that waste producers have to transfer all their radioactive waste (present, past and future) to COVRA as soon as reasonably achievable. All low level waste stored in Petten was transferred in the 90's. The intermediate level waste, mixed waste and more complex waste streams (e.g. containing alpha emitters) remained in Petten awaiting a high and intermediate level waste storage building at COVRA's new location. Since the start of the project in 2003, the approach of the owner of the waste and license holder (The Nuclear Research and Consultancy Group (NRG) has been varying along the years but is still based around the same important principles: recovery of the waste package, characterization of their content and repacking of their content into appropriate waste streams and waste categorization. The various aspects of this complex project (technical, logistical, financial and organizational, …) are a challenge for all the parties involved in seeking the proper balance. The Dutch nuclear regulatory body has been following, stimulating and supervising the transfer of the legacy waste to COVRA throughout the years, from the start in 2003 to the now projected end in 2026. The intertwining of conflicting aspects of the project (cost vs. time vs. resources for instance) has revealed the key role of the regulatory body to monitor and to guarantee the long term control and ensure the safety of the legacy wastes.

National Programmatic Perspectives / ID 195

RADIOACTIVE WASTE MANAGEMENT FACILITY REGULATION IN THAILAND: HISTORY AND CHALLENGES

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Thailand has been using radioactive materials since the first brachy therapy of radium-226 in 1938. However, the history of radioactive waste management in Thailand is not so apparent. The first recorded regulation on radioactive waste management is the Ministerial Regulation (No. 2) issued under the Atomic Energy for Peace Act 1961. From 1961 to 2006, the Office of Atomic Energy for Peace was the only waste management provider in Thailand. In April 2006, the Office of Atomic Energy for Peace was separated into the Office of Atoms for Peace (OAP), the regulator, and the Thailand Institute of Nuclear Technology (TINT), the operator. The TINT has assumed the waste management responsibility of Thailand since April 2006. The latest regulation on radioactive waste management is the Ministerial Regulation on Radioactive Waste Management 2018, issued under the Nuclear Energy for Peace Act 2016. This paper will discuss about the history and challenges of radioactive waste management facility regulation in Thailand.

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CHALLENGES OF IMPLEMENTING THAILAND'S POLICY AND STRATEGY FOR MANAGEMENT OF RADIOACTIVE WASTE

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Thailand has been continuously developing policies and strategies for the management of radioactive waste. In the last five years, Thai government by Ministry of Higher Education, Science, Research and Innovation, has developed the national policy and strategy documents regarding radioactive waste management. This growth improves the assurance of the protection of the environmental and the public from all potential risks due to handling radioactive waste. This paper intends to presents a compendium of this development of the current radioactive waste management policy, and the capability of implementing such development are also considered, along with the infrastructure arrangements. Thailand nowadays also faces with a crucial problem of the existence of a large volume of the radioactive waste from industrial facilities. Therefore, the optimal solution method with necessary infrastructure for managing this kind of waste is extremely desired.

National Programmatic Perspectives / ID 205

STUDY ON THE FAST REACTOR SYSTEM CHARACTERISTICS IN THE TRANSITION PERIOD FROM LWR TO FR

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In fast reactor (FR), the amount of nuclear fuel is increased by conversion. The conversion is caused by the absorption of neutrons, and therefore Pu isotopes are used as fuel because they generate more neutrons by fission reaction than other fissile such as uranium-235. The spent fuel from the FR mainly contains a relatively large amount of TRU because FR uses Pu as fuel.Since TRU has a long-term heat generation, it is assumed that all TRU in the spent fuel of FR are reused. This is called the closed nuclearfuel cycle. In the closed nuclear fuel cycle, all the actinoids are extracted in reprocessing spent fuel, and only FP is disposed as radioactive waste.When shifting from using light water reactor (LWR) to FR, it is supposed that TRU extracted from spent fuel from LWR will be loaded into initial stage of FR operation. This is called the transition period. The TRU composition of the fuel loaded in the transition period can be significantly different from that in the equilibrium period, and this difference can affect both core and waste characteristics of FR. In this study, we will quantify the difference in core and waste characteristics between these two periods.In the transition period of FR, it is also envisioned that MOX fuel will be loaded in LWR. Thus, in this study, we will quantify the differences in the core and waste characteristics of FR when using TRU originating from UO2 fuel and MOX fuel in LWR during the transition period. In addition, when considering the difference between UO2 and MOX during the transition period, it should be also noted that TRU composition in the fuel loaded in FR can be greatly dependent on the operating conditions of LWR and reprocessing conditions of LWR fuel. Therefore, in this study, for each of UO2 and MOX, we will quantify how much TRU composition can be varied due to the difference in various conditions of LWR, and how much the core and waste characteristics of FR are affected by it.

National Programmatic Perspectives / ID 222

MAGNOX TRS DRUMS: A FIRST OF A KIND NON-ROUTINE DISPOSAL AT THE UK'S LOW LEVEL WASTE REPOSITORY

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The Winfrith site in Dorset, UK has a Treated Radwaste Store (TRS) constructed in the 1980s to store ILW. The TRS contains 1068 500L stainless steel drums ("TRS drums") of encapsulated sludge. The principal hazard associated with the drums is radiological; with Cs-137, Co-60 and Ni-63 the radionuclides of concern. Following decay storage, the drums were re-categorised from ILW to LLW and need to be transferred off site for disposal at the Low Level Waste Repository (LLWR) in West Cumbria, UK to enable Winfrith to meet its decommissioning schedule. Importantly, under normal operations LLWR only accepts waste that has been containerised in half-height ISO containers (HHISOs) by the consignor. However, due to the drum dimensions, the encapsulated waste form and ALARP issues associated with decanting the encapsulated sludge into LLWR-compliant waste containers; the best available technique for the management of the TRS drums is 'direct emplacement' at LLWR without being containerised in HHISOs. Since 500L drums are not a commonly received item-type and 'direct emplacement' is not a routine disposal technique at LLWR, planning and preparation was required to enable receipt, storage and disposal of the TRS drums at LLWR. Cyclife Groupe EDF is part of a collaborative team undertaking the planning and preparation of the transfer of the drums from Winfrith to LLWR for disposal in a safe and cost-efficient manner that satisfies all stakeholders, aligns with the strategic direction of both sites and has no detriment to LLWR. Cyclife Groupe EDF is working with LLWR and industry partners in the nuclear supply chain to achieve a solution that considers radiological safety hazards, conventional safety hazards, environmental impact and stakeholder impacts. Without this solution, the drums would need to remain at Winfrith for long-term storage and delay the decommissioning site in achieving its end state.

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RADIOACTIVE WASTE MANAGEMENT IN NIGERIA – PROGRAMMATIC PERSPECTIVES

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Nigeria has been committed to peaceful uses of nuclear science and technology since the 1960s in order to adapt to technological changes using nuclear and other radioactive material for various applications for healthcare, agriculture, disease prevention, food preservation and food security), industry, construction and manufacturing (gauging systems; product quality improvement, etc), petroleum and mining (oil prospecting and exploitation), water resources management, education, research and security inspection (portal monitors, scanners). The country also recognizes that the commitment to safety, security and complete operational transparency is essential to gain domestic support and assure the international community, potential bilateral partners and international nuclear supervisory bodies of the peaceful intentions of any nu- clear program undertaken by the country. One way to demonstrate the country's commitment to complete operational transparency is to be demonstrated through safe management of radioactive wastes (RW) and spent nuclear fuel (SNF). In line with the above, the country had taken some definite and decisive steps to put in place policies, strategies and measures, which are critical requirements for nuclear science and technology application. The initial effort to develop a policy for management of radioactive waste in Nigeria began with a Technical Advisory Committee, which was constituted by the Nigerian Nuclear Regulatory Authority (NNRA) on 16th July, 2004 for the Development of Radioactive Waste Management Policy and Regulations for Nigeria. The Committee, observed that, whereas the volume and the attendant potential hazards of the radioactive waste are high, their management and disposal processes were not subject to any specific legislative control and recommended that actions be initiated for the adoption and implementation of the draft policy and regulations by government. The Committee therefore produced a draft Nigeria Radioactive Waste Management Regulations. However, a draft Nigeria Radioactive Waste Management Policy and Strategy Framework was produced based on the outcome of the National Stakeholders Workshop on Radioactive Waste Management Policy and Strategy held at Abuja on November 16 – 20, 2009 and IAEA Expert Mission to Nigeria for the National Technical Cooperation Project NIR3004. This Draft document has been reviewed, updated and restructured by experts and stakeholders at various missions and workshops. Legal and institutional framework have also been developed and established to provide effective regulations of the operations of the nuclear industry in Nigeria.

National Programmatic Perspectives / ID 240

IMPROVEMENT OF REGULATORY FRAMEWORK IN THE FIELD OF RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL MANAGEMENT IN THE REPUBLIC OF SERBIA

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The use of nuclear energy and radioactive sources, including the materials resulting from such use, must predominantly have as few negative consequences for human health and the environment, as reasonably achievable. Such requirement cannot be met without the appropriate legal and institutional framework in charge of the achievement of the concept of sustainable spent fuel and radioactive waste management. The Republic of Serbia is facing the task of long-term solution to the issue of radioactive waste generated in its territory for the past 70 years, and the waste generated in the future, particularly through decommissioning of existing facilities, as well as the task of defining its strategic commitment to the establishment of mechanisms for disposal of such material in a manner that it does not affect the environment and poses no unnecessary burden for future generations. The Government and the Parliament of the Republic of Serbia recognized the need for safe spent fuel and radioactive waste management as an issue of special importance that requires an adequate solution, together with other issues connected with radiation and nuclear safety and security. Safe and secure management of radioactive waste in line with the principles of sustain- able development and environmental protection is the ultimate objective contributing to successful functioning of the society, and well-being of the citizens. The Law on Radiation and Nuclear Safety and Security, adopted in 2018, further improves regulatory framework in the field of radiation and nuclear safety and security with the ultimate goal of full harmonization with the EU regulations. The Law provides for legal basis for passing a number of bylaws enabling full alignment with the EU acquis in the field of radiation and nuclear safety and security, as well as with the standards and recommended practice incorporated in the documents of the International Atomic Energy Agency. In order to achieve full harmonization, it is necessary to finalize the activities on the preparation of bylaws in line with the Law, serving to define the actions, procedures, criteria and other respective issues. Implementation of the Law together with development of specific policies, strategies and by- laws presented in this paper, supplemented by the policies in the field of environmental protection, produce a sustainable solution to the management of spent nuclear fuel and radioactive waste with the lowest impact on the environment achievable, in line with the international recommendations and standards.

National Programmatic Perspectives / ID 241

ESTABLISHING A RADIOACTIVE WASTE REPOSITORY IN ESTONIA

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In 2016, Estonian government made a decision to establish a final repository for radioactive waste have to be established. The need for a repository originates from the former nuclear site in Paldiski, where nuclear submarine training center with two reactor compartments were operated. Nuclear fuel was removed from the reactors in 1994, whereas the reactor compartments were partially filled with concrete and surrounded with reinforced concrete sarcophagi. It was the responsibility of Estonia to safely handle all other facilities located on the site – radioactive liquid waste treatment complex, storage facilities, contaminated sewage and ventilation lines and warehouses. Intermediate storage facility for institutional and decommissioning waste was established in 1997 and is in use today. The estimated amount of waste to be disposed of is approximately 3000 m3 LLW and ILW, including waste from decommissioning. The European Union funded project 'Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository' was implemented in 2014–2015. In the course of the studies, recommendations together with an economic analysis were given for the decommissioning of the reactor compartments and the establishment of a radioactive waste repository. The repository must be established by 2040, after which the decommissioning of the reactor compartments will begin. Generated waste will be conditioned and placed in the repository by 2050. According to the initial plan, site selection for the repository will be finished by 2025. This step will be followed by an application of a construction permit to be obtained in 2027. During the period of 2027-2040, construction of the final repository will take place, ending with an acquisition of a facility operation permit. In the beginning of 2021, two procurements were carried out in order to characterize the existing site, find the most suitable location for the repository and conduct a strategic environmental im- pact assessment. Several conclusions and lessons to be learned can be derived from the rather short planning stage of the first actions. However, Estonia sees that, by learning from the international practice, thorough planning and systematic approach, the establishment of the repository is achievable.

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IMPLEMENTATION OF NATIONAL STRATEGIES FOR RADIOACTIVE WASTE MANAGEMENT IN AN INCREASINGLY INTERNATIONAL CONTEXT – OPPORTUNITIES AND CHALLENGES FROM A REGULATORY PERSPECTIVE

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The IAEA Safety Standards constitute the main global reference for nuclear safety requirements as well as for requirements for spent fuel and radioactive waste management. IAEA Members States are expected to implement the elements in the IAEA Safety Standards in their national framework, but the safety standards are not legally binding for IAEA Member States. But on the other hand, these standards constitute the basis for international treaties and regional legislation of a more binding character. This paper discusses implementation of national strategies for radioactive waste management with regards to the interface between international treaties and standards, as well as between regional legislation and standards, and national legal and regulatory frameworks on the European level. The starting point for the discussion is the national responsibility for radioactive waste management as defined in the Nuclear Safety Convention and the Joint Convention as well as in two corresponding European Council directives, the Nuclear safety directive and the Spent fuel and radioactive waste directive. These international and regional instruments unanimously emphasises that the prime responsibility for safety rests with the implementing organisation, whereas the ultimate responsibility rests with the state. But these instruments at the same time define obligations for Contracting Parties to the conventions, as well as requirements on the European level, to be transposed into national legal and regulatory frameworks in European member states. A driver for the development on the European level is to strive for improved conditions for regional cooperation between European member states, with the overarching objective to aim for increased optimization of the use of existing and planned national infrastructure for radioactive waste management. This paper presents an approach for better understanding how specific characteristics of national legal and regulatory frameworks influence the implementation of binding international obligations and regional legislation in European member states. In doing so, this paper also explains some opportunities and challenges related to increased intra-European harmonisation of national legal and regulatory frameworks, as well as to harmonisation of radioactive waste management in European member states.

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ESTABLISHING A NATIONAL WASTE MANAGEMENT STRATEGY: CHALLENGES AND EXPERIENCE OF A NEW REGULATORY BODY

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Despite using radioactive materials and nuclear technology in the medical, industrial, research, agriculture and educational sectors for decades, Jamaica has only recently developed and implemented a comprehensive national legal and regulatory framework for the safe and secure use, as well as, the effective waste management and disposal of radioactive materials. Additionally, this framework established an independent regulatory body, the Hazardous Substances Regulatory Authority (HSRA) in 2017, who is tasked primarily with administering the new legislation, licensing and inspecting activities, practices, and facilities for compliance and regulating the importation and exportation of radioactive materials. During the initial phase of instituting the new regulatory programme and enhancing its human, equipment and technical resources and capabilities, the HSRA faced a plethora of radioactive waste management issues. Among these issues were the inheritance of legacy sources, the discovery of orphaned sources in shipments marked for the international scrap metal trade and the detection of radiologically contaminated commodities at the port of entry. While the HSRA was able to effectively assess and respond to these vulnerable source situations, the resultant temporary storage solutions created additional challenges. As these sites were outside of regulatory control and man- aged by entities lacking the technical acumen needed to provide adequate safety and security, and there were major concerns over public acceptance. The lessons learnt from these situations, galvanized the HSRA to implement holistic waste management strategies geared towards resolving the current situations and preventing future occurrences. The multifaceted strategies employed encompassed an assessment of the current and future radioactive waste management needs; increasing Jamaica's capacity to respond to abnormal events; exchange of information with various local and international partners to identify current and previous users of radioactive materials; robust education program; and requesting international assistance to identify potential sites and develop a conceptual design for establishing a centralized radioactive waste management facility. These strategies were effective, as the owners of the orphaned sources were identified and subject to the licensing regime and the recommendations for long term storage solution for Jamaica's present and future needs was developed.

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NATIONAL PERSPECTIVES OF RADIOACTIVE WASTE MANAGEMENT

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Since 2007, the number of imported radioactive sources (Category 1 to Category 5) continues to in- crease in Madagascar. Whereas, after a few periods, they are not usable and become waste. Most of them are not stored in safe and secure places and that is why establishments holding these dis- used sealed radioactive sources are obliged to return them to suppliers or manufacturers. Faced with this situation, the Malagasy State in cooperation with the International Atomic Energy Agency (IAEA), through the RAF9062 Project entitled: “Strengthening Radioactive Waste management” are in the process of the establishment of a national storage center of radioactive waste. To prevent loss, sabotage and theft, the national perspectives are to collect all radioactive waste generated by establishments using radioactive sources in a safe and secure location, to centralize all disused sealed radioactive, to reinforce and strengthen this national infrastructure and to implement an adequate legal framework tackling with the safety and security of radioactive waste management.

National Programmatic Perspectives / ID 282

THE DEMAIN PROJECT: AN ACADEMIC RESEARCH CENTER ON NUCLEAR DISMANTLING AND DECOMMISSIONING

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In 2019, the IdEx of Bordeaux started a Project Call to set up ambitious and innovative research programs. The CENBG laboratory is involved in several research field around the nuclear energy. It then started to develop a research project on decommissioning and dismantling of nuclear installations called DEMAIN (DEMantèlement & Assainissement des Installations Nucléaires). The goal of this project is to build up a scientific community on this topic in Bordeaux, and to establish there a research pole on decontamination, remediation, wastes management and dismantling. This pole will be unique due to the academic nature of its research, in partnership with industrial and commercial players in the sector. Numerous laboratories have shown interest in this project, covering large fields of scientific research from hard sciences to humanities and social sciences. In 2020, the project was supported by the IdEx of Bordeaux in order to start preliminary researches and to structure the community. In the poster, we will show that the project is divided into major scientific questions: How to im- prove on-site operations? What is the impact on health and environment? What is the impact on populations and territories? … We will also present the skills that have been gathered around this topic. These skills come from many laboratories of the Bordeaux region from various research fields, in order to tackle the dismantling issue from different perspectives.

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MOROCCAN EXPERIENCE ON MANAGING RADIOACTIVE WASTE

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As a Member State of the IAEA and a Party to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management, the Kingdom of Morocco Country is committed to managing radioactive waste in a safe, secure and sustainable manner in accordance with internationally recognized At the beginning the management of radioactive waste was regulated through a series of articles (laws and decrees) of the existing regulatory framework, but since 2014 after the enactment of Law 142-12, this Law enabled the creation of AMSSNuR as an independent regulatory body under the direction of the government. The operation of the centralized system for radioactive waste management in Morocco relies upon the Centre National de l'Energie, des Sciences et des Techniques Nucleaire (CNESTEN) established under the Ministry of Energy, Mines, Water, and Environment (MEMEE)'s authority. CNESTEN is the waste management organization responsible for the collection, transport, processing, and storage of all radioactive waste, spent nuclear fuel, and DSRS generated Waste operators include license holders of facilities generating radioactive waste mostly from nu- clear applications (research, medicine, industry) and practitioners licensed to utilize radiation sources and also responsible for the management of their sources once they become disused. The National Strategy for the management of radioactive materials and waste is elaborated under the responsibility of the main operator CNESTEN in consultation with all the organizations involved in RWM activities, generators of RW, owners/users of radioactive source. The RWM infrastructure in place takes care of all LILW generated in Morocco and covers all the management steps from generation to storage through transportation and processing. Radioactive wastes collected by CNESTEN at the generators' sites are transported to La Maâmora CENM to be processed and then stored. Aqueous radioactive effluents are treated by evaporation while solid wastes are segregated into compactable and non-compactable waste. An in-drum compactor is used for compactable waste placed in 120-l drums. Organic wastes are solidified and conditioned in 120-l drums. Cement mortar mix is used as immobilization matrix. The waste classification enforced by Morocco which is consistent with the IAEA RW classification specifies suitable disposal modes from a safety standpoint as final end points for each class of radioactive waste generated in the country. According to their radiological characteristics, RW currently generated in the country which cannot be stored for decay and then cleared under regulatory control, require disposal in dedicated facilities.

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RADIOACTIVE WASTE MANAGEMENT PROGRAMS IN SIERRA LEONE

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The use of radiation sources and radiation generating equipment started in Sierra Leone even before the establishment of the Nuclear Safety and Radiation Protection Authority (NSRPA). The country experienced a boom in mining activities after the civil war was declared over in 2002, which brought about an exponential increase in the use of radiation sources and radiation generating equipment. However the mining companies which were operating and folded up before the establishment of the NSRPA left a lot of orphan and legacy sources that require being brought under regulatory control. Cognizance of this fact, the NSRPA established the Nuclear Safety Source Search and Radioactive Waste Management Department and embarked on a nation-wide source search operations. This resulted to the discovery of a 1.2 GBq Cs137 radioactive source (we refer to as June Mansaray) in a residential home at Kissy Bye Pass Road in Freetown. This source has however been brought under regulatory control. However, the Authority requested for a plot of land for the development of the Central Storage and Radioactive Waste Management Facility in order to manage, safely and securely store this source and others that may subsequently be discovered during the search and secure operations. The land has been allocated but the institution is yet to secure funds to develop this facility. The Authority intends to train Regulators to manage the disused orphaned and legacy sources at different stages including handling, segregation, transportation etc. The NSRPA categorized radioactive waste into low level waste, intermediate waste and high level waste. It is hoped that when this facility would have been completed orphan and legacy sources in the country would be, to a very large extent brought under regulatory control. This policy by the authority every year to embark on source search with emphasis in former Mining Companies sites, brought another success story by finding a nuclear density gauge (we refer to as September Sesay), in a defunct site of one of the mining companies. Thus, the authority would be better prepared to safely and securely store orphaned and legacy sources and as a result being able to manage effectively the radioactive waste in the country. This research will focus on generation, categorization and processing of radioactive waste.

RADIOACTIVE WASTE MANAGEMENT IMPLEMENTATION OF WASTE MANAGEMENT STRATEGIES

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POSIVA PREPARING FOR OPERATING A FINAL DISPOSAL FACILITY FOR SPENT NUCLEAR FUEL

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Posiva is approaching to submit, as the 1st in the world, an operating licence application for an encapsulation plant and a final disposal facility for spent nuclear fuel situated at Olkiluoto, in South- West Finland. The application gathers decades of scientific and technical research, development and experimental work of the final disposal concept, the safety case addressing safety of the disposal and design and construction of the facilities. During the handling of the application, Posiva is preparing for operating the facilities by performing a final disposal system test, so called trial run of final disposal. The trial run comprises the whole disposal process from interim storage, with dummy fuel assemblies, to the encapsulation plant and finally to the final disposal facility with final disposal systems and machinery. The trial run addresses Posiva's preparedness to start the final disposal of SF.

Implementation of Waste Management Strategies / ID 167

RADIOACTIVE WASTE MANAGEMENT STRATEGY IN THE REPUBLIC OF KOREA

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In the Republic of Korea, 24 Nuclear Power Plant (NPP) units are operating, with an installed capacity of 23 GWe. 2 units have permanently shut down, and 4 units are under construction as of March 2021. Approximately 75% of the radioactive waste is generated from the operations of NPPs.The Republic of Korea is safely managing low and intermediate level radioactive wastes (LILW) in the Wolsong LILW Disposal Center (WLDC) in Gyeongju city. However, there are still many challenges to overcome for managing high-level radioactive waste including Spent Nuclear Fuels.Korea Radioactive Waste Agency (KORAD) began construction of the Phase 1 of Korea's first disposal facility, WLDC, in 2007, and was granted the operation of Phase 1 in July 2015. Phase 2 is undergoing the licensing process for construction, and KORAD is undertaking the conceptual design of Phase 3. A unique feature of WLDC is that different disposal components are incorporated within a single disposal facility for the efficient and effective management of LILW:

- Phase 1 : is an underground silo-type repository for the disposal of LILW;
- Phase 2 : is an engineered vault-type repository for the disposal of LLW; and
- Phase 3 : is a near surface trench-type repository for the disposal of VLLW.

WLDC is the first radioactive waste disposal facility across the globe that has been developed to host three different types of repositories in one site. KORAD's strategy for repository development features a specific disposal system for containing and isolating radioactive waste away from the human population. Environmental protection also needs to be commensurate with the hazard of the radioactive waste.The Republic of Korea is in the middle of reviewing national spent fuel management policy and will reestablish a basic plan by amending the previous plan established in 2016 for managing high-level radioactive waste after a review process. Based on this plan, the project to manage spent nuclear fuel, including securing a site for the spent fuel management facilities, and constructing a storage facility and a final repository, will begin in earnest.The review committee for the policy collected opinions with an emphasis on communication and participation of stakeholders such as experts, citizens and local residents in the nuclear power plant areas, with 5 basic principles: fairness, transparency, deliberation, representativeness and integration. In March 2021, the review committee submitted a recommendation to the government.

Implementation of Waste Management Strategies / ID 288

ASSE AND KONRAD – GERMANYS LAW/MAW CONSTRUCTION PROJECTS AT FULL STEAM

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The Asse salt structure is located in the Southwest of the Hercynian Mountains in Northern Germany. Mining took place from 1906 to the 1960s. Between 1967 and 1978, 47.000 m³ of low- and intermediate level radioactive waste was emplaced in the old mine, labeled as research program. The bearing structure of the mine is unsuitable for long-term stability due to the high extraction ratio. In 2009, German authorities decided to recover the waste.The former Konrad iron mine is located 20 km west from Asse site. After mining ceased in the 1970s and due to favorable dry geological conditions, Konrad becomes the first deep geological repository for LAW/MAW waste, licensed under the federal atomic law of Germany and finally granted in 2007. Since then, BGE is working on both shafts, all buildings and the underground infrastructure. In 2017 the newly established BGE became the new operator of the Asse and the Konrad mines. The merger of BGE with the former contractors DBE and Asse GmbH created a powerful company, better than any of its predecessors. Consequently, construction activities accelerated, and projects came to rapid progress. The combined turnover 2021 at both sites exceeds 350 Mio €. More than 1500 staff (in- and external) build houses, drill holes, sink shafts and develop underground infrastructure. Current highlights at the Asse site are the continued exploration of the salt structure in preparation for the new recovery shaft, the hydraulic encapsulation of the waste and the development of recovery technology within the emplacement chambers. The Asse recovery project entered the stepwise per- mitting process in 2020. Until 2033 the infrastructure for recovery will be developed with a new shaft, buildings and infrastructure, especially an 200.000 m³ intermediate storage at the surface. Konrad will start emplacement in 2027. At the surface more and more buildings rise up. The inlet at the second level of the emplacement shaft sets new standards for large, long-term stable underground infrastructure. The refurbishment of the shafts goes into its final stages, with the installation of both hoists of shaft #1 and #2. During installation, access to the mine has to be guaranteed at all times. The organization of simultaneous activities at the surface, in the shaft and underground is complex and requires a large degree of detailed engineering.

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ADVANCES IN IMPLEMENTING STRATEGY FOR MANAGEMENT OF RADIOACTIVE WASTE IN PAKISTAN

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In Pakistan, management of radioactive waste exists right from the operation of first Nuclear Re- search Reactor PARR-I in 1965 and first Nuclear Power Plant (NPP) in 1972. With the passage of time more nuclear reactors were added to national fleet. Besides, there are numerous nuclear medical, agriculture and research centers working in the country generating radioactive waste including Disused Sealed Radioactive Sources (DSRS). The radioactive waste generated from these facilities was managed at facility level. There was lack of harmonization in practices with each facility having their own waste processing and packaging techniques. For the safe final disposal, there was a need to synchronize the waste processing and packaging techniques generated by each facility. To manage these issues, Pakistan formulated a National Strategy for Safe Management of Radioactive Waste in 2011. Currently the strategy is being revised. The strategy lays out objectives of safe management of radioactive waste under all conditions and for all the time it remains hazardous to human health and the environment. This strategy helped out in achieving the harmonized radioactive waste management practices throughout the country. Adoption of modern procedures and optimized waste processing techniques are implemented to align with storage and disposal requirements. As a result of this strategy, the waste generators focused on avoidance, minimization, reusing and recycling of radioactive waste. This leads to proper segregation, decontamination for recycling, evaporation, incineration and super-compaction for volume reduction, standardized waste packages for storage and disposal. Moreover, for disposal of radioactive waste, two near surface disposal facilities are planned to accommodate LLW – one in northern part and other in southern part of the country. In northern part, site has been selected and detailed site characterization is in progress. In parallel, the process for designing and safety assessment has also been initiated. For disposal in southern part of the country, candidate sites are being studied. For sustainability of the disposal projects, finances are assured. The strategy has proven useful as an instrument to implement the plans and goals set out in the National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel in Islamic Republic of Pakistan.

Implementation of Waste Management Strategies / ID 132

THE NATIONAL STRATEGY OF THE RUSSIAN FEDERATION IN THE FIELD OF RW MANAGEMENT: MAIN PROVISIONS AND PROGRESS IN ITS IMPLEMENTATION

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The report presents the results of a decade of efforts addressing the main focus areas of the National RW Management Strategy of the Russian Federation with its main provisions specified in the new Federal law on RW Management enacted in 2011.
The following aspects are considered:

- Fundamental changes introduced to the regulatory framework.
- Results of the RW inventory campaign of 2013-2014.
- Development of federal RW disposal facilities. In 2015, a near-surface disposal facility was commissioned in the Sverdlovsk Region in the vicinity of Novouralsk city. Relevant procedures addressing public acceptance of a project on the establishment of near-surface disposal facilities in the vicinity of Ozersk (Chelyabinsk Region) and Seversk (Tomsk Region) have been completed. A comprehensive R&D program is being implemented and an underground research laboratory is being built as part of the deep geological disposal project development.
- Enhancing the safety of facilities holding non-retrievable RW. The most challenging facilities of this type are surface LRW storage reservoirs. To date, significant progress has been achieved in their upgrading to ensure their long-term safe storage configuration (the term referred to as conservation in Russia): 5 facilities have been completed, including the symbol of Russian nuclear legacy, V-9 reservoir (Lake Karachay) located at PA Mayak site. A long-term safety strategy (several hundred years) has been developed for the world’s largest surface LRW disposal facility, the Techa cascade of water reservoirs. The report presents the implementation experience of associated activities. Transfer of industrial uranium-graphite reactors to a safe state is still underway.
- Retrieval and processing of accumulated RW. Until 2030, activities on accumulated RW retrieval, conditioning and disposal should start being managed consistently. The report summarizes the corresponding results.
- Other major focus areas, such as the comprehensive dismantlement of nuclear submarines, remediation of coastal bases (including global partnership initiatives), long-term safety demonstration for LRW deep well injection facilities, development of radiation monitoring systems, computational safety assessment tools, as well as enhancing international cooperation on RW management.

In the context of the management of RW types from advanced fuel cycles, the report briefly overviews the goals and the progress achieved in addressing some key integral problems, such as the long-term centralized SNF storage and development of a new WWER-1000 SNF reprocessing facility.The report concludes with some main Russian RW management policy challenges to be addressed in the next 5 years.

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FRENCH PROGRESS ON RADIOACTIVE WASTE MANAGEMENT DISPOSAL PROJECTS

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The year 2020 was an important year for the French overall radioactive waste management strategy. An updated version of the Multiannual Energy Plan (PPE) has been published by the French government presenting plans for achieving the goal of reducing the share of electricity produced by nuclear reactors to 50% by 2035 and the objective of carbon neutrality by 2050. In addition, conclusions of the 4th Radioactive Materials and Waste Management Plan (PNGMDR) were released. Conclusions include specific commitments on roles and responsibilities of the Owners and contributing parties, wider involvement of society (local elected officials, the general public and NGOs); recycling and re-use of decontaminated materials; additional disposal capacities to ensure a consistency with the PPE milestones and a need for clarifications concerning reversibility of Cigéo (French Deep Geological Repository project).2020 was also the year of launching of the licensing process of Cigéo. In August, the French national radioactive waste management operator, Andra, submitted the application for a Declaration of Public Convenience and Necessity (DUP). First conclusions on the environmental impact assessment and the socio economical study of the project should be made available at the time of the conference. If the Declaration is endorsed by the Prime Minister, it will give to Cigéo its status of “project of a national importance”, and enable Andra to ensure the land management for the project and to apply for the numerous authorizations needed to prepare the site for the construction and later, the operation of Cigéo. Since 2019, Andra is actively preparing the construction license application (DAC) of the Cigéo, compiling all information, assembling all puzzle pieces, in a structured and consistent set of files. With a detailed description and role of the initial Industrial Pilot Phase, the project is gradually giving consistence to the implementation of the governance of the project with the involvement of all stakeholders. By the date of the conference, an update description of these final license application stages will be proposed. In parallel to Cigéo project, significant progress were made by Andra in its industrial activities as for the project of extension of the Cires capacity (VLLW disposal facility) to accompany the acceleration of the French dismantling program in line with the PPE. A complete update of these activities will be also presented in the article.

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PERSPECTIVES OF DECOMMISSIONING AND WASTE PROCESSING OF OLD RADON-TYPE NEAR-SURFACE REPOSITORY

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Radioactive waste inventory at the Waste Management Organization in Moldova includes Disused Sealed Radioactive Sources (DSRS) safely stored in an above ground storage facility and legacy DSRS and solid waste (Radium contaminated soils and solid waste of different origin) disposed of in an old Radon-type facility. This latter facility is of concern from the point of view of long-term behavior, since there are long lived isotopes, which may be inadvertently released by human intrusion. Sampling and analysis of surrounding soils and groundwater, demonstrated contamination of soil and groundwater by radium and strontium nuclides. The existence of leakage from the Vaults is evident. Various Expert Missions reviewed the conditions of the site and assessed the work to be performed, and concluded that based on available measurements and data, wastes from the near surface trenches should be recovered, because they represent a serious radiation hazard in their present state both from operational and post closure points of view. Scientifically proof of the Expert opinions regarding waste retrieval was done with the support of SSM Sweden. A “zero alternative scenario” risk assessment has been undertaken in order to evaluate the potential radiological impact on humans and the environment of the facility, were it to be left in its current state with no remediation. The results have been used as a basis for regulatory decision making regarding remediation and decommissioning of the legacy radioactive waste facility. Thus, the retrieval of legacy waste from the near surface concrete trenches of the old repository followed by characterization and conditioning of this waste, decommissioning of the trenches, cleaning of local contamination is a challenging task which should be well prepared, taking into account bur- dens arising from retrieval and processing operations. In this regards, has been initialized and supported by International Atomic Energy Agency several National Technical Cooperation Projects, based on which has been already developed Feasibility study for the waste retrieval followed by Development of Decommissioning Plan and Technical De- signs of the infrastructure for Decommissioning. Since 2020, new IAEA TC project MOL9009 is supporting the creation of the infrastructure and technical capacity building of the legacy waste retrieval activities.

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ENSURING THE SAFE, SECURE AND SUSTAINABLE DISPOSAL OF RADIOACTIVE WASTE: A SOUTH AFRICAN PERSPECTIVE

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The Republic of South Africa generates radioactive waste through numerous activities such as the generation of nuclear power and manufacturing of radioisotope. To ensure the long term viability and public acceptance of nuclear energy and its applications, it is essential that any radioactive waste generated is safely, securely and sustainably managed from the point of generation through to disposal (the cradle-to-grave approach). The disposal of radioactive waste on a national basis has been entrusted to the National Radioactive Waste Disposal Institute (NRWDI), a public entity wholly owned by Government. Radioactive waste has been disposed since 1986 at our National Facility Disposal Facility for Low Level Waste, Vaalputs. Vaalputs has an impeccable operational and radiological safety track record. There is widespread acceptance of the Vaalputs radioactive waste disposal programme and operations within the local communities as well as the public at large. Public engagement, based on the principles of transparency, fairness, openness, inclusivity, confidence and trust, is the cornerstone and bedrock on which the success of our radioactive waste disposal programme is established. To accomplish the strategic goal of continuously improving, maintaining and further developing Vaalputs as a world class near surface disposal facility, much effort is applied in keeping abreast with international radioactive waste management and disposal practises as well as evolving regulatory requirements. The establishment and implementation of a successful radioactive waste disposal programme is not predominantly a technical issue. It is imperative that all key stakeholders be involved in a stepwise process of consultation, involvement, technical work and decision-making. The paper will provide information on how South Africa has implemented a successful low level waste disposal programme that is technically sound, socially acceptable, environmentally responsible and economically feasible and sustainable for protecting the health, safety and security of humans and the environment, now and in the future without putting an undue burden on future generations.

Implementation of Waste Management Strategies / ID 143

COMPLETE RECYCLING OF BORIC ACID FROM THE PRIMARY CIRCUIT COOLANT OBTAINING COMMERCIAL BORATE PRODUCTS

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Every year, tens of tons of boric acid and various chemical reagents are used and disposed of at each VVER-1000 unit for the regeneration of ion-exchange filters applied for treatment of boron- containing solutions.Currently, hundreds of thousands of tons of radioactive boron-containing solutions of a very com- plex composition have been accumulated and stored on the territories of the nuclear power plants (NPP), because boric acid used is mixed with numerous radioactive solutions, produced during the operation of the NPPs (decontamination solutions, regenerates of ion-exchange filters, liquid techno- logical environments, drainage waters, etc.). After energy-consuming concentration in evaporation plants, these liquids are discharged into liquid radioactive waste storage facilities and are evaporated once again periodically to reduce the volume, because an overflow of these storage facilities may lead to a shutdown of the nuclear power plant. The borate-ion content in evaporated solutions reaches 20-30%.Therefore, it is necessary to review the treatment of the boric acid at the nuclear power plants and ensure its full recycling obtaining borate products that meet all the criteria for a borate materials used in the industry.The proposed method for the full recycling of boric acid includes a treatment of boric acid after its use in the coolant of the primary circuit of a nuclear power plant from radionuclides using selective inorganic sorbents, bypassing thus the purification on the ion-exchange filters. After that, a commercial borate product is made from the resulting radiochemically pure boric acid solution.Boric acid can be purified from radionuclides in containers by mixing it with the selective sorbents. Sulfides, hydroxides, phosphates, ferrocyanides, metal silicates or their mixtures can be used as selective sorbents for the treatment of the boric acid from radionuclides.Reducing the amount of the isotope boron-10 in the primary circuit coolant is compensated by adding the required amount of new boric acid. An increase in the consumption of boric acid, due to the refilling of the primary circuit coolant with portions of fresh boric acid will increase its annual consumption by 10-15%, but at the same time, all boric acid used at the NPP will be converted into a commercial product. Also, hundreds of cubic meters of radioactive solutions and tens of cubic meters of spent ion-exchange resins will not be produced. In addition, the procedure of the boron 10 content monitoring in the coolant will be significantly simplified, and the dose load on personnel will be reduced.

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DISMANTLING AND REMOVAL OF CS-137 BLOOD IRRADIATOR FROM JORDANIAN HOSPITALS

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Hospitals in Jordan and around the world are addressing concerns about radiological security, safety and liability by replacing blood irradiators that use radioactive cesium-137 with safe and effective x-ray technology. Jordan Atomic Energy Commission (JAEC) collaborated with the United States Department of Energy's National Nuclear Security Administration (NNSA) through an initiative to reduce the threat of a radiological dispersion device incident. The project aims to dismantle, transport and long-term store the Cs-137 Disused Radiological Source (DRS) used in the blood irradiator devices at different Jordanian hospital to the Centralized Storage Facility (CSF) at JAEC. This paper describes the radiation safety and security measures that were taken while executing the removal of the Cs-137 Blood Irradiator at King Abdullah University Hospital (KAUH), to guarantee the radiation protection of the staff and all other involved personnel and to avoid the dispersion of radioactive materials to the environment.

Implementation of Waste Management Strategies / ID 37

AN INTRODUCTION TO THE NEW NEAR SURFACE DISPOSAL REPOSITORY IN CHINA

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With the rapid development of the nuclear energy and nuclear technology in China, radioactive waste disposal has attracted more and more attention. The paper briefly reviewed the operational disposal repositories, Northwest Disposal Repository and Beilong Disposal Repository, and introduced the new near surface disposal repository.The new disposal repository was sited and authorized by NNSA in 2020. It is located in Gansu Province with a capacity of 1 million cubic meters of low level radioactive waste from nuclear power plants and nuclear technology utilization facilities. The selected new site has stable geological conditions and is located in desert area with few residents. It is shown in EIA and SAR that the site could provide effective isolation, containment and retardation of waste from the environment and meet the long-term safety requirement for waste disposal.

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ASSESSMENT OF COMPLETENESS AND SUFFICIENCY OF ONGOING RESEARCH ACTIVITIES IN UNDERGROUND RESEARCH LABORATORY OF THE NIZHNEKANSKY MASSIF

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At present in accordance with the Strategy of Implementing Deep Geological Disposal Facility for Radioactive Waste (Strategy) the underground research laboratory (URL) is being created in the Krasnoyarsk region (Russia) at a depth of approximately 500 m in which characterization, testing, elaboration of technological solutions and transportation and handling operations will be carried out in support of the development of the geological disposal facility for high-level and intermediate- level long-lived radioactive waste (GDF). Within the framework of the Strategy, a Comprehensive Research Program was developed and ap- proved for the purpose of demonstrating the long-term safety of radioactive waste disposal and optimization of operational parameters (Strategic master plan for R&D demonstrating the safety of construction, operation and closure of a GDF in the Nizhne-Kansk massif (Krasnoyarsk Region) (Re- search program). In 2020 Rostechnadzor initiated the work "Assessment of completeness and sufficiency of ongoing research activities in URL of the Nizhnekansky Massif" as part of the implementation of Research and Development (R&D) carried out in the URL of the Nizhnekansky Massif. This work is carried out by the Scientific and Engineering Centre for Nuclear and Radiation Safety (SEC NRS). At the moment the following work has been done:

- assessment of completeness of R&D programs aimed at studying the characteristics of the URL site, in order to confirm its compliance with the requirements of the Russian Federal rules and regulations in the field of atomic energy use, recommendations of international organizations, imposed on the characteristics of the GDF site and its region;
- analysis of the R&D in URL carried out in 2019.

The assessment of the completeness of the R&D programs showed that the operating organization considered all necessary studies in the URL, aimed at confirming the suitability of the selected site for the placement of the GDF. As part of the analysis of R&D for 2019, the results of seismic and geophysical studies, hydrogeological studies, regime water balance observations, observations of processes, phenomena and factors of natural origin were considered. Based on the results of the analysis of the implementation of R&D programs in the URL, proposals to the State Atomic Energy Corporation Rosatom were formulated to continue investigation of the URL site and its region.

Implementation of Waste Management Strategies / ID 54

DEVELOPMENT OF A QUALITY MANAGEMENT SYSTEM FOR THE ACCREDITATION OF THE RADIOACTIVE WASTE MANAGEMENT SERVICE IN THE PHILIPPINES

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The Philippine Nuclear Research Institute – Radioactive Waste Management Facility (PNRI-RWMF) is authorized to treat, condition, and store radioactive waste. The PNRI-RWMF is under the Radiation Protection Services Section (RPSS) of the Nuclear Service Division (NSD) of PNRI. Services provided by the RPSS are accredited under ISO 9001:2015 Quality Management System (QMS) except for the Radioactive Waste Management Service (RWMS). The Fundamental Safety Principle 3 states that it is important to establish and sustain an effective leadership and management that concerns the safety of the concerned organization and the associated facilities and activities that pose radiation risks. Therefore, it is essential to demonstrate safety at the highest level through an effective management system. To achieve this, the RWMS was enrolled for accreditation under the ISO 9001:2015 QMS. The accreditation of the PNRI-RWMF was accomplished by (1) adapting requirements of the ISO Standard, including preparation of Procedure Manual and Work Instruction, (2) monitoring and documenting the effectiveness of implementation, and (3) participating in internal and external audit for the review and evaluation of compliance with the system. In summary, the RWMS received its accreditation under the ISO 9001:2015 QMS by showing its capability in providing its service that is amenable to the customer's needs as well as regulatory requirements. Through successful enhancement and application of its process, the RWMS has consistently ensured that customer satisfaction is prioritized.

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MANAGEMENT OF DISUSED SEALED RADIOACTIVE SOURCES IN SYRIA

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Safe management of disused sealed radioactive devices/sources (DSRS) implies dismantling, conditioning, long-term storage and safe disposal. Recently, the International Atomic Energy Agency (IAEA) prompts reuse and recycling of DSRS as alternative options to consider prior permanent disposal. In this regards, national programme has been carried out on management of DSRS including registry, characteristics and dismantling. This study focuses on the establishment of a retrieval storage to ensure safety and security of recovered sealed radioactive sources pending further action such as recycling or conditioning for final disposal. The retrieval storage, contains 21 boreholes, each of 2 m depth, is constructed at the central ra- dioactive waste facility. Each borehole comprises 7–8 stainless steel capsules with capacity of ca. 393–1,963 cm3. The capsules are home-made in compliance with the international standards. Implementation of the storage is based upon a radiation protection programme approved and licenced by the regulatory body. The retrieval storage's design and the construction details are further documented into a movie. The work enables to draw a strategy for an efficient and effective conditioning of disused sealed radioactive sources for safe and secure management programme.

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REGULATION OF SEALED RADIOACTIVE SOURCES IN PAKISTAN

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A large number of Sealed Radioactive Sources (SRS) are used in medicine, industry, agriculture, education and research in Pakistan. These SRS normally contain high concentration of radionuclide and are imported from various countries worldwide. Regulatory framework of Pakistan Nuclear Regula- tory Authority (PNRA) requires the importer to obtain Permit and NOC for the import of SRS. At the time of acquiring NOC for import of sources, the importer/user is required to inform PNRA about the time frame of returning the source to the supplier or handing over to the designated radioactive waste storage or disposal facility. During the operation, regulatory inspections are conducted for the verification of regulatory compliance. The SRS are termed as Disused Sealed Radioactive Sources (DSRS) after completion of the useful life and are considered as waste. However, these DSRS are still potentially hazardous for the people and the environment. DSRS needs to be properly handled, stored and disposed of in order to reduce the associated risks to acceptable level. Accordingly, the user handover its DSRS to designated radioactive waste storage/disposal facilities of Pakistan Atomic Energy Commission (PAEC) in accordance with acceptance criteria established by designated waste storage facility whereas the DSRS containing long lived and high activity radionuclide are returned back to the country of origin. Keeping in view of the long term safe management in future, the DSRS which could not be returned will be disposed of at a centralized disposal facility for which site investigation studies are in progress. PNRA is responsible to regulate SRS from cradle to grave in the country. In this regard, PNRA in collaboration with other relevant national stakeholders has formulated and issued a National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel in Islamic Republic of Pakistan. This policy is an intent of the government and relevant organizations that appropriate safety measures are adopted for managing DSRS. PNRA has also gazette notified the Regulations on Radioactive Waste Management which set the detail requirements for the safe management of sealed radioactive sources. According to these regulations, the licensee is responsible for the safe management of its DSRS and manage it in accordance with the radioactive waste management program approved by PNRA in such a way as to protect human health and the environment. This paper presents the process for long term safe management of SRS in Pakistan.

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LICENSING OF PINSTECH PRE-DISPOSAL RADIOACTIVE WASTE MANAGEMENT FACILITY - PNRA EXPERIENCE

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Pakistan Nuclear Regulatory Authority (PNRA) was established by the Government of Pakistan with the promulgation of PNRA Ordinance in January 2001as an independent regulatory body. The Ordinance empowered PNRA to control, regulate and supervise all matters related to nuclear safety and radiation protection in Pakistan. Pursuant to PNRA Ordinance, licensing and authorizations of nuclear installation is one of the main functions of PNRA. These licenses and authorizations are issued on the basis of review and assessment of licensees submissions and feedback of regulatory inspections. Depending upon the potential magnitude and nature of the hazards associated, authorizations are issued at various stages of nuclear installations as prescribed in PNRA Regulations for Licensing of Nuclear Installation(s)-PAK/909. The Pakistan Institute of Nuclear Science & Technology (PINSTECH) is a national research and development institute managed by Pakistan Atomic Energy Commission (PAEC). Various facilities are operating at PINSTECH including Pakistan Atomic Research Reactor (PARR-1), Pakistan Atomic Research Reactor (PARR-2), Molybdenum Production Facility (MPF), etc. The radioactive waste generated with the operation of these facilities was managed by waste management division of PIN- STECH. The radioactive waste management facility was initially covered under the operating license of PARR-1. Later on, the waste management facility was declared as designated radioactive waste management facility for the radioactive waste generated in private and public sectors in the northern part of the country, therefore, PAEC realized to obtain a separate license for the waste management facility. In 2012, PNRA received PAEC intention for grant of license to the waste management facility as per PAK/909. Keeping in view the licensing process laid down in PAK/909, PINSTECH submitted a number of documents such as safety analysis report, radioactive waste management program, radiation protection program, quality assurance program, etc. Since, the facility was already in operation, therefore, graded approach was applied in the licensing. PNRA formulated a team of experts for the regulatory review of licensing submissions and upon satisfactory completion of the review, PNRA granted operating license to PPRWMF in January 2016. The main purpose of the facility was to receive and manage low and intermediate level radioactive waste including disused sealed radioactive sources (DSRS) from various nuclear/radiation facilities and activities. The facility was named as PINSTECH Predisposal Radioactive Waste Management Facility (PPRWMF). This paper present the experience of PNRA regarding licensing of PPRWMF.

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DEVELOPMENT OF NATIONAL INFRASTRUCTURE FOR RADIOACTIVE WASTE MANAGEMENT (GEORGIAN CASE)

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Currently, Georgia operates two radioactive waste management facilities: Centralized Storage Facility (CSF) and closed "Radon" type facility. Georgian national strategy considers serious upgrade of the national infrastructure for radioactive waste management. According to the goals and tasks defined by the strategy and based on the conducted investigations, a decision for the construction of new radioactive waste storage, treatment and conditioning facilities was reached. The preliminary investigations showed acceptance of "Radon" type facility as an appropriate place for the allocation of all new radioactive waste management facilities. Based on the support of the EU and Sweden radiation regulatory authority (SSM), a comprehensive project was developed to identify the design and construct new facilities. The first phase of the project was implemented by a German organization DMT together with Georgian specialists, in which identification of the methods for treatment and condition of radioactive waste (considering future disposal options) and of basic design of the facilities as well as their preliminary safety assessment were conducted. The second phase considers issuing of the detail design, conducting of safety and environmental impact assessments and obtaining of necessary authorization for construction and commissioning of the facilities.

Implementation of Waste Management Strategies / ID 105

THE BOREHOLE DISPOSAL SYSTEM - A SAFE DISPOSAL OPTION FOR MANAGEMENT OF DISUSED SEALED RADIOACTIVE SOURCES

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The peaceful application of Sealed Radioactive Sources (SRS) in medicine, industry, agriculture, and various research activities results in the generation of disused sealed radioactive source (DSRS). The DSRS can be highly radioactive thereby causing significant security and safety problems. The management option includes decay storage and return of the sources to the supplier which are not always possible. Disposal is the only viable management option. The Borehole Disposal System (BDS) for Disposal of Disused Sealed Radioactive Sources (DSRS) provides a safe, sustainable and economic long term management solution for DSRS especially for countries with limited volume of radioactive waste, mainly or only DSRSs. In addition to the surrounding geosphere, the BDS design incorporates many natural and passive engineered barriers, entailing an interior stainless-steel capsule (which grips the sources), an internal cement containment barrier, an external stainless steel container and exterior cement backfill. A project on the borehole disposal of DSRS is on-going in Ghana. A suite of safety case documentation is being prepared by Ghana Atomic Energy Commission for submission to the national regulator, the Nuclear Regulatory Authority (NRA), for their review and authorization as a part of a licensing process to implement the Borehole Disposal System in Ghana.

Implementation of Waste Management Strategies / ID 108

CONCEPTUAL DESIGN OF DISPOSAL FACILITY FOR VERY LOW-LEVEL, LOW-LEVEL AND SHORT-LIVED INTERMEDIATE-LEVEL RADIOACTIVE WASTE OF THE BELARUSIAN NPP

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The paper briefly presents the principal technical solutions for radioactive waste disposal facilities (RWDF), as well as for auxiliary buildings, structures and engineering systems for this RWDF, which ensure safe and economically feasible disposal of radioactive waste (RW) generated from two units of the Belarusian NPP during 60 years of operation and during decommissioning. The suggested conceptual RWDF design includes an assessment of its radiation safety during operation and long-term post-closure safety. It is shown that the suggested RWDF concept ensures safe RW disposal in the period of potential danger of RW taking into account possible external impacts of natural and man-made origin. The aggregate technical and economic parameters of the suggested RWDF project were evaluated both in general and for the first stage of construction.

Implementation of Waste Management Strategies / ID 128

EVOLUTION OF THE ENVIRONMENTAL MONITORING PROGRAM IN 40 YEARS OF OPERATION OF THE LOW AND INTERMEDIATE RADIOACTIVE WASTE REPOSITORY BAITA BIHOR / ROMANIA

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Monitoring, according to International Atomic Energy Agency (IAEA), is the continuous or periodic observations and measurements regarding engineering, environmental, or radiological parameters in order to evaluate the repository system components behavior or the repository and its operations environmental impact. In general, the environmental monitoring program consists of three phases: preoperational, operational, and post operational. The operational environmental monitoring pro- gram for Baita Bihor National Radioactive Waste Repository started in 1986 and it was designed in accordance with national and international regulations at the time. The reports with the quarterly measurements on the monitoring of the DNDR area of influence have been made out annually, from 1986 to the present. It has been continuously improved, in order to achieve a more accurate characterization of the Baita Bihor DNDR area of influence. This paper is a review regarding the improvements of the environmental monitoring program activities during its 40-year operations: dosimetric measurements, measurements of the potential β contamination on the DNDR platform, gamma spectrometric analysis on environmental samples (water, soil, sediments, milk and vegetation), determination of tritium concentration in water samples, physicochemical analysis of water samples. New perspectives regarding monitoring will be considered and integrated in the program for further improvement and effectiveness.

Implementation of Waste Management Strategies / ID 173

REGULATORY AND INFRASTRUCTURAL FRAMEWORK FOR RADIOACTIVE WASTE MANAGEMENT IN CAMEROON

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During the twentieth century, the use of ionizing radiation was not made in the framework of regulatory control in Cameroon since the first general manager of National Radiation Protection Agency (NRPA) has been appointed in 2007. Legacy sources which are those that pre-date effective regulatory requirements have been found. According to this, measures have been taken to address the management of radioactive waste and others legacy disused sealed radioactive sources through various actions including: The publication of the law N° 2019/012 of 19 July 2019 on lay down the general framework for radiological and nuclear safety, nuclear security, civil liability and safeguards enforcement;

- The construction of disused sealed radioactive sources centralized storage facility;
- The elaboration and finalization of national radioactive waste management policy and strategy;
- The repatriation of sealed high activities radioactive sources (SHARS).

As per Section 60 of the above mentioned law, without prejudice to existing legislation on the management of dangerous wastes, radioactive waste management, shall be subject to prior authorization by the authority in charge of regulation and regulatory control. As per Section 62 any natural or legal person that imports a high-activity radioactive source shall, prior to importation, show proof to the authority in charge of regulation and regulatory control that it has taken appropriate contractual and financial measures to ensure that such radioactive source is returned to the supplier after use. The national centralized storage facility funded by the DoE/USA has been constructed in order to manage category 3 to 5 disused sealed radioactive sources. The National Radiation Protection Agency (NRPA) is the responsible of this infrastructure. Equipment to implement security functions are in place within the storage facility, including detection and delay equipment. The response procedure is tested through initiation of alarm to verify the coordination with response force and actions for the staff to take in the event of a security incident and the response duration.The national policy and strategy, gives responsibilities of the involved administration and technology options planned, management of category 3 to 5 low activity disused sealed sources and the return to the suppliers for category 1 to 2 disused sealed sources.The repatriation of 02 category 1 60Co sources located in Yaounde General Hospital and Polyclic Bonanjo and 01 137Cs located in Department of Physics of the University of Yaounde has been con- ducted according to the IAEA safety standard.

Implementation of Waste Management Strategies / ID 183

DISMANTLING OF A RADIOPHARMACEUTICAL PRODUCTION PLANT: WASTE MANAGEMENT STRATEGY AND ACHIEVEMENTS

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Due to the bankruptcy in 2012 of a radiopharmaceutical production plant, ONDRAF-NIRAS, according to its legal mission, had to take on the remediation and dismantling of all its installations. These include two cyclotrons and various hot cells and laboratories. A specific concern with the site was the presence of numerous isotopes in very different proportions depending on the equipment or installation. The preparation of the dismantling included a large effort to define and implement a robust waste management strategy. This strategy was based on minimising radioactive waste for final disposal by decontamination, metal melting with unconditional release and maximising conditional and unconditional release for other materials including lightly activated concrete from the cyclotron bunkers. It has been implemented in four important steps: acquiring a good knowledge of the history of the installation, establishing complete isotope vectors for all areas, developing a comprehensive general methodology for characterising the materials and the implementation of a high degree of material sorting. Nine years into the dismantling, this strategy has proven to be very successful. More than 50% of all materials have been unconditionally released or recycled. With thousands of characterisations performed during the project, no significant changes to the initial isotope vectors have been necessary. The general methodology has been successfully applied on the most basic items up to, and including, complete buildings. For the remaining radioactive waste, the physical-chemical and radiological characterisation satisfied or exceeded the proposed stringent requirements set by ONDRAF/NIRAS for the surface disposal facility for low-level radioactive waste currently in development. This shows that successful waste management can be realised in the reality of day-to-day operations in dismantling.

Implementation of Waste Management Strategies / ID 190

MODULAR AND TRANSPORTABLE CONDITIONING SYSTEMS FOR LLW/ILW – SOGIN EXPERIENCE

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Italian situation is characterized by the presence of radioactive wastes of many different types and forms localized in many different sites.Usually, for the conditioning of each waste type on each site, there will need several years for design and build a specific plant. That plant will be operated, often, for short campaigns, and then put in decommisioning phase. Possible better approach could be the using of modular and transportable plants.Such plants are realized in modules. Each module contains the systems and components for one or more process phases. Module can be preassembled in factory and can be designed as transportable as is it. The full plant will be made by one or more modules that are coupled together on site.Modular plant can be more flexible, can adapted to different situations and the same plant can be used on different sites. Moreover, plant dismantling operations are simplified.Sogin have been used in the past modular and transportable plants for waste conditioning (cementation). More than 3.000 cemented manufacts have been produced.Basing on the acquired experience, Sogin in the last years have designed a new Modular plant: the SiCoMoR system, which will be used on various Sogin sites.SiCoMoR system is designed for conditioning different types of radioactive waste (liquids, sludges, Ion resins, powders or granular wastes), implementing the «in drum mixing and cementation» process.SiCoMoR system is realized in separated modules (process and auxiliary modules). Each module is preassembled and transportable and will be coupled to the other modules on site of installation.The process modules coupled together configures a confined process area put in depression by venti- lation system respect to external area. Confinement and ventilation system of SiCoMoR are designed to allow the conditioning of LLW and ILW radioactive wastes containing beta/gamma and also alfa emitters.SiCoMoR can accept drum or drum inside shielding overpack (maximum weight=5 t).The moving of drum through various sections of the plant is made by motorized rolley conveyor put inside modules.Process operation are made in remote control mode, with operators positioned in the Control Room Module.Due to modular concept, the plant can be assembled for different productivity. The current design provides a productivity of 5 manufact/day.SiCoMoR system is now in the final stage of construction, and final general test of plant is foreseen in 2021.

Implementation of Waste Management Strategies / ID 198

PRE-DECOMMISSIONING OF BANGKOK RADIOACTIVE WASTE INCINERATION PLANT

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For 40 years, the radioactive waste incineration plant in Bangkok had been employed to treat the combustible radioactive waste obtained from various units, especially hospitals and laboratories. According to deterioration of the plant structure and the incineration system, then this plant was terminated and no longer used. There was ultimately an intention to decommission it and rehabilitate the plant site to be used for other purposes. The decommissioning project was designed to dismantle and decontaminate the incineration system, and also rehabilitate the plant area. The report intends to present the pre-decommissioning activities carried out to gain the beneficial data for the decommissioning authorization, which include the radiation measurements of environmental materials around the plant (i.e., surface soil, grass, surface water and suspended particulate matter), a list of the components in the incineration system, the examination of the dose rate and contamination level of such devices, the assessment of the waste generation quantity, as well as the waste management method. The particularly provided guideline from OAP and the authorization procedure are also described here.

Implementation of Waste Management Strategies / ID 207

DEVELOPMENT OF A NON-DESTRUCTIVE GAMMA SPECTROMETRY TECHNIQUE FOR VALIDATION OF NEUTRON ACTIVATION CALCULATIONS

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The objective for decommissioning planning, is to obtain a radiological understanding of the involved installation. The characterization at this stage could be carried out by means of: 1) neutron activation calculations based on reactor design and neutron flux; 2) dose rate measurements; 3) in- situ gamma spectrometry; 4) sampling for determination of the scaling factors in activated and contaminated components.Neutron activation calculations contains several uncertainties. These uncertainties are based on the input data - such as material data (composition and impurities), neutron flux and energy, nuclear data libraries - and on the methodology of the process and the simulation codes.Taking into consideration all these modeling uncertainties, this work is focused on the development of a technique for validation of the calculations. A non-destructive gamma spectrometry technique by using MCNPX simulations is under development for interpretation of the resulting gamma-ray spectra of the radionuclides in activated components. In particular, a spectrum will be produced, based on the activities of the main radionuclides in the activated component and the results of MC- NPX simulations. This spectrum will be compared with the experimental spectrum.Furthermore, the radiological characterization of activated components, which appeared with sur- face contamination, is essential for the decision making process during decommissioning. The cut- ting techniques to be followed in order to reduce the production of secondary waste and limit the doses to personnel and the selection of decontamination techniques should be based on accurate determination of the radionuclides inside the material and/ or in the surface contamination. The proposed method could also be helpful in this case. The activities inside and on the surface of the components could be determined by comparing the experimental spectrum with that produced by MCNPX simulations, using the arisen activities from the scaling factors and the dose rate measurements.

Implementation of Waste Management Strategies / ID 208

DEVELOPMENT OF A NON-DESTRUCTIVE GAMMA SPECTROMETRY TECHNIQUE FOR OPTIMIZATION OF METALLIC WASTE CHARACTERIZATION

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Adequate radiological characterization is important for optimization of metallic waste management. For decommissioning planning, the objective is to obtain a radiological understanding of the involved installation. The characterization at this stage could be carried out by means of: 1) neutron activation calculations based on reactor design and neutron flux; 2) dose rate measurements; 3) in-situ gamma spectrometry; 4) sampling for determination of the scaling factors in activated and contaminated components. During dismantling, in-situ characterization is carried out to classify and package the generated waste. This is usually achieved by using portable devices to measure dose rates or total counts. Then, the packages are monitored for assessment of activity and determination of the management route. The radiological characterization of activated components, which appeared with surface contamination, is essential for the decision making process during decommissioning. The selection of cutting and decontamination techniques should be based on accurate determination of the radionuclides inside the material and/ or on the surface contamination. Also, after dismantling, the metallic waste may be activated and/or contaminated with radionuclides which are products of neutron activation or fission. It is important to decide in which cases the decontamination will be efficient as well as to select the appropriate decontamination techniques based on whether the waste is slightly activated or contaminated or both. A Semi-empirical technique for optimization of determination of contamination and activation of components and metallic waste is under development based on combination of gamma spectrometry measurements and MCNPX Monte Carlo simulations. Firstly, the technique aims at reduction of the uncertainties related to the density and activity distribution. The specific activities inside and on the surface of the materials could be determined by using the measurement results of the proposed non-destructive technique in combination with the use of the scaling factors for activation and/ or contamination.

Implementation of Waste Management Strategies / ID 233

THE DEVELOPMENT OF BEISHAN UNDERGROUND RESEARCH LABORATORY FOR GEOLOGICAL DISPOSAL OF HLW IN CHINA

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With the rapid development of nuclear power in China, the disposal of high-level radioactive waste (HLW) has become an important issue for nuclear safety and environmental protection. This paper introduces the overall planning and the latest progress of China's URL (underground research laboratory).The Xinchang site in the Beishan area, located in Gansu Province of northwestern China, has been selected as the final site for China's first URL. In the process of characterizing the Xinchang URL site, a series of investigations, has been conducted. The investigation results indicate that the Xinchang site are very suitable for URL construction. From 2016 to 2020, the main functions and structure of the Beishan URL have been designed, examined and updated. The main functions of the Beishan URL are designed to develop disposal technologies and disposal concept, and estimate the cost of a repository, characterize the site by obtaining key parameters of the deep geological and hydro-geological conditions, carry out engineering-scale tests, verify the safety performance of engineered barriers, provide parameters for repository safety assessment and environmental impact assessment, and establish a platform for the public communication to increase public confidence and support rate. The main structure of the Beishan URL consists of one personnel shaft, two ventilation shafts, one sprial ramp, and two experimental levels. The maximum depth of the URL is -560 m. The ramp is about 7 km in length, with a cross-sectional diameter of 7 m, maximum inclination of 1:10. The use of tunnel boring machine (TBM) is proposed for the ramp excavation as it will less disturb the rock mass and be faster and safer than traditional drill-and-blast excavation. From the shafts, horizontal tunnels are planned to be constructed at two levels for in situ experiments, i.e., the main level at -560 m and the auxiliary level at -240 m.The Beishan URL is currently under construction and it is expected to be completed in 2027. Mean- while, many tests focusing on site characterization and engineering technology is planned to be performed during construction. Site characterization activities will continue along with ramp excavation. Activities related to construction technology will be conducted along the ramp and at the level of -560 m. It is anticipated that the technologies and experience obtained from the Beishan URL will contribute greatly to the future success of a HLW geological repository in China and similar facilities around the world.

Implementation of Waste Management Strategies / ID 245

OPTIMISED WASTE MANAGEMENT FOR NUCLEAR SITE DECOMMISSIONING - ON-SITE DISPOSAL TECHNICAL LEARNING TO INFORM REGULATORY ADVICE AND ASSESSMENT

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The environment agencies in Scotland, England and Wales published 'Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation' (GRR). It clarifies our expectation that operators should optimise both the decisions on how best to manage wastes (e.g. whether on-site or off-site) as well as any on-site disposal (should that be deemed the best solution), demonstrating the eventual suitability of a site for release from regulatory control through a Site Wide Environmental Safety Case (SWESC). The UK is committed to working towards delivery of the UN's Sustainable Development Goals and this is a key driver for our expectation that a holistic range of issues should inform nuclear decom- missioning and clean-up, including decisions on waste management. Together with other considerations, our guidance has driven a key shift in ways of working within the industry, away from the presumptions that any radioactive wastes generated at a site should be disposed 'elsewhere' to, instead, the appraisal of a full range of options including those of more local or on-site solutions. It recognizes that, irrespective of the waste disposal route chosen, the disposal will only be authorized if its safety can be demonstrated through a robust environmental safety case. Consequently nuclear operators in the UK are now actively considering options for their waste management which include the option of on-site disposal of radioactive wastes (OSD). OSD may take the form of in-situ disposal (e.g. making the case for leaving a lightly contaminated below-ground concrete pond in place), or 'disposal for a purpose' (e.g. where waste is used for void filling). For any nuclear site to be released from our regulatory control, any waste or contamination remaining must meet the protective criteria set out in the GRR and remain safe into the future. To inform our readiness to regulate any proposals we may receive for OSD, we have been gathering knowledge and experience internationally, as well as learning from other industries. This work has generated a matrix of technical 'consideration factors' (albeit taking account of different regulatory and technical contexts). We are liaising with the UK nuclear industry to ensure their plans for waste management, site characterisation and decommissioning meet regulatory expectations. New guidance on protection of groundwater has been developed to ensure any OSD is appropriately assessed and regulated. We are working on addressing a range of technical and regulatory challenges to enable sustainable solutions.

Implementation of Waste Management Strategies / ID 265

REGULATORY EXPERIENCES IN POLICIES AND STRATEGY IMPLEMENTATION FOR RADIOACTIVE WASTE AND DISUSED SOURCES MANAGEMENT

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For more than 30 years, the Cuban Regulatory Authority has established the legislation, and has controlled the fulfillment of requirements for adequate attention to radioactive waste management. The strategies for this activity were specified from the issuance of Decree Law 207 - the highest legal body -, the Basic Radiation Protection Standards, the Regulation "For the safe management of radioactive waste" and the Guide "About unconditional declassification levels of solid materials with very low radioactive content and discharges of liquids and gases into the environment ", in the years 2000-2004, structuring the regulations for the control of radioactive waste generation and management, aimed at the identification, prevention and control of the generation and management of radioactive waste and disused sources, mainly from medical practice, nuclear gauges in industrial radiography, industry and construction, radioactive lightning rods, educational sources and smoke detectors.The paper describes how this strategy is reflected in the aforementioned regulations and shows a quantitative evaluation of the way in which this policy has been controlled by the regulatory authority in the institutional licensing processes and inspections of the waste generating entities. In compliance with the recommendations of the International Atomic Energy Agency, the strategy has been directed towards the management of low-level wastes with a short half-life. In the case of Teletherapy, the replacement of Co-60 radioactive sources has been carried out in compliance with the provisions for this process. In nuclear medicine, attention has been directed to minimize the generation of radioactive waste, both in its liquid form and some contaminated solids, no forgetting liquid and gaseous discharges to the environment. One aspect that required arduous regulatory activity has been the elimination of radioactive lightning rods in the country as well as the evacuation of low-activity radioactive sources used in fire protection, in laboratories as chemical reagents and in teaching. Regulatory control also led to an adequate management of sources declared in disuse from the industry.In conclusion, one can affirm that the existence of an appropriate regulatory framework and a disciplined action of the entities that generate and make first waste management, controlled by the regulatory authority, trough authorization and inspection processes have guaranteed compliance with established policies and strategy in the country. This has made it possible to avoid radiological accidents or radioactive contamination and exposure of people and the environment, which could de- rive from an inadequate management of radioactive waste and disused radioactive sources.

Implementation of Waste Management Strategies / ID 274

END-OF-LIFE CONSIDERATIONS DURING THE TRANSITION TO ALTERNATIVE TECHNOLOGIES

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The National Nuclear Security Administration's Office of Radiological Security (ORS) works to enhance global security by preventing the use of high activity radioactive materials in acts of terrorism. ORS accomplishes this mission through three strategies: Protect, Remove, and Reduce. The ORS Reduce mission utilizes a holistic approach to achieving permanent risk reduction through the implementation of non-radioisotopic alternative technologies for both U.S. and international partners. ORS promotes this approach through policy development, education, and outreach on the status of cutting-edge technologies; research, development, testing and evaluation of non-radioisotopic technologies; and direct replacement programs where possible both domestically and internationally.This paper will use case studies to highlight ORS experiences with radioactive source end-of-life management as a part of the transition to alternative technologies, particularly in the Cs-137 blood irradiation and Co-60 radiotherapy sectors. Replacement efforts for radioisotopic devices require identifying a strategy for source removals, whether through storage or disposal at a secured facility in-country or the return of the source to a supplier. Through these case studies, we intend to draw attention to the challenges of safe and secure end-of-life source management, how ORS supports safe and secure disused source management, and crucial partnerships that can make management viable. The paper will also emphasize the importance of thorough planning for end-of-life management for users of radioactive sources and highlight the value of non-radioisotopic alternative technologies in eliminating the need to dispose of disused sources.

Implementation of Waste Management Strategies / ID 276

DEMONSTRATION OF AN END-TO-END PROCESS FOR ILW DECOMMISSIONING WASTE

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In order to achieve high hazard reduction within legacy ponds at Sellafield, there is a requirement to remove inventory from the pond floor and create space to enable sludge and fuel removal. Included in this inventory are ~1000 redundant Intermediate Level Waste (ILW) fuel skips that have been generated during operations and fuel consolidation. This presentation will outline the end-to-end process for retrieving the fuel skips from the ponds through to the interim storage of the waste in an above ground facility. The scope will include an explanation of the opportunities and constraints that affected decisions at each stage of the process. These include pond operations, buffer storage, size reduction and characterization of the waste. The focus of the presentation will be on the innovation deployed throughout the lifecycle of the waste. It will discuss why the current options have been selected and the potential benefits for further developments and opportunities for additional waste forms. It will also discuss how this demonstration can be used to inform to future strategies for dealing with contact handleable ILW.

Implementation of Waste Management Strategies / ID 290

RECONDITIONING OF HISTORIC RADIOACTIVE WASTE IN AUSTRIA - EXPERIENCES WITH AND STATUS OF THE PROJECT

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At Nuclear Engineering Seibersdorf GmbH (NES) all radioactive substances produced in Austria are, on behalf of the Republic of Austria, collected, safely conditioned and temporarily stored until their final disposal.This agreement has been expanded until 2045, leading to investments in new buildings and technical equipment to assure the stability of the waste until final disposal. The main projects to achieve this goal are: The construction of a New Handling Center (NHZ) for radioactive waste, the construction of new interim storage halls ("Transfer Storage") and the reconditioning of old, historic waste drums.The project has been implemented in three phases which correspond to the three main types of drums to recondition:The first phase concerned 200-Liter drums with supercompacted pellets. The pellets therein have been repackaged, dried and analyzed by gamma-scanning. About 1500 drums were treated that way. This phase has been completed.The second phase concerns homogenously cemented sludges, salts and ashes. These drums are being dismantled using custom made machinery and then milled (for sampling and reduction of the radius) before they are being repackaged and analyzed via gamma-scanning. The milling samples are also being analyzed chemical and radiochemical. This phase of the project is ongoing. Over 1000 drums have been reconditioned in this way.The third phase concerns 100-Liter drums with raw radioactive waste that hase been formerly cemented into 200-Liter drums. We call these drums in-homogenously cemented. These drums are also being dismantled using the same machinery as in phase 2. Then the concrete lining is being removed before the 100-Liter drum is inspected. Depending on the contents of the inner drum, these are being repackaged into cartridges for supercompaction or – in case of burnable waste – repack- aged into plastic bags for incineration. Sampling is also done on one drum per week. This phase of the project is ongoing. Over 400 drums have so far been reconditioned this way.In all phases – especially in phase 2 and 3 – considerations for waste minimization are being upheld. Especially phase 2 drums are being considered for free release and phase 3 drums are being reduced in volume.

Implementation of Waste Management Strategies / ID 291

INTEGRATED WASTE STRATEGY FOR CANADIAN NUCLEAR LABORATORIES

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Canadian Nuclear Laboratories (CNL) and Atomic Energy of Canada Limited (AECL) have been instrumental in the development of Canada's nuclear industry. For more than 70 years, nuclear technology has evolved to meet the needs of the world for clean, reliable energy; sustainable economic growth; and public health, safety and security. Today, CNL is actively restoring and protecting Canada's environment by reducing and effectively managing AECL's nuclear liabilities at multiple sites across Canada.CNL has an Integrated Waste Strategy which considers current and planned future waste management requirements. This includes activities associated with operational, research & development, post operational clean out, facilities decommissioning, environmental remediation, legacy and historic wastes, and waste received from small generators across Canada. Due to the history of re- search and science at the large and complex CNL sites, there is a breadth of waste management challenges that requires integration. A long term view is required with consideration of the full waste management lifecycle, ensuring there are long-term waste management solutions for all categories of radioactive waste. This strategy enables the integration and planning across all activities and sites.CNL is actively implementing long-term waste management solutions through three proposed waste management projects currently undergoing federal environmental assessments and regulatory li- censing. The Near Surface Disposal Facility (NSDF) is a proposed disposal facility for AECL-owned low-level waste and enables the environmental cleanup mission underway at AECL owned sites. The in-situ disposal of the Nuclear Power Demonstration (NPD) and Whiteshell Reactor (WR1) completes the decommissioning of these two below grade reactors and ensure long-term safety of the public and the environment.

SOLUTIONS FOR SPECIFIC WASTES

Solutions for Specific Wastes / ID 262

INCREASED SAFETY MEASURES FOR REMOVAL OF SELF-SHIELDED IRRADIATORS CONTAINING CATEGORY 1 AND 2 SEALED RADIOACTIVE SOURCES

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In response to lessons learned from a 2019 contamination incident during a source removal in Seattle, WA, the National Nuclear Security Administration's (NNSA), Office of Radiological Security's (ORS) Off-Site Source Recovery Program (OSRP) has implemented new procedures and contracting requirements to enhance safety during the removal of self-shielded irradiators containing Category 1 and 2 sealed radioactive sources. These new measures are applied based on the risk of each removal, which is determined by the irradiator and shipping configuration. For lowest risk removals, the entire irradiator is packaged in a certified transportation container after the electronics and motor, etc. are removed. If the radioactive sealed source are removed from the source holder and packaged into a certified transportation container would be the highest risk removals. New OSRP safety requirements include submission of detailed work-control documents, including site-specific hazard analyses and emergency response plans, which will be reviewed by an independent panel of subject matter experts. All parties, including the in-site facilities representative, contractors, and regulators have the right to pause work in the event of an unanticipated condition related to safety or other events that may impact the removal work. These improvements to OSRP's irradiator removal process were developed to address lessons learned from a recent contamination event and ensure safe and secure disposition of these Category 1 and 2 sealed radioactive sources.

Solutions for Specific Wastes / ID 36

APPLICATION OF DIRECT CEMENTATION SYSTEM FOR SMALL VOLUME OF ALPHA CONTAMINATED AQUEOUS WASTE (CEMENTATION SAG IPU)

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Management of small volume of alpha contaminated liquid waste can pose significant challenges during the pre-disposal and disposal phases. The radiochemical characteristics of the waste have the major influence on the selection of waste management technology but of course the quantity of the waste may have a considerable influence on the scale and design of the waste treatment and conditioning facility. In the Sogin Casaccia Plutonium Plant (IPU) are stored about 310 l of alpha contaminated aqueous liquid wastes (ILW) arose from the past activities conducted in the Plant: REBA Project (that in- volved TESEO Process and PUREX Process) and from other laboratory activities. Followed by a preliminary evaluation of the possible technical and strategical options to be applied, Sogin selected the on-site direct cementation as the best one. Due to the limited amount of waste a dedicated processing plant has been designed in order to implement both the treatment and conditioning process in a small volume process system inside a Glove Box (Cementation SAG IPU). The design of the drum to be coupled with the cementation system has been included within the project. The characterisation of the waste evidenced the presence of two main streams: acidic stream (about 70 l) and alkaline stream (about 240 l). A laboratory scale testing program has been carried out to select the treatment and conditioning materials and to define the main process parameters. The stability and durability of the cemented waste form have been verified through a specific qualification program. A final full-scale mock-up test has been conducted to complete the process and waste form qualification activities. This paper describes the results of the performed testing activities and the development of the Glove Box cementation system (Cementation SAG IPU).

Solutions for Specific Wastes / ID 295

RADIOACTIVE WASTE MANAGEMENT ISSUES AND CHALLENGES IN IRAN

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IRWA is designated by the AEOI and Iran Nuclear Regulatory Authority (INRA) as the Central Waste Management Organization in Iran to be responsible for performing all aspects of Radioactive Waste (RW) management activities for fuel cycle facilities and minor waste generators, long-term storage and disposal of all radioactive wastes including operational and decommissioning wastes are the most important responsibilities of IRWA. This vast scope of responsibilities causes challenges and need practical efforts in order to satisfy regulations and stakeholders simultaneously. Effective and safe management of such wastes requires a comprehensive program, coordinated un- der a defined national waste management strategy, based on the present and future requirements. From 2001, IAEA has provided technical assistance and support for the development of national WM Strategy & Policy (WMSP) and Radioactive Waste Disposal Program, covering the whole spectrum of radioactive waste generated and anticipated radioactive waste. Operation of the first NPP in Iran, limitation on accessing to novel technology and expertise, undefined responsibilities and shortages in design and sometimes trainings, caused problems that need special solutions in a short time. On the other side, the sudden increase in the application of Sealed Sources and Radioisotopes and operation of nuclear fuel cycle facilities in the country generated large amount of DSRSs and a variety of waste streams. In the last decade, IRWA started siting and construction of a near surface disposal facility in order to increase its capabilities for dealing with such a sudden increase in waste streams and volumes. The NPP's wastes issues were quite varied: unsuitable formulation for stabilizing the wastes which lead to improper final waste packages, im- proper design of stabilization process devices which lead to cost increase and non-conformances, lack of final solution for high activity wastes (group III), non-compliance in number and radioactivity of generated final waste in comparison to FSAR document Licensing process and dealing with INRA for the disposal facility was also a challenge because of the lack of experience on the waste disposal and the specific and unique issues in disposal of radioactive waste. By increase in the generation of DSRS, IRWA devised a methodology for their storage in order to store large no. of DSRSs in a small and controlled area and to retrieve them for reuse. Reuse is one of the main solutions in the management of DSRS.

Solutions for Specific Wastes / ID 242

MELTING OF CONTAMINATED METALS FOR CLEARANCE AND RECYCLING – 30+ YEARS OF PRACTICAL EXPERIENCE

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Treatment of contaminated metals by melting in Sweden started 1987 as a joint initiative by the licensee at that time (Studsvik) and the regulators in Sweden. Since 2016, the metal treatment facility is owned and operated by Cyclife Sweden, a company within the EDF Group. Over the years the facility and the operations has developed, including extensions of the cutting and segregation areas, a larger furnace hall, installation of abrasive decontamination units as well as advanced equipment for treatment of large components. The treatment methods have been extended and enhanced over the years, as well as the type of metals possible to treat aiming for clearance. The installation of the advanced mechanical decontamination technology in year 2000 increased the potential for clearance of contaminated metals after treatment significantly to the benefit of the licensees in the countries sending scrap metals and redundant large components to the Swedish facility for treatment. Their common objective has always been to reduce the amount of radwaste for disposal as radioactive waste. As an average, more than 95% of the metals sent for treatment have been subject to clearance. One of the largest projects performed was the shipment of 15 Magnox boilers from the UK for treatment in Sweden. Other projects which have been discussed broadly are the PWR steam generator treatment campaigns. This paper will summarise the experiences from more than 30 years of operational experience, how the introduction of the waste hierarchy and focus on sustainability have affected the decisions within the nuclear industry etc. The paper will also discuss how to optimise the management of large com- ponents and scrap metals in power upgrade and decommissioning projects to make management of the contaminated materials even more sustainable and the projects more cost efficient.

Solutions for Specific Wastes / ID 308

APPLICATION OF GEOPOLYMERS IN MANAGEMENT OF PROBLEMATIC RADIOACTIVE WASTE

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In the context of decommissioning of many various NPPs worldwide and also a remediation of old legacy sites, it is necessary to process various problematic waste streams, which have been stored for many years, and for their properties were not processible by classical technologies. These include solid and liquid wastes, in varying quantities, sometimes located in a variety of difficult-to-access locations across large sites. The longer these RAWs are stored, the harder they can be processed - both from technical and economical point of view. The general trend in the world is therefore gradual replacement of conventional radioactive waste processing technologies by new, more efficient and more versatile ones. There is a portfolio of methods to safely treat these materials in readiness for long term storage or disposal. The choice of an appropriate method depends on various aspects and influencing fac- tors such as the categorization of the waste to be treated in terms of radioactivity, its chemical and physical properties and homogeneity. The decision-making also includes security aspects, economic issues, availability and sustainability of raw materials. Moreover, the final product processed by this technology must comply with the Waste Acceptance Criteria for disposal or storage and the whole process must be approved by the competent supervisory authorities. Encapsulation of the waste using geopolymer matrices (e.g. Jacobs' SIAL®) is an example of new generation waste solidification technology, that offers a safe and cost-effective alternative conditioning technique. The process is based on polycondensation reaction of aluminosilicate materials (solid phase) in a basic medium (liquid phase) at room temperature and pressure, producing a crosslinked, inorganic geopolymer which has good physical strength, hardening characteristics, leachability performance, radiation stability, biodegradability, flammability, explosivity and stability in frost. The SIAL® geopolymer solidification technology now has a track record of over 20 years which includes on-going research and development In this presentation we aim to summarise the most interesting performance records of this technology, the applied mobile devices as well as the characteristics of final products.

Solutions for Specific Wastes / ID 59

TECHNOLOGICAL ADVANCEMENT IN EFFECTIVE MANAGEMENT OF LOW LEVEL RADIOACTIVE SOLID WASTES

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In India, Low Level (LLW) Solid Radio-Active Wastes (RAW) contributes more than 90% of the total RAW generated from regular Operation and Maintenance of a typical Nuclear Fuel Cycle facilities. The volume generated from a typical nuclear facility ranges from 200 to 600 M3 depending on type and number of the facilities at a site. These wastes, in general are segregated as combustible, compressible and non-compactable/compressible based on the processing considerations. Predisposal processing is an essential task for optimal utilization of Near Surface Disposal Facility (NSDF) to contain the radioactivity and isolation from the environment meeting regulatory guidelines. Combustible waste forms viz. Cellulosic. Rubber and Plastics, contributes about 50-60% of the total VLLW and LLW solid wastes. Predisposal steps employed for these combustible radioactive solid wastes are compaction, melt densification and incineration based on type of waste forms. Cellulosic waste is incinerated using oil/diesel fired incinerator. Rubber and plastics wastes are compacted using hydraulic compactor and plastic wastes having thermoplastic behavior is processed through melt densification mode achieving volume reduction factor (VRF) of ,30-40 3-4 and 3-10 respectively. Rubber and plastic wastes mainly PPEs, contributes about 70-80% of the total combustible waste. As advancement in technology with high temperature based processing of these wastes, has certain ad- vantages to nullify formation of toxic compounds like dioxin and Furans. The plasma based process having ease of higher temperature availability, is seen as the promising solution for management for all type of combustible radioactive wastes. To achieve higher volume reduction for rubber and plastic wastes, an engineering scale Plasma pyrolysis based incineration demonstration setup of 25 kg/hr capacity has been commissioned at Bhabha Atomic Research Centre (lndia) utilizing in-house developed 30 kW DC air plasma source. After lab studies and simulated waste trails, the setup was commissioned with actual radioactive waste. More than 2000 kg waste has been successfully processed through the setup in various trials. VRF achieved for all combustible type of waste forms is ranging from 30-40. The paper highlights waste processing aspects, laboratory scale study for waste decomposition and demonstration of plasma processing of solid RAW.

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CURRENT STATUS OF SOLID WASTE MANAGEMENT ON FUKUSHIMA DAIICHI NUCLEAR POWER STATION

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Ten years have passed since the Fukushima accident occurred. TEPCO is undertaking decommissioning of Fukushima Daiichi Nuclear Power Station (NPS) steadily and safely, incorporating domestic and international expertise, to fulfill its responsibility for the March 11, 2011 accident. From all of the decommissioning works, various types of solid waste have been generated. These volume are about 475,000m3 on February 2021. We have continuously improved waste management manner. For example, incinerator for burnable waste was built and started operation on March 2016. Waste storage facility No.9 which can store the solid waste about 33,600 m3 was built and started operation on February 2018. However, most of the waste is still stored on outside temporary storage area. “Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station Units 1 to 4” which is published by Inter-Ministerial Council (December 2019) shows the milestone (main target processes) for solid waste management on site. The milestone is as follows:

FY2028, TEPCO will eliminate temporary storage area outside for all solid waste (fallen tree, rubble and others, soil, used protective clothing and others) except for secondary waste from water treat- ment and waste to be used for reuse/recycle, in order to lessen the workers’ risk such as radiation dose risk. TEPCO predict solid waste generation over the next 10 years based on the planned decommissioning activities every year. According to the latest prediction (July 2020), waste volume generated from decommissioning works will reach about 784,000 m3 on March 2032. Based on this prediction, we release the Waste Management Plan which showed how to improve waste management manner and to achieve the milestones on Mid-and-Long-Term Roadmap. The overview of this plan is to reduce the waste volume as much as possible and to store the waste inside the buildings. According to the plan, the other incinerator is under construction. This facility is scheduled to start operation with in FY2021. And also we have designed other storage facilities and the volume reduction treatment facility. We have a plan to achieve milestone by utilizing these facilities.

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SOLIDIFICATION OF RADIOACTIVE RESINS WITH GEOPOLYMER PACKAGE: A CIRCULAR ECONOMY CONCEPT OF HANDLING NUCLEAR WASTE WITH MINE TAILINGS

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Notwithstanding the advantages of environmentally-friendly nuclear power plants in the new energy industry, efficient disposal of radioactive nuclear wastes is still lacking. Up-to-date, encapsulation of radioactive ion-exchange resins with green and cost-effectiveness packages such as geopolymer has recently emerged. In this contribution, geopolymer packages were elaborated up to 42 wt.% of un-calcined-phosphate tailings to encapsulate radioactive ion-exchange resins under different alkali-mixed content and environments during the long term leaching tests. The alkali mixed content-dependent and environmental-dependent chemical stability and leaching kinetics, as well as their leaching mechanisms, have been revealed. The addition of sodium citrate (Na-citrate; 1.5 wt. %) was also assessed. The results showed that non-activated phosphate tailings-based geopolymer pack- ages exhibited better stability and encapsulation performance than that of individual metakaolin- based geopolymer matrix and Portland cement binder, recording compressive strength values greater than the waste acceptance criteria. For the encapsulation of 134Cs, the Na-citrate addition positively affected its retention and leaching rates under the same leaching conditions. Both higher alkali-mixed content and acid solution destroyed the chemical stability and accelerated the leaching behaviors of 134Cs from the encapsulation packages. XRD, FTIR-ATR and SEM/EDS examinations of geopolymer packages reflected their multilayered structures and semicrystalline natures and to what extent these packages and the encapsulated resins had good/ poor stabilities. This research enables NPS, which is traditionally considered as a by-product from the Moroccan phosphate industry, to be used as a replacement and partially reactive material in MK-based geopolymer packages for encapsulation/immobilization of radioactive wastes.

Solutions for Specific Wastes / ID 5

WASTE SOLIDIFICATION USING CRT GLASS FOR RETARDATION OF HAZARDOUS ELEMENTS IN SPENT RESIN

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Spent ion exchange resins were generated from TRIGA PUSPATI Reactor (RTP). Spent resins were used in water purification in nuclear facilities. Spent resins can be classified low level waste and intermediate-low level radioactive waste depend on concentration activity for water treatment and time taken for treatment Generally, these spent ion exchange resins are used 10 – 15 times in nuclear reactor depending on the exchange capacity and regeneration efficiency. A new ion exchange resins will be used to replace resins which have been contaminated with radioactive. The RTP produces approximately 50 kg per year of spent ion exchange resins. Thus, a treatment and disposal method is needed due to continuous generation of spent ion exchange resins and limited storage capacity. According to IAEA, immobilisation is one of the effective ways to overcome this problem. Thus, in this research vitrification is applied. Spent resins were mixed with glass to produce glass waste form. From the result, the optimum composition of spent resins mixed with CRT glass were between 10% -15%. Then, the waste glass form was tested XRD to identify crystal in the sample. The waste glass form is amorphous phase. For chemical durability, leaching test had been conducted and used Product Consistency Test. The normalized released for B (0.001 - 0.006 g/m2) and Na (0.010–0.088 g/m2) and the result were within standard environmental-assessment glass which is for B (5.36 – 8.35 g/m2) and Na (4.28-7.61 g/m2). Then, these normalized releases were compared with previous study for ceramics glass waste form for B and Na which are 27.8 g/m2 and 23.7 g/m2, respectively.

Solutions for Specific Wastes / ID 12

URANIUM RECOVERY FROM LIQUID WASTE COMPOSED OF URANYL NITRATE SOLUTION

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The nuclear fuel cycle operates producing uranium in power generation, in use in medicine and industry, among other areas. This cycle produces various kinds of radioactive waste. Among these, uranyl nitrate solutions with enriched uranium are produced, mainly in the chemical decontamination of parts and materials with fixed contamination. Uranyl nitrate, as addressed in this paper, has inherent risks as it is a hazardous material in addition to risks of radioprotection, proliferation and nuclear criticality, requiring strict control. Until November 2020, there were 3 m³ of uranyl nitrate awaiting treatment at the nuclear facility and an average enrichment content estimated at 3.05% of U-235 in solution. The solution to be treated has a concentration of 15% HNO3. The volumetric reduction of this waste, reducing the concentration of uranium contained in the solution, removing the characteristic of radioactive waste is the main objective of this paper. A secondary objective is recovery of enriched uranium for reintroduction into the production process, and finally, the proper disposal of the nitrate solution. Among the methods studied, chemical precipitation with hydrogen peroxide was chosen to remove uranium in solution. Preliminary experiments were carried out to evaluate responses and then a rotational central composite design (RCCD) was carried out to find the optimum point for treating this solution, considering the greatest uranium precipitation and consequent removal in the solution as optimal. All analyses to identify uranium were performed by means of plasma optical emission spectrometry - ICP OES. As a result, maximum removal was achieved by precipitation with hydrogen peroxide at 200 g/L, pH 1.75, with a reaction time of 8 hours, where 99.7% of the uranium solution was removed. Thus, the initial solution had 13.9 g·L-1 and 36·10-3 g·L-1 of uranium enriched in solution remained. The precipitation with hydrogen peroxide was efficient in removing uranium in uranyl nitrate solution. With the treatment applied, it was possible to economically recover uranium, previously in solution, since it can be returned to the production process for the production of UO2 tablets, estimating the possibility of recovering up to 63 kg of enriched uranium, which corresponds to approximately US$ 4,000.00. The release value for liquid solutions containing uranium is 5·10-3 g·L-1. For future studies, there is the possibility of carrying out a new stage of precipitation treatment for final polishing of this solution, with the application of ion exchange to achieve the release value as non-radioactive waste.

Solutions for Specific Wastes / ID 13

SAFETY AND SECURITY OF RADIOACTIVE SOURCES: THE ROLE OF THE RADIOACTIVE WASTE MANAGEMENT CENTRE OF GHANA

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Hazards associated with ionizing radiation are deleterious to all living organisms and the environment in general. Sealed radioactive sources are the major sources of anthropogenic ionizing radiation in Ghana. They are applied in hospitals for x-ray imaging, cancer diagnosis and treatment; in industry and civil constructions for moisture and level gauge determination; and in agriculture for pest control and extension of shelf life of foods. Other sectors where radiation sources are used in the country include the gold mines and oil and gas exploration fields. When radioactive sources become deficient and do no longer serve the purpose for their intended manufacture, they become disused and are termed radioactive waste. Despite being disused, their activity are often high enough to cause radiation injury when mishandled or overly exposed to. Aside the safety concerns, radioactive sources are subject of national security. Their theft and unauthorized use have serious security implications. In view of these, the Radioactive Waste Management Centre (RWMC) of the of the Radiation Protection Institute (RPI) of Ghana was established with a core function of retrieving all radioactive waste generated in the country for further management. The RWMC operates a licensed Centralized Radioactive Waste Management Facility (CRWMF) where pre-disposal activities such as waste characterization, waste conditioning, re-containerization (in case of leakage) and storage are carried out. The Centre also undertakes radiation safety assessment and radiation protection training for users and transporters of radioactive sources.

Solutions for Specific Wastes / ID 19

PROGRESS ON THE MANAGEMENT OF DSRS AT CHINA INSTITUTE FOR RADIATION PROTECTION

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This document has suggested a conceptual design for an infrastructure to recover, handle and condition SHARS for long-term storage.The stumbling block on the international level was the management of Spent High Activity Radioactive Sources (SHARS) because of its high potential radiological risk. Based on the design concept of IAEA and the practice of NECSA, with slightly different design requirements but with basically the same concept, IAEA cooperated with China to develop a Mobile Hot Cell specifically to deal with SHARS from irradiators. The development has provided an opportunity to develop for the first time the required infrastructure in an Asian country and to test some new features of the infrastructure. A pilot conditioning operation with an activity of an around 1000 Ci Co-60 irradiator sources had been carried out in September, 2010 that the sources were handled and conditioned very successfully. The new features have provided for a more efficient source conditioning operations and increased the potential SHARS activity acceptance capacity of the hot cell. The performance testes conducted by the Agency and the team from China Institute for Radiation Protection (CIRP) showed that the mobile hot cell meets all performance requirements.

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CONTROL & MANAGEMENT OF NUCLEAR WASTE WATER WITH A NOVEL NANO TECHNOLOGY METHOD

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In this study, iron oxide super paramagnetic nanoparticles, Fe3O4@MnF2O4 and Fe3O4@SiO2 core/shell Nano composites synthesized via ultrasonic assisted chemical co-precipitating technique to remove heavy metals from wastewater, especially nuclear wastewater. Optimization method under con- trolled conditions was used to increase the adsorption of heavy metals by nanoparticles as adsorbent. Thus, the adsorption percentage of lead, nickel, chromium and mercury metals were determined 95.4%, 90%, 75% and 70.26% via Fe3O4 super paramagnetic nanoparticles, respectively, by atomic absorption spectroscopy. Finally, the absorbance of this Nano composite for 4 solutions of lead, nickel, and chromium and mercury metals was 90.87%, 90.56%, 71.36% and 73%, respectively. At the end, the core/shell Nano composite of the iron oxide/silica was also fabricated by reflux-assited chemical co-precipitation method and the absorption percentage of this Nano composite for 4 pollution solution of lead, nickel, chromium and mercury contaminants were calculated 94.25%, 87%, 79.57% and 76.14%, respectively. At the end step, the zirconium wastewater was prepared and the iron oxide nanoparticles and their Nano composites were tested according to the optimum conditions. The adsorption percentage of the zirconium ion source pollution was reported about 75.33% and 77.08%, respectively, indicating that the nanoparticles would have better adsorption conditions without applying the temperature. Also, the amount of adsorption of the zirconium wastewater by Nano composites was investigated with silica and manganese ferrite coated around Fe3O4 super paramagnetic nanoparticles and the main amounts of zirconium after the application of the above Nano composites were reported at 623.88 ppm and 838.1 ppm, respectively The absorption efficiency was 64.69 % and 58.28 % which shows that the it is decreased due to the increase in the size of the Nano sized composites compared to the nanoparticles.

Solutions for Specific Wastes / ID 32

MANAGEMENT OF DISUSED RADIOACTIVE SOURCES FROM THE IRRADIATION FACILITY PRODUCT I IN CUBA

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The industrial irradiation facility, type Product I from the former Soviet Union, was put into operation in Cuba in 1987, in the Research Institute for Food Industry. It was used for irradiation of foodstuffs and other types of products. According to the IAEA classification, this is a category II irradiator, panoramic irradiator with dry storage of the radioactive sources. The facility was initially charged with 52 Co-60 sources, with total activity of 2.50E+15Bq. The facility stopped operating in the nineties. In order to recover the irradiation capacities, it was necessary to recharge the irradiator with new Co-60 sources. The 52 disused radioactive sources (DSRS) had to be previously removed from this facility. Adequate container was not available to put the DSRS and transfer to the National Radioactive Waste Storage Facility. So a decision was taken to transfer and temporary store the sources in the reserve pit, located in the same room. The authorization from the Regulatory Body was necessary for this operation. Operational and safety procedures, radiation protection program, safety analysis, as well as the emergency plan were prepared and presented to the Regulatory Body to apply for authorization. A transfer container was available in the facility, but it had to be checked and repaired. Some auxiliary devices were designed and constructed to facilitate operations and to optimize operator doses. License was granted and the DSRS were transferred to the reserve pit in 2015, with the assistance of an IAEA expert. The irradiator was then prepared and recharged with new Co-60 sources. Last year, a container for the 52 DSRS was received with the support of IAEA. The design of the container allows the direct loading of sources from the channels of the reserve pit, using a special tool. It provides adequate shielding for the 52 sources with total activity of 4.0E+13Bq. Operational and safety procedures, radiation protection program and safety analysis were developed for the operations, including: transfer of the DSRS from the reserve pit to the container, preparation of the package and transport to the Storage Facility. The required documents were presented to the Regulatory Body for evaluation. The transportation should be carried out under special arrangement. There is a plan to remove the 52 DSRS from the irradiation facility and transfer to the Waste Storage Facility this year, once the authorization for removal of sources and the Special Arrangement for transport are granted by the Regulatory Body.

Solutions for Specific Wastes / ID 38

THE CONCEPT OF NUCLEAR POWER PLANT WASTEWATER TREATMENT USING TWO-COMPONENT SYSTEM UNITS

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The report presents an innovative concept of wastewater treatment of nuclear power plants (NPP) using modules of two-component system for maintenance of VVER-1000 and other nuclear facilities. The idea and the basic principles of NPP wastewater treatment, as well as the results of its verification, are presented. Liquid radioactive waste has the highest percentage of all nuclear power plant radioactive waste and is the most difficult to process and dispose of. Solving this problem is important for managing the risks at all stages of NPP life cycle. To improve the quality of handling liquid radioactive waste generated as a result of the activities of nuclear power plants, the concept (idea) of multi-stage treatment of liquid radioactive waste by cleaning it from dangerous radioactive particles and molecules in two-component aggregates is proposed. The first barrier is the membrane modules that allow the sorption of radionuclides on the pore walls due to the charged chemical radicals formed as a result of the track formation process. At the second stage, the liquid radioactive waste cleared of radionuclides on the membrane is additionally filtered, then treated with ozone. Thus, LRW is divided into two main components - radioactive sludge in the form of spent membrane modules to be disposed of as solid radioactive waste (SRW) and an aqueous solution cleared from radioactive substances. This concept ensures high-quality treatment of nuclear power plant LRW and reduces labor costs for their disposal, including the cost of disposal of radioactive fallout. The concept of NPP wastewater treatment using modules of two-component plants can be used to model the behavior and predict the risks of nuclear power plant production activities.

Solutions for Specific Wastes / ID 39

INVESTIGATING THE FEASIBILITY TO CHARACTERISE NUCLEAR WASTE FROM THE ASSE II MINE USING COSMIC-RAY MUON TOMOGRAPHY

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In Germany, the Asse II mine was originally used for the commercial potash and rock salt production and later on for the emplacement of radioactive waste. Between 1967 and 1978, nearly 47,000 m3 of low- and intermediate-level waste were emplaced in the Asse II mine but the exact composition of the disposed waste is poorly known. At the time of emplacement, the waste acceptance criteria did not require information about the nuclide mixture and the chemical composition. Since 1988, saturated brine is entering the mine in the upper part of the south flank, where the distance to the overburden is short. The main problems in the Asse II mine are the high degree of rock deformation, the distance of the emplacement chambers to the overburden in combination with the permanent brine inflow of about 12 m3 per day. Because, there is a risk that waterways formed by undergone fracture deformation will access the emplacement chambers at some point. Since April 2013 the so-called “Lex Asse” (§57b of the Atomic Energy Act) is the legal basis to accelerate the retrieval of the radioactive waste in the Asse II mine as well as its closure by simplifying licensing methods and speeding up work but ensuring long-term safety. In April 2017, the Bundesgesellschaft für Endlagerung mbH (BGE) became responsibility for the Asse II mine as operator and licence holder. After retrieval and before the waste may be stored again in a future facility, it will have to be characterised. Cosmic-ray muon tomography utilises muons created by high-energy cosmic-rays in the atmosphere for the imaging of shielded structures, e.g nuclear waste containers. Muons are highly penetrating, natural, ubiquitous and health and safety neutral. Muon tomography for nuclear waste containers has been developed by the University of Glasgow and the UK National Nuclear Laboratory since 2009. It has been commercialised through the award-winning start-up company Lynkeos Technology. The worldwide first muon tomography system for nuclear waste containers, the Lynkeos MIS, is operating on the Sellafield site since 2018. BGE and Lynkeos Technology have carried out a feasibility study on the use of cosmic-ray muon tomography for the waste containers to be retrieved from the Asse II mine. The study focusses in particular on the imaging of the contents of concrete shielded 200 l drums (“Verlorene Betonabschirmung (VBA)”) that are otherwise impossible to image. Detailed results of the study will be shown in this presentation.

Solutions for Specific Wastes / ID 56

WASTE MANAGEMENT IN A URANIUM ENRICHMENT PLANT

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With the population growth and the technological advances, the demand for efficient and environ- mentally friendly electric power sources is a certainty that all countries will face in a near future. Despite the usual concepts of green energy, one must agree that nuclear energy is one of the few technologies current available with low carbon emissions and is highly efficient. The raw material necessary in nuclear power plants is the nuclear fuel obtained through the enrichment of the uranium isotope, 235U, present in the uranium ore. All commercial technologies of uranium enrichment are based on processing uranium hexafluoride (UF6) which must be handled properly due to the great chemical reactivity. Thus, any plant that process UF6 must have the capacity to treat the hydrolysis products that can expose the substance to the atmosphere which will result as process waste. The main goal of this article is to present a case study of the waste management of the Brazilian Uranium Enrichment Plant, that process low enriched uranium, up to 5% of 235U, with the purpose to produce the fuel necessary to supply the Brazilian commercial nuclear plants. In this article, it is shown the radiological and toxicological aspects of the UF6, the means to neutralize the handle gaseous, liquid and solid effluents of a Uranium Enrichment Plant.

Solutions for Specific Wastes / ID 62

CHEMICAL DURABILITY AND STRUCTURE ANALYSIS OF SIMULATED RADIOACTIVE WASTE GLASSES

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Alkali-borosilicate glasses (ABS) are used to accommodate wastes arising from day to day operations and the decommissioning of nuclear installations. Investigating the immobilization systems, chemical durability and structure under normal conditions have gradually increased and in the next two decades will become the prime focus. In this study some physical properties such as Dietzel field strength are measured for three Alkali-borosilicate glasses (ABS-waste) in the viewpoint of applicability to the waste form. Chemical durability was evaluated for three Alkali-borosilicate glasses (ABS-waste) by immersed in hydrogen peroxide. By applying a modular approach, the disposal system is divided into near- and far-field subsystems that are subsequently divided into engineering barriers and the dynamic nature of hydrological and biological subsystems in the host environment. The Dietzel field strength amplitude varies within a relatively broad range of 1.2 to 0.1 and is indicative of the magnitude of the electrostatic attraction force between element and oxygen. The ordered sequence of oxides is relatively convincing in the range of A 1 > 1. Results indicate that oxides form the glass network have A <0.35, as these oxides (alkali in particular) are known to modify network. Between these two extreme behaviors, intermediate oxides may show both behaviors according to glass composition. Dietzel approach suggests that both smallness and high charge of the cations favor the formation of glassy oxides.

Solutions for Specific Wastes / ID 65

SEGREGATION AND DISPOSAL OF LEGACY MIXED ORGANIC LIQUID WASTE IN MALAYSIA

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Waste Technology Development Centre (WasTeC) of the Malaysian Nuclear Agency has been man- aging various forms of radioactive wastes since 1984. Among liquid wastes managed at the centre, the type that is most challenging is perhaps the mixed organic liquid waste. This kind of wastes consist of a multitude of scintillation liquids, mineral processing solvents, and medical radiotherapy fluids. The hazardous-radioactive combination of this waste type requires both regulations to be fulfilled when it comes to disposal. Firstly, the radioactivity of the waste has to be reduced to safe levels by means of reprocessing, radionuclide extraction or simply decay storage before it can be dis- posed according to hazardous waste disposal procedures. However, considerations on the disposal economics makes only decay storage a viable option for the waste. All in all, there were about 3100 2.5 -litre bottles of mixed organic waste of various types. After being kept for over 30 years, signs of container degradation were obvious. This possessed a threat to the overall safety of the workplace should the waste containers fail. Furthermore, long term storage results in involuntary loss and deterioration of records. Considering the urgency of the matter and limited number of available records, a rapid characterization protocol was developed to separate the still-radioactive and decayed legacy organic wastes prior to disposal. The establishment of a correlation between two methods for this particular case; the determination of activity concentration using Geiger-Mueller Ludlum 185-8 and the dose rate using ThermoScientific RadEye B20-ER was attempted. Among 3100 bottles of waste, 55 bottles were randomly selected for the study. The established correlation was used to develop a characterization and segregation protocol for the waste disposal. The protocol was also backed by the decay information of radionuclides (where available) and observations of the would-be physical attributes of the waste. The protocol successfully segregated the radioactive from the decayed organic waste whereby only less than 100 bottles from the estimated 3100 bottles of waste were determined to be of higher activity and continued to be kept.

Solutions for Specific Wastes / ID 67

SORPTION ON INORGANIC SORBENTS SUPPORTED BY ULTRAFILTRATION-HYBRID METHOD FOR TREATMENT OF RADIOACTIVE LIQUID WASTE

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In the paper, a sorption assisted ultrafiltration (SAUF) hybrid method is proposed for treatment of the radioactive wastewater. Removal efficiency (E), function of the specific activities of the permeate and feed, have been determined and discussed. It shows, that SAUF technique is promising for the radionuclide's effective removal from aqueous solutions.

Solutions for Specific Wastes / ID 68

SORPTION OF SELECTED RADIONUCLIDES FROM LIQUID RADIOACTIVE WASTES BY SORBENTS OF THE BIOLOGICAL ORIGIN

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Expansion of novel radiochemical separation methods must take into account using ecologically-friendly solvents and reagents. One method to fulfil this new trend is to use chemicals from natural resources. In the paper, we present in brief the obtained in our group results for removal of the radionuclides from aqueous solutions with the composite alginic sorbent used in an unconventional method. We have also tested possible at home to be used method of removal the radionuclides from aqueous solutions using carrot roots.

Solutions for Specific Wastes / ID 69

CHARACTERIZATION AND PRELIMINARY STUDY FOR SOLIDIFICATION OF ORGANIC ALPHA-CONTAMINATED LIQUID WASTE

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Organic Alpha Contaminated Liquid Waste because of their dual nature of organic and radioactive compounds can affect nuclear safety and have harmful effects on health and environment. These kinds of contaminated liquid must be immobilized into a waste forms that can prevent their long- term release avoiding the contact with water and any loss of containment. There are very few official analytical methods that may be directly used to design reliable solidification protocols of radioactive waste organic liquids especially when their volume is too small to perform complex treatments. A correct management of radioactive waste, which takes into account the necessary health protection and environmental protection safeguards, makes it necessary the definition and classification of radioactive waste. The characterization of radioactive waste is one of the fundamental keys of waste management for the safety assessments during transport or storage and for the determination of waste treatment and conditioning methods. From a radiological point of view, waste characterization can be performed through different methods, destructive and non-destructive. Destructive techniques are used to analyse samples that need to be chemically processed before ap- propriate measurements are carried out. They are more accurate and sensitive than non-destructive techniques, but they are time consuming and highly linked both to the quality (e.g. homogeneity) and the representativeness of the material. Non-destructive techniques identify and quantify the intensity of sample emitted radiation, spontaneous or induced. These methods don't require any physical and chemical modifications, but, show lower accuracy and a strong influence of the matrix composition. Different samples of organic alpha contaminated liquid waste, which have been produced in the past activities of the plant IPU (Plutonium fuel experimental facility), a Sogin facility in Rome, have been fully characterized by physical and radiochemical analyses. The results of the characterization activities can be used to simulate the radioactive organic liquid waste in order to perform laboratory trials for the study of a direct solidification process and experimental tests to evaluate the properties of the solidified waste form (in terms of stability and durability, with reference to its physical-chemical behaviour and, if available, the waste acceptance criteria). This paper summarise the results of the characterisation activities and the very preliminary trials carried out for the solidification study.

Solutions for Specific Wastes / ID 87

DEVELOPMENT OF MID AND LONG TERM STRATEGIES FOR TRR SPENT FUELS DRY STORAGE

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There are significant numbers of produced spent fuels (SFs) eligible to take out from storage pool and transfer to store in dry condition due to more than 50 years operation of Tehran Research Reactor. A multi-phase plan was conceived, designed and has implemented to prepare an infrastructure and re- quired equipment for converting the wet storage to dry for the first try in the country for TRR spent fuels. The plan is initiated with an in-site dry storage of sample SFs in lead-steel casks since 2014. Then, the design and fabrication of a DPC basket type made of alloy steel at 2018. The TRR-SFDPC is a B(U) type of radioactive container which could load 16 standard fuel elements (SFE) and is adopted for both transport and storage purposes. The loading examinations and pre-send preparations are accomplished successfully. The cask surface dosimetry shows acceptable dose values and the desiccation and leak tests are done well. The safety mechanical experiments are planned base on SSR-6 standard to get the exploitation license. A low and medium waste storage site is considered to retrofit and licensing for final destination of DPC cask. A mid-term inside cask storage and a long-term in concrete modules storage is upcoming stages of the SFs waste management plan.

Solutions for Specific Wastes / ID 93

TREATMENT OF LIQUID RADIOACTIVE WASTE CONTAINING ORGANIC SUBSTANCES

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Polish research laboratories and hospitals produce liquid organic waste among which are organic solvent waste and aqueous waste contaminated with organic pollutants (waste with high COD), some- times containing long-lived alpha emitters that require different treatment pathways. The presence of organic substances affects further stages of radioactive waste processing and the safety of its final disposal. Therefore, it is advisable to render this admixtures harmless in an appropriate manner before the next stages of the treatment. The removal of organic compounds could be achieved by sorption method or in advanced oxidation process. In present work three methods of removing organic compounds from the low-level liquid radioactive waste were studied:

- physical separation of organic compounds by adsorption on activated carbons;
- chemical removing of organic compounds by ozonation and ultraviolet light decomposition and
- separation of organic substances from inorganic compounds (including radioisotopes) using a electromembrane process – electrodialysis (ED). The research on the treatment of liquid radioactive waste was accompanied by development of analytical methods necessary for process control and characterization of the waste at each stage of processing. The main techniques of characterization of liquid waste streams was the Alpha and Gamma spectrometry, Inductively Coupled Plasma Mass Spectrometry ICP-MS, and Total Organic Carbon (TOC) spectrometry.

Solutions for Specific Wastes / ID 95

DECOMMISSIONING OF RADON TYPE RADIOACTIVE WASTE STORAGE FACILITY IN LITHUANIA

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Maisiagala Radioactive Waste Storage Facility (MRWSF) in Lithuania is a Radon type disposal facility that had been in operation from 1963 till 1988 and was closed in 1989. It consists of a subsurface concrete vault with an overall volume of about 200 m3. The vault was filled to about 60 % with legacy radioactive waste (RW), ~114 m3) generated at industrial, medical, military and scientific research institutions. The RW was grouted layer by layer inside the vault cells. Since 2002 it has been super- vised by the SE Radioactive Waste Management Agency (RWMA) established in 2001 to deal with RW disposal. In 2019, after reorganization by merging RWMA to SE Ignalina NPP the supervision of MRWSF was transferred to Ignalina NPP which is also is charge of MRWSF decommissioning. Based on the results of safety assessment, in 2006 MRWSF was upgraded. Two protective HDPE membrane layers were installed on the top of the vault to prevent penetration of precipitation. After upgrading, MRWSF was licensed as an RW storage facility. However, high activity Cs-137 and Co-60 as well as long-lived disused sealed radioactive sources (DSRS) were placed into the vault during its operation, and hence this facility does not meet long-term safety requirements. In 2016 the decision was taken to retrieve RW from MRWSF and transport it to Ignalina NPP for further management. The site of MRWSF shall be remediated and released for unrestricted use. In 2011 Preliminary Decommissioning Plan of MRWSF was developed. In 2018 EIAR and FDP of MRWSF were developed and approved by the regulator and other state institutions. In 2020 Description of Decommissioning Project, SAR, Radionuclides Discharge into the Environment Plan and Radiation Protection Programme were developed and approved by the regulator. In 2021 Demolition Project was finalised. The tendering for installation of the support infrastructure for decommissioning has started. It is planned to finish the retrieval of RW from the site and to transfer it to Ignalina NPP in the beginning of 2023. In the paper, a detailed description of MRWSF and the waste loaded in the vault will be provided. The selection of the decommissioning strategy based on the MCDA analysis will be described. The auxiliary systems designed in the Demolition Project for the retrieval and transport of RW to Ignalina NPP will be analysed. Main safety issues analysed in the Safety analysis report and their results will be highlighted.

Solutions for Specific Wastes / ID 97

EFFECTS OF THERMAL LOAD ON BEHAVIOR OF CHERKASY BENTONITE AS A BUFFER MATERIAL

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The Ukraine a DGR concept considers the crystalline rock environments. The solution is based on the multiple barriers principle. The most common buffer material for engineered barrier system (EBS) is compacted bentonite, which features low permeability and high retardation of radionuclide trans- port. The task "Influence of temperature on clay-based material behaviour" of the EURAD project aims to develop and document improved thermo-hydro-mechanical understanding of clay-based materials (host rocks and buffers) exposed to high temperatures (>100°C) or having experienced high temperature transients for extended durations. Establishing the thermal limit for bentonite in a nu- clear waste repository is a potentially important, as the thermal limit plays on a major financial challenge requiring long-term strategic planning for used fuel management. Characterization of long-term mineralogical changes for EBS concerning the long-term geological evolution is needed for safety assessment purposes. To test the suitability and predicted functions of bentonite-based buffers under simulated repository conditions and to assess geochemical changes in minerals and porosity variations, thermal dehydration studies of bentonite were carried out at the temperature 150°C in "dry" and "wet" conditions. Commercial calcium bentonite (PBA-22 «Extra») was chosen as clay component of the buffer materials as less sensitive for saline rock water. The expected porosity enhancement and reduction as a result of mineral dissolution and precipitation, respectively, have been evaluated in experiments with elevate temperature in autoclave. Total surface area measurements show decreases with increasing of treatment temperature for this range. The decrease in cation exchange capacity also displays with increasing temperature. The connection between structural peculiarities of bentonite, and processes of heat treated is considered. The montmorilonite indicates changes induced by dehydration with temperature, there are change and a decrease of the XRD profile intensity with heating to 150°C. The predicting evolution of bentonite behavior so as the degree of montmorilonite hydration is a very important parameter for cation behavior as a function of the thermal load. Further studies will be focused on heat effects on hydrothermal alteration of bentonites on permeability and swelling pressure.

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LIQUID RADIOACTIVE WASTE TREATMENT – VOLUME REDUCTION IN SOLUTION THAT CONTAINING URANYL NITRATE

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The purpose of this work is to develop a concentration and precipitation process of uranium contained in radioactive nitric liquid waste, in order to improve conditioning and storage features of these wastes. Lab trials were performed using radioactive nitric liquid waste samples that contain natural uranium, with a concentration of 2 [g/L], which were concentrated in a solid phase by ions precipitation of metal method, using as reactive the ammonium hydroxide. This precipitation, filtration and drying reduces the volume until 85%, and also it transforms the liquid waste in a solid material that will be stored in physical and radiological protection conditions. On the other hand, the treated liquid is radioactively decontaminated, with an efficiency over than 99%. The lab trials results are the basis for taking this process into bigger volume treatment of radioactive liquid waste.

Solutions for Specific Wastes / ID 114

NON-DESTRUCTIVE MATERIAL CHARACTERIZATION OF RADIOACTIVE WASTE PACKAGES WITH QUANTOM®

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During the last decades, the nuclear and non-nuclear industry has produced a considerable amount of low (LLW) and intermediate level (ILW) radioactive waste. Though the waste form and streams might be different, such radioactive waste must be safely disposed in a final repository under the same strict waste acceptance requirements (e.g. the radiological and material characterization) de- fined by national licensing and supervisory authorities. Material characterization remains an indispensable criterion to prevent pollution of the ground water with toxic materials. Nowadays material description stays very challenging for waste producers, especially for legacy waste. It can be per- formed on the basis of existing documentation or, if the documentation is insufficient (e.g. legacy waste), on further destructive or non-destructive analysis. Destructive analysis is not favored as operating personal is exposed to radiation, the waste volume is increased, it is very time-consuming and generates high costs. Therefore non-destructive methods are to be preferred. Here, we present an innovative non-destructive technology called QUANTOM® (QUantitative ANal- ysis of TOxic and non-toxic Materials) based on Prompt and Delayed Gamma Neutron Activation Analysis (P&DGNAA). This technology is able to identify, verify and quantify the amount of hazardous and non-hazardous substances in waste packages such as 200-l radioactive drums. The technology can also be applied for larger volumes. The first prototype of QUANTOM® is already in operation and the results of the validation phase will be presented for the first time.
The main benefits of QUANTOM® are summarized below:

- Non-destructive multi-element analysis with high sensitivity (ppm-range) of the entire matrix
- Fast measurement process (2h-4h per waste drum) with high measurement precision
- No repackaging and no increase of waste volume
- Reduction of costs (min. 50% per waste drum) compared to destructive analysis processes
- Minimizing the transportation of radioactive waste drums and radiation exposure of the operationstaff.

Solutions for Specific Wastes / ID 115

CHARACTERISATION OF RADIOACTIVE BOUNDARY WASTES: A BAYESIAN SOLUTION

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Bayesian statistics is highly complementary to the Data Quality Objectives approach due to their underlying iterative principles. For waste characterisation this provides an opportunity for greater information for decision makers when analytical data approaches a waste boundary. The Bayesian t-test is analogous to the current statistical approach advised by CL:AIRE (Contaminated Land: Ap- plications in Real Environments) with the benefit of more completely using Prior information and allowing for the introduction of adaptive sampling strategies based on developing knowledge. This iterative approach provides a more fully underpinned justification for sampling numbers and provides increased flexibility for the DQO team than the more traditional statistical approach. Developed in a UK regulatory context and translated to a specified waste stream (fallen trees) from the Fukushima Daiichi Nuclear Power Station, this paper demonstrates potential benefits of this methods for a waste nearing the characterisation boundary and shows how the approach can be used to support decision making on radioactive waste disposal in a global context.

Solutions for Specific Wastes / ID 118

CONDITIONING AND IMMOBILIZATION OF INACTIVE ION EXCHANGE RESINS IN THERMOPLASTIC POLYMERS

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Radioactive waste as spent ion exchange resins (IER), must be conditioned for storage and disposal, in order to reduce the possibility of dispersion, elution and diffusion of radioactive elements to the environment. In this work, the immobilization of 0, 10, 20 and 30 wt% of dry cation exchange resins (CER), in linear low density polyethylene (LLDPE), high impact polystyrene (HIPS) and recycled polyethylene (RPE), was studied. Each blend specimen was studied non-irradiated and gamma irradiated with 100 kGy in 60Co facility. The properties studied were swelling, mechanical properties (flexural tests) and leaching resistance. The materials were formulated in a discontinuous mixer. The properties of the materials were measured using thermo- molded compression test specimen. The leaching tests were carried out only for the 30 wt% CER composition, loaded with an inactive solution of Cs+, Co2+, Ni2+ and Sr2+ cations measured by Total Reflection X-ray Fluorescence (TXRF). The study was carried out following procedures and recommendations of international standards. For CER immobilized in LLDPE, an increase in flexural modulus was observed as the percentage of CER increased as well as irradiated compared to non-irradiated samples. In the case of RPE, no differences were observed in flexural modulus, when varying the percentage of immobilized CER or for the irradiation condition. The materials formulated with HIPS showed a decrease in the flexural modulus with increasing the percentage of immobilized CER, with rupture of the test specimen. However, no difference was observed between the irradiated and non-irradiated samples. The cumulative fraction leached values were between 0.008 and 0.006 for Cs+ and 0.004 and 0.001 for Co2+, Ni2+ and Sr2+, respectively, for blend of 30wt% CER content in LLDPE and RPE. An increase was observed in the leaching values of the non-irradiated specimens compared to the irradiated ones for LLDPE. This effect was not observed for RPE matrix. The cumulative fraction leached for HIPS was 0.015 for Cs+ and 0.002 for the other cations, being higher in the irradiated than in the non- irradiated samples.No swelling effect was observed for any condition and studied material. The results obtained in this study showed that RPE presents the best performance as immobilizing matrix for 30wt% CER content. Using recycled plastic in nuclear industry is an opportunity to include plastic waste as a resource in the context of a circular economy.

Solutions for Specific Wastes / ID 122

THE IMPACT OF RADIATION LOADS ON THE STRUCTURE AND PROPERTIES OF THE CEMENT COMPOUND AS A PROMISING MATRIX FOR THE IMMOBILIZATION OF HIGH-LEVEL WASTE

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Cement materials have attracted great research interest as potential matrixes for the immobilization of high-level waste (HLW) due to their good mechanical properties and thermal stability. However, the effect of radiation on a cement compound containing HLW has not been enough studied. Therefore, the purpose of the research is to assess the regulated properties, composition and structure of cement matrixes based on Portland cement and granulated blast furnace slag after exposure to high doses of the ionizing radiation corresponding to HLW. Hot isostatic pressing (HIP) was chosen as a highly promising method for the synthesis of cement matrixes with HLW in an airtight container. Cement matrixes based on Portland cement and slag with a water-cement ratio 0,2 including imitators of liquid and solid HLW were prepared by HIP at the temperature range 200-300 ℃ and the pressure range 50-100 MPa. Test of cement matrixes for mechanical strength, frost resistance, and chemical resistance were performed. Results showed the compliance of their properties with the regulated requirements for hardened HLW. The effect of temperature (exposure at temperature up to 120 ℃) on the strength of cement matrices was estimated. The compressive strength of all samples at the 28 day of hardening was higher than the regulated value for cemented liquid radioactive wastes (LRW) (10 MPa). The strength of the samples did not depend on temperature. The reduction in strength after 30 freeze-melting cycles was less than 25%. The rate of leaching of Cs after 28 days was less than 10-6 g/(cm2·day). No structural and morphological changes were found after exposure to 120 ℃ and dose loads up to 109 Gy (electrons) and 1019 decay/g (alpha particles). The rate of Cs leaching on the 28 day of testing did not exceed 10-6 g/(cm2·day). The impact of radiation had a greater effect on the strength of cement matrixes based on Portland cement than on the strength of matrixes prepared based on granulated blast furnace slag. The use of slag, i.e. waste from metallurgical production, can be considered as a cheaper substitute for Portland cement.

Solutions for Specific Wastes / ID 123

PROCESSING DESIGN FOR A PYROCHEMICAL-DISTILLATIVE RECOVERY ALTERNATIVE IN NUCLEAR WASTE MANAGEMENT

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A conceptual design of a chloride distillation-based processing plant for spent nuclear fuel, also known as used nuclear fuel (UNF), processing, including recycling of the zirconium cladding material, was developed and fully simulated. First, the fuel is separated from zirconium cladding material. Cladding material and fuel are chlorinated and the components, mainly as chlorides, are separated by fractional distillation, respectively: for the fuel at ambient pressure and the cladding material at pressures above 23 bar. Simulation results have shown that neptunium tetrachloride and uranium tetrachloride as light boilers and plutonium trichloride with lanthanum, cerium and praseodymium trichloride impurities can be separated excellently within a distillation column with a minimum height of 1.22 m, applying the fractional distillation. The separation of these impurities can be carried out by a fractional distillation. If higher separation effort of maximum separable chlorides is required, the minimum column height increases to 4.25 m. Pre-fractionation of the chlorinated fuel material by, among others, single-stage distillation processes with crystallization at 625 K - 1135 K serves to separate volatile components and solids from the remaining chlorides. Fundamental goal of the present study was to propose entirely new options in nuclear waste management leading to reduction and closing fuel cycles to avoid final disposal. Furthermore, combination of the distillation process with reactors utilizing fast neutrons and operating at high temperatures of order 1200 K, proposed within the Dual Fluid principle, makes it even possible to burn out UNF material, and the remaining waste would only need to be stored for a few hundred years. Consequently, only 6 distillation-based separation units of 1000 t/a capacity each, working together with liquid fuel reactors for about 60 years, could completely consume the nuclear waste collected by the reactors of the second generation.

Solutions for Specific Wastes / ID 133

IMPROVEMENT OF ACCURACY IN WASTE CHARACTERISATION BY APPLYING INNOVATIVE TECHNIQUES (ASGS)

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The safety consideration in the management of radioactive waste is largely related to its radionuclide inventory due to the harm of ionizing radiation. Depending on the origin and the purpose (free-release or disposal), different pre-conditions such as activity levels or waste container properties need to be applied. The most effective and accurate method to determine the nuclide inventory of a waste drum is Gamma-Spectrometry using High Purity Germanium Detectors (HPGe). These detectors allow the direct measurement of decay-radiation from the nuclear waste and, due to the high energy resolution, the determination of activity for each gamma-emitting nuclide. In the last decades, several measurement approaches based on HPGe detectors have been developed and all approaches are using the principle that the detector "views" the drum from the outside. The advantage is that the waste drum does not need to be opened, but since the waste matrix has some shielding effects for the gamma-radiation, detailed knowledge about the drum content needs to be obtained in order to be able to calculate the nuclide activities. The less information that is available, the higher the uncertainties of the results are, which needs to be mitigated by adding some additional activity as a safety margin - so called virtual activity - to the best estimate of the activity obtained from the measurement. A large fraction of radioactive waste may deviate from calibration conditions applied in spectrometric radiation measurement, assuming a uniform activity distribution in their analysis model. This deviation results in a bias of the measurement result which needs to be accounted for as a so-called model-uncertainty of the measurement. Mirion Technologies (Canberra) developed and validated in cooperation with Aachen Institute for Nuclear Training (AiNT) an innovative measurement approach which allows more accurate results and therefore applying lower uncertainties. This new measurement approach extends the concept of a standard Segmented Gamma Scan (SGS) by performing sectorial measurements of single drum sectors in addition to segments, hereby gaining information on the spatial distribution of the activity within the drum. The goal is to perform gamma scans with high throughput and an accurate analysis based on the reconstruction of activities for each sector. The new approach has been developed, tested and validated with a measurement system and calibration drums. The comparison with SGS shows, that the novel method increases the measurement accuracy for non-uniform activity distribution hereby allowing the reduction of model uncertainties by a factor two to three, depending on the density of the waste matrix.

Solutions for Specific Wastes / ID 136

ONE STEP LOW TEMPERATURE THERMOCHEMICAL PROCESS IN AIR AT ATMOSPHERIC PRESSURE TO DENITRATE A SIMULATED HLLW WITHOUT OR WITH ADDITION OF AN ALUMINOBOROSILICATE GLASS POWDER

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A novel method published as patent WO2021019319 [1] was applied to denitrate a 3 M nitric acid stream of uranium, lanthanides, metals and non-metals which simulates the high level liquid waste (HLLW) arising from heavy water reactor (HWR) spent fuel reprocessing [2]. Once the denitration of the simulated HLLW was demonstrated a second and third set of tests were run by adding 50 wt.% or 90 wt.% of the German SG7 aluminoborosilicate glass powder to the HLLW in order to denitrate the mixture for obtaining the high level waste (HLW) form material. Once the 3 M nitric stream of nitrates or oxides of uranium and lanthanides, metals and non-metals was prepared, polyacrylonitrile (PAN) fibers dissolved in concentrated nitric acid were added. Denitration takes place in just one step by thermally treating the nitric steam without or with added glass powder in air at atmospheric pressure and temperatures between 185°C and 225°C to obtain a homogeneous nanoparticulated loose dry ash. The thermochemical process which was developed at inactive laboratory scale merges in a low tem- perature single step in air at atmospheric pressure all steps from concentration, denitrification, glass mixing, milling to drying and reduces, in this way, the formation of radioactive volatile compounds as well as the generation of secondary waste streams. The glass, glass-ceramic or ceramic matrix – in our work the German SG7 aluminoborosilicate glass in the form of a powder with a particle size in the range of 1-100 μm is added and mixed to the nitric stream to render the HLW form material which can subsequently be cold pressed and sintered or hot pressed at temperatures in the range of 610-825°C, or melted at temperatures in the range of 1100-1500°C. The resulting material from the thermochemical process is a dry ash of porous nano-metric particles which presents a homogeneous elemental distribution for both the HWR HLLW components and the German SG7 aluminoborosilicate glass. Results to be reported include scanning electron microscopy, energy dispersive spectroscopy, X-ray diffraction, thermogravimetry and differential thermal analysis.

Solutions for Specific Wastes / ID 137

PYROLYSIS AND HIGH PERFORMANCE PLASMA TREATMENT APPLIED FOR THE TREATMENT OF SPENT ION EXCHANGE RESINS

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Spent ion exchange resins (IERs) represent an important waste stream that is generated during the operation of nuclear power reactors and research facilities reactors. Over the past 70 years of nuclear activity, Argentina has accumulated near 400 m³ of spent IERs that remains storage for an adequate conditioning before disposal. An optimal processing option must involve volume reduction, production of a stable waste form and low radiological and environmental impact. Many technological options that fulfill these requirements were developed and applied in the nuclear industry worldwide, however, due to the size of the current inventory of our country is challenging to choose a favourable economic solution. In the last few years, our research group has been working on a novel two-step process involving initial low-temperature pyrolysis (< 350°C) of the IERs followed by a high performance plasma treatment (HPPT) of the produced off-gases. A bench scale arrangement that combines both technologies was assembled in our laboratory. The system works at sub atmospheric conditions and water steam is added to the gas stream as reagent. It has been observed that the presence of water in the medium results in the improvement of the properties of the solid product obtained, as well as participating as an oxidizing agent in plasma chemistry, contributing to the high performance of the off-gas treatment. The test results achieved using this arrangement were successful and demonstrate the feasibility of the proposed treatment concept. Also it is possible to take it to a reasonable scale implementation in a simple way, ensuring compliance of the requirements in terms of safety profile and minimum environmental and radiological impact. The present work will provide an overview of the overall process under development, paying particular attention to the obtained solid waste form characteristics and the efficiency of the off-gas treatment system.

Solutions for Specific Wastes / ID 145

STRATEGIES FOR THE MANAGEMENT OF GRAPHITE WASTE ARISING FROM THE DECOMMISSIONING OF UNGG REACTORS

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The decommissioning of UNGG ("Uranium Naturel Graphite Gaz" or "Natural Uranium Gas Graphite" in English) reactors inevitably creates the issue of managing the arising irradiated graphite, both from the reactor pile and from the sleeves surrounding the fuel elements. The irradiated graphite is considered as a long lived intermediate level waste in France and is not contact handle able. In France, EDF is responsible for the decommissioning of six UNGG reactors and as such EDF, along with its subsidiaries of Cyclife and Graphitech are developing innovative ways of managing the irradiated graphite that has arisen and will arise in the future from the decommissioning programme. EDF currently has three major projects underway relating to the management of graphite waste:

— The retrieval of graphite sleeves currently stored in a silo at the Saint Laurent des Eaux UNGG site will use remote handling techniques to retrieve, package and transfer graphite sleeves from an inaccessible area.
— The optimisation of the scenario for the graphite structures retrieval in line with the waste trans- fer route for graphite arising from the dismantling of the reactor pile of the Chinon A2 UNGG reactor. This has been done using digital tools developed specifically for the nuclear decommissioning industry. This has demonstrated a possible net increase in the number of packages that could be able to be evacuated from the work face each day, and which could become necessary as a result of the scenario optimisation and to face better production rates.
— EDF is constructing an Industrial Demonstrator that will be used to de-risk the UNGG decommissioning programme. A part of this will be dedicated to the cutting and removal of graphite bricks and keys from the reactor pile and how to size the resulting waste to optimise waste packing factors.

This paper will summarise each of the projects and highlight the principal strategic approaches to managing the graphite arising from UNGG reactor decommissioning and how these approaches may be implemented by graphite reactor decommissioning projects outside of France.

Solutions for Specific Wastes / ID 146

HOT RESIN COMPACTION

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Ion exchange resins (IEX) which are used in nuclear power plants have to be treated and dried, in order to ensure a safe storage in future. A main advantage of the hot resin compaction during mentioned treatment process, is the saving of limited storing capacities in comparison to non-compacted IEX based on the enlarged volume reduction factor (VRF) of compacted IEX. Supplied and temporarily stored IEX have to be transported as IEX / water mixture by piping systems and pass various treatment steps as part of the conditioning process. Some of these processes are necessary preparations for hot resin compaction. Mentioned preparations includes for example the grinding of resins via mill. The grinding process is necessary in order to avoid a possible spring-back effect of the IEX. The mentioned effect can cause the IEX to return into their original form which leads to deformation and expansion of compacted pellets. Ground IEX are transported to be dried before they are filled fully automatically into a compactable drum. Afterwards, the drum has to be transferred to the high force compactor (HFC). After entering the high force compactor, the drums are compacted before the resulting pellets are going through the last process steps as part of their treatment and subsequent storage. Various test series were necessary to adjust the individual process steps and develop the overall process. The hot resin compaction as a part of the waste conditioning and the executed test series are described more in detail in the paper. Based on experiences and successful design, the hot resin compaction process was successfully implemented in Tianwan, People´s Republic of China by NUKEM Technologies Engineering Services.

Solutions for Specific Wastes / ID 148

PILOT-INDUSTRIAL CONDITIONING OF SPENT RADIOACTIVE ION-EXCHANGE RESINS

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During the processing of liquid radioactive waste (LRW) at nuclear power facilities, concentrates (high-salt LRW) and spent filter materials are produced, the main of which are ion exchange resins (IER). The available volumes for their storage at all Russian facilities are almost exhausted. A significant share of IER in the total amount of accumulated LRW excludes the possibility of their joint processing. For the processing of IER, it is necessary to create special installations. At present moment there are no industrial installations for IER processing in Russia. Various methods of processing and conditioning of radioactive IER used in the world practice were tested at RADON FSUE. Among them, destructive methods (pyrolysis, peroxide oxidation, supercritical water oxidation) and non-destructive methods (drying, dehydration, inclusion in matrix mate- rials) were tested. The comparison of different methodes is carried out according to the following criteria: compliance with the requirements of regulatory documents, the specific activity of the IER and the availability of certified packaging, the capacity of the installation. The cost of IER processing by technologies that meet the selected evaluation criteria is estimated. Minimum handling costs are typical for dewatering and incorporation into the polymer binder. Therefore, further work was aimed at testing this technology of IER conditioning on a pilot-industrial scale.

Solutions for Specific Wastes / ID 149

HARDNESS BEHAVIOR OF U3O8 PELLETS: AN OPTION FOR THE MANAGEMENT OF RESEARCH REACTOR SPENT FUEL

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The CERUS project was developed by the Argentinean National Atomic Energy Commission (CNEA) according to the strategies of spent fuel management policy declare at the National report for the Joint convention on the safety of spent fuel management and on the safety of radioactive waste management, in order to achieve a predisposal treatment to the conditioning of U3Si2-Al clad spent fuel. Research Reactor Spent Fuel (RRSF) management is challenging due to the enrichment at discharge higher than 11% of 235U . Due to criticality considerations and susceptibility to materials degradation, direct disposal cannot be a viable option for U3Si2-Al clad RRSF management (IAEA-TECDOC- 1508, 2006). The main idea of the process consists of the use of natural (or depleted) uranium oxide to achieve the isotopically dilution down to 1% 235U and seeking for a monolithic ceramic wasteform with uranium octoxide (U3O8) as immobilization matrix. Previous research works carried out at the Bariloche Atomic Center (CAB) focused on the characterization of a mixture of natural U3O8 and, calcined and milled aluminium clad-uranium silicide (natural) plate (Russo et.al. 2002). This study proposes the continuity of the research of U3O8 pre- cursor powders that began with the study of densification behaviour by Chavez et.al. (2018). Several samples 9 mm in diameter, uranium oxide pellets, cold-pressed and sintered, were obtained by two routes of powder synthesis: AUC-ammonium uranyl tri-carbonate (Argentina's UO2 industrial process), and ADU-ammonium diuranate. Finally, were characterized by Archimedes method of immersion to obtain the porosity as well as ceramography, optical and electronic microscopy to reveal the shape and morphology of the ceramic matrix. This work addresses the response of micro-indentations on the sintered pellets. Indentation measurements of Vickers and Knoop were done to relate with the hardness of U3O8 ceramic matrices. Lastly, samples were observed in a Scanning Electron Microscope (SEM) to characterize the fractures initiated in the notches.

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MANAGEMENT OF LIQUID RADIOACTIVE EFFLUENTS FROM HOSPITALS WHERE PUBLIC SEWAGE SYSTEM IS NOT ESTABLISHED

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The prime source of liquid radioactive waste generation in hospitals is high dose radionuclide therapy facilities, as high levels of activity is handled in such facilities. The most common radionuclide therapy world-wide is radioiodine therapy and the same is the case in India too. As per the existing regulations, radionuclide therapy using I-131 with activity more than 1.11 GBq is carried out in isolation wards with attached toilet facilities. Plumbing lines from these toilets are connected to a delay- decay tank in order to allow the radioactive effluents to decay to an acceptable limit, and eventually released to the Public Sewage System. Though, radioiodine therapy is a proven method for the treatment of Ca- thyroid patients, it was limited, till recent times, to hospitals in major cities mainly because of the difficulties in management of Radioactive liquid effluents arising from the therapy wards. Around 80% of the administered activity is released through patient excreta in first 48 hrs of treatment. Hence, an effective waste management system should be in place in order to reduce the environmental radiological Impact. In India, there are “110” hospitals providing high dose radioiodine therapy and radioactive waste generated in the form of liquid effluents from these facilities is decayed using a dual delay-decay tank system before discharging to main sewage line. The capacity of the tank is 3000 litres per patient bed. The radioactivity concentration should not exceed 22.2 MBq/m3 when releasing it to the main sewage system as stipulated in Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. In few occasions, when the hospital is in the outskirts of cities, they are not connected with the established sewage systems and hence management of such wastes becomes a challenge. In order to facilitate the patient treatment and management of radioactive waste generated in such scenarios, a potential alternative to public sewage system for radioiodine therapy facilities have been established. One of the solution would be that after due decay to an acceptable limit from delay-decay tank, the effluents can be transferred to a septic tank, made of concrete. Further management of these wastes from septic tank is either by manually collecting and transferring these wastes to municipal sewage plants or by permanently storing in soak pits within the facility.

Solutions for Specific Wastes / ID 153

PALM OIL FUEL ASH (POFA) SUPPLEMENTED CEMENTITIOUS MATERIAL FOR CONTAINMENT OF RADIUM

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Safe and secure management of disused sealed radioactive sources (DSRSs) represent a challenging topic in the field of radioactive waste management. In particular the end of life-cycle management of these sources is not a straightforward problem due to the variability of the radioactivity content and the half-lives. Among the different end of life cycle management strategies for these sources, storage and disposal strategy represents an appealing solution from the technical, safety, and security points of view. In this respect, small diameter borehole disposal concept was recommended by IAEA, as an efficient, economical, and secure disposal concept for these sources. This disposal concept relies on the use of cementitious backfill, as a part of the engineering barriers, to support the structural integrity of the facility and to confine radioactivity within the facility. An integrated research project was established to support the design phase of the borehole disposal facility in Malaysia that aims to optimize the cementitious backfill barrier by investigating its mechanical and confinement performances. The mechanical performance was optimized by varying the mix design of the backfill materials. The confinement performances of radium, caesium, and strontium was studied by assessing the batch kinetic, isotherm, and equilibrium sorption behaviour for optimum palm oil fuel ash (POFA)-supplemented cementitious and control OPC backfill materials toward these contaminants. In addition, diffusion experiments were carried out to study the migration of the radio-contaminants of interest. This paper is devoted to summarize some of the important findings from this integrated research project on radium containment in POFA-supplemented cementitious material. A summary of the batch investigation results will be presented, where results of sorption equilibrium time in both POFA cement and OPC materials, the nature of the reaction and the controlling sorption mechanism will be identified. The diffusion experiment setup will be presented and results will be used to calculate the diffusion coefficient in the proposed backfill materials.

Solutions for Specific Wastes / ID 170

MONTE CARLO FORECAST FOR ^{241}AM/BE DSRS MANAGEMENT OPTIMIZATION

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The present research provided an optimal option for Disused Sealed Radioactive Sources (DSRS) management based on Monte Carlo simulation. The objective is to design the appropriate means for radioactive waste conditioning so as to avoid material and economic losses based on trials during the sources' dismantling. The Particle and Heavy Ion Transport code System (PHITS) was used to design waste containers with appropriate DSRS to get the ALARA principle of dose limitation in the boundary of the waste cast. The investigated radioactive waste was made of several disused Am-241/Be neutron sources previously used in well-logging and petroleum exploration in the Gulf of Guinea (CAMEROON). From the obtained result, the effective thicknesses of the provided P60 capsule, the paraffin material, and the barite concrete were sufficient to set the effective dose in the adjacent areas less than 2.5 µSv/h. The 08 DSRS used for the simulation totaled an effective activity of 450 mCi on June 1st, 2021, which is less than the recommended value of 2 TBq as recommended by the P-60 capsule manufacturer. In addition, the simulation using the source activity limit as recommended by Eckler & Zekler company demonstrate an agreement with the targeted result of less than 1 mSv in the adjacent public area to the interim storage facility. Further investigations are under de- velopment regarding gamma sources in Cameroon. The obtained results are stored for the upcoming IAEA expert mission with the purpose of dismantling and store the DSRS in Cameroon.

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NOVEL TECHNOLOGY DEVELOPMENTS FOR WASTE CONDITION MONITORING & INSPECTION BY SELLAFIELD LTD THROUGH COLLABORATION WITH THE SUPPLY CHAIN

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The safe storage of chemically reactive radioactive waste, under water cover within a robustly engineered system, for a prolonged period requires understanding of its history and the ability to predict future behaviour. Condition Monitoring and Inspection (CM&I) is seen as the final step in the hierarchy of controls used to demonstrate the longevity of interim stored waste. Such monitoring and inspection will provide evidence that the waste packages continue to be compliant with the safety case requirements and that Sellafield Ltd. (SL) is complying with the Site Licence Conditions through confirmation that evolution is progressing as expected throughout interim storage whilst remaining compliant with the Radioactive Waste Management Ltd disposal requirements. CM&I takes account of the technical risks, potential waste evolution and performance requirements of both store and waste container. It should be proportionate to the levels of concern (residual risk) associated with each of the waste types. This provides reassurance that the overall performance of the storage system is protective of people and the wider environment. A number of technologies are being developed to support monitoring of packages in the stores (in- situ) or for more detailed examination on packages retrieved from the stores (ex-situ). This presentation describes the novel technologies developed by Sellafield Ltd through collaboration with the supply chain to meet our CM&I requirements - specifically:

— Muon Tomography, for viewing inside the packages for waste expansion, water consumption, corrosion/deformation of package internals.
— Range-resolved Hydrogen Detection (raman spectroscopy at distance). The rate of hydrogen gas release is a useful indicator of reactions taking place, however it is very difficult to measure in a real system constrained by space, access, remote operations, competing ventilation flows, and low hydrogen release rates.
— Acoustically detecting and locating deflagrations (not expecting any but cannot be dismissed),
— Real-time image enhancement for existing camera systems (currently installed store cameras were not intended for CM&I),
— and a summary of others being evaluated such as High Energy X-Ray, filter performance monitoring, thermal imaging, LiDAR, and structured light scanning.

The paper also addresses deployment challenges in remote handled vault stores and how engineering, operational and maintenance requirements can be considered in early stage technology development.

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PROMISING PRE-DISPOSAL SOLUTIONS TO MANAGE SPENT RADIOACTIVE ION- EXCHANGE RESINS

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Nuclear decontamination processes generate a wide range of radioactive waste to be properly man- aged. Spent ion-exchange resins (IER) are a large component of radioactive low and intermediate level waste. The development of suitable treatment and conditioning processes is an urgent task to address, as the challenging waste nature (flammability, dispersivity, swelling), high radionuclides leachability (e.g.: Cs) and final waste package volumes do not comply with Waste Acceptance Crite- ria (WAC) of modern nuclear waste repositories. Nowadays, advanced pre-treatment processes are preferred to direct encapsulation of spent IER, to reduce organics content and volume of the package, thus limiting corrosion and flammability troubles, and optimizing footprint and costs of the final repository. In this work, IER thermal incineration and Fenton-like wet oxidation have been studied at laboratory scale. A stepwise thermal treatment based on spent IER incineration is being optimized by slowing the gasification process to gradually convert cesium volatile species into inorganic and thermally stable compounds. A simplified surrogate waste was prepared by loading nuclear grade cationic IER with CsNO3 solutions. Thermo- gravimetric analysis has allowed to optimize residence time and temperature ramp rate, to enhance the conversion of the (-SO3-Cs+) functional group into less-volatile cesium sulphate. Incineration has been performed into a muffle furnace up to 800 °C. The obtained ashes have been characterized by Raman and X-Ray Diffraction (XRD) analyses, while Cs retention efficiency has been calculated by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) analysis. The wet oxidation process has been optimized by tuning temperature, catalyst and oxidant concentration. The decomposition over time of a surrogate waste containing Cs, Co, Sr and Ni, as representatives of activation and fission products contamination, has been monitored by Raman and FT-IR spectroscopy. The residue left after treatment has been investigated by XRD to prove the process efficacy. The nuclides distribution has been monitored by ICP-MS analysis. Finally, the obtained ashes and sludges will undergo encapsulation into a geopolymer matrix as promising alternative to Ordinary Portland Cement, to provide physical and chemical stability according to the WAC. Dry and wet oxidation tests showed a promising weight reduction and good organic decomposition of the treated spent IER. For resin batches treated at 800 °C, promisingly high cesium retention into the ashes has been obtained. A homogeneous residue and a weight reduction rate of 40% turned out from optimization of wet oxidation. Ongoing activities are focused on developing and characterizing residue geopolymer encapsulation for long-term disposal.

Solutions for Specific Wastes / ID 179

ELECTROCHEMICAL DECONTAMINATION OF RADIOACTIVE SOLUTIONS FROM PHADEC-BASED PROCESSES ENHANCED BY ADDITION OF CO-PRECIPITATION AGENTS

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An advanced Phosphoric Acid Decontamination (PHADEC)-based process is being developed to manage the large amount of contaminated metallic materials coming from dismantling activities in nuclear decommissioning. Volume savings of the final waste, lower environmental footprint and reduction of secondary waste by declassifying scrap metals and reusing decontaminated phosphoric solution are the main goals of the process. This PHADEC-like method relies on the following steps: i) dissolution of the superficial contaminated layer of scrap metals by phosphoric acid, ii) oxidation of the pickling solution, iii) electrochemical precipitation of iron and contaminants phosphates, and iv) conditioning of the dried precipitate by vitrification. From commercial steel pickling and oxidations steps, a simplified surrogate metal liquor was pre- pared by adding 500 Bq each of Co-60, Sr-85, Cs-137 and Ni-63 radiotracers, as representatives of activation and fission products contamination. The electrochemical process conducted at laboratory scale (120 mL) showed a precipitation yield of about 35% for Co-60 and Ni-63, 25% for Sr-85 and 50% for Cs-137. To reuse the phosphoric acid solution in a pilot plant, the electrochemical decontamination needs to be improved. The concentrations of the radionuclides in the dissolved metal liquor might be much too low to reach the product solubility constants of the contaminants phosphates. Research efforts are being focused on the potential role of co-precipitation agents in the electrochemical precipitation step. Notably, precipitation tests have been performed in the same configuration cell by adding stable Co, Cs, Sr and Ni ions and introducing BaSO4, Ca2P2O7 and Ca3(PO4)2 com- pounds in the concentration range 0.1-0.3 M. BaSO4 and Ca2P2O7 at a concentration of 0.3 M showed a slightly improved abatement of contaminants into the precipitate (both around 50% against about 30% without adding co-precipitation agents). More promising results have been found after using 0.2 M Ca3(PO4)2, that promoted an abatement of about 70-75% of initial contamination. Focused improvement of the decontamination yields is carried out by tuning the concentration of the co-precipitation agents and investigating new experimental setups by varying the solution volume or managing more electrochemical precipitation stages. The best experimental conditions will be adopted in performing electrochemical decontamination tests, by adding the most promising co- precipitation compounds to surrogate metal liquors spiked with radioactive solutions. The outcomes of this research will encourage a large-scale implementation of the process.

Solutions for Specific Wastes / ID 181

MANAGEMENT OF CO-57 & GE-68/GA-68 SEALED RADIOACTIVE SOURCES THAT ARE USED FOR CALIBRATION OF NUCLEAR MEDICINE SYSTEMS

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A variety of sealed radioactive sources, such as Co-57 and Ge-68/Ga-68, are used for the precise calibration of nuclear medicine systems. After their useful life, these sources need to be handled and kept into storage until they meet the general clearance criteria. For clearance after storage, it is necessary to determine the source activity by measurement. The only way is to evaluate the detector efficiency for specific source-detector geometry. In case of complex geometries, a common approach to perform the efficiency calibration is simulation by Monte Carlo. The aim of this work is to determine the activity of spent sealed radioactive sources of Co-57 and Ge-68/Ga-68. Based on Monte Carlo simulation, a semi-empirical method was developed by utilizing the MCNPX code for evaluation of the 3'x3' NaI(Tl) detector efficiency for specific source–detector geometries. More specifically, gamma-ray spectrums were taken by a NaI(Tl) detector for two types of sealed radioactive sources: 1) flood sources containing Co-57; 2) line sources containing Ge-68/Ga-68. The characteristic gamma ray peaks in the resulted spectrums by the decay of Co-57 (122 keV (85.6%), 136 keV (10.68%), 692.03 keV (0.157%)) and Ge-68/Ga-68 (1077 keV (2.93%)) [1], were analyzed with the software package SPECTRW [2]. For the specific source-detector geometries and gamma ray energies, simulations were performed with the MCNPX code for evaluation of the NaI(Tl) detector efficiencies. The MCNPX models were validated by the use of sources of the mentioned types with certified nominal activities. Gamma-ray spectrums taken for different time intervals (7h, 2h, 15min for Co-57 and 7h, 1h, 15min for Ge-68/Ga-68) showed that, 2h measurement was adequate for the activity determination of the flood source Co-57, while 1h measurement provided adequate statistics for the activity determination of the line source Ge-68/Ga-68. The deviation from the nominal activity was 13.6% and 26.8% for Co- 57 and Ge-68/Ga-68 source respectively and can be interpreted by the 15% uncertainty of the certified sources activities. The sources after meeting the clearance criterion can conservatively be kept in the interim storage additionally for four months before release from regulatory control. These techniques proved accurate for the clearance of Co-57 and Ge-68/Ga-68 sealed radioactive sources.

Solutions for Specific Wastes / ID 184

IMPURITIES CHARACTERIZATION TO SUPPORT DECOMMISSIONING AND MANAGEMENT OF IRRADIATED GRAPHITE WASTE

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Nuclear graphite has been widely used as moderator and reflector in I and II generation reactors and it is being considered for some next generation projects. Several graphite-moderated nuclear reactors have already been permanently shut-down, and others will be in the next years. Therefore, decommissioning of this material is becoming an important issue, given that an ultimate strategy for treatment and disposal has not been found, yet. In fact, the very large use of nuclear graphite is often accompanied by some knowledge gaps, such as activation of impurities in the irradiated material. Experiments reported in the paper aim at obtaining a complete characterization of virgin graphite: an accurate elemental composition of the non-irradiated material is a vital input data for those neutron activation models that are commonly used to estimate radionuclides inventory and to support the radiological characterization before dismantling operations. Inductively coupled plasma mass spectrometry (ICP-MS) analysis can be implemented to quantitatively assess the presence of large numbers of analytes, with high sensitivity. On the other hand, neutron-activation based techniques, as prompt gamma neutron activation analysis (PGAA), can be effectively applied to measure those lighter elements for which mass spectrometer would be ineffective. The proposed experiment con- siders samples obtained from a virgin graphite rod. ICP-MS results revealed to be mostly consistent with literature history on different types of nuclear-grade graphite, while PGAA confirmed with a good margin the bulk concentrations for most of the nuclides obtained by ICP-MS analysis, and allowed evaluations on the lighter ones. Future works on nuclear graphite could involve analysis on activated samples, in order to compare and validate the already obtained characterization on virgin graphite.

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CHARACTERIZATION AND INVESTIGATION ON LONG-TERM STABILITY OF SODIUM ACTIVATED METAKAOLIN-BASED GEOPOLYMERS

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Geopolymer is a group of newly derived barrier materials for stabilization of radioactive wastes. In this study, we characterized the sodium activated metakaolin-based geopolymer (Na-MKGP) including the base material, metakaolin, and additionally processed sample which is stated as treated Na-MKGP. Furthermore, the long-term stabilities of the Na-MKGP were investigated as a function time to see their mineralogical and structural changes through 6 months period by sampling of 20 supernatant and 3 solid samples. The solid samples were examined by FT-IR, Raman spectroscopy, XRD, and XRF for the changes of their mineralogical and physicochemical properties. In addition, the supernatant samples were analyzed with ICP OES for Na, Si, and Al concentrations to trace any dissolution process while the pH of suspension was monitored regularly before each sampling. The aim of the study is to deepen our knowledge on the physicochemical stability and robustness of the Na-MKGP for its application to the nuclear industry.

Solutions for Specific Wastes / ID 203

TAKING A LIFECYCLE VIEW FOR THE MANAGEMENT OF LEGACY METALLIC FUEL

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Metallic uranic fuel has been used in the United Kingdom's Magnox fleet of reactors since the 1950s, with the Magnox reprocessing plant at Sellafield forming a key part in the management of spent fuel with over 54,000 tonnes reprocessed to date. Following the retirement of the Magnox reactor fleet and planned completion of reprocessing, the UK will possess an inventory of several hundred tonnes of metallic uranic fuel that will need to be managed and dispositioned. Metal fuel is not passively safe; its chemical reactivity poses a problem across the lifecycle of storage, treatment and ultimate disposal. At each stage of this lifecycle, the potential for expansive corrosion, gas generation, fission product release and uranium hydride formation must be managed to ensure ongoing human and environmental safety. This paper describes the approach being undertaken to manage the remaining inventory of metallic uranic fuel in the UK to understand how this material should be stored, packaged and ultimately disposed of in a geological disposal facility. The paper will describe how the following key questions are being considered to manage the lifecycle balance of risk for the remaining inventory:

— How do you make hundreds of tonnes of metal fuel passively safe and what is the right disposal concept for metallic fuel?
— How do you minimise the impact of dose and cost now while ensuring long-term passive safety, sustainability and intergenerational impacts?
— How do you balance the risk of near-term safety with long-term uncertainty?

The paper explains the collaborative approach that has been adopted between the material custodian (Sellafield Ltd) and the geological disposal facility developer (RWM) to understand the risks at each stage in the waste management lifecycle. This information will then be used by the waste owner (NDA) to make risk-informed decisions on the questions set out above.

Solutions for Specific Wastes / ID 209

DISMANTLING AND SAFE MANAGEMENT OF IONISATION SMOKE DETECTORS AND LIGHTNING PREVENTORS CONTAINING RADIOACTIVE SOURCES IN THAILAND

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Ionization smoke detectors as a kind of fire alarm device mounted on the building ceiling and the lightning prevention containing radioactive substances were collected from building construction companies and radioisotope users in Thailand. The most common ionization smoke detectors contain americium-241 with activities up to 0.666 MBq lightning preventers contain americium-241 or radium-226 with activities up to 695 and 432 MBq, respectively. Several thousand pieces of these de- vices were labeled, recorded, packed, and stored in the radioactive waste storage building for several decades. Although the activities of these devices are low however due to a large number of these devices and the long half-life of the radioisotopes, special attention was considered. In the year 2020, Radioactive Waste Management Center (RWMC), Thailand Institute of Nuclear Technology (TINT) launched the management plan to improve the safety and security of the category 3-5 dis-used sealed radiation source in Thailand. The management plan is considered to conduct in compliance with Thai's regulation, the IAEA safety standards, and international practices. Dismantling and conditioning of these devices were planned. The relevant documents for conditioning authorization were submitted to the nuclear regulator, Office of Atoms for Peace (OAP), for approval. Ionization smoke detectors and lightning prevention using radioactive substances were dismantled. Radioactive sources were removed from the devices, encapsulated in the stainless-steel tube containers, and overpacked in the lead shielded concrete drums for future management. Source inventories were registration recorded. Successful implementation of the plan was achieved. 6,000 pieces of sources were conditioned and the volume reduction of the devices was more than a thousand times.

Solutions for Specific Wastes / ID 210

LIFETIME OF LONG-LIVED NUCLEAR WASTE IN ACCELERATOR-DRIVEN SUB- CRITICAL SYSTEMS UNDERGOES TRANSMUTATION PROCESS

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Nuclear waste is one of the big issues of public acceptance of nuclear energy or nuclear uses in general. Nuclear waste is classified into high-level waste, transuranic waste and low-level waste. High level waste (HLW) can be transmuted into non-hazardous materials. Accelerator-driven system is used to transmute nuclear waste, moreover it can produce energy for generating electricity at the same time. ADS consists of two main parts: the accelerator and the subcritical reactor. In this study, the fuel density inside the subcritical reactor depends on the concentration of U-ThO2(NO3)2, PuMA(NO3)4 dan HNO3 (liquid phase). The reactor reaches subcritical conditions for RGPuMA, WGPuMA, SGPuMA when the concentration of PuMA-Nitrate is above 62.6 kmol/m3, 65.6 kmol/m3 and 66.6 kmol/m3 respectively. The investigation is to determine time taken of a subcritical reactor transmuting the long-lived nuclear waste to shorter-lived. Therefore, after the transmutation process the waste can be saved safely inside the nuclear waste repository.

Solutions for Specific Wastes / ID 211

THE IAEA DATABASE ON RADIOACTIVE DEVICES CONTAINING DEPLETED URANIUM (DU) AS RADIATION SHIELDING

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There is a large inventory of disused sealed radioactive sources (DSRS) that have been accumulated in various Member States, and it is likely to continue increasing over time, given the current and future potential use of sealed radioactive sources worldwide. In the context of the safe management of DSRS, an important and emerging issue of immediate concern is the management of Depleted Uranium (DU) contained in radiation shielding materials. In order to enhance the safe management of devices containing DU, the IAEA has developed a database that includes information about devices which contains DU as shielding materials for sealed radioactive sources (SRS). The Database contains basic information on more than 500 models of radioactive devices (used in medicine, industry, research and agriculture) that contains DU as shielding material. The information includes (1) the device model, (2) the manufacturer and/or distributor, (3) the amount of DU (in Kg) in each model, (4) the use of the device, and (5) Pictures of each device to facilitate the proper identification. Additional relevant information (e.g. years of production/distribution, radionuclide shielded) is included in the "comments" field. The Database is published under the Professional Network DSRSNet, and it is readily accessible to all professionals registered users for the DSRSNet. The Database is particularly useful for Member States to compete their national inventories of DSRS and, prepare their national strategy for the safe management of DSRS. The database also helps Member States in complying with their safeguard obligations. The database is being recurrently used by safeguard professional and inspectors in identifying such nuclear material.

Solutions for Specific Wastes / ID 221

OVERALL OPTIMIZATION OF RADIOACTIVE WASTE PROCESSING AND DISPOSAL FOR PROBLEMATIC WASTE MANAGEMENT

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Japan Atomic Energy Agency (JAEA) has stored much of its waste generated from R&D activities related to nuclear science and technology. A part of these wastes contains compressed waste without prior radiological, chemical or physical characterization assessed, as well as mixed waste containing lead and mercury with little information about its contents. Such problematic wastes have been manually unpacked and segregated to separate combustibles and hazardous materials for final disposal and these pretreatment efforts are very time consuming and costly. Additionally, since radionuclide composition of problematic wastes is complex and variable, the wastes are planned for homogenization through plasma melting and destructive radiological analysis is considered as a method for its radioactivity characterization. Such characterization efforts are also very time consuming and costly. In order to optimize the processing and disposal of problematic wastes, a method to balance the processing work and disposal facility robustness was studied. This makes sense as JAEA is not only a waste generator but also the implementation body for the near-surface disposal project. Regarding the separation of combustibles, total volume of the combustibles will be evaluated using nondestructive inspection technique such as high-energy X-ray CT and the waste that does not comply with the waste acceptance criteria should be mixed with low combustible material waste in order to satisfy the waste acceptance criteria on a disposal facility average. Regarding the separation of hazardous materials, they will be identified using records and nondestructive inspection. The waste identified as hazardous will be unpacked and segregated. Based on preliminary inspection of about 1,000 drums, only 10 % of stored drums contain hazardous materials and need segregation. Regarding radiological characterization, the establishment of a conservative scaling factor method and non-destructive gamma-ray measurement can eliminate the need of plasma melting. It was estimated that processing throughput of compressed waste should be increased about 5 times more than present method by applying the countermeasures.

Solutions for Specific Wastes / ID 223

MANAGEMENT OF RADIOACTIVE CONTAMINATED ELECTRIC ARC FURNACE SLAG USING CEMENT IMMOBILIZATION METHOD

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Scrap steel metals have played an important role in the steel manufacturing industry because they can be recycled without any damage or degradation of its property. Like other countries, scrap steels are imported from abroad. Some were found radioactive contamination both natural and artificial radioisotopes. In case, once contaminated scrap steels are introduced into the melting process, radioactive electric arc furnace slag is produced. In order to prevent migration of radionuclide contaminated in the furnace slag, immobilization of such radioactive waste by cementation was con- ducted. In this work, we studied the physicochemical and mechanical properties of waste form that is appropriate for store and transfer to long term disposal site. The element compositions of Port- land cement type I (PC) and EAFS were characterized by X-ray fluorescence (XRF), they were found that the main element composition of PC and EAFS is Calcium oxide (CaO) and Iron oxide (Fe2O3), respectively. The EAFS waste forms were produced using water/cement ratio of 0.40 and EAFS re- placement of 0%, 15%, 25%, 35%, and 50%. All samples were cured at ambient temperature for 14 days and 28 days. It was observed that the compressive strengths of EAFS replacement of 0%, 15%, 25%, 35%, and 50% were found to be 111.28, 109.35, 107.58, 93.64, and 65.02 kggf/cm2, respectively, for 14 days curing. The compressive strengths of all samples were measured to be 93.57, 105.53, 80.73, 111.90, and 102.88 kggf/cm2 for EAFS replacement of 0%, 15%, 25%, 35%, and 50%, respectively, for 28 days curing. The mixing between PC and EAFS of all conditions exhibited good workability for cementation. The EAFS replacement of 50% seems to be appreciable for cementation due to the high increasing compressive strength.

Solutions for Specific Wastes / ID 226

RADIOACTIVE WASTE INCINERATION TECHNOLOGY OF CHINA INSTITUTE FOR RADIATION PROTECTION

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Incineration technology is one of the most effective ways to treat radioactive combustible waste, with high capacity reduction ratio, stable products, strong economy and mature technology. China Institute for Radiation Protection has been conducting research on radioactive waste incineration technology since the 1970s, and has developed ZRF series pyrolysis incineration technology, ZKF series compact incineration technology and ZYF series mobile incineration technology. ZRF series pyrolysis incineration technology has the characteristics of strong adaptability to waste, energy saving, high capacity reduction coefficient, high efficiency purification, etc. It can adapt to the incineration needs of waste containing a high percentage of chlorine-containing plastics and rubber, and the technology is at the international leading level, and has obtained a number of national patents and excellent invention patents, and has been applied to many domestic and foreign units. ZKF series compact incineration technology is based on ZRF series, by improving the process, under the premise that the treatment capacity remains unchanged and the tail gas emissions meet the standards, the incineration technology with compact equipment layout, small footprint, short construction cycle, easy operation and operation, etc., has been realized in the domestic engineering applications. ZYF series mobile incineration technology is based on the development of the ZKF series, through further optimization of the process, streamlining equipment, optimizing the layout, etc., to improve the material receiving capacity, reduce the generation of secondary waste, and finally achieve the device of the vehicle mobile, the technology can be more flexible to waste treatment, construction costs, floor space, the number of operating personnel to further achieve a significant reduction. At present, the key technology research of mobile incineration has been completed and the prototype has been established, with the feasibility of engineering applications.

Solutions for Specific Wastes / ID 236

THE STUDY OF ALTERNATIVE ENCAPSULANTS FOR THE TREATMENT OF INTERMEDIATE LEVEL RADIOACTIVE WASTE

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In the UK, currently the preferred method of immobilising intermediate level waste (ILW) is through the use of Portland cement (PC) based grouts. However, certain types of ILW present a challenge, with the result that PC-based matrices may not represent the optimum encapsulant. Such challenges are related to either chemical compatibility issues between the waste and encapsulant, or those related to rheology such as the infilling of wastes with tortuous pathways, or the ability to mix viscous wastes, which may all serve to restrict waste loadings or produce wasteforms with higher inherent voidage. A potential alternative is the geopolymer system which may provide product, cost and process resilience improvements over conventional PC-based matrices for the treatment of such 'problematic' ILW. The paper presents preliminary results from a structured research programme using statistical analysis to define suitable geopolymer formulations for subsequent waste interaction studies, in which the surrogate ion exchange resin waste, clinoptilolite, has been immobilised at ~120 L scale. The study has shown that a high fluidity geopolymer formulation developed at small scale can potentially offer a significant improvement in the ability to mix the high viscosity surrogate to produce a homogeneous wasteform, in comparison to a baseline PC-blend matrix. The resultant geopolymer/clinoptilolite matrix had significantly higher compressive strength than the PC-blend product at equivalent waste loading, whilst both products were dimensionally stable over the 90 d curing period. The geopolymer formulations developed in this study were shown to have high heats of hydration where the exotherm obtained for the Metamax®/clinoptilolite wasteform at ~120 L was 79 °C. As a result, the exotherms at full scale will need to be assessed, in conjunction with studies to assess the effects of such temperatures on the resultant geopolymer wasteform.

Solutions for Specific Wastes / ID 251

CAN AL AND ZN SIMULATE THE BE CHEMICAL BEHAVIOR IN AQUEOUS SOLUTION AND CEMENTITIOUS MATRICES?

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In future experimental fusion ITER facility, beryllium (Be) constitutes the main first wall plasma- facing material. ITER will then produce Be waste, either in the solid or in powder form. It is important to anticipate the management of the generated radioactive waste. To manage Be, direct immobilization in a cementitious matrix seems to be an option. A research project has then been undertaken to select the best matrix for a safety storage of Be. Nevertheless, Be powder is known as carcinogen and it can cause a respiratory disease, the berylliosis. It then seems interesting to find a surrogate to understand the Be reactivity without handling it. Our work focuses on comparing the reactivity of massive Be with its known substitutes Al and Zn to find the proper surrogate for prospective powder experiments. Thermodynamic data on the stability of Al and Zn in water at 25°C are known: their passivation zone is respectively between pH 3-10.5 and pH 7.5-13 and they corrode into ionic species bellow and above these pH. On the contrary, the calculated data for Be reported in the literature differ especially in basic media: calculations of Pourbaix predict an aqueous corrosion of Be starting at pH 10.5 while recent studies shows a corrosion above pH 13.5. Owing to the incertitude of thermodynamics for Be, the conditioning of metals (Be, Al and Zn) have been studied in 5 cements with different interstitial pH: brushite, magnesium phosphate cement, calcium sulfo aluminate cement, portland cement and activated slag. The pore solution pH of these matrices ranges from very acid to very basic values. Corrosion studies have been also made in aqueous solutions in a wide range of pH (HCl-NaOH solutions). The metal reactivity is followed mainly by electrochemical impedance spectroscopy in both solutions and cements. Corrosion measurements on Al and Zn are consistent with the literature for both solution and cement experiments. Results on Be can confirm thermodynamics: Be is corroded at low pH with production of hydrogen gas (brushite cement) and Be is stable in cement having a neutral pH pore solution (magnesium phosphate cement) like Al. However, the electrochemical experiments in alkali solutions and cements having a basic pore solution are in agreement with the most recent thermo- dynamic data: Be seems to be protected against the corrosion by a stable protective layer in a pH range from 10 to 13 but strongly corrodes in high alkalis cement (slag) like Zn.

Solutions for Specific Wastes / ID 255

EFFICIENCY OF THE EMULSIFICATION OF ORGANIC LIQUIDS IN ALKALI-ACTIVATED CEMENTS FOR RADIOACTIVE WASTE ENCAPSULATION PURPOSES

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The incorporation of organic liquids in cement-based materials is of interest for various applications like the formation of porous material through emulsion templating and removal of the dispersed phase, the design of composite materials with improved and/or combined properties or the immobilization of industrial wastes. Immobilization of wastes into cementing materials by stabilization and solidification (S/S) is a common procedure, because it ensures chemical stabilization of many compounds and produces a mechanically stable waste form. Several ways of incorporating organic liquids into cementing materials are distinguished. It is either a direct incorporation into the reactive cementing slurry, a pre-emulsification prior to the addition of solid precursor or a solid impregnation prior to the addition into the cementing slurry. The pre-emulsification process is particularly interesting because it offers the possibility of incorporating a large amount of organic liquid, while ensuring that no phase separation will occur until hardening of the continuous cementing phase. Portland cement has been widely studied for the immobilization of many organic compounds with issues encountered in regards to strength development. Comparatively, alkali-activated materials (AAM), and particularly geopolymers, display superior performances against organic contamination com- pared to Portland cement. Indeed, while the presence of organic compounds generally disturbs the hardening of hydraulic binders, the mechanism of geopolymer formation is such that liquid/liquid emulsion might be easier for the synthesis of composite organic/inorganic materials. In this research, a significant amount of low viscosity pure mineral oil (20%vol) is successfully im- mobilized in alkali-activated materials (AAM), either based on metakaolin or blast furnace slag. Surfactants are required to achieve oil emulsion stability. Visual observation, torque measurement and rheology evidence two distinct groups of surfactants. One group contributes to structuring the oil/AAM fresh mix, with greater torque and viscosity than without surfactant; the other is made of non-structuring surfactants, with no change in torque or viscosity. Each group depends on the AAM considered. Whatever the surfactant, both the interfacial tension between oil/activating solution and the oil droplet size decrease significantly. However, although contributing to stabilize the emulsion, interfacial tension alone does not explain the structuring behavior. Characterization of diluted ternary suspensions (solid particles-oil- activating solution) relates the structuring effect to interactions between oil and solid particles, through the surfactant molecule polar heads and tails. An original mechanism explaining structuration is discussed.

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DURABILITY OF ORGANIC LIQUIDS ENCAPSULATED IN GEOPOLYMER CEMENT COMPOSITES

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The incorporation of organic liquids in cement-based materials is of interest for various applications, and in particular for the immobilization of radioactive industrial wastes. Immobilization of wastes into cementing materials by stabilization and solidification (S/S) is a common procedure, because it ensures chemical stabilization of many compounds and produces a mechanically stable waste form. For the immobilization of organic liquid compounds, Portland cements have been widely studied, but issues are encountered in terms of cement setting and strength development, whenever more than a few percent of organic liquid are involved. Comparatively, alkali-activated materials (AAM), and particularly geopolymers, display superior performances against organic contamination compared to Portland cements. Indeed, while the presence of organic compounds generally disturbs the hardening of hydraulic binders, the mechanisms of geopolymer formation involve water only as a dissolution medium, which is released in the pore system upon solid gel formation (polycondensation). This specific property of geopolymers eases significantly the synthesis of organic liquid/inorganic cement materials. This research investigates the durability of two given geopolymer cement formulations, either based on alkali-activated metakaolin (MK) or on a mix of MK-blast furnace slag. The cement is mixed with different organic liquids (pump oil, TBP/dodecane) at 20%vol, and hardened for at least 28 days. Durability is determined as the water transport ability of the organic liquid/geopolymer composite (GEOIL), when it is flown through by a water typical of its expected in situ environment (i.e. in the vicinity of Portland-based concrete). An original experimental set-up is devised to avoid carbonation of the highly alkaline water, during tests lasting for up to 40 days. The potential water flow paths are determined by characterizing the geometry and the percolating part of the geopolymer pore structure (by mercury intrusion porosimetry coupled to nitrogen sorption-desorption isotherms), and of the organic liquid emulsion (by using X Ray micro-tomography). Coupled to 3D numerical simulations, the most probable flow paths are discussed, and the ability of the oil to migrate through the cement is determined depending on its amount in the geopolymer.

Solutions for Specific Wastes / ID 258

MICROWAVE ASSISTED SYNTHESIS OF PEROVSKITE CERAMIC WASTE FORM

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Perovskite is proposed as a potential host for immobilizing the highly active short lived radionuclide strontium, which is discarded in the form of medical devices from the hospital. In the present work, strontium perovskite ceramic matrix has been successfully synthesized by employing microwave (MW) assisted method at MW power of 800W and at a frequency of 2.45GHz in multimode applicator. The X-ray diffractograms show that the as-prepared ceramic by MW processing method is composed of cubic perovskite SrTiO3 along with minor impurities of TiO2 and SrCO3. In order to remove impurity phases, subsequently MW processed perovskite is calcined at 900°C in muffle furnace. The X-ray diffraction pattern of calcined specimen confirms the formation of single-phase cubic strontium perovskite. The electron microscopic images indicate the uniform microstructure. The aqueous durability studies have been carried out as per MCC-1 static leach test protocol, in deionized water at room temperature and 90°C. Attempts have been made to understand relation between microstructure and chemical durability.

Solutions for Specific Wastes / ID 260

TRAPPING EFFICIENCY OF AN ENCAPSULATION MORTAR INCORPORATING A TRITIUM GETTER FOR RADIOACTIVE WASTE CONDITIONING

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This research is performed in the framework of the MACH3 project, which is funded by the French PIA (Future Investment Plan). MACH3 contributes to the management of radioactive waste containing liquid and gaseous tritium. The reference conditioning process for these waste is cementation, i.e. the immobilisation of the waste using a hydraulic binder. The acceptance of tritiated waste on storage sites depends on a low release level of gaseous tritium (tritium in its liquid form being less mobile). Currently, the two main options are to incorporate low levels of waste in the storage pack- ages, or to perform a costly preliminary de-tritiation process. In order to improve this situation, the MACH3 project has developed cement matrices for the encapsulation of tritiated waste, and able to limit tritium degassing by an irreversible trapping of its gaseous forms. Our method has consisted in developing cement mortars incorporating a tritium getter (based on Ag2O/MnO2) in a powdered or aggregate form. The developed mortars allow both gas transport and tritium gas trapping (controlled gas flow). They have adequate workability and a minimal mechanical performance of 20 MPa after 7 days endogenous curing. To this purpose, the mortar granular skeleton has been slightly destabilized to increase the pore pathways accessible to gas. Thanks to in situ gamma irradiation tests, the formulated mortars display an excellent trapping ability.

Solutions for Specific Wastes / ID 264

POLYMER TECHNOLOGIES FOR THE SOLIDIFICATION OF COMPLEX L/ILW LIQUID RADIOACTIVE WASTE: GLOBAL CASE STUDIES OF APPLICATIONS AND DISPOSAL OPTIONS

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Legacy liquid radioactive waste streams from the Cold War still exist and newly generated waste streams from nuclear power plants and research institutes go untreated and expose environmental hazards at many nuclear sites. The nature of the waste is diverse, depending upon the source or the process from which it originated. The most problematic waste streams include complex liquids such as organic (tri-butyl-phosphate TBP) solutions contaminated with Pu and U isotopes, mixed organic and aqueous sludge types, nitric and mixed acid waste streams, H-3 contaminated organic and aqueous streams, etc. Technological, environmental and economic challenges exist for the treatment and disposal of such waste streams. A proven technology since 2001 that has been applied to LRW on a global basis provides one option as a low-cost solution to legacy streams, large and small volume complex LRW frequently found during decommissioning at nuclear power plants and weapons sites. The engineered polymer technology from Nochar, USA, is capable of solidifying standard and highly complex LLW and ILW waste streams for interim or final storage, or for incineration.

Solutions for Specific Wastes / ID 268

CHOLINE CHLORIDE-BASED DEEP EUTECTIC SOLVENTS AS AN ALTERNATIVE DECONTAMINATION AGENT FOR RADIOACTIVE METAL WASTE

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Deep eutectic solvents (DES) are a mixture of a hydrogen bond acceptor (HBA), commonly quaternary ammonium salt, and a hydrogen bond donor (HBD), such as a carboxylic acid or alcohol. These solvents are readily synthesized from easily accessible materials. DES are characterized by their low cost, melting point, flammability, toxicity and wide electrochemical windows. Chemical and physical properties of DES can be tuned through judicious choice of HBA and HBD such as acidic HBD's which readily dissolves metal oxides. This illustrates novel advantages over currently used or proposed decontamination agents such as ionic liquid, molten salts or strong acids. In this research, we tested the feasibility of DES synthesized from choline chloride (ChCl) and ptoluenesulfonic acid (PtsA) as a decontamination agent. ChCl:PtsA was selected owing to its high metal oxide solubilizing power. Metal oxides such as Fe3O4, CoO, Cr2O3, and NiO present in the contaminated layer of stainless steel 304 were studied and were shown to have good solubilities in ChCl:PtsA. To simulate decontamination process, simulant contaminated stainless specimens were produced. Stainless steel 304 samples were oxidized at 800°C for 30 minutes with constant steam supply and were cooled gradually in the furnace. The formation of layer was evident from SEM images, and the layer composition was studied by SEM-EDS. Laser-induced breakdown spectroscopy (LIBS) data was collected for oxide layer, which showed peaks that correspond to metals aforementioned. The simulant contaminated stainless specimens were leached, and their oxide layers were success- fully removed in ChCl:PtsA. ChCl:PtsA solvent leaching kinetics and final concentration of metals were investigated using ICP-OES. SEM-EDS and LIBS results of specimen surfaces pre-leaching and post-leaching were compared to assess decontamination ability. SEM images showed that the oxide layer was efficiently removed after the leaching. LIBS data of specimen pre-oxidation and post-leaching were almost identical, which shows that the metal oxide layer was removed and the base metal was exposed. These results corroborate that the eutectic mixture formed from two bio- compatible components has an excellent solubilizing power which efficiently dissolves and removes oxidation layer from the contaminated stainless steel. This work proposes and proves the possibility of using ChCl:PtsA as a decontamination agent. It was shown that while ChCl:PtsA with good metal oxide solubilizing power has numerous advantages over conventional leaching agents, it was also able to decontaminate simulant contaminated steels. The efficiency of the process is expected to be further improved when electrochemical process is combined.

Solutions for Specific Wastes / ID 277

DEVELOPMENT OF A CATALOGUE OF CHARACTERIZATION METHODOLOGIES FOR DEMONSTRATING COMPLIANCE WITH WASTE ACCEPTANCE CRITERIA

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The safe management and disposal of low and intermediate level radioactive waste requires accurate and quality assured characterization by non-destructive and destructive methods, and determination of the radionuclide inventory, chemical, physical properties in the different steps of waste management. Relevant procedures, standards and practices have been developed and continue to be refined in waste characterisation facilities in Member States. Sharing of information between facilities and practitioners underpin the ongoing development of such procedures, standards and practices. The International Network of Laboratories for Nuclear Waste Characterization (LABONET) is focusing its attention on proven practices and successful implementation. During the 2019 LABONET Technical Meeting held in parallel with the LABONET Steering Committee Consultancy Meeting, attended by more than 60 participants from 25 Member States, it was decided to start with the implementation of the project “Catalogue of methodologies for demonstrating compliance with Waste Acceptance Criteria (WAC)”. This paper will discuss the following issues: 1) Aim of the Catologue; 2) The general and typical requirements of WAC; 2) Category of requirement items; 3) Items for considering WAC; 4) Executors of verifications; 5) The work plan and potential working groups to establish the Catologue; 6) Example of appropriate waste characterization method; 7) A concept of a questionnaire of the “List of aspects relevant to radioactive waste package acceptance criteria” to be send to WMO’s in order to collect the information for establishing the Catalogue of methodologies.

Solutions for Specific Wastes / ID 281

A PROTOTYPIC DESIGN OF DEPLOYABLE MOBILE HOT CELL FOR SAFE AND REMOTE HANDLING OF RADIOACTIVE SOURCES

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This paper depicts a deployable system with safety measures in place and mission achievable tasks for handling medical related radioactive sources. Radioactive sources are used around the world to support life-improving and lifesaving industries. However, disposition or consolidation of radioactive sources pose safety risks to operators, making a well-designed remote handling system desirable. Robots can fill this need and are often used in hostile, radioactive environments, either to inspect the restricted area or to destroy harmful objects. Precise communication is required between robots and controllers for safe operations. The collaborative robots (cobots) are used in conjunction with the lighting and vision systems to provide a robust operating platform. The main challenges current mobile hot cells face are long deployment and assembly times, inferior design which results in unsafe working condition, and high costs of operation. This paper describes the application of cobots in the hazardous (radioactive) environment, and system requirements and challenges to incorporate safety while deploying cobots in a mobile hot cell. The overall design, transportation configuration, deployment features, required equipment, personnel, and device interfaces of an innovative mobile hot cell with remote handling capabilities are incorporated. Also, the best safety measures to handle unsafe/contaminated disused sources using our technology are portrayed. The better design structure of the mobile hot cell with back up cobot will result in significantly reduced time to deploy the mobile hot cell, even in unexpected situations. Using simple operating systems, like Raspberry PI and Arduino, with remotely and precisely controlling the lighting system and camera system, a cost-effective safe handling environment will be ensured. This new hot mobile cell design will provide handling infrastructure and the means of safely and securely conditioning sources for end-of-life management to facilities that have limited radioactive materials.

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INNOVATIVE APPLICATIONS OF ABRASIVE WATERJET FOR IRRADIATED GRAPHITE DISMANTLING AND DECOMMISSIONING

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The characterization, dismantling and pre-disposal management of radioactive materials have an important role in view of safe decommissioning of nuclear facilities. One of the main challenges is related to the management of irradiated graphite (i-graphite) used as moderator and reflector in several nuclear power plants and research reactors. In addition to common radioprotection issues typical of most radioactive waste, easily volatizing long-living radionuclides (above all 3H, 14C, and 36Cl) and stored Wigner energy can be released during imprudent retrieval and processing of i-graphite, that hence require careful considerations and precautions. It is well known that Wigner energy release can be avoided by monitoring the i-graphite temperature, that must be kept below its irradiation temperature, with about 50 °C safety margin. This is especially important for those blocks irradiated below 100 °C. With this regard, among all cutting techniques, the abrasive waterjet (AWJ) can be a promising technical solution that achieves all the thermo-mechanical and radioprotection objectives. In this work, the application of AWJ to segmentation of graphite blocks has been explored, aiming at optimizing the retrieval, storage and disposal of such waste. This would have benefits from the points of view of both safety, management, and costs. AWJ technology may represent a valuable alternative to mechanical dismantling techniques from the perspective of the following process requirements:

— Restraint of suspended dusts;
— Low cutting temperature;
— Limitation of secondary waste;
— Easy remote use;
— Low cost.

This work was aimed at characterizing the AWJ machining capability of 100x100x600 mm blocks of non-irradiated graphite. Several factorial experiments were designed to investigate the effects of the machining process parameters (e.g. traverse speed, abrasive mass flow rate, water pressure) on graphite temperature and on the material removal rate for the purpose of secondary waste evaluation.

Solutions for Specific Wastes / ID 309

RETRIEVING LEGACY WASTE FROM THE SWEDISH GEOLOGICAL REPOSITORY FOR SHORT-LIVED WASTE

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At the geological repository for short-lived waste (SFR) at the Forsmarks NPP, radioactive operational waste from NPP:s and similar waste from other nuclear facilities in Sweden is disposed. This includes short-lived waste from e.g. research and industry treated at the facilities in Studsvik. SFR, operated by Swedish Nucelar Fuel and Waste Management Co, is located at a depth of about 50 meters below the seabed. This location reduces the risk of inadvertent human intrusion. Due to land uplift, the risk of intrusion (drinking water well) increases approximately 1000 years post closure. In 2012, SKB reported that some of the disposed waste had been insufficiently characterized. Further studies reviled that the waste unexpectedly contained a significant number of Ra-226-sources. The Swedish Radiation Safety Authority (SSM) requested an analysis of the long-term safety due to these sources. Furthermore, SSM requested a cost-benefit analysis between the long-term safety with the costs and risks that a retrieval of the waste can entail. The presence of Ra-226 and other long-lived alfa emitters increases the estimated total risk to the critical group due to releases from the SFR by some factor of 5. This risk increment might not necessarily have justified the retrieval of the waste. The report also showed that the doses from a drinking water well into the rock vault where the waste is placed would be significant, in the order of 0.1 – 1 Sv per year. This is partly due to the lack of credible technical barriers surrounding the waste packages in this rock vault in SFR. With regards to inadvertent human intrusion, SSM's regulations primarily addresses measures taken to limit the probability of inadvertent intrusion rather than the level of exposure. However, the prob- ability of inadvertent intrusion in a repository at such shallow depth as 50 m cannot be judged to be negligible. Given this, together with the risk for deterministic effects from ionizing radiation from intrusion, SSM supported SKB's intention for retrieval. SKB plans for a retrieval in the coming years.

ROLE OF THE SAFETY CASE DEVELOPMENT IN SUPPORTING RADIOACTIVE WASTE MANAGEMENT

Role of the Safety Case Development in Supporting Radioactive Waste Management /
ID 188

ROLE OF THE SAFETY CASE DEVELOPMENT IN SUPPORTING RADIOACTIVE WASTE MANAGEMENT- FRENCH ILLUSTRATION ON HLW AND ILW MANAGEMENT- THE CIGÉO DISPOSAL

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In the continuity of the safety options, Andra is currently in the license application process of a deep geological disposal facility for HLW and ILW in a clay formation, The Callovo-Oxfordian, in the eastern part of France. This process started in 2011 by the development of an industrial design phase that consists in the proposal of an overall underground architecture for the repository and the definition of the operating principles and the name given to the project was defined: the “Centre industriel de stockage en milieu géologique” (Cigéo, Industrial Center for Geological Disposal). The files and in particular the safety case that will support the demand for license application results on a continuous increase in knowledge, project’s development and associated safety assessment for several decades. Since the French Act in 1991 on the long-term plan for the management of the intermediate-level (ILW) and high-level (HLW) radioactive waste in France, Andra is running a comprehensive research project including a broad combination of laboratory research, surface and drilling based site investigations, research in the Bure URL and model development. The preparation of the license application is thus the result of a step-wise accumulation of knowledge and iterative process including several safety cases as well as their regulatory review. The safety case development plays a key role in supporting the development of the technical solutions to manage HLW and ILW. It is based on successive “knowledge/design /safety” iterations. Each iteration involves scientific and technological knowledge acquisition, study of the layout de- signs consistent with this knowledge and safety assessment. Each safety case is associated with key milestones (reliability, siting, underground research, industrial design development, safety options, licensing) based on the “knowledge/design /safety” iteration providing lessons learnt. The successive iterations gradually help to guide the choice toward design solutions, R&D programs, and safety studies. Andra collects and documents knowledge R&D data and analyses residual uncertainties in the knowledge.

Role of the Safety Case Development in Supporting Radioactive Waste Management /
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DEVELOPMENT OF A SAFETY ASSESSMENT FOR THE BRAZILIAN NEAR-SURFACE REPOSITORY IN THE SITE SELECTION PHASE

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The internationally accepted approach for developing a safety case focuses on the integration of repository design and site characteristics and the safety demonstration through the elaboration of safety assessments and it may relate to a given stage of project development. This paper describes a safety assessment for the Brazilian Near-surface Repository for Low and Intermediate-Level Radioactive Waste at the current site selection stage. Given the lack of data in terms of isotopic inventory, detailed deposition system and site characteristics, the main objective was to indicate which radionuclides are most significant, the most important pathways and input parameters for the current knowledge of the repository design and possible site characteristics in order to meet the requirements of the Brazilian nuclear regulatory standards. This analysis was based on the methodology established by the ISAM reports (Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities). A conservative reference scenario was assumed based on the review of international experiences of repository safety assessments and safety cases, as well as information about possible sites for the repository. The reference scenario includes the release of radionuclides from the deposition zone (source term), radon release and dust suspension; transport of radionuclides through the deposition zone, geosphere (unsaturated and saturated zones) and biosphere (atmosphere and soil); and estimation of the dose evolution over time for a rural resident farmer scenario, considering the pathways for ingestion (water and food produced locally), inhalation (radon and air particles) and direct external exposure, both in onsite and offsite areas. RESRAD-OFFSITE code version 4.0 was used to implement the assumed conceptual model. A sensitivity analysis was carried out considering a single-parameter variation (deterministic analysis) and probabilistic simulation with multiple parameters, identifying which are the most sensitive parameters for different pathways. The results showed the evolution of the total specific dose over time obtained for the reference scenario. Three specific peak doses were observed: the first at the beginning of the simulation time (right after the repository closure), of short duration (due to Ra-226); the second of lower magnitude, around 1,000 years (related to the I-129), and the third, of greater magnitude and duration, between 4,000 and 19,000 years (related to the process of erosion of the cover layer). Carried out at the early stages of the development of a repository project, such analysis can be useful to support decision makers, to assess needs for further analyses and to build confidence.

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THE SAFETY STUDY IN SUPPORT OF THE DEVELOPMENT AND IMPROVEMENT OF WASTE MANAGEMENT AT EL CABRIL DISPOSAL FACILITY

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The El Cabril facility, located in the province of Cordoba in southern Spain, is the national disposal site for low- and intermediate-level radioactive waste. In addition to separate areas for the disposal of very low-level and intermediate- and low-level waste, the facility is equipped with processing and conditioning capabilities, laboratories to support waste characterisation and acceptance activities, and buildings for the temporary storage of waste to regulate operations. El Cabril obtained its operational authorisation in October 1992, along with approval of the Safety Study licensing document. The facility has ever since, for nearly 30 years, been required to adapt to new technological, regulatory and management needs and/or realities, turning the initial project into a project which is constantly changing to handle and optimise the management of such radioactive waste, while maintaining national and international safety standards. The Safety Study has proved an essential tool in this adaptation process to demonstrate compliance with the conditions of the operational licence, and in response to the demands of the regulatory body - the Spanish Nuclear Safety Council.

Role of the Safety Case Development in Supporting Radioactive Waste Management /
ID 111

R&D PROGRAM FOR THE DEVELOPMENT OF A DEEP RW DISPOSAL FACILITY IN THE RUSSIAN FEDERATION: BASIC PRINCIPLES OF DEVELOPMENT, STRUCTURE AND SPECIFIC FEATURES OF ITS IMPLEMENTATION

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In 2016 siting and construction license was issued for an underground research laboratory construction in Russia. The Yeniseiskiy site (granite-gneiss massif, Krasnoyarsk Region) is considered as potentially suitable to host the HLW disposal facility. During the licensing process, a safety case has been developed based on relevant data available at that time. This report reflects the progress of the Russian URL project in the context of obtaining new information on the properties of the geological environment and the characteristics of the accumulated waste that has been achieved over the past 5 years. The current stage is mainly aimed at verifying the disposal concept. The exact characteristics of the disposal concept will be refined during URL activities. Currently, the main focus of research activities is an iterative process of computational modelling, as well as field and laboratory experiments to provide reference data for the verification of numerical models. Particular emphasis is placed upon the completeness of the information on potential safety-relevant factors addressed in the safety case. In 2018, the development of the RD&D program covering the main research areas was completed. Particular attention was paid to the analysis of both Russian regulatory requirements on safety assessment documents and international recommendations (IAEA and NEA) on safety case development. A separate area of focus is the development and maintenance of the knowledge base. The most intensive efforts are now being devoted to further geological survey of the selected site both from the surface (using drilling wells (including deep ones) by deploying an integrated monitoring system) and during mining. The safety case for the deep geological disposal facility mainly relies on safety arguments based on the predictive models of various scenarios of the long-term evolution of the system influenced by external factors. And the validity of the corresponding findings is supported by:

- The quality of the modeling software;
- The quality of the models themselves, including the balance between the level of detail in the de- scription of physical, chemical, and biological processes and the data for model parameterization;
- The results from both field and laboratory investigations. To date:
- All types of activities (surveys, long-term observations, and experimental research) required for the URL construction are specified.
- The lists of experimental studies, requirements regarding their location and arrangement, stages of experiments are defined.
- And the structure of information flows during URL construction and operation is designed.

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ID 191

THE BENEFITS OF A TARGETED R&D PROGRAMME TO ADDRESS KEY QUESTIONS

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The Low Level Waste Repository (LLWR) is the UK's national low level waste disposal facility and has been operational since 1959. The site comprises historical clay-lined trenches and engineered vaults. Once each disposal vault is filled, an engineered cap will be emplaced that covers the vault and the adjacent strip of trenches. The LLWR operates under an Environmental Permit that is granted by the Environment Agency. One condition of the permit is that the operator must develop, maintain and submit updates to an Environmental Safety Case (ESC). The regulator did not fully accept the submission made by a previous operator in 2002 on the grounds that it had not adequately addressed optimisation, the potential disruption scenario of coastal erosion, and that calculated doses and risks exceeded regulatory guidance. The Environment Agency required that LLWR submit a revised ESC by 2011. One of the main aspects the 2011 ESC aimed to address was the criticisms of the previous safety case. An R&D work programme was developed to address these key problems. Focussing the R&D programme on these key areas underpinned an ESC that both met the regulatory requirements and that could become a tool to manage the repository, and hence LLW in the UK. The 2011 ESC was successfully delivered and a disposal permit was granted in 2015. Since then the ESC has been maintained as a 'live' safety case, supported by an ongoing R&D programme. This has enabled new wastes to be considered and accepted for disposal and also changes to the design of the closure engineering to be radiologically optimised. During the process of detailed design for the closure engineering it became apparent that the facility cannot be closed in the way assumed in the 2011 ESC without deformation of the containers. Work was undertaken on physical testing of the containers, which was further supported by FEA modelling. The ESC was used to inform and consider the subsequent proposed design change. Using the ESC, LLWR is assessing the potential to dispose of a wider range of wastes using a risk-based approach. LLWR is undertaking work to consider the capability of the site, if enhanced disposal facilities were to be constructed, to safely dispose wastes of higher specific activity. The R&D programme developed to support this work is designed to enable the optimisation of any such facilities.

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WASTE ACCEPTANCE CRITERIA (WAC) FOR UNDERGROUND RADIOACTIVE WASTE REPOSITORY IN REPUBLIC OF KOREA

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Radioactive waste management organization (RWMO) is in charge of developing the waste acceptance criteria (WAC) and providing radioactive waste producers with the WAC for safe, effective and efficient disposal of radioactive waste. The WAC needs to be developed in the framework of safety case and is interconnected with other key components of the safety case in order to ensure the operational and post-closure safety of the disposal facility. Korea Radioactive Waste Agency (KORAD) got permission for the operation of the first radioactive waste repository in the Republic of Korea, Wolsong Low- and Intermediate-Level Waste Disposal Center (WLDC), in 2015. The 1st phase of the WLDC is operational, and the 2nd phase is in licensing process for construction. KORAD prepares the comprehensive WAC in accordance with legal and regulatory requirements. The WAC for the WLDC consists of technical requirements and administrative requirements, and technical requirements contained general, solidification, radiological, physical, chemical and biological requirements. KORAD has successfully developed the WAC provided to waste producers. The WAC is periodically reviewed and updated in response of meeting any changes of legal and regulatory requirements and stakeholder expectations.

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ID 302

CURRENT STATUS AND CHALLENGES OF CHINA'S LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE (LILW) DISPOSAL

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Based on the safe disposal goal, China implements classified radioactive waste management according to the potential hazards of radioactive waste and the degree of containment and isolation required for disposal. LILW shall be disposed by near-surface disposal or intermediate-depth disposal at the sites in compliance with requirements of nuclear safety stipulated by the State. Currently China has three LILW near-surface disposal sites in operation, which has disposed approximately 57,000 cubic meters LILW in total. This effectively guaranteed the nuclear industry development.With the rapid development of nuclear energy and nuclear technology applications, the disposal of LILW and disused sealed radioactive sources (DSRS) has put forward new requirements and brought new challenges. By studying the multi-channel disposal of LILW from NPPs, we implement the strategy of "Combination of Centralized disposal and Regional disposal", which can reasonably respond to these challenges. China is now constructing Longhe near-surface disposal site for the centralized disposal of NPP waste, and organizing the site selection of LILW disposal facilities in provinces where NPPs are relatively concentrated. Research and exploration on the intermediate depth disposal of radioactive waste, as well as the strategy for DSRS disposal and the acceptance criteria for near-surface disposal, is being carried out in China so as to speed up the implementation of ILW intermediate depth disposal and DSRS near-surface disposal in China.

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CANADIAN REGULATORY REVIEW OF WASTE ACCEPTANCE CRITERIA FOR A LOW-LEVEL NEAR SURFACE DISPOSAL FACILITY

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The Canadian Nuclear Safety Commission (CNSC) is reviewing the licensing submission for a proposed near surface disposal facility (NSDF) for low-level radioactive waste (LLW) at Chalk River Laboratories in Deep River, Ontario, Canada. A crucial part of the application is the waste acceptance criteria (WAC). The NSDF WAC defines the criteria for the acceptance of LLW and ensures that all waste received for disposal complies with the facility design and licensing basis. The CNSC's review of the NSDF WAC was an iterative process conducted using both Canadian and IAEA regulatory requirements and guidance. Specifically, CNSC regulatory document REGDOC-2.11.1, Waste Management, Volume I: Management of Radioactive Waste requires that a licensee receiving waste for storage or disposal develop waste acceptance criteria consistent with, and derived from, the site-specific safety case. From this requirement, the CNSC uses the results of the operational and post-closure safety analysis to inform its regulatory assessment of the WAC.
Key topics of regulatory interest were:

- the WAC development
- waste inventory and the identification of "key radionuclides"
- the evaluation of compliance with the WAC, acceptance of waste and the waste assurance program
- the roles and responsibilities for waste generators and the facility operator
- non-compliant waste and the "infrequently performed operations" process
- the disposal of mixed waste

The WAC also plays a key role in the assessment of post-closure safety. This was a particular area of regulatory attention both from the perspective of the WAC development and the role of the WAC in ensuring safety during the 10,000 year assessment timeframe. Using the CNSC's technical assessment process, comments and requests for clarification or additional information were communicated to the licensee. In response, the WAC was revised and responses were prepared for each information request.

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ID 2

GEOLOGICAL ENVIRONMENTS OF THE KLEDANG RANGE, PERAK TRIASSIC CRYSTALLINE ROCK IN SUPPORTING SAFETY CASE DEVELOPMENT FOR RADIOACTIVE WASTE DISPOSAL

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Kinta Valley consists of Kinta river and its tributaries, while the Kinta river itself is a tributary of the great Perak river. To the west of Perak river locates the Kledang Range and to the east is the Malaysia Main Range. The geology of Kinta Valley consists of crystalline rocks, sedimentary rocks, and alluvium. Crystalline rocks in the Kledang Range consist of medium grained muscovite-bearing biotite granite, greenish medium to fine grained felsic, muscovite-bearing leucogranite, highly disrupted and altered granite (PTG) containing large K-feldspar megacrysts, fresh biotite granite (PTG) with weak alignment of K- feldspar phenocrysts and biotite, coarse grained biotite granite (PTG) with 5 cm large K- feldspar megacrysts and foliate biotite granite. The understanding of crystalline host rock behaviour and factors that influence waste isolation performance over a long period of time are important as technical basis for future surveys of the area and siting investigations for radioactive waste repository applications.

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ID 15

EXPERIENCE ON THE APPLICATION OF SAFETY ASSESSMENT TOOLS TO THE RADIOACTIVE WASTE MANAGEMENT IN CUBA

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The safety assessments allow to evaluate the fulfillment of the regulatory requirements for the different applications of the ionizing radiations in the society including the radioactive waste management. The national strategy of radioactive waste management in Cuba includes among the foreseen options the interim storage of the radioactive waste until its radioactive decay to exemption levels and for the long-lived radionuclides the extended storage until a disposal facility is available. The disused sealed radioactive sources (DSRS) are included in the national wastes inventories with the higher risk, the final management defined in the national strategy is their disposal in borehole facilities. The long-term storage and the DSRS disposal were evaluated applying tools developed in the framework of several projects of the IAEA (SADRWMS, CRAFT). The SAFRAN tool was applied in the development of the safety case to evaluate the option of the long-term storage of the radioactive waste. The BDC Screening tool, a software sponsored by the IAEA which is dedicated to assess the post-closure safety for the borehole disposal facility was apply to assess the suitability of different sites for the DSRS disposal. According the results the application of the SAFRAN allows to incorporate the up- to-date methodologies, to integrate the process of safety assessment and to facilitate the tracking of the safety case among other advantages. The results are more conservative in comparison with previous assessments, the main differences are associated to the calculation models, mainly for the scenarios which include the geosphere pathways. The results of safety assessment allowed to define the scope of the maintenance works to extend the life service of the storage facility. The preliminary safety assessment using the BDC Screening tool was carried out for two different disposal sites for DSRS, a site in granodiorites rocks and other in sedimentary rocks which are main lithology in the country. The analysis identified the differences in the time lengths (of the barriers degradation and radionuclides transport) associated to the role played by the different geologies, preliminarily the site with igneous rocks is the most suitable for DSRS. The application of these tools have been useful supporting the implementation of the national strategy of radioactive waste management in the country.

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ID 31

RADIATION PROTECTION FOR THE RADIOACTIVE WASTE MANAGEMENT IN CUBA

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The Centre for Radiation Protection and Hygiene is the organization responsible for the management of radioactive waste in Cuba, and carries out the collection, transport, treatment, conditioning and storage of radioactive waste and disused radioactive sources generated from nuclear applications. Adequate infrastructure is in place for this purpose, including a Waste Treatment and Conditioning Plant and a Storage Facility. A License from the Regulatory Body is required for the operation of facilities and for waste management activities. The safety case has been developed to demonstrate the safety of the facilities and the practice and to support license application. According to national regulations, the safety case should include operational and safety procedures, radiation protection program, safety analysis, among others The radiation protection program includes the arrangements aimed at providing adequate consideration of radiation protection measures during the work with radioactive materials and inside the facilities, to guarantee the radiation protection of the operators and to avoid the dispersion of radioactive materials to the environment. The radiation protection program and its implementation are described in the paper, as well as, the elements of facility design and operations that influence into safety. The safety analysis includes the estimation of expected doses during normal operations and in radiological emergency situations and the risk evaluation. The risk matrix methodology is used for the safety analysis. It is a tool to establish risk management priorities based on a combined analysis of the probability of occurrence of an undesirable event and its consequences. This method has been widely applied in high-risk industries and more recently to radioactive facilities such as radiotherapy and industrial radiography practices. The application of risk matrix approach for radioactive waste management is described in this paper. It consists of the identification of possible initiating events of accidental sequences, the description of radiological consequences and their classification in levels of risk, and the safety barriers to pre- vent accidents or to mitigate their consequences. Twenty eight initiating events were identified for all the stages of radioactive waste management. As a result of applying the risk matrix methodology it was obtained that none of identified accidental sequences had neither high nor very high risk, 13 have medium risk, while the rest have low risk. A second analysis was not necessary and the practice was considered safe The safety case was evaluated by the Regulatory Body and approved. The License was granted for a 5 year period.

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ASSESSMENT OF HUMAN INTRUSION AND IDENTIFICATION OF R&D NEEDS FOR NEAR SURFACE DISPOSAL FACILITY OF PAKISTAN – A PART OF SAFETY CASE

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Development of radioactive waste disposal facilities needs to fulfill the licensing requirements. These requirements are achieved through development and demonstration of the safety case. It assists in optimizing the facility design and identifying the further R&D needs. To demonstrate the long term safety for disposal facilities, one of the major pillars of safety case is post closure safety assessment. As part of the long term post closure safety assessment, impact of human intrusion scenarios has to be taken into account. This study describes the inadvertent drilling intrusion into the Near Surface Disposal Facility for Low and Intermediate Level Radioactive Waste (LILW). This Human Intrusion scenario could in principle result in contaminated borehole core to be released to the surface. It is assumed that such events occur after the institutional control of the facility has been lost and there is degradation of various man-made barriers. Calculations have considered the direct exposure of the drill crew, site workers and exposure to the residents occupying the contaminated land and farming on land with drilling mud. Investigations are conducted using modeling methods described in the ISAM and BIOMASS projects. A safety assessment model has been developed using GoldSim for performance evaluation of the facility. The model evaluates nuclide release and transport into the biosphere resulting from Human Intrusion scenarios. Main focus is on determination of key radionuclides, peak dose and expected annual dose to a person from potentially exposed group. Uncertainty analysis has also been carried out. The results of analysis have helped to identify parameters that need further refinement to increase the confidence in the assessment and safety of the facility. The results will not only be used to update the facility design but also to focus on the R&D needs for future work.

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ID 44

PROPOSED DISPOSAL SOLUTION FOR ACTIVATED CALANDRIA TUBES AND PRESSURE TUBES OF KANUPP-1, PAKISTAN

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Government of Pakistan has decided to decommission its first and long-operated CANDU type Pressurized Heavy Water Reactor (PHWR) commonly known as Karachi Nuclear Power Plant-1 (KANUPP-1). It was commissioned in 1971 and is scheduled to be permanently shut-down in 2021. It is foreseen that during decommissioning of reactor vessel, specific radioactive waste will be generated. Management of such waste is a challenging task due to presence of long-lived radionuclides and its disposal is being planned in advance. In this study, only activated calandria tubes and pressure tubes are considered. In order to address this issue at first stage neutron activation calculations of calandria tubes and pressure tubes have been performed using ORIGIN computer code. These calculations are carried-out by considering the reactor power history and in-core neutron flux distribution. At second stage, safety assessment is used as guiding tool to find a suitable disposal option. GoldSim computer code is employed to perform the assessment. Two types of near-surface disposal options are explored: i) disposal of waste in a dedicated vault and ii) uniform distribution of waste in whole repository. Preliminary results show that the total annual effective dose is dominated by the radionuclides having long half-lives. 94Nb, 59Ni and 14C are identified as key radionuclides. It is found that for water release scenario in both options, total annual effective dose received by an in- dividual is lower than the regulatory limits. Moreover, for Human Intrusion scenario, dose received by an individual is significantly higher, if such waste is disposed of in a dedicated vault. This study suggests to minimize the consequences of Human Intrusion, activated calandria tubes and pressure tubes waste should be evenly distributed in the whole repository.

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ID 45

APPLICATION OF ARTIFICIAL INTELLIGENCE FOR OPTIMIZED AND COST-EFFECTIVE DISPOSAL OF RADIOACTIVE WASTE

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Artificial Intelligence (AI) is an exponentially growing field to solve real-world challenging problems. It is successfully being applied in a variety of fields such as engineering, physics, biology, mathematics, chemistry, medicine, astronomy, etc. It is an established area to identify hidden patterns and make predictions to analyze large data within a short time-frame. AI has the potential to find optimal solutions complex problems in the domain of radioactive waste disposal such as multi-scale flow patterns and radionuclide transport for the safety assessment of disposal facilities. Availability of data and domain expert knowledge is mandatory for the development of AI-based solutions. Several experiments are performed to understand the environmental influences and related process to demonstrate the long-term safety of disposal facility. However, lab experiments are expensive, time-consuming, and usually limited to study of a few samples. To develop radioactive waste repositories, various experiments are performed to acquire data for understanding long-term behaviour of surface and geological environment. Such experiments may include; long-term cement life studies, hydrogeological characterization of fractured rocks using borehole camera images, temperature effects on backfill materials, flood detection and susceptibility, material corrosion and permeability tests, earthquake prediction, etc. Moreover, there are conventional prediction models, which rely on simplified assumptions and might not address the non-linearity exists in natural processes. These limitations decrease the confidence over large time- scales of concern. Alternatively, AI has the ability to solve non-linear problems and extract the complex hidden pat- terns for prediction of accurate and reliable results. Moreover, it reduces experimental efforts and saves both time and cost. This paper explores the power and capability of AI approaches for the management of radioactive waste. As a case study, we may demonstrate the application of AI for identification of fractures present in host rock using borehole camera images or prediction of distribution coefficients (Kd) for transportation of Cesium in geological environment. The proposed work will be performed in two stages: pre-processing stage and model development stage. In pre-processing stage, discriminant features will be extracted from experimental dataset. After this, these features will be used to train the machine learning based algorithms such as Deep Neural Networks, Support Vector Machines, Decision Trees, etc. These models will be evaluated using various performance metrics like accuracy, sensitivity, specificity, precision, etc. The results may indicate that the developed AI models could be extended to solve prediction, classification, regression and pattern recognition related problems for the management of radioactive waste.

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ID 49

SAFETY ASSESSMENT OF THE DOST-PNRI RADIOACTIVE WASTE MANAGEMENT FACILITY RECEIVING AREA USING THE SAFETY ASSESSMENT FRAMEWORK (SAFRAN) SOFTWARE

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In the past, the Philippine Nuclear Research Institute's (PNRI) Radioactive Waste Management Facility (RWMF) has no formal receiving area for solid and liquid radioactive wastes, as well as DSRS. In 2020, through a project funded by the Institute, a receiving area was constructed for incoming radioactive wastes. A safety assessment of all activities at the receiving area was performed as part of the Radiation Protection, Safety, and Security Program as required by the regulatory authority. In this paper, the safety of the receiving area of the RWMF was assessed following regulatory requirements before the construction started. The PNRI-RWMF is authorized to treat, condition, and store radioactive waste until a final disposal facility is established in the country. The Philippines has not yet developed a formal national pol- icy and strategy for radioactive waste management; however, existing regulations are being implemented to control the use of RAM in the Philippines. These regulations are the guidelines of the RWMF operators in providing the radioactive waste management service. One of the regulatory requirements for nuclear facilities is to conduct a safety assessment on all its processes. This can be performed with various software to model different parameters of these processes. SAFRAN or the Safety Assessment Framework was used to carry out the safety assessment of the receiving area. A facility, named as PNRI-Radioactive Waste Management Facility was created in the SAFRAN project with the Receiving Area as one of its facilities. The activities defined based on practice were dose rate monitoring, contamination monitoring, unloading of the waste package, and transferring it to the processing area. Moreover, the incoming waste packages are defined as DSRS only because there is no major generation of solid and liquid radioactive waste from other fields. The DSRS was further divided into two categories namely, Category 1-2 and Category 3- 5 DSRS. For the regulatory framework, the Code of PNRI Regulations Part 3 was the basis of the occupational dose limits and the dose limit for the public, which is 20 mSv/y and 1 mSv/y, respectively for normal operations. SAFRAN has a built-in database for PIEs or postulated initiating events that were incorporated in the safety assessment due to accidental situations. Results of the assessment show that the calculated doses during normal operations and accidental situations were within the limits prescribed. To conclude, SAFRAN is an effective tool in performing the safety assessment of radioactive waste management facilities.

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GEOLOGICAL DISPOSAL PROGRAMME IN THE RUSSIAN FEDERATION: AN OVERVIEW

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Ensuring safety for radioactive waste management is one of the most important components of peaceful nuclear development of nuclear in the Russian Federation and a prerequisite for use of nu- clear energy now and in the future. In the Russian Federation, the main law in field of radioactive waste (RW) management is Federal Law N190 “On Radioactive Waste Management and Amendments to Certain Legislative Acts”. This law identifies the National Radioactive Waste Management Operator the only organization responsible for the disposal of all classes of RW in the Russian Federation. According to the requirements of national legislation and regulation in field of radioactive waste management, high-level and long-lived radwaste must be safely isolated in disposal facilities located at a depth of more than 100 m. Searching of the site for disposal of such waste in the territory of the Russian Federation has been carried out since the seventies of the twentieth century. Siting process for deep geological disposal of radioactive waste (DGR) was implemented using a phased approach. The phases or stag of this process is regulated by the national legislation in field of natural entrails use. Completed results of research at each stage are confirmed by the positive conclusions of the authorized Federal state body (Rosgeolekspertiza) and are enshrined in regulatory reporting documents. To date, a site for the Underground Research Laboratory (URL) has been selected. The National Operator (FSUE “NORW”) obtained the license for geological study of the site for the purpose its acceptability for placement of DGR, and also the license from the nuclear regulator for constriction an Underground Research Laboratory as part of a disposal facility for radioactive waste, Within the framework of obtained licenses, a preliminary safety assessment of disposal facility was performed, including long-term safety. An extensive base of hydrological, geological, hydrogeological and engineering-geological data was formed, and the main directions of research in the URL were determined. At present, the program for detailed study of the site and obtaining the most complete data on the initial (predisposal) state of the rock massif and its near zone, is being implemented; preparations for conducting mining operations have been started. During construction of mines, updated data on the geological structure, physical, mechanical proper- ties and water permeability of the host rocks are planned to be obtained for following use in studies to assess and confirm safety of the facility being created and to reduce uncertainties of this assessment.

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UNDERSTANDING THE BRITTLE DEFORMATION OF THE HOST ROCK – AN EXAMPLE OF INVESTIGATIONS NEEDED FOR THE SAFETY CASE DEVELOPMENT SUPPORTING RADIOACTIVE WASTE MANAGEMENT

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The most important requirements for safe nuclear waste management are related to the long-term safety of the repository. In case of deep geological disposal in crystalline bedrock environment, the main role of the bedrock is to provide a stable environment for the engineered barrier system. It is recognized that the requirements for the host rock should cover the issues of mechanical stability and favorable groundwater conditions. The stability, local seismic risks, groundwater flux and evolution, and transport properties are all strongly linked to the brittle deformation features: faults and fractures. This is considered in developing the geological understanding: in mapping, interpreting and modeling the structural elements of the bedrock in a selected site. It needs to cover the fabric of intact rock, general characteristics of brittle deformation, fracture data collection and processing, characterization of brittle deformation zones and identification of fracture and fault systems. The geological data are used for conceptual understanding and building deterministic and stochastic models. In a nuclear waste disposal program, typical downstream users of these data and models are modelers of other disciplines, safety assessment team and those responsible of design, construction, licensing, and operation of the repository. Therefore, geologists need to be able to answer questions about the host rock during the operation but also about the future evolution. One example of extensive characterization programs of brittle deformation is Posiva's project in the Olkiluoto site, Finland. Geological investigations started in the early 1980s, and after a multi-stage process, Olkiluoto was selected for the final disposal site of spent fuel from the Olkiluoto and Loviisa nuclear reactors. During this long process, geological investigations have been in a major role in the disposal project and its licensing and acceptance, but mutually the disposal project has been beneficial for developing investigation methods and better knowledge of bedrock in general.

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ID 85

REGULATORY RESEARCH IN PREPARATION FOR THE REVIEW OF SAFETY CASES FOR GEOLOGICAL DISPOSAL OF USED NUCLEAR FUEL

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Geological disposal initiatives typically take decades to develop from conceptualization to implementation. In Canada, research on geological disposal of used nuclear fuel started since the 1970s. The implementer of Canada's plan for the safe, long-term management of used nuclear fuel, the Nuclear Waste Management Organization (NWMO), is currently performing site selection activities between two potential sites in the province of Ontario. One site is located in sedimentary rocks in the Michigan Basin, and the other one in crystalline rocks of the Canadian Shield. The NWMO currently expects to select a final site by 2024, and then apply to the Canadian Nuclear Safety Commission (CNSC) for a site preparation licence. In support of the licence application, the NWMO must submit a safety case that presents multiple lines of evidence and arguments for the long-term safety of the geological disposal facility for periods of up to one million years. Following international best practice, the CNSC has been involved from an early project stage, through dialogue with the NWMO, monitoring of their engineering, site characterization and research activities, developing regulatory guidance and through the conduct of independent regulatory research. In this paper, a rationale and overview of CNSC's research and the progress on different research activities in the area of geological disposal will be presented. The CNSC's research activities into geological disposal options is designed around key safety arguments presented by the NWMO, for both rock types. The CNSC research spans multiple disciplines including geomechanics, geochemistry, hydrogeology, coupled processes and the study of natural analogues. Examples of most recent research will be presented together with a discussion on how they would help the CNSC make independent, objective and science-based assessment of the NWMO's future submissions.

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DERIVATION OF ACTIVITY CONCENTRATION UPPER LIMITS FOR LOW LEVEL SOLID RADIOACTIVE WASTE

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The derivation method of activity concentration upper limits for low level radioactive waste is put forward. The activity concentration upper limits for low level solid radioactive waste will be ascertained, on the basis of safety assessment of near surface disposal. On the premise of basic safety requirements about radioactive waste near surface disposal, taking Yaotian disposal site and Feifengshan disposal site as the reference sites, the post-closure digging well scenario, drilling scenario, after drilling scenario, and house construction scenario after the institutional control period when the disposal sites have been closed are considered. The radionuclide transfer process and exposure pathway of various scenarios are analyzed, the conceptual model and mathematical model of radionuclide transfer are established, and the effective dose to human from various scenarios is calculated. Assuming a linear relationship between the inventory and the impact, the activity concentration upper limits of various scenarios are then derived for each radionuclide that meet the appropriate dose criteria. The smallest upper limit is choosed, by the approximate integer principle, the magnitude of upper limit of each radionuclide for low level solid waste is then ascertained.

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POST-CLOSURE SAFETY ASSESSMENT FOR BOREHOLE DISPOSAL OF DISUSED SEALED RADIOACTIVE SOURCES IN GHANA

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The over six decades of use of sealed radioactive sources in Ghana has resulted in the generation of disused sealed radioactive sources (DSRSs) that need to be managed and dispose of safely. Ghana has a Centralised Radioactive Waste Storage Facility that can be considered as an adequate final management option for DSRSs containing short-lived radionuclides. However, for the long-lived radionuclides, a suitable disposal option is required. The Ghana Atomic Energy Commission (GAEC) intends using the International Atomic Energy Agency (IAEA) developed Borehole Disposal System (BDS) for final management of all the DSRSs. The BDS is based on a narrow diameter (0.26 m) design drilled to depth of 150m. The proposed site for implementation of the BDS is on the GAEC premises at Kwabenya. The site has been characterized based on geological, hydrogeological, geophysical and hydrochemical methods to gain a general understanding of the site. A post-closure safety assessment (PCSA) has been undertaken using an approach consistent with the recommendations of the IAEA safety guide on safety case and safety assessment for radioactive waste disposal with the aim of ensuring that the assessment is undertaken and documented in a consistent, logical and transparent manner. A scoping tool developed by Quintessa on behalf of the IAEA was used to evaluate the containment provided by the capsule and the disposal container as well as the containment barrier and backfill in the post-closure period (i.e provide indicative failure times for the engineered barriers). The AMBER software was used to implement the assessment model. A total of 13 waste packages will be required to dispose the inventory of disused sources. The scenarios identified in the IAEA Generic Safety Assessment for the borehole disposal concept were reviewed and, where necessary, modified to produce Ghana site-specific scenarios. The assessment result for liquid releases for the Design Scenario in terms of the calculated peak total dose is around 2.2E-12mSv/y which is significantly lower than the dose constraint of 0.3mSv/y. The combination of the surface erosion rate (1E-3 m y-1) and the depth of the disposal zone from the ground surface (136.58 m) results in the waste being uncovered after 136,000 years. Peak dose rates for the Design Scenario were calculated to occur at about 10,000 years and seven orders of magnitude lower than the regulatory dose constraint. The assessment indicates that Ghana's current inventory of DSRS can be safely disposed using the BDS.

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CLAIMS, ARGUMENTS & EVIDENCE (CAE) FOR CRITICALITY SAFETY AS AN EXAMPLE OF ENVIRONMENTAL SAFETY CASE (ESC) DEVELOPMENT

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The UK Government policy for the long-term management of higher activity waste is deep geological disposal, and a new siting process has been launched to identify a suitable site for the construction of a geological disposal facility (GDF). In terms of long-term environmental safety, a suitable site will be one where the geology and appropriately designed engineered barriers work together to isolate and contain the radioactivity, and any potential non-radiological hazards presented by the waste, for as long as required. The environmental safety case (ESC) for a GDF will be a set of structured claims arguments and evidence (CAE) that demonstrates how the radioactive waste will be isolated and contained. Radioactive Waste Management's (RWM's) 2016 generic ESC was based on three generic illustrative disposal concepts. This generic understanding is supported by RWM's knowledge base, which captures research and design engineering work undertaken over many decades by RWM and its con- tractors, relevant international organisations, and overseas waste management programmes. The 2016 generic ESC explains why RWM has confidence that a safety case, consistent with UK environmental regulations, could be made for a suitable UK site and geology. RWM is further developing it's CAE approach allowing us to link safety arguments to underpinning research evidence, identify knowledge gaps to help us develop a needs-driven prioritised research programme, and link the outcomes of that research directly to relevant safety functions and arguments. The CAE cover a wide range of topics, with one example being criticality safety. A proposed GDF will contain significant amounts of fissile material, spread across a large number of packages, that will be sub-critical when emplaced. Claims arguments and evidence need to demonstrate criticality safety of the facility over very long timescales, even when the engineered barriers may start to degrade. In this submission, an overview of RWM's current ESC and future development plans will be given, along with an overview of the regulatory requirements. There will then be a specific focus on the CAE structure, using criticality safety as the example. This will include an overview of the current approach and research underpinning the CAE for criticality safety for geological disposal. Future plans for CAE for criticality safety, wider lifecycle considerations and knowledge gap identification (e.g. building the evidence as more site information becomes available) and needs driven research will also be discussed.

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WASTE SHIELDED CASKS TRANSFER BY FUNICULAR FROM THE SURFACE TO DISPOSAL LEVEL IN CIGÉO

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Andra just completed the detailed engineering phase of Cigéo – the French Deep Geological Repository for High-Level Waste (HLW) and Intermediate-Level Long-Lived Waste (ILW-LL) - and plans to submit its construction license application within a year. Andra has chosen in 2009 a funicular ("cable-car") system for transferring, into a 5km straight nuclear access ramp, shielded casks housing one waste disposal container, from the surface to the underground facilities. Most of the technological issues related to the funicular have been solved and few are at final demonstration stages that is the purpose of the article. The paper proposes, at first, a brief description of Cigéo overall architecture and underground layout to illustrate the transfer route that a disposal package would have to accomplish to reach its final destination. A focus is given to the nuclear access ramp hosting the funicular which is designed to transport downward HLW and ILW-LL shielded casks (of weights reaching 100 to 130 tons). The main characteristics and mechanical performances of the cable-car system are then presented. The second part of the paper presents the incremental stages of qualification of the most innovative components, and more specifically the vehicle brakes. The brakes are to be assessed as key safety components of the system. At first, elementary tests were performed to validate the design basis of such a critical components and today, a pre-qualification program of breaking solutions (emergency and ultimate emergency brakes), developed by Andra and its co-developers, is on-going. A full scale funicular demonstrator of 130 tons payload capacity, moved by cables along a 100m long inclined railway with a slope of 12%, will be commissioned soon. The construction of the demonstrator started in 2020 and the test program, which is as close as possible to Cigeo operating conditions, will be launched by mid-2021. These overall systems should be reaching level 6 on the International Technology Readiness Level scale at the end of the demonstration program. The third part of the article presents preliminary results of trials and elementary tests of safety brakes, and first feedbacks on the funicular design. The last part of the article sheds light on first results obtained with demonstrator in full-scale. The outcomes of this technical test campaign will feed the instruction of the future evaluation of Cigéo construction license application documents.

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TOWARDS UNDERSTANDING THE IMPACT OF AN EXCAVATION DAMAGED ZONE IN A RANGE OF ILLUSTRATIVE GEOLOGICAL ENVIRONMENTS AND IMPLICATIONS FOR BACKFILL AND WASTE PACKAGE EVOLUTION

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In 2018, Radioactive Waste Management Ltd (RWM) established the Backfill Integrated Project (IP), aimed at providing the scientific, technological, and engineering underpinning for the development of backfill solutions for a future Geological Disposal Facility. The Backfill IP [1] is complemented by a parallel workstream investigating the impact of void space on repository performance [see 2 and e.g. 3,4]. One aspect of RWM's backfill development work has been to model the mechanical evolution of a proposed backfill material in a GDF. This work has also reviewed the potential effects of excavation within three illustrative host rock types, establishing a preliminary view of Excavation Damaged Zone (EDZ) development. The task has examined the possible impact of excavation activities and interactions with the developing EDZ over time, on both an illustrative backfill material and subsequent waste packages. Over the initial phases of these two projects, the approach to modelling has been to consider some key inputs such as geological boundary conditions, appropriate stress-strain ground models, and key methodologies. Outputs have aided a preliminary understanding of the development of an EDZ across the three potential categories of host geology and explored the potential implications for backfill selection criteria. Crucially, at this early stage, the projects have also identified gaps within which further work will be required. Ongoing development of analytical models across the next phases will further explore the interaction between the EDZ and the backfill material, examining key geotechnical properties that impact this relationship. Key aspects include backfill stability upon loading due to lining degradation over time and its ability to support the host rock. The impact of creep in relevant geologies will also be explored. Further work will also examine the evolution of crown space within the vaults and its impact on backfill stability and the EDZ over time.

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NUMERICAL STUDY OF PERFORMANCE OF PLACEMENT ROOMS FOR DEEP GEOLOGICAL ISOLATION OF HIGH-LEVEL RADIOACTIVE WASTE

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Evaluation of long-term stability of the placement rooms and damage in the surrounding geological formations in a deep geological repository (DGR) for high-level nuclear waste are essential fac- tors for overall repository performance assessment. Prediction of the long-term performance of the placement rooms usually requires numerical models capable of simulating coupled thermo-hydro- mechanical (THM) processes over different time and length scales caused by natural and repository- induced perturbations. The constitutive model that represents the host medium should be capable of representing highly nonlinear response to stress changes, including development of damage and fracturing. This paper is based on numerical studies aimed at predicting the long-term (1 million years) performance of two different designs of placement rooms in different rock types and for different hydrological conditions. One case is the emplacement drift, which is not backfilled, in an unsaturated tuff at the Yucca Mountain project, the proposed DGR for high-level nuclear waste in the U.S. The other case is a backfilled placement room in a saturated crystalline rock in a generic high-level waste repository design considered for the Adaptive Phased Management (APM) program by NWMO of Canada. The important and novel feature of the presented modeling approach is using a bonded-block model, based on the distinct element method (DEM), to represent deformation, damage and fracturing of the surrounding rock that can potentially impact the placement rooms. The approach can explicitly simulate initiation and propagation of cracks in the rock as a function of transient stresses and pore pressures. These cracks can potentially form loose blocks, which, if unsupported, will result in a gradual collapse of the placement room. As part of the study, coupled THM processes were analyzed in a sequence of bounding numerical simulations of relevant loading scenarios, including in-situ stresses, used-fuel canister heat generation, strong earthquakes, advancing and retreating glacial ice loading, and extreme repository-induced effects. Important processes for long-term performance of the repositories, such as time-dependent rock strength degradation, were also included in the analyses. The details of the THM modeling approach and the selection and evaluation of the model parameters used in the analyses are de- scribed. The sensitivity of the response to variations in model parameters is discussed. Performance of the placement rooms in the two analyzed cases are compared as a function of room design, use of backfill, mechanical characteristics of the rock mass, groundwater saturation and different loading scenarios.

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CLASSIFYING THE RADIOLOGICAL HAZARD DUE TO FIRE ON DISUSED SEALED RADIOACTIVE SOURCES AND STORED RADIOACTIVE MATERIALS IN GREECE

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The routine safety assessments of an interim storage facility for Disused Sealed Radioactive Sources (DSRSs) and stored radioactive wastes, inter alia concerns (a) the development of justified risk- scenarios, (b) the formulation of the appropriate models, (c) the collection of the input data, (d) the performance of calculations and (e) the evaluation of the results. In this work, the radiological risk due to fire is estimated in several case-studies, considering scenarios of different meteorological conditions applied on hypothetical inventories of DSRS and other radioactive materials, similar to those stored in the interim storage facilities in Greece. A specialized code developed for the calculations, implementing the equations of plume dispersion for specific radioisotopes, specific terrains and meteorological conditions, like wind and rain. The dose calculation in long term takes into account the ground deposition of the radioactivity, while in short term takes into account the airborne radioactive plume as well. The breathing rate and the thyroid uptake are considered as well. The dose, calculated for the first responders and for the public, based on realistic scenarios of engagement with the radioactive pollution. The comparison of the outcomes with assessment criteria, like the annual dose limits, yields a classification of the radiological risk for each case of inventory and indicates, with graded approach, adequate safety measures of preparedness and response. Specific examples of common inventories are studied: (a) an interim storage of lightning rods with Am-241 and Ra-226 pellets of about 30 GBq total activity, (b) a centralized interim storage of about 400 DSRSs of IAEA's category 2 to 5 and (c) nuclear moisture density gauges, which combine sealed sources of Cs-137 and Am-241 of 0.30 GBq and 1.48 GBq, respectively. The results indicate different grade of risk for single DSRSs, small inventories and bigger ones. The IAEA's category of the sources or the activity of the stored radioactive wastes, their housing and the conditions of their storage are the major factors for this differentiation of the radiological risk raised by an accident of fire.

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GRADED DEVELOPMENT OF GEOLOGICAL DISPOSAL TOWARDS OPTIMIZED SOLUTION

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Posiva is finalising the world's first safety case the operating licence application to be ready by the end of 2021. The application and the safety case gathers the work that has been done since the 80's when the Finnish Government determined the guidelines, overall plan and target schedules for nuclear waste managementThe first safety case for Olkiluoto was made in 1999. In 2000, the Finnish Government made a decision-in-principle, according to which "out of the investigated final disposal options, final disposal deep in bedrock, i.e. geological final disposal, offers the best and most realistic possibilities to isolate high-level nuclear waste from the biosphere, i.e. the human habitat". During the same year Olkiluoto was chosen as the final disposal site. The first safety case for Olkiluoto was relatively generic but after Olkiluoto was chosen as the final disposal site, the site investigations and the know-how of Olkiluoto geology, hydrogeologigy and hydrogeochemistry increased and the safety case became more site specific. The safety case published in 2012 to complete the construction license application was the first one that included well characterised site investigation data. Ever since Posiva haves been updating and expanding the safety case according to the feedback received from the Finnish Radiation and Nuclear Safety Authority and international reviewers including the increase in the process and knowledge understanding. Together with the Full Scale In Situ System Test (FISST) and the underground construction experience of ONKALO® the concept readiness has raised up to a level where we can see that the final disposal can be done safely. All this experience will be taken into account in the safety case of the operating licence application which describes the long term safety of the final disposal for a one million year in timescale.

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THE SAFETY CASE AND SAFETY ASSESSMENT FOR RADIOACTIVE WASTE RETRIEVAL FROM HISTORICAL RADON-TYPE STORAGE FACILITY

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The main objective of this study was to apply the GSG-3 (The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste) methodology and the SAFRAN tool (which utilized the SADRWMS methodology) to waste retrieval from a typical near surface Radon-type facility. The secondary objective was to support decision making for planned operational waste retrieval operations and predisposal radioactive waste management activities at a near surface historical disposal facility for solid institutional radioactive waste. Our safety case was structured following the template provided in Section 4 of GSG-3. The Radon-type facilities took their name from the RADON system that was established in the former Soviet Union in 1950s and early 1960s of the 20th century for collecting, transportation, processing and near surface disposal of low and intermediate level institutional radioactive waste including dis- used sealed radioactive sources. Typical initial design of a Radon-type facility includes three or four disposal vaults of 200 m3 each. In the majority of Radon-type facilities, there are a few common problems relating to waste inventory records. One specific problem relates to the uncertainty associated with insufficient information on waste inventory, e.g. the waste is commonly labeled as ‘mixed fission products’ or simply ‘radioactive waste’. Results of SAFRAN calculations indicated a maximum dose rate to a worker of 6.2 mSv/a under normal conditions and 7.0 mSv under accident conditions during radioactive waste retrieval. The maximum public dose under accident conditions is 0.8 μSv, with negligible public dose under nor- mal conditions. The safety case demonstrates full compliance with national and international dose limits and dose constraints. The IAEA GSG-3 methodology is applicable for the issue of safety assessment of radioactive waste removal from historical near-surface storage facility of the Radon type. This work was important not only from the methodological point of view, but also from the practical one, since there are many similar storage facilities in the former USSR countries and countries of the Eastern Europe. Practical experience of SAFRAN tool (Sweden) application has shown that it can play a significant role in managing records and knowledge on radioactive waste, nuclear facility site, characteristics of geological environment and safety barriers. It can provide reliable long-term storage and effective management of safety related records for the purposes of safety reassessments, review and supervision.

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DISPOSAL SAFETY CASE FOR NEAR SURFACE DISPOSAL FACILITY

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Canadian Nuclear Laboratories (CNL) proposes to develop a Near Surface Disposal Facility (NSDF) at the Chalk River Laboratories (CRL) site in Ontario, Canada for disposal of Atomic Energy of Canada Limited (AECL) radioactive Low Level Waste (LLW). A safety case was prepared using the safety arguments presented in a number of technical supporting documents and integrated them into a single body of evidence in order to demonstrate the operational (near term) and long-term safety of the proposed Near Surface Disposal Facility. The NSDF Safety Case was developed to meet Canadian Nuclear Safety Commission (CNSC) requirements and International Atomic Energy Agency (IAEA) safety standards for radioactive waste disposal. The NSDF Safety Case was structured to align with IAEA guidance and included sections discussing the introduction, safety strategy, system description, safety assessment, iteration and design optimization, management of uncertainties, limits, controls and conditions, integration of safety arguments, and the management system. Independent Third Party Reviews were conducted and the feedback from those reviews was incorporated into the final document. Existing research programs or additional technical studies were useful in dispositioning key concerns from the public and Indigenous groups.

SOCIO-ECONOMIC ASPECTS OF RADIOACTIVE WASTE MANAGEMENT PROGRAMMES

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 312

OPEN, TRANSPARENT BUT NOT INVISIBLE

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Over the past decades, there has been a growing social awareness of the need for transparency and openness, and the dialogue with stakeholders in decision-making processes throughout the life cycle of radioactive waste facilities. Member States approach the dialogue on long-term radioactive waste management in different ways, depending on cultural, political, institutional and economic factors. The planning of the radioactive waste programme determines when, how and with whom dialogues have to take place. In the Netherlands, the factor of time plays a decisive role in the dialogue about radioactive waste. As the Netherlands has an interim storage period of at least a hundred years, communicating time is a specific challenge for COVRA, the national organization for the management of radioactive waste. This paper explains how COVRA's communication activities evolved over time to meet that challenge. Like many other (nuclear) organizations, the objective first was to be as transparent, factual and objective as possible. But if you are too transparent, you become invisible to your stakeholders and the general public, which is not a good basis to start a dialogue. To create opportunities for dialogue, people need to notice you: you have to show yourself, standout, be proud of what you do, show that radioactive waste management can be done in not only a safe, effective and efficient manner but also with beauty. This is why COVRA started using its buildings as communication instruments. COVRA's communication became not only factually and objectively, but also based on emotion, art, and cultural heritage.

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 106

ATTITUDINAL SOCIAL IMPACTS ON RADIOACTIVE WASTE MANAGEMENT PROGRAMS AND PRACTICES: A CASE REVIEW OF THE ETHIOPIAN RADIOACTIVE WASTE MANAGEMENT AND PROCESSING FACILITY ACTIVITIES

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One of the utmost challenges of countries in radioactive waste management activities is the link it has with the socio-economic undertakings of the host communities. Appreciation of perceived socio- economic impacts and benefits to be drawn from radioactive waste management activities is crucially important for maintaining facilities, fulfilling missions, and building a sustainable relationship with the host community and relevant stakeholders. Understanding the attitudinal social impacts towards radioactive waste management strategies practices and activities, the useful relationship between the facility and the host community, the experiential gains and risk perception in line with the level of public awareness programs in progress in detail is pivotal to investigate the overall picture of the community/residents living in the case study area and the degree to which they could be positively or negatively impacted by activities run within the facility. Coming up with concrete evidence on attitudinal social impacts of radioactive waste management activities fosters the exchange of experiences among potential stakeholders and partners. It could also facilitate the development of a custom-made radioactive waste management plan and stakeholder consultation for engagement and participatory processes. It provides options for comprehensible radioactive waste management strategy formulation that is dependable with other national priorities. Analysis of attitudinal social impacts of radioactive waste management strategies, practices, and activities enables to have an appropriately informed public and develop all-inclusive approaches for the management of social radiological risks. This paper aims to specifically explore the attitudinal social challenges affecting the host community, residents near the Ethiopian Radioactive Waste Management and processing facility, and citizens that are most likely susceptible to disused sources exposure by their profession. Investigating the social benefits realized through radiological waste management activities is also another focus area of the study.

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 304

STRATEGIES AND PRACTICES TO ENHANCE PUBLIC AWARENESS FOR IMPLEMENTING RADIOACTIVE WASTE MANAGEMENT PROGRAMMES IN JAPAN

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The Japanese Government enacted a law in 2000 that prescribed that the high-level radioactive waste (HLW) from the reprocessing of spent fuel should be disposed of in the geological repository (GR) by NUMO, an organization authorized by the Government, based on the fee collected for this purpose as a part of electricity bill. To maintain these policy decisions, it should be kept in mind that every public policy in our society is under democratic political process that is essentially a chain of decisions, implementations, changes, and implementations, accompanying various forms of public consultation and involvement at each step. The law specifies three stage consent-based process for the determination of one site for the GR and that NUMO can start each stage only when approved by mayor of the municipality where an interested area is located. Therefore, NUMO informed in 2002 all municipalities in Japan the open solicitation for the acceptance of the Literature Survey (LS), the first stage of the process and has been holding seminars on a nationwide scale to communicate with the public on the safety of the GR and the importance of both implementing it and showing the public's respect to the municipalities that participate in the process. The Government established a scheme to provide area-development subsidy to municipality that accepts the LS for the benefit of society. Fortunately, NUMO has started the LS at two municipalities in Hokkaido, Suttu-cho and Kamoenai-mura in last December. As this siting process is designed so that the applying municipality can leave the process at any stage, NUMO should, in parallel with carrying out desk-top study about the geological environment of these applied areas, do its best for these municipalities to learn the importance, the safety and the process of the project and what participation means for the area during the site investigation and facility construction and operation periods if the area is selected as the site. NUMO is opening Information Centers in each municipality and is supporting jointly with municipal office the operation of Community Dialogue Committee that is comprised of 20 municipal residents. The Committee in each municipality is starting to support community members to learn about geological disposal of HLW and the social and environmental impact of siting the GR. NUMO should continue diverse efforts for sincerely communicating with the public in this endeavor, so as to be recognized as a competent, caring, and faithful organization.

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 284

SOCIO-ECONOMIC EFFECTS OF DEEP GEOLOGICAL REPOSITORIES: OPPORTUNITIES OR THREATS? THE SWISS CASE

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The Swiss site selection procedure for deep geological repositories (DGR) for both waste categories (L/ILW and HLW) is regulated by a sectoral plan, a comprehensive federal spatial planning instrument. The Swiss Federal Office of Energy (SFOE) is responsible for its implementation. The procedure was started in 2008 with the adoption of the initial conceptual document by the federal council (national government) and consists of three stages. In order to incorporate the local stakeholders' interests into the planning process governed by national law, specific participation bodies – so-called regional conferences – were set up by SFOE. With the reduction to three remaining potential siting regions in 2018, the final stage was initiated. It is to be terminated with the siting decision in 2029, subject to ratification. The consideration of potential future socio-economic effects caused by a repository has enjoyed a high priority since the beginning of the procedure. Extensive socio-economic baseline studies to assess social, demographic, ecologic and economic effects of a DGR were conducted in the six initial potential siting regions. They involved a four-stage benefit analysis comprising 40 indicators in the dimensions society, environment and economy. In areas where regional conferences demanded further clarifications, additional studies were conducted. Until the siting decision, the activities relating to socio-economic aspects are concentrated on regional development, long-term monitoring of socio-economic indicators and so-called in-depth studies. With regard to regional development, the regional conferences are asked to analyze regional development strategies and draft measures supporting the region's desired development with a DGR. The SFOE's activities include preparations for an adequate institutional set-up for the management of compensation funds expected to be distributed to the final siting region(s). Concerning monitoring of socio-economic indicators, a pilot study has demonstrated the methodology and feasibility of a comprehensive long-term surveying. The in-depth studies deal with specific questions of concern. So far, a methodology has been proposed to assess potential causal effects of a DGR on a siting region as a residential and business location and an analysis on leveraging positive economic effects of a DGR on the regional economy has been completed. The presentation will summarize the most important contents and findings of the socio-economic evaluations that have been conducted so far. It will shed light on the regional conferences' activities with regard to regional development and will present an outlook over the planned activities related to socio-economic aspects for the remaining part of the selection procedure.

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 172

FOSTERING STAKEHOLDER ENGAGEMENT: SELF-ORGANIZATION AS A NEW APPROACH TO PUBLIC PARTICIPATION IN THE CONTEXT OF THE GERMAN SITE SELECTION PROCEDURE

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In 2017, Germany has started the search for a final disposal site for high-level radioactive waste. Viewing transparency and public participation as essential prerequisites for creating credibility and legitimacy, the law stipulates extensive participation opportunities for the public during the complete procedure. Following the publication of first interim results in autumn 2020, the first formal participation format has started – the "sub-areas conference". With the aim of enabling a broad societal discussion process, legislators have introduced a completely new form of organisation for this participation format: self-organisation. This means that the participants can determine the agenda, their way of working and the main topics for discussion. The goal is to promote the involvement of the general public by enabling them to take on responsibility and shape the process. As the competent authority for public participation, the Federal Office for the Safety of Nuclear Waste Management (BASE) was responsible for implementing the conference. The paper provides first insights into the perspective and learnings of BASE regarding the concept of self-organisation from a practical point of view. A central finding of the paper is that the concept of self-organisation reinforces individual responsibility and therefore the involvement of the participants and creates well-functioning working structures and results. During the course of the discussions, the conference increasingly became an independently acting alliance of interested stakeholders with its own decision-making structures and content priorities. However, it also became clear that self-organisation involves a great deal of effort by those involved in it and that it requires time. Also, it should be recognised that individual interest groups, which can strongly affect the process, can particularly emerge in formats that are self-organised. The format at best only represents a part of all societal interests.

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TOOLS AND METHODOLOGIES FOR ENGAGEMENT WITH THE PUBLIC AND AFFECTED COMMUNITIES FOR REGULATION OF RADIOACTIVE WASTE MANAGEMENT PROJECTS

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The Canadian Nuclear Safety Commission's (CNSC) regulates all nuclear facilities and activities throughout their lifecycle. The Commission's decisions are based on the evidence presented in the context of an open and transparent hearing process, including information brought forth by the public, Indigenous peoples, and other stakeholders. In Canada, the regulation of new radioactive waste management projects includes both an environmental review (ER) and a licensing process. Public and Indigenous engagement allows the CNSC to obtain valuable information and to hear concerns and address questions about proposed projects, which strengthens the quality of reviews and informs the Commission's decisions. The CNSC facilitates public and Indigenous participation throughout the ER and licensing processes in a number of ways. The CNSC notifies the public of new information and milestones through websites including a public registry, social media channels, and mailing distribution lists. The CNSC also provides opportunities for real-time engagement through webinars, open houses and other local public events. In addition, the CNSC's Participant Funding Program (PFP) provides financial assistance to participate in key phases of both processes. Finally, participants can submit comments or concerns regarding proposed projects undergoing ERs or licence applications in an oral and/or written intervention to the Commission as part of hearing proceedings. The CNSC engages with local Indigenous communities over a project's lifetime. In Canada, Indigenous and Treaty rights are protected under the Canadian Constitution. The Government is legally required to consult potentially affected Indigenous groups when making decisions that could impact them. As an agent of the Crown, the CNSC is committed to meaningful consultation with Indigenous communities that is in line with best practices and goes beyond the legal bare minimum. The CNSC ensures that Indigenous groups have opportunities to participate in all aspects of ER and licensing processes, in order to ensure all issues and concerns are considered. Information gathered, including Indigenous Knowledge, is used to inform decisions under federal impact and environmental assessment legislation. The CNSC has adapted to the realities of the pandemic by adapting how it interacts with the public and Indigenous groups. This includes implementation of various video and teleconferencing platforms and interactive webinars, responding to the technological availabilities of the other par- ties. The CNSC's transparent and collaborative approach to consultation and engagement for all nuclear projects in Canada helps contribute to the CNSC's strategic goal of being a trusted regulator and enhancing the CNSC's regulatory oversight of the nuclear industry.

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SOCIOTECHNICAL SYSTEMS DESIGN FOR CONSENT-BASED SITING OF NUCLEAR WASTE FACILITIES

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Successfully executed radioactive waste management projects are critical to the sustainability of the nuclear industry. While there's a tendency to think the challenges to successfully manage radioactive waste are technical, public acceptance is perhaps the biggest challenge. The social aspects of nuclear waste storage, transportation and disposal cannot be understated, hence the growing emphasis on consent-based siting. While there are a number of examples of successful and unsuccessful consent-based siting efforts, there is no single "roadmap" or "framework" to describe how to secure community consent. We believe one such potential roadmap or framework could be Sociotechnical Systems Design. Sociotechnical Systems Design recognizes the interaction between people and technology and con- siders both social and technical factors that influence the functionality, practicability, acceptability, and usage of a system. A holistic analysis of any system considers five work system elements (people, technology/tools, tasks, policies/organization, and the environment) and identifies where requirements or conditions of these elements have consequences triggering changes on the others. Concurrent Engineering is a systematic approach to enable designers to consider all system elements and their interfaces throughout the lifecycle from the outset by incorporating stakeholders early in the pre-design stages. This paper describes how a radioactive waste management project could be implemented as a sociotechnical system that relies on a concurrent engineering process to achieve consent-based siting of a nuclear waste management facility. The resulting framework addresses the socio-economic requirements of communities while facilitating communication and interaction opportunities between technical, political, and social stakeholders. This will allow communities to access information and raise concerns about waste management locally, while letting technical specialists factor these concerns into the waste management program design, providing information where needed, and reducing the need for rework and retrofitting. Staged implementation of sociotechnical systems design supported by concurrent engineering can be key to consent-based siting and a successful waste management program.

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SITE SELECTION METHODOLOGY FOR THE BRAZILIAN REPOSITORY FOR LOW AND INTERMEDIATE-LEVEL RADIOACTIVE WASTE THROUGH GEOSPATIAL ANALYSIS

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The implementation of a radioactive waste repository will be an important milestone for the Brazilian nuclear sector as it will enable the correct management of a large amount of radioactive waste generated in the country. The site selection process is guided by CNEN Standard NE 6.06, which establishes minimum requirements for the process of selection and choice of sites for repositories for low and intermediate-level radioactive waste in order to ensure the safe containment of these materials. Accordingly, the site selection process is divided into four distinct stages and for the current scenario geospatial analysis procedures were applied in each stage, mostly by means of the ESRI ArcGIS® Software: Region of Interest, Preliminary Areas, Potential Areas and, finally, Candidate Locations. For each stage established by this standard, thematic criteria and numerical parameters for the inclusion or exclusion of areas were considered, covering all standardized topics. The Region of Interest was defined as the area that a truck, leaving the Angra Nuclear Power Plants (the only Brazilian nuclear district), can travel six hours for two-day journey, at 60 km/h. Preliminary Areas were defined by the application of the following criteria for inclusion and exclusion process: Environmental Protected Areas; Indigenous Reserves; Rural or Quilombola Settlements (former fugitive slaves regions); Urban Areas; Hydrogeological Studies; Average Annual Rainfall, Flood Records and Vulnerability to Flooding; Relief Study; Geological Faults, Lineaments and Fractures; Climatological Scenarios; and Mining Areas. Once the Preliminary Areas were defined, the choice of Potential Areas was proceeded in a very similar and complementary way (ranking procedures) to the previous step, covering the following themes: Evaluation of the Road Network; Distances to Airports with Regular Flights; Distance Ranking to Radioactive Waste Generators; Local Lithology; Vulnerability to Flooding Areas, with a better geographic base, and Swamps; Analysis of the Ownership of the Lands under study, through the Rural Environmental Registry; Areas with Archaeological Interest or Recognition of Historical, Artistic or Cultural Heritage; Environmental Reserves. Finally, for a pre-survey of Candidate Locations, a refinement of the Potential Areas through a visual analysis was carried out using satellite images. The site selection team sought excluding areas with evidence of relevant rural activities, water bodies and native forest. The next step was to build diagram blocks of the areas using a Photoshop plug-in “3D Map Generator - Atlas” with their subsequent submission to project coordination. Appropriately, 30 areas suitable for receiving the repository were selected.

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NATIONAL RADIOACTIVE WASTE MANAGEMENT INFRASTRUCTURE IN MYANMAR

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Myanmar has used radioactive sources for peaceful purposes in medical, industrial, research and education. These sources are imported and are safely and securely controlled under the IAEA issued International BSS and Security Guidance. The volume of radioactive waste produced is small and only low-level radioactive waste arising from medical and industrial applications exists in Myanmar. Relatively low activity and small quantity of disused sealed radioactive sources (DSRS) that cannot be returned to their suppliers, are managed locally to safely and securely for long term storage in central radioactive waste storage facility. Codes of Practice on occupational protection, public protection, medical exposure, radioactive waste, and transport of radioactive materials are being pre- pared and controlled by the Division of Atomic Energy (DAE) in Myanmar. The policy and strategy for radioactive waste management in Myanmar has yet to be established. To achieve the set objectives for effective waste management regime, the regulations on radiation and waste safety have been drafted, revised internally, reviewed by the Agency and approved by the Myanmar Attorney General's office but in under processing, that ensure to develop relevant codes of practice to guide operating in waste management facilities and the regulatory authority. Myanmar has made political commitment for code of conduct on safety and security of radioactive sources in 2017 and for enhancing capacity building on strengthening legislative and regulatory framework for nuclear and other radioactive materials safety, security and safeguards, the new nuclear law is in the progress of drafting that coverage of atomic energy law, placed in 1998. Myanmar has made continual efforts on radioactive waste management activities with regional, international Training, Workshop and has participated in IAEA TC regional projects including: RAS/9/071 and RAS/9/085. To develop national radioactive waste management infrastructure and to increase national operational capabilities and capacities, Myanmar initiated the IAEA TC project MYA 2020010 in 2022-2023; safety and security management of DSRS, through Agency's support, funding availability, mitigation measures on DAE as main driving force of inclusive and sustainable development for relevant technologies including appropriate equipment, effective operational procedures leading to identification of potential pre-disposal options for DSRS and human resources to operators of waste management facilities. Myanmar is currently being developed through internationally harmonizing with the improvement, fulfilled international and regional commitments and activities in the areas of radioactive waste management that ensure to be effective and address to strengthening regulatory infrastructure and sustainable development for radiation and waste safety management.

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EDUCATION AND RESEARCH ON RADIOACTIVE WASTE HANDLING FOR PUBLIC ACCEPTANCE: UNIVERSITAS GADJAH MADA'S EXPERIENCE

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Pros and cons always arise when a country, including Indonesia, plans to build a nuclear power plant (NPP). The primary question from the disagreed people with NPP utilization is how to treat the waste generated. So, the capability to handle radioactive waste is believed to be a key success fac- tor to increase national public acceptance. Education, including universities, should be the essential players in building this radioactive waste management capability. According to this role, radioactive waste management has become an important topic in the curriculum of the nuclear engineering study program of Universitas Gadjah Mada (NE-UGM) Indonesia. In NE-UGM, radioactive waste management is taught in a course and studied in several research topics. The radioactive waste management and handling course is a three credits course for the 3rd-year student. The students learn about the waste classification, the related regulations, some technologies to handle radioactive waste, and the 3S related to the waste management facilities. Some practitioners and researchers, mostly from the National Nuclear Energy Agency of Indonesia (BATAN), were also invited to enrich the student's knowledge. To get a safety feeling in handling the waste, students also visit the radioactive waste management center of BATAN that in 2020 was conducted virtually during the Covid-19 pandemic condition. They are also exposed to several advanced reactor types to build their imagination to the new form of radioactive waste that will be handled in the future. In completing the course, students are assigned to design a simple radioactive waste management system, including radioactive waste arising in hospitals that are the most founded in Indonesia. The radioactive waste research group of NE-UGM studies the materials to reinforce the immobilization process and tests the substitute materials. We also investigated the use of new methods and materials for processing the waste, such as the electrocoagulation method and MOF material, to improve waste treatment's safety and effectiveness. The group also designs the transportation container for nuclear spent fuel and disuse gamma source to strengthen the national radioactive waste handling capability. Hopefully, by publishing all of the activities, Indonesia's public trust in handling radioactive waste is improved and impact the public acceptance of NPP in Indonesia.

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SITEX BENCHMARK ON SAFETY CASE REVIEWING APPROACHES

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The SITEX.Network (Sustainable network for Independent Technical EXpertise on radioactive waste management) aims at enhancing and fostering cooperation at the international level in the field of safety of radioactive waste management. It acknowledges the important role of the civil society in the decision making process, in synergy to the independent expertise of the nuclear regulatory authorities. SITEX.Network activities are related to training and tutoring, reviewing the safety case, developing a research strategy and workforce at the national and international levels and interacting with the civil society. The SITEX.Network initiated a benchmark exercise focusing on review approaches of safety cases by different parties and on the evaluation of benefits of early civil society engagement in a decision process related to geological disposal. A fictive safety case has been developed in the context of the site selection of a geological disposal facility. It covers the safety strategy, the safety concept, the design and the assessment basis. It then focuses on the safety assessment of a human intrusion scenario caused by deep geothermal energy activities. Two workshops have been organised to present and discuss the fictive safety case. These work- shops simulate interactions that might be organised as part of the engagement process between implementers and other stakeholders. The participants took over different roles, which covered the fictive waste management organisation (prospective licensee) developing and implementing a geological repository, the regulatory body (including both the regulatory authority and its technical support organisation) and representatives from the wider community partnership and civil society organisations. During the first workshop, the participants provided feedback on the fictive safety case and on the human intrusion scenario to be explored. Then, the fictive safety case was updated and shared for 'offline' review prior to a second feedback workshop to discuss the assessment per- formed by the different actors. At the end of the process, a reflexion took place on the experience gained by all participants during the exercise. Our paper reports the lessons learned for improving the actual decision processes related to geological disposal of radioactive waste in respect of stakeholders' interactions and collective intelligence. It also evaluates how the available resources of the reviewing organisations, which differ between stakeholders and from one country to another, impact their review approach.

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A SOCIETAL LICENCE AS A KEY STEP TOWARDS IMPLEMENTATION OF A SURFACE DISPOSAL PROJECT IN BELGIUM

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From the start of the search for a long-term solution for the disposal of low- and intermediate-level short-lived waste, ONDRAF/NIRAS began cooperating with several Belgian municipalities. The partnerships STORA in Dessel and MONA in Mol were set up to investigate the feasibility of such a project in their municipality. Both neighbouring municipalities imposed conditions on the possible construction of a facility on their territory. The partnerships, established for the research phase, representing all actors of the local society, celebrated their 20th anniversary last year and are still privileged partners in the development of the disposal project. After many years of preparation, the implementation of the disposal project is now visible on the ground. ONDRAF/NIRAS is building facilities for conditioning disposal waste and the disposal facility will be constructed soon. This is a key moment for all parties involved. ONDRAF/NIRAS therefore considered it advisable to make an assessment of the project and of the fulfilment of the conditions. Do the existing subprojects and cooperation meet the expectations? Have things evolved that will force us to make changes? And is our way of working suited to the challenges ahead? ONDRAF/NIRAS entered into a dialogue with the partnerships and municipalities with the aim of learning lessons from the past and working out a plan for the future. A number of complex issues came up in the discussions. The most difficult issues are related to the long duration of the project. Organising public participation over a very long period of time is not straightforward and there are few examples to serve as good practices. How do you enthuse new generations? How can the partnerships continue to represent the wider community? In short, how do we turn partnerships into flexible organisations that are ready for the future? The result of this fascinating review is written down in two documents. First, ONDRAF/NIRAS drafted the Societal Contract together with STORA, MONA and the municipalities. This document outlines the future vision on the further implementation of the project. It can be seen as a green light from the partnerships and municipalities for the further implementation of the project – a ‘societal licence’ in a way. It is also a reaffirmation of ONDRAF/NIRAS’ commitment to continue fulfilling the conditions. The way in which we will continue to cooperate with the various partners and respond to the above challenges will be laid down in a second document, a cooperation agreement.

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A PRELIMINARY PUBLICITY PROGRAM FOR THE EARLY CONSTRUCTION STAGE OF URL FOR HLW DISPOSAL IN CHINA

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China has begun to build its underground research laboratory for high-level radioactive waste disposal in Beishan area, a preselected area of the repository, located in the Gobi hinterland of Gansu Province in northwestern China. The construction of URL will arouse the attention of surrounding residents. During the site selection for more than 30 years, the research team has established a good relationship with the national authorities, the local governments, and the only herdsmen family nearby. However, since the URL site is still 70 kilometers away from the nearest city, there has been no in-depth communication with the surrounding general public. At present, the general public has limited knowledge of HLW disposal strategy and technologies. In this context a preliminary public communication program for the early stage of URL construction has been put forward, including online and offline publicity. A cartoon named "A Fu's way to future home" was designed for online publicity. The HLW was personified as its protagonist "A Fu". The animation first introduces his origin and contributions to human society, with the intention of conveying the value of "human beings are responsible for the proper disposal of HLW since it is an inevitable product of human benefit". Similarly, the waste canister, bentonite and host rock were also personified as three partners of "A Fu", vividly illustrating the containment and isolation features of the multi-barrier system. The criteria for repository site selection was explained through their tortuous experience of searching for a future home. It also emphasizes that under the joint action of suitable site and engineering barrier system, the safety of HLW repository can be fully guaranteed. With the characteristics of wide spread, fast speed, convenience and flexibility of online publicity, the scope of information dissemination will cover the surrounding areas and even the whole country. Offline publicity will mainly rely on the visitor center in URL project to help the public form an intuitive impression while visiting, and understand the geological disposal technology through face to face communication with technical experts. Before the completion of the URL visitor center, there will be an exhibition hall to play some alternative role. On the basis of this preliminary plan, we can carry out public communication to achieve the goal of improving the public's awareness and shorten their psychological distance from HLW disposal.

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THE RELEVANCE OF HUMAN FACTORS IN SUSTAINABLE NUCLEAR WASTE MANAGEMENT – PROMOTING META-COMPETENCES AS PART OF THE HOLISTIC EDUCATION OF YOUNG ACADEMICS

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Processes are the glue that holds systems and organisations in nuclear waste management together. People enable and control these processes. This requires both specialist knowledge and experience as well as the competence to tackle tasks, challenges and problems in the specific area in a targeted manner. To act appropriately and efficiently however, corresponding personal meta-competences are necessary. This includes all qualities that enable people to deal well with their own and other people's competences and to develop problem-solving skills. In Germany, many experienced practitioners in operational nuclear waste management will retire in the next few years, including the majority of executives. Demands for specialists cannot be met without a greater number of young academics. However, academic training in nuclear waste management has been greatly reduced in recent years. Remaining study programs mainly focus on the aspects of the search for a final HLW repository rather than practical predisposal management. The alternative of on-the-job training requires the availability of appropriate professional supervisors. However, these are hardly available or free due to their operational tasks and important functions. Therefore, there is a need for a new study program in practical nuclear waste management or predisposal that is adapted to the situation. It must provide students and future managers with both the necessary technical knowledge and at the same time enable them to build up competences independently. Such a targeted academic education has now been established in cooperation between the BGZ and the FH Aachen University of Applied Sciences, focussing on both individual disciplines (science and technology) and holistic components (processes, systems, people). It is a focus field within the inter- national study course "Master Nuclear Applications" (MNA), which has already been awarded twice as one of the world's best nuclear study programs. Aiming at a requirement-oriented "holistic" education, the new education program shall enable young academics to continue their professional development independently, to deal well with their own and others' competences and to develop problem-solving skills. For this purpose, a special course linked to the nuclear subject matter was created with experienced psychologists. Important components are dealing with complexity, the correct assessment of one's own abilities, and particularly the requirements to exercise superior responsibilities. This includes understanding human behaviour, coping with leading teams and personnel, successful methods of leading interdisciplinary staff, as well as intersystem thinking and communication with various stakeholders.

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INFRASTRUCTURE AND GEOLOGICAL DISPOSAL: THE USE OF LOW CARBON CONSTRUCTION MATERIALS IN A NET ZERO WORLD

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The UK's legally binding target of Net Zero by 2050 is a backdrop against which the construction sector can explore low Carbon alternatives in the context of sustainable development and meeting the ambitious Net Zero objective. A GDF presents the opportunity to implement numerous, more sustainable materials such as alternative cement formulations, substitute tarmacs and 'green' steel. Without any intervention of low carbon materials the construction and operation of a GDF has been estimated to have an associated embodied emissions footprint of between 2 and 7 million tCO2e largely depending on whether the rock type of the selected site is higher strength, lower strength sedimentary or Evaporite rock (RWM, 2016.) The paper looks at a non-exhaustive set of the possible materials and technologies that are in commercial production or those that are potentially viable, for application within large-scale nuclear infrastructure projects looking to benefit from a lower carbon footprint in the context of a net zero world.

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SOCIO-ECONOMIC ASSESSMENT OF THE CIGÉO PROJECT

Or how to deal with decision-making around the societal opportunity of the French project to build and run an industrial deep geological repository designed for the most radioactive waste

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Andra has carried out a socio-economic assessment of Cigéo, the French project for an industrial deep geological repository center designed for the most radioactive waste, known as high-level and long-lived intermediate-level waste. This assessment is a genuine tool for public decision-making, as required by French law. It questions any large-scale project involving a significant amount of public investment. The aim is to assess the benefit of the investment for the community by comparing its effects in monetary terms over its entire lifetime with a so-called "counterfactual" situation, representing what would be done if the project was not carried out. For the first time, this socio-economic assessment is applied to the nuclear field and concerns a non- standard project. The aim is to objectify the investment in Cigéo in terms of its fundamental long time safety objective while limiting the burden of future generations. Led by Andra, the assessment required three years of research and active collaboration with a committee of five experts in economy and two specialized consulting firms. The economic considerations were thus extended to an unprecedented time frame of several centuries, given the time required to complete the project and the time scale of radioactive decay. Numerous methodological challenges were addressed: uncertainty, update, risk assessment, societal collapse, insurance benefits, etc. The modelling was conducted in a scenario of different macroeconomic contexts. It compares the concept of deep geological disposal to other options such as temporary storage, or a prospective technology illustrated by deep drilling repository. For the first time, this work sets out in terms of economic analysis, the issues at stake in the debate and in the decision-making process concerning the societal opportunity of the project. In 2021, with the uncertainties that are now palpable (climate, health, geopolitical crises), the question is "to initiate Cigéo" today, while leaving open the adaptability of the project within a governance structure to be built. This choice amounts to taking insurance for the benefit of present and future generations, while organising a coherent phasing between the use of electricity, the responsibility of nuclear operators, the availability of skills and financial resources. The socio-economic assessment of Cigéo, which has been counter-examined by the State, has resulted in a favorable opinion for the Cigéo project, with recommendations associated with the conditions for the project's success. The article will present in detail the different stages of this assessment as well as its conclusions and recommendations.

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GEOLOGICAL AND NON GEOLOGICAL CRITERIA OF SITE FOR NEAR SURFACE DISPOSAL IN INDONESIA

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The objective of radioactive waste disposal is to isolate the waste so that there is no radiation effect to human and the environment. The level of isolation needed can be obtained by implementing the various methods of disposal, one of which is a near surface disposal (NSD) for low level radioactive waste. Based on the performance assessment, it's concluded that the effectiveness and safety of waste isolation are dependent on the performance of whole disposal system which consists of three barriers, that are site, disposal design and waste package. Site selection of NSD is a fundamental step in the development of waste disposal which will give the best suitability to cover the demand effected by accumulation of waste from national nuclear programs. Besides, simultaneously, it's can fulfil all requirements in safety, technology and environment aspects determined by national regulation and international guidance. To fulfil the requirements, it needs some criteria as a guidance in site evaluation. So that, it is important to formulate the geological criteria of site refers to which considers various guidance from national and international level, and the experiences of advanced countries in NSD field. Generally, the criteria of NSD site can be grouped in two aspects, which are 1) geological aspects, which consist of geomorphology, rocks/stratigraphy, geological structure, hydrology/hydrogeology, mineral resources, geological hazards; and 2) non geological aspects, include climatology, landuse, location-area-accessibility of land, position and distance from settlement, and land ownership.

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 252

HUMANISING NUCLEAR WASTE
Addressing the legacy of communication failures and building sustainable communication strategies

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The international community faces a number of tremendous challenges, be it anthropogenic cli- mate change, environmental degradation, starvation and food insecurity, zoonotic diseases or water scarcity. Nuclear technologies have played a major role in addressing many of these challenges and will have to play an even larger role in the future in order to building a more sustainable and equitable world. However, public perception and acceptance remain as one of the central challenges facing the deployment and use of nuclear technologies around the world. This is most evident in relation to nuclear power, and especially facilities designated to the disposal of various radioactive substances colloquially labelled as "nuclear waste". However, this is a perennial issue in the nuclear debate, having been a major course of controversy since the 1960s – and with the recent focus on sustainability, the issue of waste has once again reemerged. Whilst the technical challenges posed by the management, potential recycling, and eventual disposal have in many ways been addressed, considerable challenges remain in terms of addressing public acceptance and understanding public perceptions of nuclear waste within the nuclear community – despite decades of research within fields such as psychology, sociology, anthropology, neuroscience, cognitive science, and risk science. Failing to address the perception and communication challenges nuclear waste poses fundamentally risks undermining the immensely positive impact that the use of nuclear technologies can have. This presentation will draw extensively upon the latest developments within the perception and communication research, exploring the challenges which nuclear waste management poses from a psycho-social and cognitive perspective. This presentation will be arguing that resolving the question of nuclear waste management will, from policy and psychological perspectives, crucial in ensuring that nuclear technologies can continue their humanitarian work. However, this will require a humanization of nuclear waste communication, and this presentation will argue that most communication efforts continue to be undermined by the notion of "facts will correct any misunderstandings", whereas a considerable body of science suggests that it is perception – driven largely by cognitive imagery and affective markers – that shapes public reactions to nuclear waste. This presentation will, therefore, be offering insights into building different communication strategies, anchored in the latest scientific findings. Central to these strategies will be the "humanization" of the waste discourse, through the creation of alternative narratives and stories, and young professions will have a crucial role in the creation of these.

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SELLAFIELD: A CASE STUDY OF THE SOCIAL LICENCE TO OPERATE
Social Impact Multiplied

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This study demonstrates how the social licence to operate for the UK's oldest nuclear facility is maintained over decades as the operations of the Sellafield nuclear facility continue to change. It illustrates how community support for changing operations are established and preserved through civic engagement, pioneering approaches towards social impact interventions and the pursuit of economic growth and diversification for the host community through effective partnership working. The study will demonstrate how and why partnership working succeeds, the central importance of effective communications and stakeholder relationships and the growing emergence of a multi- generational approach towards sustainability: environmentally, socially and economically.

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THE SOCIO-TECHNICAL MULTI-CRITERIA EVALUATION (STMCE) METHOD FOR RADIOACTIVE WASTE MANAGEMENT STRATEGIES
From the U.S. Experience to Other Applications

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The nuclear fuel cycle generates a variety of radioactive waste materials coming from many and diverse production points. Yet, different radioactive waste types imply that different management and disposal strategies must be developed. Moreover, because radioactive waste materials are connected to a highly regulated and socially debated nuclear energy technology, their management strategies raise technical challenges, as well as potential social conflicts and public controversies. Radioactive waste management (RWM) is indeed increasingly seen as much a technical issue as a societal issue affected by social, environmental, political, and legal constraints. Consequently, it is now well accepted that a "workable" approach to RWM is towards finding compromise solutions that provide adequate levels of both safety and social and political acceptance. Consequently, it has become evident that RWM cannot be limited to a discussion among experts and scientists who advise on the "best" technical and policy strategies. Rather, the scope of the discussion and decision-making process must be broadened to consider both technical and societal dimensions, as equally important. The paper presents the Socio-Technical Multi-Criteria Evaluation Method (STMCE) that was developed in the U.S. context of commercial spent fuel management. STMCE offers a framework and method for the socio-technical, multi-criteria evaluation of RWM strategies, as well as a coalition formation process of social actors. The paper then discusses other potential applications of the STMCE method in the broader context of RWM.

Socio-Economic Aspects of Radioactive Waste Management Programmes / ID 289

A MORE CONCERTED EDITION OF THE 5TH FRENCH NATIONAL PLAN FOR RADIOACTIVE MATERIALS AND WASTE MANAGEMENT

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In France, the national framework for the management of radioactive materials and waste is defined by the Environment Code and by the Programme Act 2006-739 of 28th June 2006, which define inter alia the policies for the management of all radioactive waste in France, basic principles underlying policy, such as limiting burdens for future generations, the main responsibilities for the management of radioactive waste and spent fuel, and the National Plan (PNGMDR – Plan National de Gestion des Matières et des Déchets Radioactifs) as a policy implementation tool and a road map for future management steps. The PNGMDR is issued by the ministry in charge of energy (MTE) with the participation of a pluralistic steering committee. It is updated every five years. Since 2016, the PNGMDR is the subject of an environmental assessment and an opinion from the Environmental Authority, followed by a public consultation. Moreover, for the first time, the preparation of the fifth Plan (2021-2025) was the subject of a national public debate in 2019, followed by a national concertation that ended in April 2021. Following these new public consultations, the fifth edition has put in place a new governance system. The French national safety authority (ASN) is not anymore in charge of the writing of the plan, to take into account a recommendation of the Artemis mission in 2018, and the results of the public debate. Furthermore, an independent committee was created, which gathers all stakeholders and gives its opinion on the proposals of the government. The next edition of the plan will also focused on all transversal aspects of the waste management: specific actions are planned to take into account in a more efficient way transversal issues such as territorial, economic, ethic, environmental or sanitary impacts. Finally, the next edition will aim at increasing the public participation to the waste management system.

INTEGRATED WASTE MANAGEMENT

Integrated Waste Management / ID 303

WHAT IS INTEGRATED WASTE MANAGEMENT AND WHY WE SHOULD USE IT? A VIEW FROM THE UK'S NUCLEAR DECOMMISSIONING AUTHORITY

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Effective, optimised waste management is essential for the delivery of the NDA mission where radioactive waste must be appropriately managed until the point of disposal. The overarching NDA Integrated Waste Management (IWM) Strategic Objective is "to ensure that wastes are managed in a manner that protects people and the environment, now and in the future, and in ways that comply with government policies and provide value for money".For more than a decade the NDA has evolved its Integrated Waste Management strategic concept that advocates a holistic risk-informed approach to radioactive waste management across the waste spectrum guided by seven Key Principles. The IWM strategic concept supports a process of close con- sideration of the radiological, physical, and chemical properties of the waste, the facility it currently resides in, the lifetime management and how waste management directly supports decommissioning or operations. This risk-informed approach embraces a more effective application of the Waste Hierarchy, which underlines the importance of avoiding waste generation, minimisation, re-use, re- cycling, and other environmentally sustainable options, as well as more optimal use of all waste infrastructure.In 2019, NDA published its Radioactive Waste Strategy that committed to the creation of an Integrated Waste Management Programme (IWMP). The IWMP has now been established and is actively exploring new management and technical solutions that will help to drive forward decommissioning in the UK, building on existing good practices. The vision is to develop a 'world-leading waste management programme' that delivers safe, sustainable, timely and cost-effective management of all radioactive waste in the UK. The paper will set out in more detail the aims and objectives of the NDA IWM Strategy, outline the programme for its implementation, illustrate the benefits with case studies that explore a variety of waste types and their lifecycle management.

Integrated Waste Management / ID 301

INTEGRATED WASTE MANAGEMENT IN THE RUSSIAN FEDERATION

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In 2011, the Russian Federation adopted Federal Act No. 190-FZ “On the RWM…”, which significantly changed the concept of RMW in the country. The paper provides a description of the Unified State System of RWM (USS RWM) in the Russian Federation, organized in accordance with the new Federal Act, and the 10-year history of its formation.

The paper is highlighting the:

— Changes in the activities and the management in radioactive waste area, which were introduced in 2011 by Federal Act No. 190-FZ.
— Complexity of the national waste management system in a country with a long history of the nu- clear industry, accumulated problems and at the same time implementing a large-scale program for the construction of new facilities and the development of nuclear technologies. Principles of organizing activities in accordance with the new Federal Act, which ensure the sustainability of RWM in the long term.
— Inventory of accumulated radioactive waste and modeling of waste streams generated by the commercial organizations. Analysis of the regulatory legal framework and its improvement.
— History of the formation of the USS RWM: planning the construction of waste disposal infrastructure facilities; creation of a national operator for managing the construction of infrastructure facilities and their subsequent operation; setting tariffs for waste disposal; modernization of the state waste accounting and control system.
— Prospects for the development of the USS RWM: the formation of a Community of Practice in the field of RWM and the implementation of programs of interaction with interested parties on the disposal of radioactive waste and the solution of accumulated problems.

Integrated Waste Management / ID 43

DEVELOPMENT OF NATIONAL INTEGRATED RADIOACTIVE WASTE MANAGEMENT INFRASTRUCTURE IN PAKISTAN

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Pakistan Atomic Energy Commission (PAEC) is a sole nuclear facilities operator in the country. Pakistan Nuclear Regulatory Authority (PNRA) is an independent body to regulate all the nuclear facilities. The use of nuclear technology is generating radioactive waste in various amounts and forms, from different facilities and activities. Major portion of this waste comes from Nuclear Power Plants (NPPs) having total installed capacity of ~2,400 MWe. To meet the energy demand, PAEC is planning to increase the existing installed capacity of nuclear power. Moreover, increase in use of other ap- plications of nuclear technology is foreseen. This will increase generation of radioactive waste. This arises the importance to establish well integrated radioactive waste management infrastructure (IR- WMI) to minimize the waste at source, maximize recycling/reusing of materials, adopt the modern technologies, and strong cooperation with other stakeholders. The effort is made to develop IRWMI in the Pakistan. It enhances the efficiency and sustainability of national nuclear programme in a systematic manner. Devising of this integration requires systemic analysis of all applicable necessities which are directly or indirectly involved in the development of infrastructure for radioactive waste management. The core of IRWMI is the radioactive waste management lifecycle, which is influenced by various key factors and are discussed in the paper. Examples of such factors include policies & legal framework, safety case, international cooperation, financial management. It is a robust system to efficiently and effectively handle the unforeseen events and future developments regarding addition of new nuclear facilities and activities like decommissioning. The implementation of IRWMI has benefitted the national nuclear programme by harmonizing the waste management practices in entire country while reducing the costs, efforts, and also build and maintain public confidence on safe solutions for management of all types of radioactive waste.

Integrated Waste Management / ID 313

PROSPECTS OF INTEGRATED WASTE MANAGEMENT PLANNING

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The objective of an Integrated Waste Management Plan is to ensure that chosen Strategy for Waste Management that addresses safety boundaries, environmental concerns and stakeholders' interest can be implemented on the level of the country, but also on the level of individual waste generator, predisposal facility operator and disposal facility operator. The paper will discuss major prerequisites for establishment of an Integrated Waste Management Plan based on knowledge of inventory of waste streams in stock, forecast of waste streams that will be generated during established timeline for integrated planning, assessment of needs for different waste management facilities and selection of technologies to deal with waste from "cradle to grave" during the envisaged timeline, establishment of cost estimates and scenarios for different alternatives for waste management during planning period and approaches to funding for implementation. Iterative nature of planning process focusing of integration of top-down and bottom-up approaches will be discussed as well as advantages of waste minimization at the source during operation and by the design of facilities , as well as limitations, and restrictions to develop a flexible plan to address envisaged needs. Approaches to planning of NPP and NFC waste generators and operators versus institutional waste generators and operators practices and impact of these differences to integrated plan will be pointed out and solutions proposed. The integrated plan needs to consider waste from decommissioning and remediation of nuclear facilities, legacy wastes and eventual accident waste meaning that the plan requires establishment of different planning scenarios as well as "holding points" to allow for adequate flexibility to address inevitable changes. In addition, an early assessment of waste management needs from development and use of advanced reactors and innovative nuclear fuel cycles is required to aid design and operation of such facilities as well as to understand their impact to overall waste management planning. The paper will point out experiences gained during presentations of principals for establishment of an Integrated Waste Management Plan during IAEA TC expert missions at different regional and national events. The discussion on prospects of integrated planning will conclude presentation.

Integrated Waste Management / ID 311

INTEGRATION OF WASTE MANAGEMENT – GOING BEYOND TECHNICAL ASPECTS

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Integrated waste management is the process of approaching all the aspects of the radioactive waste lifecycle holistically, with the aim of optimizing outcomes, including minimizing negative impact on the environment and the broader business, and engaging with stakeholders. In addition to integration of the activities touching the various phases of the lifecycle, integration can also be important across facilities, sites and missions. This is particularly relevant for multi-mission sites and organizations such as Atomic Energy of Canada Limited (AECL), where ongoing nuclear science and technology activities need to coexist with building decommissioning and site revitalization. AECL's approach has focused on leveraging international expertise and experience through its contractor, Canadian Nuclear Laboratories, under a Government-owned, Contractor-operated model. Significant work has been done over the last five years to develop an integrated waste strategy for all AECL sites and waste, taking account of the waste hierarchy. This presentation will provide an overview of the progress to develop and implement the integrated waste strategy for AECL-owned wastes, which result as a by-product from decades of research and development into nuclear technologies for the benefit of Canadians and the world. It will also look at stakeholder and Indigenous engagement aspects, and how those are taken into account in early waste management planning activities.

Integrated Waste Management / ID 178

THE SOLUTIONS STATEGY: THE NEED FOR A GLOBAL, CONSISTENT, AND PROPORTIONATE APPROACH TO RADIOACTIVE WASTE MANAGEMENT

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The objective of Andra's waste management strategy is to build an overall vision of existing and future management methods, based on the development of a coherent and proportionate safety and environmental policy.First of all, there is a diversity in the types of waste or radioactive materials present in France. The development of a range of management solutions requires each solution to be adapted to the characteristics and hazardousness (radiological and non-radiological) of the waste. This involves revisiting historical approaches and definitions, mainly based on the radiological classification of waste. For some categories, this classification is not well suited to define a disposal pathway. For example, studies and research to identify disposal solutions for LL-LLW (Low Level Long Lived Waste) have highlighted the difficulty in defining what a LL-LLW is. It can be close to other waste categories due to the continuum of its activity level. It is clear that the waste category alone is not sufficient to qualify the hazardousness of the waste and therefore the choice of its management disposal route. Thus, work is done to identify waste management scenarios. Particularly, the methodology to carry out these scenarios is being developed in order to justify the choices that will be made from the point of view of both nuclear safety and environmental impact.Finally, methodological tools are developed to assess the environmental, health and economic im- pacts of radioactive materials and waste management choices. These tools can also contribute to transversal activities and issues, including the public debate on the National Radioactive Waste Management Plan (transport, environment, health, economy, harmfulness of waste, territorial impacts, etc.).This overall vision contributes to the search for technical and economic optimisation of the distribution of the various categories of waste between the different disposal facilities, taking into account the timeframe of waste production and the best available technologies. This strategy provides a gen- eral framework for planning and coordinating Andra's actions according to the guidelines set out in the National Radioactive Materials and Waste Management Plan.

Integrated Waste Management / ID 193

STUDY ON ADVANCED NUCLEAR ENERGY SYSTEM BASED ON THE ENVIRONMENTAL IMPACT OF RADIOACTIVE WASTE DISPOSAL - AN INTEGRATED CROSS-DISCIPLINARY APPROACH TO DIVERSIFYING NUCLEAR FUEL CYCLE CONDITIONS

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To present effective technical options for reducing the environmental load (amount of waste and radiation impact) in the disposal of radioactive waste, it is necessary to evaluate the relationship between the nuclear fuel cycle conditions and the waste characteristics quantitatively. In that case, exposure dose based on the nuclide migration, which is a long-term safety evaluation for geological disposal, radiotoxicity of the waste, quantity balance of the full nuclear fuel cycle, effect of nuclide separation, and combustion characteristics of separated nuclides in fast reactors are involved. The outline of and progress in our cross-disciplinary nuclear systems research to support efforts to reduce the load of radioactive waste disposal are presented.

Integrated Waste Management / ID 150

SITE CHARACTERISATION INPUTS TO SAFETY CASE DEVELOPMENT FOR AUSTRALIA'S NATIONAL RADIOACTIVE WASTE MANAGEMENT FACILITY

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The Australian Radioactive Waste Agency (ARWA) is progressing plans to establish a National Radioactive Waste Management Facility (NRWMF). This facility will be the first of its kind in Australia, designed to dispose of Australia's low level radioactive waste (LLW) and store Australia's intermediate level radioactive waste (ILW) until a permanent ILW disposal pathway is developed. A site near the town of Kimba in South Australia has been identified as a suitable site for the NRWMF, based on technical suitability and broad community support.

The next phase of work will involve the preparation of regulatory applications. In Australia, the relevant regulators are:

- the Australian Radiation Protection and Nuclear Safety Authority (ARPANSA), which is responsible for regulating the siting, construction and operation of any radioactive waste management facility;
- the Australian Safeguards and Non-proliferation Office (ASNO), which is responsible for regulating nuclear materials; and
- Australia's Commonwealth Department of Agriculture, Water and the Environment (DAWE), which is the federal regulator for projects that are of significant environmental interest.

These regulatory applications will consolidate an extensive program of site characterisation, facility design, waste acceptance criteria, safety case and national inventory analysis. Throughout 2018 and 2019, ARWA undertook comprehensive site characterisation activities during the site assessment process to demonstrate the site's technical suitability. Key themes and activities included:

- Flora and fauna surveys of local ecological communities
- Predictive flood modelling
- Groundwater sampling and analysis
- Seismic surveys and fault identification
- Borehole logging to determine lithological profiles
- Analysis of landform stability.

More detailed site characterisation activities focused on these themes are being planned to obtain the necessary samples and data for developing a regional hydrogeological model, solute transport model, and subsequently geosphere and biosphere models. Activities such as climate change risk analyses, seismic hazard analyses and geotechnical assessments will also be important inputs to progress facility design. A set of sampling and monitoring activities will establish a radiological baseline for the local environment, to support comparisons against future monitoring during construction and operation. The safety case will demonstrate the operational and long-term safety of the facility, taking account of the existing environmental conditions at the site, the design of the facility, and the characteristics of the waste to be disposed or stored.

Integrated Waste Management / ID 20

KEY ASPECTS OF EDUCATION AND KNOWLEDGE MANAGEMENT IN THE NUCLEAR SECTOR OF GERMANY

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Nuclear Waste Management (NWM) is about safe and reliable processes in a complex system, competent people being essential for planning, implementation and execution as well as a framework for systematic creation, capturing, sharing and utilization of knowledge. However, in recent years many NWM professionals have moved into other fields of work. The average age in the remaining community of professionals is comparatively high. Many experienced specialists and especially executives will retire soon. To ensure that the nuclear waste management processes can continue to run the development and transfer of competence in practical NWM must take place with sufficient lead-time. This is especially true for the system-forming companies like the BGZ – Gesellschaft für Zwischenlagerung mbH. The BGZ was founded to ensure reliable and safe interim storage of nuclear waste packages and is operating both central interim storage facilities and the licensed decentralized interim storage facilities at the sites of the nuclear power plants. However, many universities either have closed their nuclear degree programs or have partially relocated them to another subject such as geo-management. There is already a shortage of appropriate graduates. Forward-looking, Germany must set-up and invest in both new academic courses and further training seminars on NWM in order to meet future requirements. This conference paper describes both objectives and status of the implementation of a targeted academic education in cooperation between the BGZ and the FH Aachen University of Applied Sciences, as well as its links and references to the IAEA-supporting activities. In particular, the international study course “Master in Nuclear Applications” (MNA), which has already been awarded twice as one of the world’s best nuclear study programmes, is expanded with a new focus field on NWM. In comparison to traditional programmes, also holistic components (processes, systems, people) are highlighted, with a focus on predisposal activities and a balanced share of know-why and know-how content. National and international scientific or technical experts and practitioners from a wide range of fields work on or contribute to this new concept, including experts in the field of systems thinking and human factors. To enhance core (or 21st century) skills for successful and sustainable leadership in NWM, experienced psychologists teach necessary meta-competences. This includes human relations abilities, such like communication, conflict- and crises management and principles of emotional intelligence. A first master’s thesis on analysing and optimising operational processes at BGZ was successfully completed last year.

Integrated Waste Management / ID 25

ENHANCING SUSTAINABILITY IN RADIOACTIVE WASTE DISPOSAL PROGRAM - A MALAYSIAN CASE STUDY

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The radioactive waste management strategies in Malaysia outlined several key milestones towards strengthened, sustainable, safe and secure management of radioactive waste. Major initiatives were implemented in the year 2018 until 2020 to improve the overall operational safety of the current infrastructure. Acknowledging the safety and security risks of prolonged disused sealed radioactive sources (DSRS) storage, Malaysia took an initiative to plan for the disposal of DSRS using the borehole disposal technology. Preliminary works have begun back in 2013, further propelled by the strong technical support from the IAEA, leading to the award of the construction license in 2019. The actual construction of the Borehole Disposal Facility (BDF) is pending until contractual matters are completed. When the BDF is eventually closed, about 85% of the current DSRS inventory will be permanently disposed of here.While the BDF focuses on the disposal of DSRS in a facility analogous to an intermediate depth geological repository, Malaysia also recognized the need to have a national low-level waste repository to sustainably dispose low and intermediate level radioactive waste, accumulated from research institutions, medical sector and waste projected from the decommissioning of the research reactor and laboratory facilities. In 2011, a nationwide site screening campaign was conducted based on the siting criteria set out then. In 2013, progress on the national repository halted to solely focus on the BDF project. Now, the national repository project is relived with a more robust project structure, clearer direction and constructive milestones.Implementation of the disposal program in Malaysia is steered by graded approach; according to the type and radioactivity of the waste. The first radioactive waste disposal facility in Malaysia was a privately funded near surface repository for the disposition of thorium waste. Post-closure responsibilities however were given to government bodies. Another private-funded disposal facility is also in the pipeline, involving disposal of very low level NORM waste.Political, economic and social standing imposed strong influences towards a successful implementation of any disposal project. The upcoming national repository project will have much to learn from the previous experiences by examining key elements as well as issues that need to be thoroughly de- liberated and addressed. Being accepted as one of the ministry's initiatives for year 2021, the direct involvement of the ministry is hoped to bring in more positive outcomes to the project.

Integrated Waste Management / ID 40

MANAGEMENT OF THE ACCIDENT-ORIGIN RADIOACTIVE WASTE OF THE DESTROYED 4-TH POWER UNIT OF THE CHORNOBYL NPP IN VIEW OF THE NEW SAFE CONFINEMENT OPERATION

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The construction of the New Safe Confinement (NSC) within the framework of the International Shelter Implementation Plan (SIP) at the Object Shelter (OS) of the destroyed 4th power unit of the Chornobyl NPP was completed in 2020. The main protective structure (Arch) of the NSC ensures the prevention of the release of radioactive substances into the environment, and, accordingly, the protection of the population. Conditions for safe work of personnel are provided inside the NSC. The NSC is equipped with a number of systems, in particular, a main cranes system, an integrated control and management system. The NSC and the special technological building provide sufficient technological space for the dismantling of unstable structures of the OS, retrieval of emergency radioactive waste (RW) and primary management with them. Today the trial operation of the NSC is being carried out. During the period of operation of the NSC (design lifetime is not less than 100 years) it is planned to ensure the maintenance of the OS in a safe condition and a gradual reduction of the degree of hazard of the OS by:reducing the risk of accidents, the greatest hazard is associated with the possible collapse of unstable building structures of the OS;retrieval of RW from the OS, the greatest hazard is associated with highly active fuel containing materials (FCM).The paper analyzes the issues of applicability of regulatory requirements on safety in the field of RW management to the activities related to the management of accident-origin RW in in view of the NSC operation. In particular, was analyzed of the requirements that concerning:

- characteristics of RW in the OS in the form of unorganized accumulations, with the purpose of forecasting the behavior of fuel-containing and other accumulations of RW, as well as the development of technologies for RW retrieval and subsequent waste management;
- maintenance in safe condition of the OS, in particular, accumulations of RW in the OS;
- gradual reduction hazards of the OS;
- the final condition of the facility upon completion of the NSC operation, in particular, regarding the possibility and features of application to this facility with accident-origin RW residues of the general safety requirements for RW disposals.

The paper provides recommendations on the scope and features of application of safety requirements in the field of RW management to the NSC and OS complex.

Integrated Waste Management / ID 121

RISK BASED APPROACH TO THE PACKAGING OF INTERMEDIATE LEVEL WASTE

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Since the 1980s the packaging of UK Higher Activity Waste (HAW) has been managed through iterations of the Letter of Compliance (LoC) process owned by Radioactive Waste Management (and its predecessor organisations). This involves the preparation of a complex, detailed submission against a set of conservative criteria which reflect the likely set of requirements against which future UK Geological Disposal Facility is anticipated to be designed and operated. If the submission is demonstrated to meet the performance requirements then it is endorsed. In 2016 senior representatives from across the UK nuclear industry including its regulators held a summit to identify where improvements could be made to our approaches to risk informed decision making and in the suitability and application of the LoC process against the modern requirements of the NDA estate. The summit concluded that, amongst other things, the Letters of Compliance and support Assessments of Disposability should make the aspect of packaging and disposability risk clearly visible and prevalent throughout the process and provide a more transparent basis of decision making. It also recognised the need for improvements in engagements between waste producers and RWM and the need to move away from transactional information exchanges and into an environment of collaborative working and support. This has led to a programme of improvement activities focused on risk based decision making processes across its sites and sharing this learning across the NDA estate. In particular the development and adoption of arrangements which enable risk informed decision making and permissioning arrangements in support of decision making on its multi-year design and construction projects. An example of this arose during the development of the packaging strategies utilising Self Shielded Duc- tile Cast Iron Containers (DCIC) which put Magnox Ltd. in a position where it could retrieve and package waste and achieve hazard reduction at a pace quicker than following standard processes would normally be able to respond. This resulted in the development of an alternate, risk informed, approach where Magnox undertake an internal assessment of the technical risk associated with proceeding with packaging, but in the absence of an LoC. This presentation will provide an overview of how these improvements led to a strong joint drive to support a more rapid rate of packing at the UKs Bradwell Reactor Site and the adoption of a risk aware clean up strategy which enabled more expedient achievement of entry of the site into care and maintenance.

Integrated Waste Management / ID 134

WASTE PACKAGE DEVELOPMENT - FOCUS ON THE RIGHT CONTAINER FOR THE RIGHT JOB

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Over the last decade Magnox Limited has challenged the long-established practise of encapsulating higher activity waste in thin-walled stainless steel containers and instead has introduced two new strategies to the UK nuclear industry. The use of self-shielded Ductile Cast Iron Containers and a 6m3 Concrete Box for packaging legacy wastes was intended to reduce project costs and accelerate hazard reduction. Neither container was initially part of the suite of acceptable packages compliant with the UK Geological Disposal Facility specification and an extensive programme of technical underpinning has been required to allow deployment of these containers. Magnox has worked with the Nuclear Decommissioning Authority's subsidiary Radioactive Waste Management Limited to demonstrate that the containers (and waste within) would be consistent with the requirements of a period of extended on-site storage prior to transport to, and disposal within, the GDF. Due to the novelty of these containers compared with established packages, modifications to the GDF design and operational safety case have been necessary to demonstrate that the risk of a non-disposable package being produced is low and tolerable. Key lessons learned from introducing these new containers are presented in the paper as a guide to waste producers considering the extensive choice of containers available for legacy wastes. By successfully introducing two new container strategies to the established GDF design concept Magnox has gained more knowledge than any other organisation in the UK; but it has been shown that it can take up to ten years to demonstrate acceptability of new containers.

Integrated Waste Management / ID 140

DESIGN AND DEVELOPMENT OF A RCF TO PROCESS POND SKIPS

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Cyclife UK has created a specialist remote cutting facility (RCF) which will process contaminated skips from Sellafield's fuel storage ponds at its Metal Recycling Facility (MRF) site in Workington, West Cumbria. Cyclife has been treating Pond Skips from Sellafield since 2014, with multiple consignments since the first trial. During this time, the treatment and processing of Pond Skips has gone through several iterations to optimise a solution that represents Best Available Technique (BAT), As Low As Reasonably Practicable (ALARP), cost effectiveness for the customer and represents the best solution for dealing with a high hazard active waste stream for the UK. In their current configuration Sellafield Pond Skips cannot be disposed of to the Low Level Waste Repository (LLWR) as they physically do not fit within a HHISO (approved UK waste container). This means that alternative treatment and disposal options were necessary to dispose of this waste safely and compliantly to prevent leaving a burden for future generations. Through experience using different hot and cold cutting techniques, both in the UK and Sweden, a new facility was developed within the UK to remotely size reduce the pond skips. The development of this facility reduced the dose uptake to operators which was key to enable further processing and disposal of this waste stream. Without development of a remote cutting facility, processing of Pond Skips would not be feasible.

Integrated Waste Management / ID 159

PLANNING MANAGEMENT OF RADIOACTIVE WASTE FROM DECOMMISSIONING NUCLEAR FACILITIES USING INFORMATION AND CALCULATION MODELS

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At present, the Russian Federation is implementing large-scale programs for the liquidation of nuclear legacy facilities, and improving the efficiency of their implementation is a key task at work planning. One of the most costly items in the decommissioning of nuclear facilities is the management of the generated radioactive waste, including its disposal. Nuclear legacy sites are often characterized by a high degree of uncertainty in data on the characteristics of radiation pollution. This situation can introduce unnecessary conservatism when planning future waste management activities.The main source of data for assessing the amount of generated radioactive waste from renewable energy is the results of the radiation survey. Radiation surveys of nuclear legacy sites are characterized by varying detail and lack of a unified data presentation format. Besides, it is often difficult to conduct a detailed radiation survey due to high radiation fields and the unsatisfactory physical conditions of the object being examined. The use of modern methods of informatization and digitalization makes it possible to eliminate gaps in the documentation, significantly increase the level of reliability of the data for planning and designing works on renewable energy. One of the ways to solve the problems associated with the lack of initial data on the pollution of nuclear facilities can be combined use of BIM-models and computational models.Calculation methods for assessing the amount of radioactive waste using BIM-models are based on taking into account the proposed decontamination technologies. At the same time, the separation of waste into groups may not be following the formal boundaries of categories by activity, but along the boundaries that determine the use of a particular chain of circulation. The proposed methods for assessing the formation of radioactive waste from nuclear facilities with the use of BIM-models make it possible to develop a scenario for carrying out practical work on renewable energy, as well as assess the radioactive waste generated in each considering scenario.The report presents the possibilities of using computational methods and BIM-models to reduce the degree of conservatism in the interpretation of radiation survey data, including for recovering missing information when assessing the volume of formation and characteristics of radioactive waste generated during decommissioning. Approbation of the developed computational methods using BIM-models was carried out on the example of nuclear legacy sites.

Integrated Waste Management / ID 171

STUDY OF EXISTING CHEMICAL DECONTAMINATION METHODS OF RADIOACTIVE METALS WITH A VIEW ON THEIR OPTIMIZATION

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Nuclear Power is a decarbonated method of electrical energy generation. Using nuclear energy as a power source is currently our best option in the fight against climate change. But the radioactive waste generated from nuclear power plants and their related facilities is a cause of concern. Though the high-level and intermediate-level activity wastes are contained in small volumes (≤ 10%), significant volumes of lower activity wastes are generated. Metallic wastes are a major component of these radioactive wastes with 500,000 to 600,000 tons expected in France alone. 130,000 tons of this is expected from steam generators. Majority of these metals are made of Stainless steel 316 alloy or Inconel 600. These makeup majority of the primary circuit of a PWR plant. Under the effect of the primary circuit water and irradiation, these components corrode and the corrosion products maybe activated when close to the fuel, and be transported throughout the circuit. These products can be deposited on the surface of other metal components, causing contamination of the latter. The contamination can be adsorbed on the surface but can also diffuse in the oxide layers and sub-surface. The oxide layer is composed of an inner layer of Cr oxide under a layer of Ni and Fe oxide. Chemical decontamination is the preferred form of treatment due to the possibility of decontamination of difficult geometries and tube bends. To decontaminate these materials, it is important to dissolve the oxide layers chemically and a few microns of base metal where it could have diffused. Some existing chemical methods used to treat these materials are studied in this paper. These methods include Chemical Oxidation Reduction Decontamination (CORD) and Metal Decontamination by Oxidation using Cerium (MEDOC). These methods are studied and a few parameters to be optimized are identified to dissolve the oxide layer and also the diffused activity by sub-surface dissolution. Surrogate steel and Inconel samples will be tested initially to optimize the processes before moving on to the real active samples. These samples are created by SORC, as a part of the PREDIS European project,using water vapor and high temperature after sample preparation and cleaning. The experiments will be carried out in the batch method with some optimizations before moving on to a loop system. The optimization steps will target reducing the volumes or treatment strategies for the effluent wastes while keeping in mind the Waste Acceptance Criteria (WAC) for nuclear waste.

Integrated Waste Management / ID 180

FAST, ACCURATE AND SIMPLE MODELLING OF COMPLEX OBJECTS WITH INNOVATIVE ISOCS-BASED SERVICE TOOL FOR COST-EFFECTIVE WASTE MANAGEMENT

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Mirion Technology (CANBERRA)'s In Situ Object Counting System (ISOCS) is an established tool used for gamma spectrometry. It allows physical representation of complex geometries and mathematical calculation of the calibration function while avoiding the need for radioisotope standards. ISOCS provides a large range of templates to generate the geometry for most nuclear waste components in nuclear facilities. According to the required measurement accuracy, users can use ISOCS or MCNP to generate the models. MCNP is recognized by the most nuclear industry and research organizations because of its excellent calculation accuracy. The constraint of using this code is with its long calculation times and very complex geometry modeling, which requires the expertise of users.An innovative ISOCS-based service tool (SuperISOCS) was developed to generate complex geometries (as MCNP) and fast calculations (as ISOCS). The principle of geometry construction is based on the composition of different primitive geometries. The primitive object can be used to remove and change a part of an object. An object can overlap another one to form a more complex object and can be rotated and moved in all directions.The definition of detectors, collimators, housings, materials, efficiency energies are the same as ISOCS, and even through with no more limit for collimator geometry design. The underlying algorithm of SuperISOCS is similar to that of the standard ISOCS. The performance of SuperISOCS calculation is accurate, demonstrated by the comparison of efficiency calculation between MCNP and SuperISOCS with more than 80 combined geometries. The average difference is less than 2% for all energy efficiency calculations higher than 50 keV. SuperISOCS has been implemented in several projects, including soil waste management in Fukushima, tank liquid waste measurement in the USA, and complex glove-box geometry measurement in France, which have all been published. The calculation results are good between SuperISOCS to ISOCS, MCNP, or Mercurad. In this work, we further demonstrate the use of SuperISOCS to build more sophisticated geometries by maintaining fast and accurate performance in the waste sorting field. This allows reducing waste management costs. In fact, this capability of building a more realistic model allows reducing the measurement uncertainty. This will effectively reduce the cost of waste management related to activity overestimated because of high uncertainty. At the same time, quick modeling and calculation time reduce the operator's cost for maneuvering.

Integrated Waste Management / ID 199

INTEGRATED APPLICATIONS OF BATAN RADIOACTIVE WASTE MANAGEMENT SERVICES (ELIRA) AND BAPETEN LICENSING AND INSPECTION SYSTEM SERVICES (BALIS)

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One of the requirements for radioactive waste management services at BATAN is that service users (customers) who will submit radioactive waste to BATAN must first obtain an approval licensing letter for the transport of radioactive substances issued by BAPETEN. In the administration process, data on radioactive substances which are not small in number (sometimes requiring accuracy) must also be filled in both in the BATAN eLIRA application and BAPETEN BALIS application. After the customer sent the radioactive waste and it was declared complete, the customer will get a Radioactive Waste Record of Transfer document from BATAN. This document is used by the party sending the waste (customer) for the approval process for the termination of the license to use radioactive substances to BAPETEN. This condition is certainly troublesome for BATAN and BAPETEN customers. This is what encourages both parties (BATAN and BAPETEN) to make an online interconnection between the eLIRA and BALIS applications. With this interconnection, it is hoped that it will make it easier for BATAN customers in matters of handing over radioactive waste and prevent data entry errors by eLIRA users. In the development of interconnection between eLIRA and BALIS online, the method used is Webservice REST (Representational State Transfer) data exchange technology or sometimes called RESTful. This method is resource-oriented and outputs in XML or JSON form. Data exchange system using RESTFul Web Service: Push and Pull JSON format. This paper discusses the stages of interconnection development between eLIRA and BALIS including identification of needs, agreement between BATAN and BAPETEN, interconnection design, guidelines, and outreach to radioactive waste management service users. Interconnection of eLIRA with BALIS is a new thing using JSON Web Service. Also, if this interconnection was carried out, the service would be faster because the verification of waste sent to BATAN with the approval of transporting radioactive waste from BAPETEN was carried out automatically by the server. With the successful integration of eLIRA with BALIS, the convenience from the customer side is no longer the re-entry of radioactive source data that will be transferred to BATAN, from the Transportation Approval Letter to Center for Radioactive Waste Technology-BATAN to the Record of Transfer of Radioactive Waste can be traced, transportation or carrier data recorded and traceable waste and notification of plans for disposal and delivery of radioactive waste are quickly accepted by stakeholders.

Integrated Waste Management / ID 204

ENVIRONMENTAL IMPACT OF RADIOACTIVE WASTE DISPOSAL IN ADVANCED NUCLEAR ENERGY SYSTEMS

Radiation impact evaluation of nuclide migration and human intrusion for geological disposal considering nuclear fuel cycle conditions

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Cross-cutting research will be important for understanding options for future nuclear systems. Based on current and future trends in nuclear power use in Japan, various fuel cycle conditions are considered, such as a longer spent fuel cooling period and higher waste loading in vitrified waste. For waste disposal, it is important to reduce the volume and radiotoxicity of high-level radioactive waste via the fuel cycle conditions. The main heat generating nuclides change from Cs/Sr to Am-241 for a longer spent-fuel cooling period. The repository footprint could be more than halved with 70–90% separation of Cs/Sr and minor actinides (MA).In the study, the exposure dose was evaluated in two scenarios with 70–90% separation of Cs/Sr and MA. The effects on the biosphere and potential radiotoxicity were evaluated for nuclide migration and human intrusion scenarios, respectively. Based on the results, the advantages and disadvantages of geological disposal with various nuclear fuel cycle conditions were compared. Combining nuclide separation and a longer spent-fuel cooling period reduced the repository footprint and the exposure dose. For example, separating Cs/Sr to reduce heat generation of vitrified waste in a short spent-fuel cooling period also reduced the long-term exposure dose because Cs-135, which gave the maximum exposure dose for nuclide migration, was also removed in this system. MA separation was particularly effective in reducing the exposure dose from human intrusion. The exposure dose from human intrusion could be reduced to the same as that of the Japanese reference case by 90% MA separation.

Integrated Waste Management / ID 235

IN-SITU DRYING FOR MAJOR VOLATILITY CONTAINMENT IN MELTER DURING VITRIFICATION OF LOW AND INTERMEDIATE LEVEL WASTE (LILW)

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Vitrification technology is emerging as the most competitive solution against Cementation; currently the only conditioning method being employed in Pakistan for low and intermediate level waste im- mobilization. Vitrification significantly improves the stability and durability of the final waste form and reduces the repository volume requirements. Hence considerable technological and financial benefits are foreseen. Small scale in-active Vitrification experiments have been carried out to verify the feasibilities to opt for Vitrification as immobilizing technique for LILW. To cater for entrainment of radionuclides / waste salts in the off-gas system, a novel In-situ drying procedure is identified to enhance volatility control in the melter. Initially, we have opted pot/in can melter vitrification technique for small scale experimentation due to its easy handling and low throughputs. In-situ drying procedure reduces the volatiles in off gas during subsequent melting operations to meet with the true essence of Vitrification i.e. to fix the activity in the immobilizing matrix. In the first stage, canister is filled with glass frits then at an In-situ drying temperature around 150-2000C, single batch waste volume is fed and dried out. Waste flow rate and In-situ drying temperature are optimized in such a way that the boiling surface in the canister remains below glass frits level. The bed height above boiling surface acts as a packed bed column, thus, provides decontamination for entrained salts present in the off-gas. Series of experiments are planned to verify the feasibility of In-situ drying during Vitrification of LILW. Results obtained will be helpful for major volatility containment in melter and consequently, minimizing secondary waste generation during off gas treatment.

Integrated Waste Management / ID 246

THE USAGE OF SCALING FACTORS FOR DETERMINING NUCLIDE CONTENT FOR CLEARANCE OR DISPOSAL

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The benefits of using validated scaling factors, also denoted nuclide vector or fingerprint, are that the number of samples and analyses for each waste package or item can be significantly reduced. The basis for a validated nuclide vector is however sampling and analyses as well as a theoretical model which includes the connection between measured and non-measured nuclides. To develop nuclide vectors, the origin and history of the item/waste package must be sufficiently known. When using a nuclide vector for calculation the nuclide content for a waste package aimed for disposal it is important to communicate with the competent authority and the owner of repository to get acceptance of the theoretical model as well as the list of nuclides. As a nuclide vector for clearance is regulated by the clearance regulations, the nuclides with high clearance levels and low scaling factors will not influence clearance of material and can therefore be screened from the full vector. A screened nuclide vector has limitations in use as the scaling factor will change with time. When time elapse screened nuclides may increase in importance for clearance and it is therefore important to save the original vector and re-screen it if it is to be used later. There are also a few disadvantages of the nuclide vector methodology, the obvious one is that it is easy to become overconfident in the application of the nuclide vector. When the sampling and analyses are evaluated, there will be a distribution in the results and a decision about the level of conservatism in the vector has to be decided. If the dispersion of data is too large the needed conservatism will be too large and render the vector useless. This will be solved by dividing the nuclide vector into two or more nuclide vectors.

MULTINATIONAL COOPERATION IN RADIOACTIVE WASTE MANAGEMENT

Multinational Cooperation in Radioactive Waste Management / ID 96

EURAD: A STEP CHANGE IN EUROPEAN JOINT COLLABORATION TOWARDS SAFE RADIOACTIVE WASTE MANAGEMENT

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In the area of radioactive waste management (RWM) and deep geological disposal, the European Commission has been funding research and development (R&D) for over 40 years, fostering what is today a strong cooperation between European implementers, laboratories and institutions. The underpinning technical knowledgebase is sufficient to allow Europe to be on the verge of operation of its first geological disposal facilities for spent fuel and other high-level and long-lived radioactive wastes. R&D will continue to be necessary to develop, maintain and consolidate knowledge through- out the stepwise development, operation and closure of disposal facilities. The European Commission has promoted a step-change in cooperation between EU Member States' (MS) National Programmes by strongly recommending the establishment of inclusive European Joint Programmes (EJP) of collaborative research. Launched in 2019, EURAD, the 5-years long EJP on RWM, is built on the basis of activities of com- mon importance between Waste Management Organisations, Regulatory Technical Support Organisations and nationally funded Research Entities. Guided by a shared roadmap, it supports MS at various stages of implementation and is focused on scientific and technological R&D, closely aligned to implementation needs, safety considerations and an ambitious knowledge management programme. EURAD's concept is to generate new and manage existing knowledge to support MS with implementation of the Directive 2011/70/EURATOM, and more specifically with the development and implementation of their national R&D programmes for the safe long-term management of their different types of radioactive wastes, taking into account different programme sizes and stages of advancement. EURAD gathers 104 organizations across 23 countries, 51 have received a mandate by their Ministries and 53 are participating as Linked Third Parties to the Mandated Actors, all willing to share and support the EURAD Vision, Strategic Research Agenda (SRA) and Roadmap. It also aims to meaningfully interact with civil society representatives, waste producers/owners, international organisations such as NEA and IAEA, and non-European partners. To achieve EURAD's objectives, four different activities have been adopted: R&D, Strategic Studies, Knowledge Management and Coordination/Dissemination. They are developed in thirteen work packages that have now reached their third year of implementation and are delivering encouraging results. Three further work packages (and two extensions) will commence in June 2021, to address additional common needs captured within the EURAD SRA. An overview of EURAD and its interactions with stakeholders and the scope of work including outcomes of the first years will be presented with an outlook of the second wave.

Multinational Cooperation in Radioactive Waste Management / ID 230

WENRA'S SAFETY REFERENCE LEVELS CONTRIBUTE TO CONTINUOUS IMPROVEMENTS AND HARMONISATION OF REGULATORY APPROACHES FOR RADIOACTIVE WASTE MANAGEMENT IN MANY EUROPEAN COUNTRIES

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The paper describes the positive impact of WENRA's Safety Reference Levels (SRLs) in helping to harmonise and improve regulatory approaches for radioactive waste management in many European countries. The Western European Nuclear Regulators Association (WENRA) is a group comprising the heads of the regulatory bodies of 18 European countries, together with 13 associated members and observers from Europe and the rest of the world. WENRA's aim is to develop a common approach to nuclear safety, and to allow chief nuclear safety regulators in Europe to exchange experience and discuss significant safety issues. WENRA has established three thematic working groups, including the Working Group on Waste & Decommissioning (WGWD) which addresses the regulatory aspects relating to radioactive waste, spent fuel and decommissioning matters, and typically comprises the national regulator's head of department for radioactive waste management for each WENRA country. WENRA has developed six sets of Safety Reference Levels (SRLs), which reflect expected practices agreed by the regulatory authorities to be implemented in the WENRA countries. SRLs are expectations against which each WENRA member state is assessed, and each WENRA member has committed to implement actions to ensure the SRLs are met within its national regulatory framework. SRLs build on, and are complementary to, the IAEA's Safety Standards. Three sets of WGWD SRLs (comprising 240 separate Safety Reference Levels) relating to the processing, storage and disposal of radioactive waste are the focus of this paper. The SRLs are administered by WGWD which gives a rating for each member state's performance against each SRL. Each country undertakes a national self-assessment against each SRL, which is then benchmarked or moderated by the members of WGWD, with a rating of A (fully conforming with SRL), B (not applicable, or SRL addressed satisfactorily in another way) or C (improvements needed). Member states which identified areas for improvement then develop a National Action Plan to respond to the findings, usually within a period of 2 to 3 years, and undergo re-benchmarking. This paper presents the harmonisation approach developed within WGWD and includes case studies on implementation of WENRA SRLs from diverse countries such as the Czech Republic, Spain, France, Ukraine, Slovakia and the UK. The paper concludes with an assessment of the significant progress made by WENRA member states in harmonising and improving their regulatory approaches for radioactive waste management.

Multinational Cooperation in Radioactive Waste Management / ID 76

THE OBLIGATION OF MULTINATIONAL COOPERATION TO PROMOTE AND ADVANCE THE SAFETY OF SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT

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Safe, secure, and sustainable management of spent fuel is an international responsibility for countries operating nuclear plants, as well as potential new entrants to nuclear power. For countries either using nuclear power for electricity generation or using radioactive materials for medical, research and industrial purposes, the main concern relies in long lived radioactive waste requiring distinctive measures to ensure the decay of radioactivity to levels not presenting a significant hazard for people and the biosphere. The Kingdom of Morocco, as a Member State, is acutely aware that cooperation between countries is very crucial in radioactive waste management. The Moroccan Agency for Nuclear and Radiological Safety & Security (AMSSNuR) has committed itself to respect the international consensus and made it not only a national responsibility but also a regional and international commitment. In this regard, AMSSNuR has developed a national policy and strategy on radioactive waste and spent fuel management, intended to address radioactive waste management in a coordinated and cooperative manner with all the concerned parties, in line with the international agreements and instruments signed and ratified by the Kingdom of Morocco. To ensure the fulfillment of its regional and international commitment, AMSSNuR is actively involved in several international knowledge networks, notably the Forum of Nuclear Regulatory Bodies in Africa (FNRBA) chaired by the Director General of AMSSNuR. Formally recognized as a regional intergovernmental organization in September 2019, the FNRBA is a key instrument aiming to enhance, strengthen and harmonize, inter alia, radiation and waste safety. To ensure the safe and secure management of radiation, FNRBA has dedicated one of its six thematic working groups to radiation and waste safety. This paper will address how AMSSNuR fosters the application of good practices in the field of radioactive waste management among the African Member States and discuss the multinational cooperation as a tool to promote and advance the safety of spent fuel and radioactive waste management.

Multinational Cooperation in Radioactive Waste Management / ID 296

MATERIAL AND WASTE MANAGEMENT STRATEGIES CONSIDERATIONS FOR DECOMMISSIONING

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According to the IEA 2020 Key World Energy Statistic edition, 4,9% of the global energy supply was from nuclear in 2019 whereas it was still above 10% in 2017. Focusing OECD countries, 9,7% of their electricity is delivered by Nuclear Power Plants. This illustrates fossil energies (Oil 31,6%, Coal 26,9%, Natural-Gas 22,8%) as a remaining significant means of global power supply despite their negative impact on climate change, whatever is the progressing share of renewables but, unfortunately, the yearly lack of compensation of NPPS being shutdowned by the new ones being connected to the grid. This emphasizes the necessity for all nuclear producers, to adjust their strategies, to strengthening the undeniable place of nuclear in the low carbon energy production mix. To reach such a global aim, it is necessary to increase nuclear industry credibility, embedding public acceptance. Among some keys (economy, efficiency, high technology, low environmental impact,…) this will result in demonstrating continuous improvements of waste management & decommissioning fields which commonly appear as the main public reluctant facet of the nuclear Industry. For operators such as EDF Group, operating totally 75 reactors in 3 countries as well as decommissioning 10 units in France, it is well experienced that a proper and cost efficient management of back-end activities, i.e. WM&D, is key for sustainable nuclear power operation and new build. Globally, 187 civilian nuclear power reactors had ceased operation in 2019. Besides these NPPs, various other types of nuclear facilities such as experimental reactors, fuel cycle, waste treatment, lab- oratories are already shutdown, awaiting, or in active decommissioning/dismantling phase. Hence, this worldwide rise of nuclear dismantling sites, emphasized that the demonstration of a technically and financially mastered decommissioning program is key to increase any nuclear operator's credibility. Furthermore, considering environmental and sustainable development, facilitates the legal, social and public acceptance, assuming the operator's responsibility in compliance with the future use of the site, whatever it is unrestricted or not. Targeting such an aim in a pragmatic and sustainable way, decommissioning is to be prepared at the earliest, since the design phase. Consequently, preparing decommissioning of nuclear installations that have not been designed for, induces to setting a number of strategies in consistency with already existing waste routes. Optimizing means, involving efficiently available resources, managing materials, reducing waste, improving techniques and perspectives, became vital for sustainable, safe and cost-efficient decommissioning in order to avoid undue burden on future generations.

Multinational Cooperation in Radioactive Waste Management / ID 306

THE NUCLEAR ENERGY AGENCY ACTIVITIES IN THE AREA OF RADIOACTIVE WASTE MANAGEMENT, DECOMMISSIONING NUCLEAR INSTALLATION AND LEGACY MANAGEMENT

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At the back end of the nuclear fuel cycle, there is a need to ensure the safety of radioactive waste at all stages including its final disposal. The NEA assists member countries in the development of safe, sustainable and societally acceptable strategies for the management of all types of radioactive waste. In addition, the NEA assists its member countries in their needs for developing, reviewing and updating effective safety cases supported by a robust scientific-technical basis. The work of the Agency in this area is coordinated through the radioactive Waste Committee in its subsidiary bodies. As many radioactive waste disposal programmes rely on volunteer or consent-based siting, safety case communication is another important aspect that is common to all types of disposal facilities. The scientific and technical basis for disposal facilities should be accessible to all stakeholders to enable them to participate in the decision making process. In this respect, it is key to build trust and confidence in the licensing process, tailor communication, explanation or concertation towards different audiences, and be concerned about stakeholder needs. As many nuclear power plants will reach the end of their operating lives over the next 20 years, decommissioning is an increasingly important topic for governments, regulators, industries and the public, among other stakeholders. Decommissioning activities must be carried out at the end of life of the nuclear facilities and sites. Some countries are further challenged with the decommissioning of legacy (i.e. complex) sites. The NEA created the Committee on Decommissioning of Nuclear Installations and Legacy Management (CDLM) was created in 2018 following the request from Nuclear Energy Agency (NEA) member countries to enhance the NEA's visibility in nuclear decommissioning and legacy management. The committee also aims to achieve collaborative advance of the state of the art of technical, environ- mental, policy, financial and societal aspects in its areas of work. The work of these two Standing Technical Committees apply a holistic as well as a sustainable approach to dealing with radioactive waste management as well as in the area of decommissioning and legacy management. In this way, the committees systematically identify its activities by focusing on three aspects 1) regulatory and legal; 2) economic; and 3) societal. These aspects, according to the holistic approach accepted by the CDLM and RWMC, are considered in the context of three frameworks: legislative, organizational and regulatory.

Multinational Cooperation in Radioactive Waste Management / ID 299

INTERNATIONAL COOPERATION WITHIN RADWASTE MANAGEMENT PROJECTS AT CHORNOBYL NPP

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The 1986 accident which took place at the Chornobyl Nuclear Power Plant and the following actions taken to mitigate its consequences have been a major challenge for Ukraine and the whole international community. This particularly applies to the task of bringing the destroyed reactor to a safe state. An equally important aspect is management of the radioactive waste generated, significant quantities of which need specific treatment and disposal solutions. Given the lack of necessary infrastructure for radioactive waste management at that time at Chornobyl NPP, except for interim waste storage facilities, the need arose to establish facilities for their treatment and processing and to develop safe management technologies both for the accidental waste contaminated with transuranium elements, and the waste resulting from decommissioning of the rest of the ChNPP power units. Up to date, ChNPP has implemented a number of projects with the assistance of such international organizations as the IAEA, EBRD, EC etc., for the creation of the following facilities: the Liquid Radioactive Waste Treatment Plant, Industrial Complex for Solid Radioactive Waste Management, Complex for Manufacturing Steel Drums and Reinforced Concrete Containers (RAW packages), New Safe Confinement covering the Object Shelter etc. These facilities are now whether at different stages of commissioning or at the initial stage of full-scale operation and progressively increasing their operational capacity. ChNPP has also partially implemented the project of the Purification facility for radioactively contaminated waters and liquid radioactive waste from TUE and organics, which has been suspended during design phase. The IAEA Technical Cooperation projects have significantly contributed to the development of approaches to management of problematic radioactive waste streams. Through joint efforts, strategic directions have been worked out in management of radioactively contaminated waters containing organics, irradiated graphite, and significant amounts of contaminated soils, and furthermore the level of characterization of radionuclide composition of radioactive waste has been significantly in- creased. When implementing these projects and choosing the waste management technologies which have been applied, sharing experience between organizations – both national and at international level – dealing with RAW management and research in the field, is a key factor of successful implementation of the projects. To summarize, it is worth noting that it was the international cooperation which played a key role in the development of radioactive waste management system at the Chornobyl Nuclear Power Plant.

Multinational Cooperation in Radioactive Waste Management / ID 155

ADOPTION AND IMPLEMENTATION OF AN INTEGRATED WASTE MANAGEMENT STRATEGY TO SUPPORT AND DELIVER THE NEXT GENERATION OF YOUNG PROFESSIONALS IN THE REMEDIATION OF THE UK'S NUCLEAR LEGACY

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The Nuclear Decommissioning Authority (NDA), an executive non-departmental public body sponsored by the UK's Department for Business, Energy & Industrial Strategy, made a commitment in the 2019 publication of the Integrated Waste Management Radioactive Waste (IWM) Strategy to:

> *"ensure that wastes are managed in a manner that protects people and the environment, now and in the future, and in ways that comply with government policies and provide value for money"*

The IWM Strategy promotes cross-category waste management optimisation within the NDA estate, with greater emphasis placed on the nature of the waste rather than classification, to aid in identifying the most appropriate management route. In this submission, an overview of how to successfully adopt and implement this strategy will be provided. This being fundamental in involving the next generation of young professionals, equipping them with the appropriate skills and knowledge to provide capability across the waste management lifecycle. By its very nature, radioactive waste management is a long-term venture with inter-generational issues, including skills retention, that need to be addressed. To attract and retain young professionals in the remediation of the UK's nuclear legacy, the IWM strategy could offer opportunities for young professionals. Industrial placements or secondments within the IWM Programme will ensure key messaging about radioactive waste will remain resilient (due to the rapidly changing technological landscape), clearly understood (due to social and organisational change) and taken seriously whilst supporting career growth. The IWM Programme is committed to working closely with Site Licence Companies across the nuclear industry, to identify key skills and knowledge requirements to develop plans to maintain capability and manage any skill gaps. The timing and availability of the required skill sets is vital to the success of the strategy and succession planning. Young professionals should be encouraged to seek and deliver innovative solutions to help shape the future of the industry and the IWM vision. In promoting the best use of our existing infrastructure and the development of new solutions, within the Nuclear Sector Deal, UK Government is committed to work with this sector to explore options for increasing the number of nuclear related PhD's. As a young professional I believe strengthening collaborative working relationships and learning from experience, the benefits of the IWM Strategy can be maximised so leading to a sustainable future.

Multinational Cooperation in Radioactive Waste Management / ID 61

DEEP BOREHOLE DISPOSAL OF INTERMEDIATE-LEVEL WASTE: PROGRESS FROM AUSTRALIA'S RD&D PROJECT

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Around the world deep borehole disposal is being evaluated for intermediate level waste (ILW), high-level waste (HLW), spent nuclear fuel (SNF), separated plutonium wastes and some very high specific activity fission-product wastes. In Australia, long-lived ILW from research reactors and radiopharmaceutical production represents the principal waste stream that requires deep geologic disposal. Whilst the Australian Government has not yet made a decision on its preferred strategy for ILW disposal, deep borehole disposal of small volumes of ILW would be a more cost-effective, and modular, solution compared to a conventional geologic disposal facility (GDF). CSIRO, ANSTO and SANDIA have created an international partnership to execute a full-scale borehole research, development and demonstration (RD&D) project in Australia. The project will demonstrate the technical feasibility of, and hence will provide a strong foundation for, the long-term safety of borehole disposal in deep geological formations. The execution of this project could also demonstrate options for nuclear waste disposal that would reduce proliferation risks, potentially up to the termination of compliance with international safeguards requirements. The RD&D includes demonstration of surface handling and waste/seal emplacement capabilities, basic research on foundational science areas, and full-scale field testing in both a deep characterization borehole, and a larger diameter (0.7 m or 27.5 inch) 2000-m deep demonstration borehole. The multi-barrier system designed for such deep disposal borehole concept places much less reliance on engineered barriers at the disposal zone to achieve safety as compared to a conventional GDF. It rather relies on geological features for waste containment. The concept being explored uses disposal containers with primary waste packages such as vitrified waste canisters inside; to be both cost-effective and fit-for-purpose, such container could have a mild steel based structural component with copper coating. So far, the RD&D has delivered novel enabling tools that assist with site screening, borehole design, and post-closure safety assessments. For instance, an automated geo- logical fault mapping and meshing tool was developed that assists with ranking the suitability of potential disposal sites based on proximity to faults. New codes were developed for better representation of fault zones in 2D/3D numerical flow and transport models while also being more efficient to execute. Post-closure safety assessments tested the sensitivity of long-term safety with respect to disposal depth, rock permeability and sorption. Heat transport calculations explored the sensitivity of temperature evolution within the borehole to parameters such as heat load, borehole depth, geothermal gradients, and rock thermal conductivity.

Multinational Cooperation in Radioactive Waste Management / ID 72

MULTINATIONAL REPOSITORIES: PAST, PRESENT AND FUTURE

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Since the beginnings of commercial nuclear power production, and especially over the past 25 years, there have been numerous initiatives assessing the potential role of multinational repositories (MNRs) in enhancing global safety, security and environmental protection. Increasingly, it has also been increasingly realised that an MNR would also enormously benefit countries with no nuclear power but with nuclear technology applications in research medicine and industry also generate radioactive wastes for which geological disposal is the only safe solution. This paper looks back over these studies highlighting the key issues they brought forward and commenting on the reception these received in the nuclear community. It identifies milestones in the international legislation related to multinational disposal and in radioactive waste management policy decisions taken by individual States. Important issues that have proven contentious are discussed. These include ethical debates regarding MNR's, impacts of MNR's on national geological disposal programmes, economic benefits and risks associated with hosting an MNR, and the big question of siting strategy. The pa- per also summarises current MNR activities being worked on by organisations such as the IAEA, EC, IFNEC, and the Arius and ERDO Associations. Finally, suggestions are put forward on progress that might be made on MNR's in the coming one or two decades, during which the vast majority of States requiring access to safe geological disposal will not yet have implemented any national repository.

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LEGAL AND REGULATORY ASPECTS OF REGIONAL RADIOACTIVE WASTE MANAGEMENT REGIMES: AFRICA AND THE SOUTH PACIFIC COMPARED

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The paper examines and compares, from a legal/regulatory point of view, the regimes for the management of radioactive waste in Africa and the South Pacific. Due to their vastness, both regions are attractive grounds for dumping/storing radioactive waste. Regarding Africa, the paper analyzes the Bamako Convention (signed in 1991), as reinforced by the right to a general satisfactory environment favourable to peoples' development, enshrined in the African Charter on Human and Peoples' Rights (1981). Regarding the South Pacific, the paper deals with the Waigani Convention (1995). Since they were established as regional regimes under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989), the paper appraises whether they exhibit similar characteristics. Their institutional set up, namely a Conference of the Parties, is also examined. Moreover, the important question of transnational criminal liability for violating regional norms is addressed. Here Africa is a world pioneer: the prohibited under the Bamako Convention trafficking in hazardous waste is considered an international crime and alleged perpetrators face prosecution before the African Court of Justice and Hunan Rights. The fact that not all States in the two regions participate in the respective regime is certainly an issue of note but is partly mitigated on account of the existence of several other multilateral instruments which, directly or indirectly, restrict and/or prohibit the movement of radioactive wastes. The paper concludes with suggesting which are the principal problems presently surrounding these two regional regimes.

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INTERNATIONAL COLLABORATION IN THE U.S. DISPOSAL RESEARCH PROGRAM: ADVANCES MADE IN TESTING AND PREDICTING COUPLED PROCESSES IN ENGINEERED & NATURAL BARRIERS

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The United States research program for geologic disposal of spent fuel and high-level waste is engaged in broad and active collaborations with several international geologic disposal programs. Such collaboration is a beneficial and cost-effective strategy for knowledge dissemination on different geologic disposal options; it also allows sharing international investment needs such as those for large-scale field experiments in underground research laboratories. To date, the U.S. program has established formal and informal cooperation partnerships with several international initiatives and institutions and has developed a number of collaborative R&D activities. This presentation gives on overview of these R&D activities, with specific focus on activities that improve our current understanding of the coupled thermal-hydrological-mechanical and chemical (THMC) processes occurring in engineered and natural barriers. We start with a brief review of selected international cooperation initiatives and then describe a few specific research projects featuring simulation of THMC processes during the early emplacement phase (e.g., heater tests, gas transport tests). We focus specifically on such studies that use experimental data sets provided by international research cooperation for joint modeling work to increase the confidence in performance-relevant predictions of coupled processes.

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THE INTERNATIONAL MASTER PROGRAM ON NUCLEAR APPLICATIONS AT FH AACHEN- NUCLEAR WASTE MANAGEMENT AS A PART OF HOLISTIC EDUCATION. A STUDENT CONTRIBUTION TO THE IAEA INTERNATIONAL CONFERENCE ON RADIOACTIVE WASTE MANAGEMENT

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The FH Aachen University of Applied Sciences, at its Campus Juelich, offers the International Masters Programme in Nuclear Applications (MNA, formerly: EMiNA - European Master in Nuclear Applications). Three faculties jointly cooperate to impart a broad spectrum of scientific/technical fundamentals and practical knowledge. According to the journal Nuclear Engineering the MNA course is among the best nuclear study programms in the world. Until now students from 14 countries and all world regions have successfully participated. FH Aachen/MNA is also a founding member of the international university network CHERNE (Cooperation for Higher Education on Radiological and Nuclear Engineering). Insofar, the FH Aachen forcefully contributes to internationally maintain nuclear safety competence, in accordance with the Vienna “Convention on Nuclear Safety” – CNS. The original curriculum includes specialization options in Nuclear Medicine, Nuclear Chemistry, Nuclear Technology. Due to the utter importance and capacity growth in NWM, the Nuclear Waste Management discipline has caught increasing attention and now has evolved into a 4th new focus field, embedded in a newly created research area on predisposal issues. Both education, research and development are linked to the IAEA and its International Predisposal Network (IPN). The first IAEA fellow (China) in NMW has already been admitted to the Juelich campus in 2019. The new focus field on NMW is grounded on a cooperation contract between the FH Aachen and the German Company for Interim Storage (BGZ), supported with state funds through the BGZ. Through- out the nuclear sector in Germany, it must timely be ensured that retiring nuclear specialists can be replaced by qualified successors. However, academic courses on practical nuclear applications and predisposal waste management during the last decade had been phased out in Germany, excepting FH Aachen. Insofar the MNA course was chosen to be extended with modules in English and German in a targeted manner. National and international experts and practitioners have worked on the courses and are involved as lecturers. The holistic approach also includes processes, systems and the impact of human factors in NMW. Special emphasis is placed on the active involvement of students, who contribute to the ongoing updating of content through their coursework including work and reviews on NMW issues in their home countries.This conference contribution is provided as a community work of the MNA students. It conveys both an overview on the entire MNA programme and on details of the focus fields, with special regard to NMW as a holistic part of the programme.

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DEEP BOREHOLE DISPOSAL AS AN AVENUE FOR MULTINATIONAL COLLABORATION

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Deep borehole disposal has received increased attention in recent years as a potential method for safe disposal of high-level radioactive waste, including spent fuel. Borehole disposal is of particular interest to small-inventory States, because the economies of scale are different than for deep geological repositories that involve access tunnels, shafts, and tunnel galleries (mined repositories). The driver for countries to combine their waste inventories in a shared multinational repository (MNR) is thus not as strong for borehole repositories, but large benefits can still result from multinational cooperation. The ERDO Association is conducting a project that assesses the strategic potential of borehole disposal for several European countries, based on their existing and projected national waste inventories. The project has identified a basic design that could enable disposal of both spent fuel and high-level waste from reprocessing, thereby enabling disposal of a significant portion of the combined waste inventory. Strategic implications, such as required support facilities, implementation time, risks, and costs have been assessed. The generic process for concept development has been described. The concept is in an early, generic stage. Central uncertainties have been assessed, and topics for continued research and development have been identified. The differences between fixed and variable costs for borehole disposal and mined repositories may enable a multinational approach that focuses on sharing R&D-resources, encapsulation facilities, tools, and methods, rather than constructing one shared repository. This may open attractive opportunities for national and international organizations, as well as commercial companies with relevant competence.

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THE EURATOM PROJECT MICADO AND ITS INNOVATIVE CHARACTERIZATION PROCESS OF THE NUCLEAR WASTE PACKAGES

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All over the world the nuclear waste management sector is always part of public debate, mainly due to complexity and costs arising from storage and management of the waste produced. It is important to underlying that this waste is not only produced by the nuclear power industry, but also by hospitals, universities, and non-nuclear industries. Regardless from its origin, the main concern is the radiation emission, which makes it a particular hazard for human health and the environment. It must therefore be managed with special care, from production to final disposal with a specific focus on the radiological waste characterization which determine the waste categorization and the consequent storage and radiological waste treatment and management.

Another relevant aspect to consider is the existence of a RWM (radiological waste management) country dependent legislation. It is not only defining the category levels, this means to have different definition of waste categories and activities (ex. Free release), but also their management and storage. For this reason, RWP (radiological waste package) are often characterized at each site with different detection systems generating a large amount of off-line data to be manually analysed.

It is in this framework that in 2019 the MICADO (Measurement and Instrumentation for Cleaning And Decommissioning Operations) project started under the H2020 Euratom call, aiming to demonstrate the feasibility of an improved characterization of nuclear waste packages.

This paper describes the MICADO structure, the technologies under integration and the software infrastructure under development to increase the characterization efficiency and to limit the human errors. All aspects that will improve the Non Destructive Assay (NDA) characterization measurement will be touched along with a quick status update of the project after two years from its starting point.

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THE IAEA'S ROLE IN ADVANCING RADIOACTIVE WASTE MANAGEMENT PRACTICES IN LIBYA

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The potential negative effects on the nation's safety and security by a weak national radioactive waste management system made the need for strengthening, and improving radioactive waste management practices in Libya a vital issue. As Libya is not a nuclear country, the main types of radioactive waste are Disused Sealed Radioactive Sources (DSRS), and Naturally Occurring Radioactive Materials (NORM) waste. Radioactive Waste Management Division (RWMD) under the umbrella of the Libyan Atomic Energy Establishment (LAEE) has been established as the national operator for radioactive waste management of Libya in the middle of 2010; As the Libyan revolution started few months later, with the low awareness and understanding of governments and decision makers of the significant role RWMD and even LAEE are playing for the country's safety and security; RWMD couldn't gain sufficient support that enable him to carry out his important duties. The situation of the RWMD was reported by two members of the division on 2015 in a published scientific paper titled (Management of Radioactive Waste in Libya: Case Study), In that paper, the weaknesses of the division were reported as: the poor experience in radioactive waste management especially conditioning and storage of DSRS, and how to deal with NORM waste; the lack of trained manpower; weak programs of human resource development; the available inventories of radioactive waste need to be properly managed. The real start of gaining knowledge and experience about DSRS management in the RWMD was associated with the establishment of the International Atomic Energy Agency (IAEA)'s Interregional Technical Cooperation project: strengthening cradle-to-grave control of radioactive sources in the Mediterranean region (project code: INT9176) that began in 2012. After that, two other INT projects with one national technical cooperation project enabled RWMD to make a professional team that can deal with DSRS and NORM waste and provided by a proper instruments and tools. the role that IAEA played in forming and improving the RWMD was particularly important and highly affected in a positive manner the implementation of his tasks. This paper demonstrated an example of how IAEA's support can make difference for member states, even for a country that still facing many security and political challenges.

Multinational Cooperation in Radioactive Waste Management / ID 131

DIGITAL TOOLS FOR CEMENTED WASTE PACKAGE AND FACILITY MONITORING AND PREDICTION

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To provide better means for a safe and effective monitoring of cemented waste packages including prediction tools to assess the future integrity development during pre-disposal activities, several digital tools are evaluated and improved in the frame of the EC funded project PREDIS. Safety enhancement (e. g. less exposure of testing personnel) and cost effectiveness are part of the intended impact. The work includes but is not limited to inspection methods such as muon imaging, wireless sensors integrated into waste packages as well as external package and facility monitoring such as remote fiber optical sensors. The sensors applied will go beyond radiation monitoring and include proxy parameters important for long term integrity assessment (e. g. internal pressure). Sensors will also be made cost effective to allow the installation of much more sensors compared to current practice. The measured data will be used in digital twins of the packages for specific simulations (geochemical, integrity) providing a prediction of future behavior. Machine Learning techniques trained by the characterization of older packages will help to connect the models to the actual data. All data (measured and simulated) will be collected in a joint data base and connected to a decision framework to be used at actual facilities. The presentation includes detailed information about the various tools under consideration, their connection and first results of our research.

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MAIN CHALLENGES AND LESSONS LEARNED OF A MULTINATIONAL COOPERATION IN RADIOACTIVE SOURCE REMOVAL AND WASTE MANAGEMENT PROJECTS

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Nowadays more and more countries -with the assistance of the IAEA -are dedicated to solve the problems of Disused Radioactive Sources in a cost-effective way paying maximum attention to the safety and security of the operations. There are a limited number of companies who can provide such services, sometimes they can cover just some particular areas of the operation. Institute of Isotopes Co. Ltd. (IZOTOP-Hungary) and NCT (France) have significant & complementary experiences in this field. During the last five years, we carried out a significant number of joint operations both for IAEA and based on bilateral contracts for different countries not only in Europe but also in Africa, Asia and South-America. We showed that the joint operations can provide better, cheaper but also safer services for the end-users. In Cyprus, under the supervision of the IAEA, 15 tons of different units containing DU and 35 pieces of high activity radioactive sources were removed from the island with a dedicated air transport within 2 weeks (after a four-month long planning and coordination), battling with COVID restrictions. Both Izotop and NCT learnt many lessons from this operation. Today, we would like to share them with the audience and provide some useful information for all interested partners in order to better prepare and be able to make a prudent planning for any future projects.

Multinational Cooperation in Radioactive Waste Management / ID 212

US-MEXICO COOPERATION ON SOURCE REPATRIATION

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In September 2019, on the sidelines of the IAEA General Conference, the Department of Energy- National Nuclear Security Administration (DOE-NNSA) Undersecretary for Nuclear Security, Lisa Gordon-Hagerty, and the director of the National Institute for Nuclear Research (ININ) of the United Mexican States, Dr. Javier Cuitláhuac Palacios Hernández, signed a Memorandum of Understanding (MOU) for the consolidation and removal of disused radioactive sources of US origin from Mexico. Annex II of the memorandum specified an inventory of low-activity sources located at the Radioactive Waste Treatment Plant (PATRADER) and the Radioactive Waste Storage Center (CADER) of the ININ, to be repatriated to the United States by the Off-Site Source Recovery Program (OSRP) part of the Los Alamos National Laboratory. Because these two facilities are located on opposite sides of Mexico City, ININ worked with staff at the CADER site to consolidate the devices and sources into PATRADER at ININ. OSRP worked with its industry partner, Qal-Tek, to make preparations to disassemble the devices and remove the sources for efficient packaging. Brokerage companies were used to support the shipments in both Mexico and the US; as was the Mexican regulatory authority, National Commission on Nuclear Security and Safety (CNSNS)consulted for approval. In preparation for recovery, Type A containers, special form capsules, radiation detection equipment, and auxiliary support supplies were prepared at ININ in late 2019. The source recovery mission was completed in January 2020. Both organizations achieved permanent risk reduction by eliminating more than 4.44 TBq of Americium-241 /Beryllium (well above the IAEA threshold for Category 2 of 592 GBq), as well as packaging a significant quantity of Californium-252. A total of 158 sources were packed and their repatriation to a consolidation facility in the US was completed. The shipment of the sources was prioritized due to the Covid-19 pandemic that occurred at the exact same time. Once the sources were received in the US, the OSRP, DOE-NNSA and ININ completed their commitment to Annex II and have improved global radiological security. Additionally, a source recovery involving US and Canadian origin sources from approximately 80 Category 1 and 2 teletherapy heads is in the planning stages and is also included in the Memorandum of Understanding.

Multinational Cooperation in Radioactive Waste Management / ID 218

CLASSIFICATION OF THE METALLIC RADIOACTIVE WASTE STREAMS OF THE DIFFERENT TYPES OF REACTORS IN PREDIS

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Metallic radioactive waste (MRW) with a wide list of radionuclides of different concentrations is one of the important issues for every nuclear power plant under decommissioning dealing with the radioactive waste management and final disposal. The best practice is needed for optimized waste classification including the quantification of specified radionuclides but also for assessment of activity reduction and declassification possibilities in the waste materials before placement in the specific disposal sites. The classification of the MRW streams is changing together with its activity: the high and intermediate activity radioactive waste (HLW, ILW) needs classification related to radioprotection and best packaging concept, low level and very low level radioactive waste (LLW and VLLW) needs decontamination and clearance or declassification afterwards to meet the waste acceptance criteria (WAC) of the disposal site. The largest volumes of waste from the dismantling of nuclear installations is mainly be VLLW and LLW [1]. In the frame of PREDIS project, one of WP4 4.5.1 subtask is aiming to provide a scheme for classification of the reactor metallic materials regarding the level of activation: highly activated, intermediate, low activation metal constructions and non-activated materials in order to facilitate the procedure of decontamination and clearance or declassification. The methodology for characterization of the metallic waste is similar to all reactors and is based on nuclide vector (NV) determination. An essential part of the metallic waste characterization is the separation of neutron activation and surface contamination activity parts to identify the best way of management. Optimized NV is obtained by analyzing and systemizing the information about radioactive metallic waste streams, identifying the optimal list of relevant radionuclides and performing numerical analysis of activation and contamination parts for the waste streams.

Multinational Cooperation in Radioactive Waste Management / ID 247

INTERNATIONAL COOPERATION ON PREDISPOSAL WASTE MANAGEMENT INNOVATION IN THE PREDIS PROJECT, ADDRESSING TECHNOLOGY GAPS AND COMMON INDUSTRIAL CHALLENGES

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Euratom has initiated a cooperative research project aimed at developing and improving, safer treatment and conditioning methodologies and processes for wastes. The project "PREDIS: Pre-Disposal Management of Radioactive Waste" develops novel methods and technologies to improve handling of low-level and intermediate level radioactive wastes. The project focuses on treatment of metallic materials, liquid organic waste and solid organic waste, which are generated in nuclear power plant operation, decommissioning and other industrial processes. PREDIS project also develops digitalisation solutions to improve safety and efficiency when handling and assessing cemented-waste packages for extended interim surface storage. An example of this is the use of digital twins and artificial intelligence for big data mining from non-destructive evaluation methods. Through all of these pre-disposal treatment activities, waste acceptance criteria are a critical parameter for optimising the safe and efficient handling and minimisation of wastes over the whole life cycle, from cradle to grave. The PREDIS project will produce tools guiding decision-making on the added-value of the developed technologies and their impact on the design, safety, environmental impact and economics of pre-disposal waste management and future disposal. It is anticipated that the project results will be close to implementation by the end user community, which is ensured through their active involvement with the partners and the co-funding structure of this EC project. The project's Strategic Research Agenda will highlight needs for future technology development, investments and needs also from the perspectives of competence development and preservation of knowledge. This paper highlights the achievements of the first year, including the detailed gap analysis and baseline strategic research agenda. The overviews about technical innovation activities from each waste stream will be presented, along with information on strategic studies relevant to all issues such as Waste Acceptance Criteria, environmental indicators and economic assessments of the improved technologies.

Multinational Cooperation in Radioactive Waste Management / ID 250

PUTTING DEEP BOREHOLE DISPOSAL OF NUCLEAR WASTE INTO PRACTICE: THE CHALLENGES OR THE INTERNATIONAL COMMUNITY

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The use of deep boreholes as a means of delivering geological disposal for higher activity radioactive waste is an option that is of increasing interest to policymakers around the world, offering a potentially attractive supplement to the established concept of geological disposal in a mined repository. Although the drilling and waste handling technologies involved are already developed and commercially deployed, deep borehole disposal (DBD) as a whole system is less mature than the mined repository concept. Against this context, the paper presents preliminary results from a survey of opinions across the regulatory, policy and practitioner communities to identify a) the key potential opportunities and benefits that stakeholders perceive DBD to offer; and b) the policy/regulatory, technical/operational and societal challenges that remain to be addressed prior to DBD implementation. Major perceived benefits are found to include: increased choice and siting flexibility; the potential for cost reductions across national waste disposal programmes; potentially attractive features from the perspective of community consent; and potential for economies of scale around regulatory processes. The single most important challenge cited by stakeholders is the need for the large-scale demonstration of DBD in operation on a whole-system basis. Other challenges include the lack of international guidance on developing and assessing the DBD safety case, and the need for further societal research to test community knowledge and opinions on DBD. Looking to the future, four out of five surveyed stakeholders agree that national waste management programmes should work together in joint projects to address these challenges and accelerate the implementation of DBD. The paper additionally presents potential priorities for such collaboration.

Multinational Cooperation in Radioactive Waste Management / ID 269

MULTINATIONAL COOPERATION INITIATIVE ON POST-CLOSURE CRITICALITY SAFETY

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Demonstrating the criticality safety of a final disposal concept in the post-closure phase, i.e. over very long timescales, is a complex and unique endeavour for many, if not all, waste management organisations (WMO) that have to dispose of spent fuel. While certain matters are intrinsically related to the particularities of each individual disposal concept, the WMOs do, in fact, address many similar aspects. Therefore, the sharing of knowledge, experience and innovative ideas between them has clear benefits. For instance, the envisioned exchange would enable the development of a method- ology to perform meaningful comparisons and increase understanding between the different WMO approaches to assessing criticality safety. This would, in turn, facilitate an informative comparison and validation between their respective results. Furthermore, this evaluation on first-principles would consolidate each WMO's individual approach by anchoring it in the appropriate international RD&D context. Consequently, a multinational cooperation effort, allowing a transparent and effective information exchange between WMOs on post-closure criticality topics, will provide a great benefit. This contribution gives an overview of the current efforts to establish and further develop such a WMO-level multinational collaboration. These efforts were recently initiated as a joint effort by the Radioactive Waste Management (RWM, UK) and the National Cooperative for the Disposal of Radioactive Waste (Nagra, Switzerland) in the context of the IGD-TP (https://igdtp.eu). The initiative presently enjoys great interest from more than 10 waste management organisations from Europe, the U.S. and Canada. Further opportunities for wider involvement are planned to ensure that those who want to be involved can do so and the collaboration maximises success. The presentation will place this initiative in context by first briefly discussing the context of post- closure criticality safety and previous international exchanges on post-closure criticality and will summarise their results and conclusions. Based on this, the motivation underpinning the present collaboration efforts will be explained. Furthermore, the main goals and benefits envisioned for the collaborative work and the current status will be presented. Lastly, the strategy and future plans for the proposed multinational cooperation will also be summarized.