

NEA News



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Radiation and thyroid cancer

The Fukushima Daiichi nuclear power plant accident:
Update on compensation

The safety case for deep geological disposal
of radioactive waste

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The OECD Nuclear Energy Agency (NEA) is an intergovernmental organisation established in 1958. Its primary objective is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes. It is a non-partisan, unbiased source of information, data and analyses, drawing on one of the best international networks of technical experts. The NEA has 31 member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, the Republic of Korea, the Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the NEA. A co-operation agreement is in force with the International Atomic Energy Agency.

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Moving towards a global nuclear liability regime

Change has always been a characteristic of the nuclear power sector and the current era is certainly no exception. Whether in nuclear safety, nuclear regulation or nuclear law, it is clear that change is underway at both the national and international levels. It is vital that we guide this period of change towards further improvements to ensure the protection of public health and safety and the continued availability of nuclear power as a safe, economical and environmentally friendly source of energy for the world.

The Nuclear Energy Agency (NEA) is also undergoing significant change. For the past 17 years, the NEA has thrived under the leadership and valuable service of Luis Echávarri, who as NEA Director-General led the Agency through an evolving nuclear energy sector with diligence and capability. As the new Director-General since 1 September 2014, it has been my responsibility to oversee the transition to a new chapter. I have been involved in NEA activities since the early 1990s, first as a member of the Nuclear Development Committee and later as Chair of the Steering Committee. I was also involved, while at the US Department of Energy, in the launching of the Generation IV International Forum (GIF), for which the NEA now acts as Technical Secretariat.

I am very pleased to be taking over the reins of the NEA to lead the Agency in its continued service to the international community. This includes the Agency's support for the transition towards a global nuclear liability regime to ensure adequate compensation for damage to persons and property in the event of a nuclear accident. The nuclear accidents at Chernobyl in 1986 and at Fukushima Daiichi in 2011 have demonstrated that having an adequate liability regime in force is a legitimate, worldwide concern. The NEA is committed to supporting further developments in this area, in line with recent statements made by NEA member governments such as France and the United States, emphasising the need to facilitate greater globalisation and harmonisation of nuclear liability regimes. An article in this edition of NEA News provides an update on financial compensation made in Japan since the Fukushima Daiichi nuclear power plant accident.

This challenge is one of several that the NEA is addressing through its broad range of activities. For example, the Agency has been active in its analysis of the future of medical radioisotope supply, also outlined in this issue of NEA News, and has been instrumental in the release of a Joint Declaration (see page 8). Other articles elaborate on NEA activities in the area of public health, notably on the development of a state-of-the-art scientific understanding of radiation and thyroid cancer, which was discussed at an international workshop co-organised by the NEA in Tokyo, Japan. Updates are also provided on the safety case for deep geological disposal of radioactive waste, a new international nuclear emergency exercise (INEX) and a new NEA publication that examines the environmental and health impacts of uranium mining.

The wide-ranging research and analyses conducted by the NEA attest to the broad range of areas in which NEA member governments seek to continue making improvements in the nuclear energy field. In this period of transition, the Agency will spare no efforts to support member countries as they address important challenges.

William D. Magwood, IV
NEA Director-General

The future of medical radioisotope supply

by P. Peykov*

The NEA and its High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) have been actively examining the causes of supply shortages of the most widely used isotope in medical diagnostic imaging, technetium-99m (^{99m}Tc), and its parent isotope molybdenum-99 (^{99}Mo). As a result of this examination, the HLG-MR has developed a policy approach that includes principles and supporting recommendations to address the causes of these supply shortages. Six policy principles were agreed by the HLG-MR in March 2011. These are implementation of full-cost recovery and outage reserve capacity (ORC) for ^{99}Mo production, a government role in the market, conversion to low-enriched uranium targets, international collaboration and periodic reviews of the supply chain (see Figure 1). This article describes progress made in the implementation of the six principles and examines the projected global capacity for medical radioisotope production in the near future.

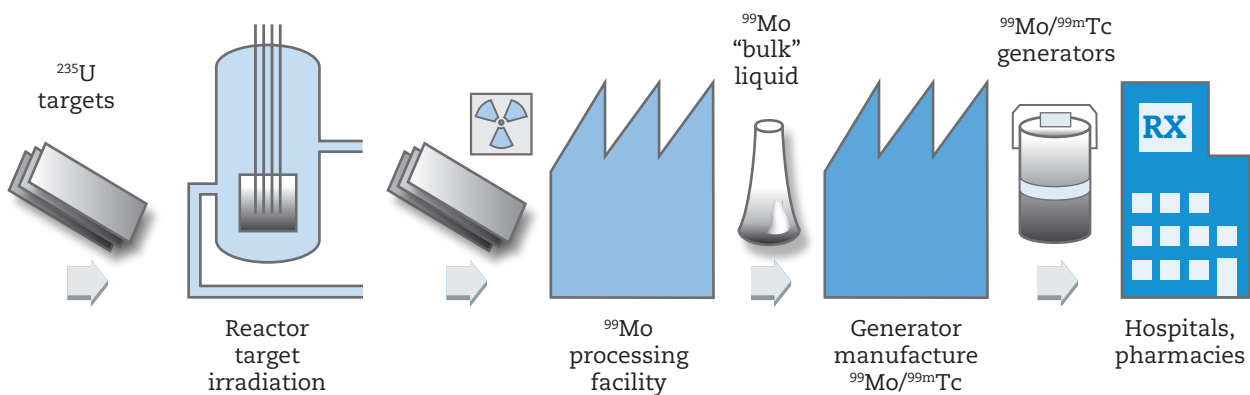
Progress towards a sustainable supply of $^{99}\text{Mo}/^{99m}\text{Tc}$

To evaluate progress made in the implementation of the HLG-MR policy principles, the NEA has undertaken two reviews (through individual country

self-assessments) of the global supply chain. The reviews found that most reactor operators and processors are gradually implementing full-cost recovery for ^{99}Mo production, although the process is taking place at different speeds or has yet to begin in some countries. Government subsidies continue to present a significant barrier to full implementation, which is particularly evident at the reactor level. In addition, some planned new multipurpose reactors for ^{99}Mo production could be built with public funds, further exacerbating the current unsustainable situation in the market. In the downstream segment of the supply chain, generator manufacturers and end-users are gradually adjusting to higher prices from the implementation of full-cost recovery upstream. However, to the extent that subsidised $^{99}\text{Mo}/^{99m}\text{Tc}$ continues to be produced, the generator manufacturers and end-users are not paying the full cost of the isotope.

The self-assessments also revealed that ORC is still not widely accepted by the market, although it contributes significantly to the security of supply.¹ At present, ORC is appropriately valued and paid for at the global level only in a few cases. In other cases, reactor operators are in the process of negotiating contracts with their processors for the provision and

Figure 1: The $^{99}\text{Mo}/^{99m}\text{Tc}$ supply chain



Source: Ponsard (2010).

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payment of ORC. There are also instances where ORC is being used but not compensated.

Although governments have historically subsidised research reactors (the dominant global source of ^{99}Mo at present and for the foreseeable future), many are withdrawing their support and encouraging reactor operators to commercialise ^{99}Mo production. However, some governments continue to provide subsidies. And yet, when ^{99}Mo is produced for the global market, governments should refrain from subsidising the ^{99}Mo -related infrastructure of existing or new/replacement reactors, processors or other supply chain participants, to comply with the principle of full-cost recovery and to avoid distorting the market. Further downstream, reimbursements of nuclear medicine have been affected by government pressure to contain costs. According to the self-assessment results, few governments have taken concrete actions on reimbursement rates for medical radioisotopes.

Current state of the ^{99}Mo market

Much greater awareness now exists of the underlying issues that led to the 2009-2010 medical isotope supply shortage and of the need to implement the HLG-MR policy principles, which were designed to improve security of supply. Increased communication among supply chain participants, diversification of suppliers, improved co-ordination of reactor schedules and a more efficient use of isotopes by end-users have all contributed to a more reliable supply and better use of $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$. This has helped to address the vulnerabilities identified in the supply chain, but more remains to be done.

The economic problems that manifested during the 2009-2010 supply shortage have not disappeared. Reactor operators who are partially subsidised by governments, and in some cases fully amortised, contribute to market prices for irradiation services. These operators have a distinct advantage over others who already operate under full-cost recovery. Processors with access to subsidised irradiation services also have an advantage that could potentially push other processors to lower their prices below a sustainable level. Further downstream, there is an additional challenge to achieve sustainable pricing: inaction on the part of governments, largely as a result of fiscal constraints, to reimburse nuclear medicine procedures based on full-cost recovery.

Projections for future capacity and demand

In April 2014, the NEA released a capacity and demand forecast for the 2015-2020 period, when two of the world's major irradiators of targets for ^{99}Mo production will exit the market and a number of potential new producers may enter the market.

Demand

The demand scenarios use the previous NEA (2012) estimate of 10 000 six-day ^{99}Mo curies² (i.e. the number of curies present six days after the end of the production process) from processors. Based on recent information from supply chain participants, the NEA estimates the annual growth rate at 0.5% in mature markets (North America, Europe, Japan and the Republic of Korea) and 5% in emerging markets.

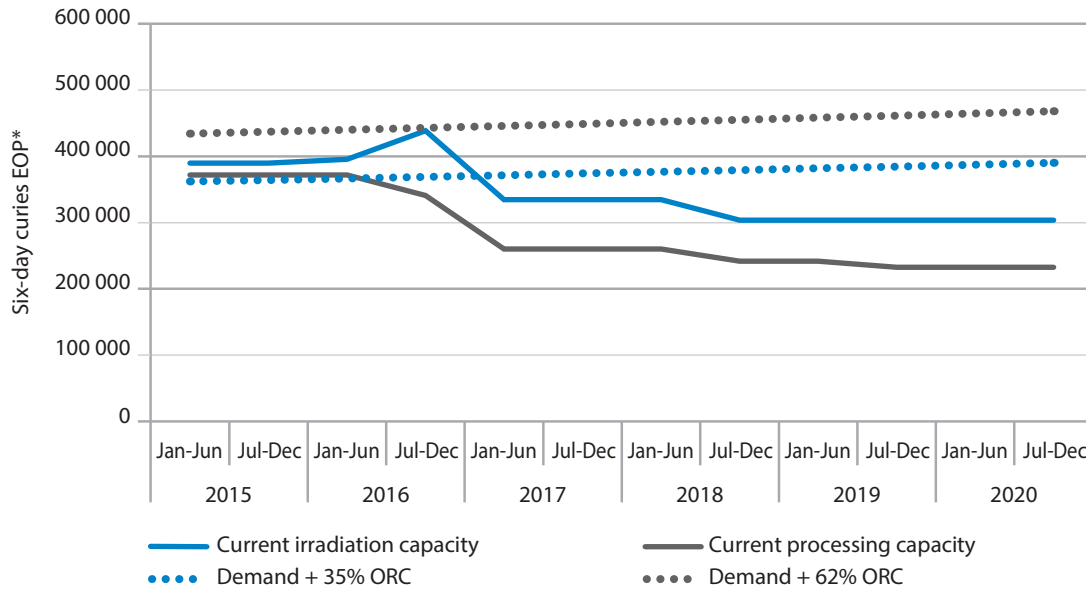
The NEA has no direct way to measure the amount of ORC in the market, but all supply chain participants agree that the principle of having ORC is essential to sustainability and reliable supply. The ageing production infrastructure and the increasing likelihood of outages in the future require the constant availability of ORC. As a result, the demand figure for $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ should include some level of ORC, as the situation in recent years has underlined the necessity of maintaining ORC. In this report, demand is expressed at two different levels of ORC: 35% and 62%.³

Current capacity

Figure 2 depicts a reference scenario which includes current irradiators and processors, as well as projected demand. The figure shows that, in 2015-2016, global irradiation capacity should be sufficient to avoid supply shortages. However, as the capacity curve falls below the lower demand curve (with 35% ORC) post-2016, there is an increased risk of supply interruptions without new capacity. Clearly, current global irradiation capacity is on a decreasing trend throughout the forecast period. The ageing of major reactors and the consequent higher probability of unplanned or extended outages, along with the impact from low-enriched uranium (LEU) conversion, could also influence the processing capacity associated with such reactors and, therefore, necessitate investment in new or replacement production capacity. This further underlines the need to implement full-cost recovery for ^{99}Mo production to help ensure that sufficient, assured irradiation capacity is available in the market.

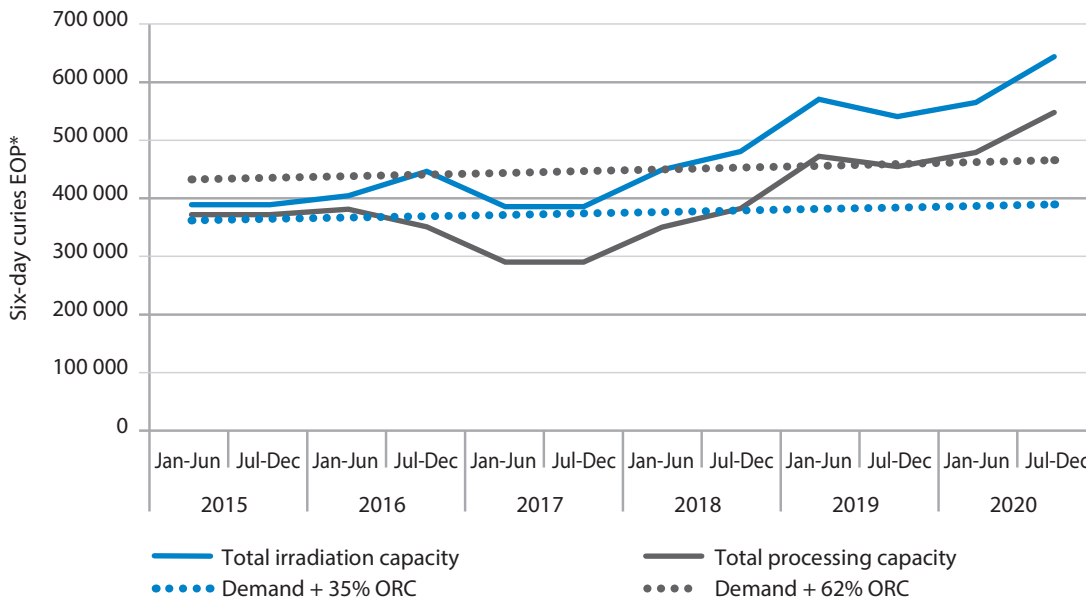
To have a better understanding of the global supply situation, both irradiation and processing capacity should be considered. Irradiation capacity presents only a partial picture and does not account for geographical limitations relating to the production of bulk ^{99}Mo . Not all ^{99}Mo -irradiating reactors have associated processing facilities, which results in some regional constraints on processing production and the loss of product through more decay during transport. This is especially true in Europe where irradiation capacity exceeds processing capacity. The regional limitations on ^{99}Mo production can be seen by comparing the two capacity curves (irradiation and processing), which are plotted together in Figure 2.

Figure 2: Current irradiation and processing capacity versus demand, 2015-2020



*EOP = End of processing.

Figure 3: Current and selected new irradiation and processing capacity versus demand, 2015-2020



*EOP = End of processing.

Clearly, the sufficiency of processing capacity will continue to be the main risk for the secure supply of ⁹⁹Mo over the next five years.

Global irradiation and processing capacity, based only on current producers, is forecast to be insufficient for the security of ⁹⁹Mo/^{99m}Tc supply, even with all producers operating under normal conditions, without any unplanned or extended outages. As a consequence, there is a high risk of supply shortages, particularly in the 2015-2017 period, which suggests a need for additional capacity.

Current and new projects

Figure 3 depicts an alternative scenario, which includes current producers and planned new projects that have a high likelihood of materialising, although new projects are assumed to be delayed by one year from their officially announced commissioning dates.⁴ In addition, this scenario assumes that the process of conversion to LEU targets for ⁹⁹Mo production will be delayed by one year, since processors are experiencing more technical and economic challenges than previously envisaged.

The projected global irradiation and processing capacity in Figure 3 is almost identical in 2015 and 2016 to that of Figure 2, although it sharply drops in 2017 due to the one-year delay of the commissioning of several major new projects in Australia, Europe and North America. Under this scenario, the delays in new capacity will have a negative effect on the availability of irradiation capacity. At the same time, delayed LEU conversion will have the opposite effect. Over the five-year forecast period, the “delayed new capacity” effect will dominate, resulting in lower total irradiation capacity.

From the beginning of the forecast period until mid-2016, global processing capacity will be slightly above the lower demand curve (with 35% ORC) in Figure 3, suggesting a small risk of supply shortages. Processing capacity decreases sharply in 2017 showing a higher risk of shortages due to the delay in planned new projects with associated processing capacity, before increasing in 2018.

Will ⁹⁹Mo supply be secure in the future?

The above-mentioned ⁹⁹Mo/^{99m}Tc capacity forecast confirms the previous NEA forecast in 2012 of a tight and potentially insufficient capacity in the short term, especially if these were unplanned shutdowns. However, this does not mean that there will be supply shortages, as this depends more on local conditions. The planned exit of the OSIRIS and NRU reactors (and especially the latter’s associated processing capacity) from the global supply chain will pose particular challenges in meeting demand. On the other hand, the anticipated commissioning of new capacity as early as 2015 raises hopes that short-term challenges can be overcome, although any delays in such commissioning, which is not unlikely given the innovative production technologies involved, could cause supply difficulties. What is also unclear is whether these alternative, commercially-based production technologies will have a competitive market price.

These forecast results reinforce the need to establish an economically sustainable ⁹⁹Mo/^{99m}Tc supply chain as quickly as possible, which would ultimately enable investment in new/replacement, non-HEU-based production capacity and its timely entry into operation. It would also provide sufficient amounts of paid ORC to the market. The ageing fleet of research reactors – the backbone of global ⁹⁹Mo production at present and for the foreseeable future – and recent extended outages experienced by major producers underscore the importance of universally adopting full-cost recovery and funded ORC.

Given this situation, the supply chain should therefore continue its communication and collaboration efforts to co-ordinate producer actions, especially in periods of potential tight supply, to help

minimise any impact on the end-users of ^{99m}Tc. Such efforts have been very effective to date, as evidenced by the lack of shortages in 2013, despite the loss of some production facilities. Until the supply chain becomes more resilient and secure, these efforts will continue to be important.

For more information about NEA work on medical radioisotopes, see www.oecd-nea.org/med-radio/.

Notes

1. Outage reserve capacity (ORC) is required to ensure a reliable supply by providing back-up irradiation and/or processing capacity that can be called upon in the event of an unexpected or extended reactor/processor shutdown.
2. Curies are still the unit used in the industry (1 Ci = 37 GBq).
3. The 35% ORC level is based on a calculation of required ORC to maintain supply after the exit of the OSIRIS reactor in France and the NRU reactor in Canada from the market, when the largest remaining reactor (HFR, the Netherlands) has an unplanned outage. The 62% level is based on a calculation of required ORC to maintain supply prior to the exit of OSIRIS and the NRU, when both the NRU and HFR (the two largest irradiators) have unplanned outages. The level of ORC actually required is likely to be somewhere between the 35% and 62% levels.
4. Non-reactor-based (e.g. linear accelerators and cyclotrons) and reactor-based projects.

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In January 2014, during the meeting of the High-level Group on the Security of Supply of Medical Radioisotopes (HLG-MR), the Nuclear Energy Agency was asked to develop a more formal statement of commitment to the six policy principles mentioned on page 4. The concept of a joint declaration was proposed and a consensus document, the Joint Declaration on the Security of Supply of Medical Radioisotopes (“Joint Declaration”) was developed. This Joint Declaration now has the formal support of 11 governments and was published by the NEA on 17 December 2014, sending a strong signal to the supply chain regarding the intentions of governments to take co-ordinated action in order to ensure the long-term reliability of supply of important medical radioisotopes. The Joint Declaration, reprinted below, remains open for adhesion by those HLG-MR participating countries that have yet to adhere, or by any other country that wishes to do so.

JOINT DECLARATION ON THE SECURITY OF SUPPLY OF MEDICAL RADIOISOTOPES

WE, the Ministers and representatives of Australia, Canada, Germany, Japan, the Republic of Korea, the Netherlands, Poland, the Russian Federation, Spain, the United Kingdom and the United States of America, **SHARE** a common interest in ensuring the security of supply of the most widely used medical radioisotope, molybdenum-99 (^{99}Mo) and its decay product, technetium-99m ($^{99\text{m}}\text{Tc}$), which is used in approximately 40 million medical diagnostic imaging procedures per year worldwide enabling precise and accurate, early detection and management of diseases such as heart conditions and cancer, in a non-invasive manner.

WE ACKNOWLEDGE, on the one part, that the production of $^{99\text{m}}\text{Tc}$ depends largely on a small number of reactors that are ageing and facing unplanned outages, planned refurbishment outages or planned permanent shutdowns, which increases the risk of disruption of the supply chain, unless new infrastructure is developed to replace these facilities before they shut down.

WE RECOGNISE, on the other part, that an unsustainable economic structure is threatening the reliability of the $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ supply chain, and that global action to move to full-cost recovery is necessary to ensure economic sustainability and long-term secure supply of medical isotopes.

WE AFFIRM that any action to ensure the reliability of supply of $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ must be consistent with the political commitments to non-proliferation and nuclear security.

WE CONFIRM our acceptance of the principles set forth in the policy approach released in June 2011 by the High-Level Group on the Security of Supply of Medical Radioisotopes (the HLG-MR principles) to ensure the long-term secure supply of medical radioisotopes, which were formally endorsed by the Organisation for Economic Co-operation and Development’s (OECD) Steering Committee for Nuclear Energy on 28 April 2011.

WE COMMIT, with the aim of jointly promoting an internationally consistent approach to ensuring the long-term secure supply of medical radioisotopes, to implement the HLG-MR principles in a timely and effective manner, and to:

- Take co-ordinated steps, within our countries’ powers, to ensure that ^{99}Mo or $^{99\text{m}}\text{Tc}$ producers and, where applicable, generator manufacturers in our countries implement a verifiable process for introducing full-cost recovery at all facilities that are part of the global supply chain for $^{99\text{m}}\text{Tc}$;
- Encourage the necessary actions undertaken by ^{99}Mo processing facilities or $^{99\text{m}}\text{Tc}$ producers in our countries to ensure availability of reserve capacity capable of replacing the largest supplier of irradiated targets in their respective supply chain;
- Take the necessary actions to facilitate the availability of $^{99\text{m}}\text{Tc}$, produced on an economically sustainable basis, as outlined in the HLG-MR principles;
- Encourage all countries involved in any aspect of the $^{99\text{m}}\text{Tc}$ supply chain, and that are not party to the present Joint Declaration, to take the same approach in a co-ordinated manner;
- Take the necessary actions described above by the end of December 2014 or as soon as technically and contractually feasible thereafter, aware of the need for early action to avoid potential shortages of medical radioisotopes that could arise from 2016;
- Report on an annual basis to the OECD Nuclear Energy Agency (NEA) on the progress made at the national level and support an annual review of the progress made at the international level, both in light of this Joint Declaration.

WE INVITE the OECD Nuclear Energy Agency (NEA) to further the objectives set out in this Joint Declaration by, among other actions, undertaking periodic reviews of the progress of the supply chain with implementing the HLG-MR principles.

Radiation and thyroid cancer

by E. Lazo*

An International Workshop on Radiation and Thyroid Cancer took place on 21-23 February 2014 in Tokyo, Japan, to support the efforts of the Fukushima Prefecture and the Japanese government in enhancing public health measures following the Fukushima Daiichi nuclear power plant accident in March 2011. The workshop, which was designed to develop a state-of-the-art scientific understanding of thyroid cancer in children and of radiation-induced thyroid cancer (papillary carcinoma) in particular, was co-organised by the Japanese Ministry of the Environment (MOE), the Fukushima Medical University (FMU) and the OECD Nuclear Energy Agency (NEA). It brought together the world's top experts in the field, including medical doctors, epidemiologists and radiological risk assessment specialists from ten countries.

Although rare, thyroid cancer occurs naturally, with the risk of developing a thyroid cancer increasing with age. Cases are usually identified when a thyroid carcinogenic nodule grows enough to be felt with a patient's fingers, at which point the patient visits a medical doctor to identify the nature of the growth. In many countries around the world, the incidence rate of naturally occurring thyroid cancer is on the order of less than 1 per year per 100 000 children (from ages 0 to 18). Statistically, this rate appears to be increasing in many countries, with young girls slightly more at risk than young boys.

A second but very different means of detecting thyroid cancer cases is through thyroid ultrasound screening examinations on subjects who do not demonstrate any symptoms. Ultrasound screening is a more sensitive approach that can detect very small nodules (< 5 mm) and cysts (< 20 mm) which would not normally be perceived through simple palpitation. However, because thyroid ultrasound screening examinations are much more effective, the number of thyroid cancer cases per examination will normally be larger than the number per capita found through national cancer-registry incidence data. This observed difference is known as a "screening effect".

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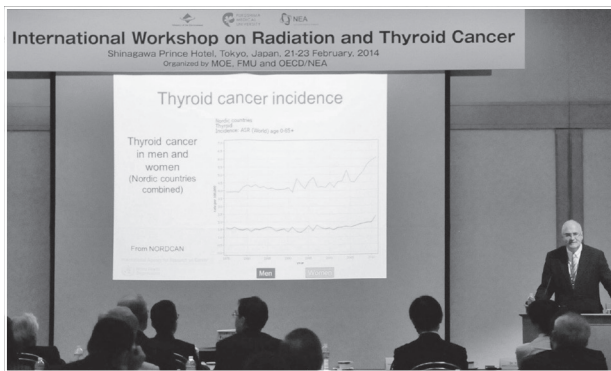
Preliminary data from Fukushima

Due to the release of iodine-131 (¹³¹I) following the Fukushima Daiichi nuclear power plant (NPP) accident, the attributable risk of developing thyroid cancer for exposed populations, and in particular for children, may have surpassed the baseline risk that exists under non-accident circumstances.¹ Shortly after the accident, direct measurements of thyroid doses were carried out for 1 080 children in the Fukushima Prefecture in order to address this attributable risk of thyroid cancer. Dose assessments revealed that thyroid equivalent doses were far less than 100 mSv – the level below which there have been no significant statistical increases in thyroid cancer observed in exposed populations. The Fukushima Prefecture also implemented a medical surveillance programme for the 2 million people living in the prefecture, which includes approximately 360 000 children. As of December 2013, 269 354 children had undergone preliminary thyroid ultrasound examinations, and of these, 1 490 had undergone secondary examinations due to preliminary screening results.

A total of 33 children out of the 269 354 who had undergone thyroid ultrasound examinations were diagnosed with thyroid cancer. Of the 34 children who underwent a surgical intervention, 32 cases were diagnosed as papillary carcinoma, 1 case was diagnosed as a suspected poorly differentiated carcinoma and 1 case was found to be benign (non-cancer nodules). All of the children who were diagnosed with thyroid cancer were cured through surgery. Examinations also identified a suspicion of thyroid malignancy in 41 children, and the medical status of these children is being closely followed, with the majority to undergo a surgical procedure.

The way forward

The risk of developing thyroid cancer as a result of exposure to ¹³¹I is a key concern in the case of almost any large nuclear reactor accident with offsite releases. Experience from the Chernobyl accident, but also from the Life Span Study of atomic bomb survivors in Hiroshima and Nagasaki, demonstrates that radiation exposure (either internal or external) can cause thyroid cancer in children from 0 to 18 years of age. Children exposed at a younger age (especially from zero to five years of age) are at a higher risk than older children.



Presentation at the International Workshop on Radiation and Thyroid Cancer, 21-23 February 2014 Tokyo, Japan.

Initial ultrasound examinations of children in the Fukushima Prefecture (360 000 preliminary thyroid ultrasound examinations will be undertaken in total) were performed within the first three years after the accident. These examinations will be followed by successive thyroid examinations from 2014 onwards, with all residents being monitored regularly thereafter.

Studies of those exposed during the Chernobyl accident indicate that the number of thyroid cancer cases begins to increase four to five years after exposure. As such, it will remain important to continue examinations into the future and to examine as many potentially affected children as possible. The results of further examinations will be analysed and confounding factors considered to update the current medical understanding of thyroid cancer in the Fukushima Prefecture.

An important aspect of this process will be stakeholder dialogues and risk communications to ensure that stakeholders are informed. The recent workshop on thyroid cancer discussed international experience and approaches in terms of how radiological protection science can best be brought to the service of society, to better understand stakeholder concerns and to better provide stakeholders (the public and decision-makers) with scientifically sound information that can be taken into account when making decisions.

In general, good cancer registries are essential for the constant monitoring of cancer incidence rates. However, it should be noted that a health risk assessment report by the World Health Organization (WHO) based on 2006 health statistics data had already indicated that thyroid cancers were increasing in Japan.

Conclusions

Given the medical understanding that thyroid cancer grows at a slow pace, the thyroid cancer workshop was able to conclude that there is no identifiable evidence to demonstrate that the increase in

thyroid cancers observed thus far in the Fukushima Prefecture has been caused by exposure to ^{131}I after the Fukushima Daiichi NPP accident. This conclusion is based on the following observations:

- Children's exposure to ^{131}I in the Fukushima Prefecture was significantly lower than the doses of exposure around Chernobyl.
- According to international observations, the latency period for thyroid cancer is considered to be a minimum of four to five years.
- Thyroid cancer cases identified or suspected in the Fukushima Prefecture concern children who were older at the time of exposure rather than children who were exposed as infants.
- The distribution of age at incidence of thyroid cancer appears thus far to be consistent with similar, naturally occurring thyroid cancer data from countries around the world, with the incidence of thyroid cancer increasing with age.
- If the thyroid cancers identified in the Fukushima Prefecture were caused by exposure to ^{131}I from the accident, one would have expected more cancers in those exposed as infants than in those exposed as older children.

It will be important to pay particular attention to thyroid cancer cases that may appear in the coming years, once the four- to five-year latency period for radiation-induced thyroid cancer has passed. Although thyroid cancer cases that may appear beyond 2016 are unlikely to be a result of the Fukushima accident, it is essential to establish a clear dialogue with affected populations and individuals so as to address their concerns. Although exposure levels have been estimated to be low, preparations for the future are nevertheless necessary, for example through continued medical surveillance of affected populations, and children in particular. In addition, because there remains a degree of uncertainty in modelled exposure, reassuring the public with regard to early detection of thyroid cancer, occurring either naturally or otherwise, is crucial. The data collected will be of value for scientific study.

Note

1. The Fukushima Daiichi NPP accident released from about 100 to 500 petabecquerels (PBq) of ^{131}I into the atmosphere. The Chernobyl accident released approximately 1 760 PBq. Note that 1 PBq = 10^{15} Bq.

The Fukushima Daiichi nuclear power plant accident: Update on compensation

by X. Vásquez-Maignan*

In the three years since the Fukushima Daiichi nuclear power plant (NPP) accident, the international community has gained perspective on the implementation of the Japanese nuclear liability regime, which reflects internationally accepted nuclear liability principles.¹ Soon after the emergency, the operator of the damaged nuclear power plant, Tokyo Electric Power Company (TEPCO), and public authorities in Japan established the basic procedures required to compensate victims for damage incurred due to the accident. Since March 2011, these procedures have been adapted to allow the processing of a large number of applications for compensation within a reasonable amount of time.

Compensating victims

As provided in Japan's 1961 Act on Compensation for Nuclear Damage (the Compensation Act), TEPCO, as the operator of the nuclear installation where the accident occurred, is strictly and exclusively liable. In essence, this means that victims do not need to prove TEPCO's fault, negligence or intention to harm, and no person other than the operator may be held liable for the damage caused by the nuclear accident. Such an approach can avoid lengthy legal disputes over liability as issues related to the determination of fault can slow the process of compensation.

"Nuclear damage" is defined under the Compensation Act as any damage caused by the effects of the process of nuclear fission of nuclear fuel, by radiation effects or by the toxic effects of nuclear fuel materials and the like, and it explicitly excludes any damage suffered by the liable operator. In order to facilitate the efficient and voluntary settlement of disputes over compensation for nuclear damage, a group of experts was established – the Dispute Reconciliation Committee for Nuclear Damage Compensation (the Reconciliation Committee) – in accordance with the Compensation Act. One of the tasks of this committee is to issue guidelines to determine the scope of compensable nuclear damage. Although the guidelines are not legally binding, they are persuasive, because the victims and the operator may invoke them before the courts. To date, the guidelines have not been challenged and have been implemented by TEPCO when providing compensation. The Reconciliation Committee has

periodically issued updated guidelines, from 28 April 2011 until 26 December 2013.

There have been no deaths or injuries attributable to radiation exposure resulting from the Fukushima Daiichi NPP accident. Most claims were a result of evacuation and restriction orders,² which have led to compensation for losses such as the partial or total loss of income or property value, business loss or reimbursement of associated costs (such as transportation and accommodation expenses), as well as compensation for mental anguish. Other types of damage have also been compensated, including rumour-related damage, which mainly affected the tourism and food industry, or compensation resulting from "voluntary evacuation" by individuals who resided in areas not subject to governmental evacuation orders. These individuals were deemed to have experienced reasonable fear of the potential exposure to radiation due to their proximity to the Fukushima Daiichi site and the lack of information at the time.

As of 23 May 2014, TEPCO had received over two million applications for compensation, around 27.5% of which were submitted by individuals. As of that same date, TEPCO had paid approximately JPY 3 837 billion (EUR 27 billion or USD 37 billion) in compensation.³

Financing the compensation

TEPCO is legally required to financially secure its nuclear power plants up to JPY 120 billion (approximately EUR 858 million or USD 1 billion) and to fully compensate victims because it bears unlimited liability by law. However, since the amount of compensation has far exceeded the financial security, the Japanese government has provided financial aid – as required by law and approved by the National Diet – in order to adhere to the objectives of the Compensation Act. This government aid can be summarised as follows:

- From September 2011 until approximately the end of the same year, as an emergency measure the Japanese government began making provisional payments directly to the victims under certain conditions; TEPCO will be required to reimburse this government aid, amounting to approximately JPY 2 billion (EUR 14.3 million or USD 19.6 million).

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Records of applications and payments for indemnification of nuclear damage (as of 23 May 2014)

	Individuals	Individuals (losses due to voluntary evacuation)	Corporation and sole proprietors
Applications			
Applications received (cumulative)	≈ 605 000 cases	≈ 1 300 000 cases	≈ 258 000 cases
Permanent indemnification			
No. of permanent indemnification cases (cumulative)	≈ 522 000 cases	≈ 1 287 000 cases	≈ 223 000 cases
Amount of permanent indemnification*	≈ 1 601.8 Bil JPY	≈ 352.9 Bil JPY	≈ 1 732.4 Bil JPY
Cumulative payments			
Permanent indemnification*			≈ 3 687.2 Bil JPY
Provisional compensation			≈ 150.2 Bil JPY
Total amounts paid			≈ 3 837.4 Bil JPY

* Amounts paid as provisional compensation are not included. Source: TEPCO (2014).

- On 12 September 2011, the Nuclear Damage Compensation Facilitation Corporation was established. The shares of the corporation are equally distributed between the Japanese government and the Japanese nuclear operators. The corporation's purpose is to provide financial support to any nuclear operator which may incur nuclear damage compensation obligations beyond JPY 120 billion, under specific conditions. To finance such support, the corporation holds "reserves", which are funded by the Japanese nuclear operators' compulsory annual contributions and are based on fixed criteria. If necessary, the corporation may also receive government bonds, but this "special support" requires that the operator requesting the financial support fulfils certain conditions, among which is the submission for approval of a special business plan that addresses business rationalisation and management accountability. The receiving operator must reimburse the financial support funded by government bonds by paying a special contribution to the corporation in addition to the annual contribution. The corporation must in turn reimburse the government. As of 22 May 2014,⁴ TEPCO has received almost JPY 3 900 billion (EUR 26.5 billion or USD 36.3 billion) from the corporation.
- As of 31 July 2012, TEPCO was placed under state control. The Nuclear Damage Compensation Facilitation Corporation, 50% owned by the Japanese government, became TEPCO's controlling shareholder after acquiring its preferred shares for JPY 1 trillion (EUR 7.15 billion or USD 9.8 billion).

Expiry of the compensation period

Under the Japanese Civil Code, all rights of action are fully extinguished 20 years following the date of the tort. Legal actions must be brought by the claimant within three years of the date on which the person suffering damage had knowledge both of the damage and of the liable entity. In the case of the Fukushima Daiichi accident, claimants in general would have had until 11 March 2014 to bring an action to court.

Most of the disputes relating to compensation have been settled out of court, either by direct amicable settlement between TEPCO and the victims or through mediation through the Nuclear Damage Compensation Dispute Resolution Centre (ADR Centre), which was established by the Reconciliation Committee in July 2011. Some victims who had submitted their claims to the ADR Centre were concerned that, if the mediation process failed, they might not be entitled to file claims with the civil court after the three-year period. Japan therefore adopted a specific act in May 2013 which provides that when a mediation process at the ADR Centre is discontinued due to the absence of settlement, and the petitioner files an action in court within one month after the notice of such discontinuance, then the petitioner is presumed to have filed such action in court at the time of submitting the case for mediation with the ADR Centre. In addition to this initiative, which would only benefit those victims who would have first tried to settle the dispute by mediation, another act was adopted in November 2013 to extend the three-year period to ten years (i.e. until 11 March 2021) in order to allow victims more time to bring unresolved disputes relating to compensation before the civil court.

Notes

- For an overview of the Japanese liability and compensation regime, see OECD/NEA (2012), Japan's Compensation System for Nuclear Damage as Related to the TEPCO Fukushima Daiichi Nuclear Accident, at www.oecd-nea.org/law/fukushima/7089-fukushima-compensation-system-pp.pdf, and Vásquez-Maignan, X. (2011), "Fukushima: Liability and compensation", NEA News No. 29.2, at www.oecd-nea.org/nea-news/2011/29-2/nea-news-29-2-fukushima-e.pdf.
- Restriction orders in relation to the shipping of certain commodities were issued by the Japanese government, and marine exclusion and no-fly zones were also established.
- TEPCO periodically updates a table of "Records of Applications and Payouts for Indemnification of Nuclear Damage" on its website: www.tepco.co.jp/en/comp/images/jisseki-e.pdf (updated monthly); source of exchange rates as of 28 May 2014: www.oanda.com/currency/converter/.
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The safety case for deep geological disposal of radioactive waste

by G. Kwong*

The concept of a “safety case” for a deep geological repository for radioactive waste was first introduced by the NEA Expert Group on Integrated Performance Assessment (IPAG). It was further developed in the NEA report entitled *Confidence in the Long-term Safety of Deep Geological Repositories* (1999), and since then it has been taken up in international safety standards as promulgated by the International Atomic Energy Agency (IAEA, 2006, 2011) and more recently in recommendations by the International Commission on Radiological Protection on the application of the system of radiological protection in geological disposal (ICRP, 2013).

Many national radioactive waste disposal programmes and regulatory guides are also applying this concept. The NEA has used the safety case as a guide in several international peer reviews of national repository programmes and safety documentation. In Europe, the EU Directive 2011/70/Euratom (EU, 2011) establishes a framework to ensure responsible and safe management of spent fuel and radioactive waste by member states that, *inter alia*, requires a decision-making process based on safety evidence and arguments that mirror the safety case concept.

In 2007, the NEA, the IAEA and the European Commission (EC) organised a symposium on Safety Cases for the Deep Disposal of Radioactive Waste: Where Do We Stand? Since this time, however, there have been some major developments in a number of national geological disposal programmes and significant experience in preparing and reviewing cases for the operational and long-term safety of proposed and operating geological repositories. A symposium on The Safety Case for Deep Geological Disposal of Radioactive Waste: 2013 State of the Art was thus organised to assess developments since 2007 in the practice, understanding and roles of the safety case, as applied internationally at all stages of repository development, including the interplay of technical, regulatory and societal issues.

The symposium was organised and hosted by the NEA, with support from the EC and the IAEA. It attracted 168 participants from 65 organisations in 17 countries and international bodies. The event commenced with two plenary sessions covering international activities and experience related to the safety case since 2007 and included perspectives from the EC, the IAEA and the NEA, as well as national safety case presentations at

different stages of programme development, from the implementer and regulator points of view. Special topical presentations followed on issues ranging from staff management, training and knowledge management to long-term governance of CO₂ storage, with four parallel sessions discussing specific issues and challenges in safety case development, performance and safety assessments, science and the technological basis and broader perspectives. The final day of the symposium was devoted to a plenary session on the societal context of the safety case, followed by a summary from the rapporteur, an open discussion and closing remarks from the chair.

Key messages



The 2013 symposium demonstrated that a clear understanding of the technical components of a safety case, as documented in a recent safety case brochure (OECD/NEA, 2013), already exists. Since 2007, further technical experience has been gained from iterative and stepwise processes, for example on aspects of incorporating new data, model development, safety concept and design refinement and performance assessment and documentation. The content and presentation of the safety case have been enhanced based on technical experience, audience responses and dialogue. Specific advancements have been made in areas such as regulator-implementer interactions, engagement with local communities and peer reviews of safety cases and repository programmes.

The definition and implementation of a safety case varies across countries and over time, with some focusing on post-closure and others covering

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subjects such as operational safety. Differences also depend on the stage of the programme and the decisions they inform, and take into account the different legal, regulatory and social requirements in any given country. For these reasons, there is no unified format for safety cases. However, it is important that internationally accepted safety case components are mapped into the content of national documents (e.g. licence applications). There is an international consensus on the elements and methodology, particularly for assessing long-term safety as described in IAEA Safety Standards and in OECD/NEA publications, and these can generally be found in most national documents.

At its core, the development of a safety case for a geological repository is a scientific and technical activity based on rigorous tools and processes that must also satisfy regulatory and societal requirements. Thus, the safety case can be seen as a “scientific and technical activity embedded in a societal context” (OECD/NEA, 2013), the latter of which is particularly important for confidence building. In practice, proposals for a geological repository and the accompanying safety case are developed iteratively. Mutual understanding and confidence in the overall outcome and processes will be improved through ongoing dialogue between the implementer, regulator and stakeholders, and particularly with representatives of potential host communities or municipalities. Through this dialogue, regulators and stakeholders can influence decisions and final outcomes, as well as ensure that the safety case contains the appropriate information. The concerns of all stakeholders must be taken into account to ensure that expectations converge and a common understanding is found.

Knowledge management and the maintenance of expertise for geological repositories are a particular challenge since the projects may be carried out over more than a century. Record management and knowledge transfer are therefore crucial in enhancing confidence in a safety case.

To ensure the competency of the regulatory body, particularly in reviewing applications during the licensing process, some regulators have maintained a strong parallel programme of research and assessment, while others rely on participation in international projects and engaging independent experts as required. Structured dialogues between policy makers, regulators, technical experts and non-technical participants will enable all stakeholders to evaluate (and re-evaluate) their perspectives in light of others, which is essential in reaching agreements. The active participation of a host community or municipality for a repository also allows for practical advice when making key decisions.

Over the several decades during which the repository programme evolves, the safety case will go through a number of steps. Newly gained knowledge, including emerging uncertainties, must be clearly communicated to all stakeholders. Each

time the safety case is revised, new needs (R&D, technological development, demonstrations), as well as areas where improvements to the disposal programme are necessary should be identified. These improvements will allow the design of the disposal system to be optimised. Taking such steps should also allow for improvements in the robustness of the disposal solution, for unexpected findings to be addressed, and for the safety case to be strengthened, ultimately leading to increased confidence in the safety of the disposal solution.

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An interview with Stephen Burns



Stephen Burns was Head of the Nuclear Energy Agency (NEA) Legal Affairs Section until November 2014 when he was appointed as Commissioner of the United States Nuclear Regulatory Commission (NRC). He had previously worked for the NRC advising on the various legal aspects of nuclear energy regulation. During his time at the NRC, he participated in numerous international projects and attended the NEA Nuclear Law Committee as part of the US Delegation. He served as NRC General Counsel from 2009 to 2012 and as Deputy General Counsel for over 11 years.

NEA: *After retiring from the NRC in 2012 with 34 years of service, did your nomination as an NRC Commissioner come as a surprise?*

Stephen Burns: It came completely unexpectedly. I was contacted about the possibility in late April and reflected on it for the better part of a month. Once you say yes, there is a background investigation, security and financial clearance procedures, requests for information from the US ethics laws, and a lot of forms to fill out. Then it goes through the approval process. The President made the nomination in July, and under the US Constitution, the US Senate must approve and confirm the nomination before the President can make the final appointment. The process was fast-tracked due to the Commission being down to three of its five members. I had asked to stay on at the NEA until the end of the Steering Committee meeting for Nuclear Energy in October. The US President then signed the appointment on 4 November 2014, and I took the oath of office the next day.

NEA: *You have been confirmed in your role of NRC Commissioner at a time when a former NRC Commissioner, Mr William D. Magwood, IV, is taking on his new role as Director-General of the NEA. Had you worked with Mr Magwood at the NRC?*

S.B.: Yes. I first met Bill Magwood when he was at the US Department of Energy (DOE) in connection with some projects in which the DOE and the NRC had mutual interest. When he joined the NRC as a Commissioner in 2010, I was the General Counsel and responsible for providing legal advice and support to the Commissioners as well as the agency staff. The Commission faced a number of important issues during this time, including evaluating safety improvements to US plants after the Fukushima Daiichi accident and considering licenses for the first new reactors in the US in almost 20 years. Bill Magwood, like me, has been involved in NEA activities for many years and so he is quite familiar with the Agency.

NEA: *How has your experience at the NEA prepared you for your new role as an NRC Commissioner?*

S.B.: My work at the NEA, not only in Legal Affairs but also in collaborating with the NEA's technical divisions, has enriched my professional experience as a lawyer and a regulator. My time at the NEA has allowed me to be exposed to the variety of issues faced by NEA countries, including those with substantial nuclear generating capacity such as France, Japan and Korea, or those like Germany, facing important questions related to decommissioning in coming years. It was interesting to follow the progress of Sweden in development of a high-level waste repository as well as developments in countries considering new build. A real strength of the NEA is its encouragement of "experience sharing".

NEA: *As the Head of the Legal Affairs Section since early 2012, you had to deal with a great deal of issues from the post-Fukushima response, compensation for nuclear damage, third party nuclear liability regimes to national legislation in member countries. Can you comment on what you feel are some of the more important issues that you had to address during your time at the NEA?*

S.B.: I would say that the nuclear liability question was one of the more interesting subjects that I had to deal with during my stay at the NEA. It was a subject with which I had had limited involvement prior to joining the NEA, and I appreciate the extensive experience of experts on the Nuclear Law Committee who made it all the more engaging. I was also an observer in the INLEX group at the International Atomic Energy Agency (IAEA), where we examined nuclear liability issues and the issue of broader adherence to liability regimes. I found this to be a very complex but important topic, and I believe that I helped to contribute to advancements in this area during my stay at the Agency. I also oversaw work on a publication examining Japan's compensation system for nuclear damage. Both our work on this publication and in the Nuclear Law Committee have fostered greater understanding of some of the practical issues involved in carrying out a compensation regime as well as the application of the common principles that underlie the international liability conventions.

At each committee meeting, the Japanese delegates would provide updates on compensation issues and so it was a good way to see how these things work in practice and how the system adapted to implementation challenges. One specific example that comes to mind is the long form that TEPCO had initially developed after the accident for victims requesting compensation. This put a huge burden on claimants and was replaced with a more streamlined claims procedure. Such work really demonstrates the need to pay attention to the practical aspects of implementing compensation measures and procedures.

The Legal Affairs Section has a support role in assisting the contracting parties to the Paris Convention on Third Party Liability in the Field of Nuclear Energy as well, which has been a rewarding experience for someone from a nuclear regulatory background. A major focus of these efforts has been to assist the parties in bringing the 2004 Protocol to the Paris Convention into force. Although some work remains, there is a good chance that the parties may be in a position to ratify the Protocol by the end of 2015. We have also done quite a lot of work on the interpretation of the Paris Convention and other efforts related to the modernisation of international nuclear liability regimes.

We also produce a biannual *Nuclear Law Bulletin* which has dealt with liability issues as well as a broad range of other subjects from decommissioning and regulatory reform to export control and transport issues. The Bulletin includes contributions from leading scholars and practitioners in nuclear law, as well as government and international officials. We report on legal developments in NEA member countries as well as in many non-member countries. Our correspondents have provided informative and enriching contributions to inform a wider audience interested in nuclear law.

NEA: *During the recent hearing to confirm your nomination as NRC Commissioner by the US Senate Committee on Environment and Public Works, you were asked about your views on the role of regulatory authorities, and about potential political pressure that you might endure as a Commissioner of an independent body. Has anything in your experience at the NEA helped to clarify your views in this regard?*

S.B.: During my tenure at NEA we held a special session at a meeting of the Nuclear Law Committee on the independence of regulatory bodies, and the topic was one on which I have lectured for several years in the context of the NEA's nuclear law education programme. My work and research in this area while at the NEA reinforced the importance of providing a strong institutional structure for regulatory bodies. It is interesting to look back at the official reports on the major nuclear accidents at Three Mile Island, Chernobyl and Fukushima Daiichi and note the severe criticism of the regulatory bodies as well as the operators in contributing to the environment in which these accidents occurred. Attention to the organisational effectiveness of the regulator

and ensuring that it has the competence to carry out its mission without undue political interference require constant vigilance. The NEA's "green booklets", such as *The Characteristics of an Effective Nuclear Regulator* produced by the NEA Committee on Nuclear Regulatory Activities, provide good insights on many of the challenges faced in ensuring effective oversight and regulation.

NEA: *You have said on several occasions that one of your most rewarding experiences at the NEA has been your involvement in the International School of Nuclear Law (ISNL) and the one-week International Nuclear Law Essentials course, an involvement which began long before you arrived at the Agency. Can you tell us why these two programmes remain an important part of NEA work?*

S.B.: Both of these programmes are designed to provide participants with a comprehensive understanding of the various interrelated legal issues relating to the safe and secure use of nuclear energy. I began participating in the programmes long before I arrived at the NEA and, yes, I continue to see a tremendous value in this form of education. The ISNL is organised with the University of Montpellier I and is an incredibly important tool of the NEA, involving co-operation between the NEA and IAEA on the choice and support of candidates. This past year a very diverse group of people attended the course from about 37 countries. Participants include graduate students, government officials, as well as those working in industry or in other organisations. Although many participants come from countries with a well-established or developing nuclear power programme, others are from countries in which maintaining an effective radiological safety programme is most important to ensure the safe use of radioactive material in medical and industrial applications. The course offers a remarkable perspective on the different issues. The invited speakers are from academia, government and other backgrounds, and all are highly experienced people in their respective fields. We have been receiving over 150 applications for ISNL and can only accept 60, so there is a huge interest and continuing need for it. Legal Affairs began holding a one-week course in Paris in 2011 called International Nuclear Law Essentials, which is designed for those with some experience or exposure to nuclear law. Both of these programmes contribute to an understanding of the international system and to improving national laws.

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The *Nuclear Law Bulletin* is a biannual publication for professionals and academics in the field of nuclear law. It provides subscribers with authoritative and comprehensive information on nuclear law developments.

Uranium mining: Environmental and health impacts

by R. Vance*

Producing uranium in a safe and environmentally responsible manner is important not only to the producers and consumers of the product, but also to society at large. Given expectations of growth in nuclear generating capacity in the coming decades – particularly in the developing world – enhancing awareness of leading practice in uranium mining is important. This was the objective of a recent NEA report entitled *Managing Environmental and Health Impacts of Uranium Mining*, providing a non-technical overview of the significant evolution of uranium mining practices from the time that it was first mined for military purposes until today.

Uranium mining remains controversial principally because of legacy environmental and health issues created during the early phase of the industry. Today, uranium mining is conducted under significantly different circumstances and is now the most regulated and one of the safest forms of mining in the world. However, public perception of uranium mining is largely based on the adverse impacts of past practices that took place during an essentially unregulated early phase of the industry. As with all forms of mining, the driving force of the era was maximising production, with little regard for environmental and health impacts.

By the 1970s, impacts from the early military era uranium mining operations on the health of workers, the environment and the communities located nearby became increasingly evident. Societal pressure, typically driven by unions representing miners, led to a number of investigation boards, commissions of inquiry and numerous health studies that identified the extent and far-reaching impact of historic mining operations that lacked proper operational and waste management practices. It is out of these investigations and associated research that modern mining and milling practices were born.

The uranium mining industry has moved from virtually no waste management planning in the early era to multistage effluent treatment processes with engineered, purpose-built waste management systems today, an arduous process built on lessons learnt that spanned more than three decades. In terms of worker protection, the industry has been transformed from one in which miners worked in poorly ventilated underground mines with minimal training and ground support, to one in which well-trained workers are managed by dedicated safety supervisors in a well-ventilated, monitored

and structurally designed underground working environment. These improvements involved the emergence of stronger regulatory and government oversight and inspections, including increasing consequences for poor performance or non-compliance through the force of law.

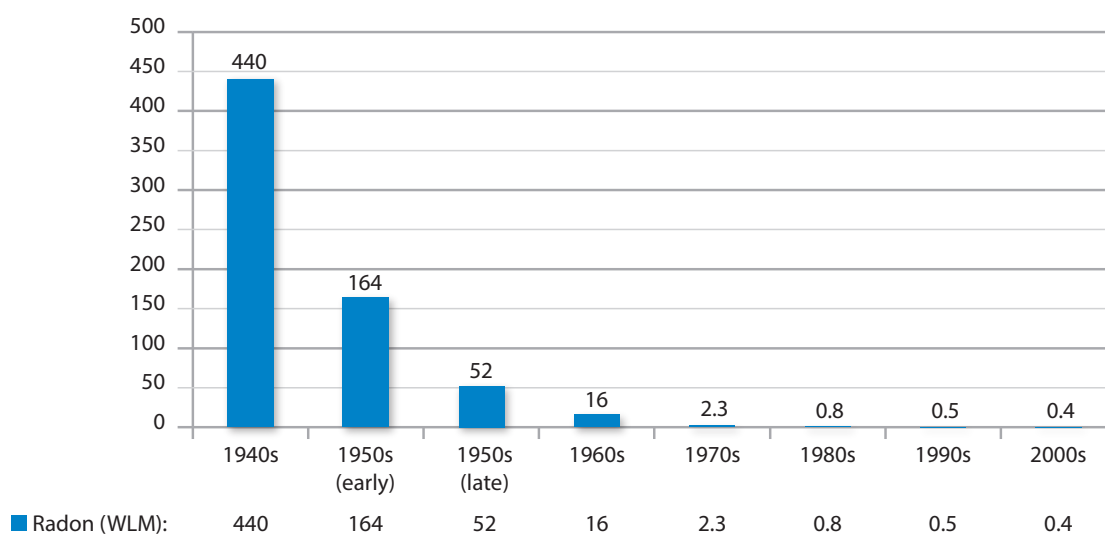
Today's leading practice uranium mine and mill sites, and other types of nuclear facilities, are regulated by an independent agency that reports to the head of state or parliament and its elected officials. This greatly reduces the possibility that political or economic goals could influence regulatory decisions. A nuclear regulatory agency ideally operates under a judicial or quasi-judicial process, making decisions in an open and transparent manner, maintaining a clear record of decisions and allowing anyone the right to be heard.

For each individual operation there are a wide range of issues that must be addressed in order to minimise health, safety and environmental impacts to acceptable standards. In the full report, these operational challenges are divided into key aspects that created environmental and health impacts and modern life cycle parameters. The key aspects are worker health and safety, radiation protection (worker and public), water (surface and underground), tailings and waste rock management. For each one of these fundamental challenges, operational practices from the past are contrasted with modern, leading practices and case studies of both historic and modern practices are provided to illustrate the differing practices and outcomes.

As the regulatory regime evolved and the industry adapted and developed innovations to meet emerging requirements and issues, a number of parameters have been introduced that were seldom, if ever, used or even considered during the early stages of uranium mining. These modern parameters include environmental assessment processes (e.g. assessments of socio-economic impacts and benefits), environmental monitoring, financial guarantee requirements to cover closure costs prior to opening a mine, emergency planning,

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Levels of exposure from radon and its decay products (RDPs) in underground mines expressed in working level months (WLMs*) in Canada from 1940



* Cumulative radon exposure in mining is specified in WLMs. If 2 000 working hours are assumed per year, then 1 WLM = 5 mSv. A working level (WL) is equivalent to any combination of short-lived RDPs in 1 L of air that generates an emission of 1.3×10^5 MeV of potential alpha particle energy. A WLM equals the exposure to 1 WL for 170 hours (working hours per month). $1 \text{ Bq m}^{-3} = 0.00445 \text{ mJ h m}^{-3}$ and $1 \text{ mJ h m}^{-3} = 1.4 \text{ mSv}$ (ICRP, 1993).

Source: AREVA, 2011; CNSC, 2011.

product transport, security and safeguard requirements and knowledge management. These additional aspects of mine development, operation and closure are considered crucial to effectively manage the environmental and health impacts of leading practice operations.

Leading practice uranium mining is highly regulated and in several important ways distinctly unlike mining practices employed in the past. Today, mine and mill workers receive significantly lower radiation exposure compared to the early era through a combination of safe working practices and, in both underground mining operations and uranium mills, high-capacity ventilation systems that continuously evacuate airborne radioactive particles from higher-risk working areas. Environmental planning and monitoring throughout the life cycle of the mine ensures that the planned life cycle performance is achieved through to the post-decommissioning period, minimising the environmental effects to acceptable standards and avoiding impacts on local populations.

Uranium will be an energy resource in demand for decades to come owing to the need to meet raw material fuel requirements for an existing and developing global fleet of nuclear power plants. New mines will be needed, in some cases in countries that have never hosted uranium mining. Key stakeholders will play an important role in facilitating the safe development, operation and closure of uranium mining operations in an environmentally responsible manner.

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SFCOMPO: A new database of isotopic compositions of spent nuclear fuel

by F. Michel-Sendis and I. Gauld*

The numerous applications of nuclear fuel depletion simulations impact all areas related to nuclear safety. They are at the basis of, *inter alia*, spent fuel criticality safety analyses, reactor physics calculations, burn-up credit methodologies, decay heat thermal analyses, radiation shielding, reprocessing, waste management, deep geological repository safety studies and safeguards.

Experimentally determined nuclide compositions of well-characterised spent nuclear fuel (SNF) samples are used to validate the accuracy of depletion code predictions for a given burn-up. At the same time, the measured nuclide composition of the sample is used to determine the burn-up of the fuel. It is therefore essential to have a reliable and well-qualified database of measured nuclide concentrations and relevant reactor operational data that can be used as experimental benchmark data for depletion codes and associated nuclear data.

The Spent Fuel Isotopic Composition Database (SFCOMPO) has been hosted by the NEA since 2001. In 2012, a collaborative effort led by the NEA Data Bank and Oak Ridge National Laboratory (ORNL) in the United States, under the guidance of the NEA Expert Group on Assay Data of Spent Nuclear Fuel (EGADSNF) of the Working Party on Nuclear Criticality Safety (WPNCS), has resulted in the creation of an enhanced relational database structure and a significant expansion of the SFCOMPO database, which now contains experimental assay data for a wider selection of international reactor designs. The new database was released online in 2014.

This new SFCOMPO database aims to provide access to open experimental SNF assay data to ensure their preservation and to facilitate their qualification as evaluated assay data suitable for the validation of methodologies used to predict the composition of irradiated nuclear fuel. Having a centralised, internationally reviewed database that makes these data openly available for a large

selection of international reactor designs is of clear interest to the nuclear energy and scientific community in general.

What is assay data?

Assay data are sets of measured nuclide concentrations of well-characterised SNF samples complemented by a minimal set of reactor operational data that describes the irradiation of the samples in sufficient detail for it to be used as a potential depletion benchmark model. An assay data set for validation of depletion calculations is therefore not only limited to the detailed nuclide concentrations in the sample but contains a much broader variety of information, including:

- radiochemically measured nuclide compositions of the sample;
- estimated burn-up of the sample;
- separation dates and cooling times;
- measurement techniques and experimental uncertainties;
- fuel design parameters;
- characterisation of the sample (position, initial composition);
- reactor operational data.

The evaluation of assay data is therefore a multidisciplinary task involving not only experts in radiochemistry, but also experts in reactor operations and in spent fuel modelling and simulation. The EGADSNF produced a state-of-the-art report on spent nuclear fuel assay data for isotopic validation aimed at reviewing the full process of obtaining these data, from the experimental methods to the choice of presenting and formatting the data. The objective is to establish clear guidelines for the evaluation (qualification) of these data before they are considered fully suitable for code benchmarking uses.

Since 2008, the expert group has focused on compiling and reviewing newly available assay data reports from the open literature. In recent years, assay data from over 500 samples emanating from over 40 reactors have been identified and are pending evaluation and inclusion into a modern, functional database.

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The new SFCOMPO database

The new database is a stand-alone Java application developed by the NEA Data Bank that currently spans over 20 000 lines of code. The application can be downloaded through an access-restricted website to remotely query the NEA database. SFCOMPO aims at providing functional access to all available experimental assay data identified by the EGADSNF and, in the long term, to fully qualify evaluated assay data sets as these become progressively evaluated by the expert group. Querying the database and performing comparisons of all the data in the database, which allows for the visualisation of general trends, greatly facilitates the analysis and evaluation of such data. Similar to other NEA databases and visualisation tools, the SFCOMPO application helps guide the analyst in identifying data that is best suited for the specific application, including the primary sources of relevant reference information.

In 2013, a substantial data capturing effort led by ORNL focused on expanding the database for international reactor designs (data for 16 reactors of different types ranging from VVER 440, VVER 1000, RBMK, Magnox and AGR to CANDU reactors) were captured in the database. In parallel to this effort, the NEA relied on the Department of Nuclear Engineering of the *Universidad Politecnica de Madrid* (UPM), Spain to carry out the compilation and verification of available PWR spent fuel assay data sets from 13 reactors in the new SFCOMPO format.

Thanks to these collaborative efforts, in July 2014 the SFCOMPO development version contained

assay data representing 30 reactors of 8 different types. The database currently hosts experimental concentrations for 95 nuclides.

Figures 1, 2 and 3 provide snapshots of the development application in its current form. They illustrate a selection of the variety of information that needs to be captured (or at least preserved) for an assay data set to be complete and therefore useful for validation purposes. These include geometry and design parameters of the fuel, the position of the specific sample within the fuel rod (Figure 1) and different operational data which are needed for a detailed depletion calculation to be performed (Figure 2). Some of these data exist at different “hierarchical” levels such as sample/rod/assembly/reactor levels. The application – and the template it uses to capture the data – tries to fit this structure as best as possible to the intended use.

All fields of the relational database can be queried (i.e. the interphase can query the database by reactor type, sample fuel type, estimated burn-up range and measured nuclide). This SFCOMPO structure allows for a unique reference to be assigned to each sample and to clearly reference all data to their primary source. The evaluator is also able to register comments at every level of the database. Primary sources such as laboratory reports and evaluator reports are not stored in the database, but links to the reports are included and can be accessed through a built-in PDF viewer. All data displayed by the SFCOMPO application in tables and graphs can be easily exported by the user. Tables are exportable in CSV format and graphic plots are exportable in PNG format.

Figure 1: Snapshot of SFCOMPO’s display panel at assembly level.
Design information is provided along with the pin-map, the identification of fuel rods containing samples and axial positioning of the samples in the fuel rods.

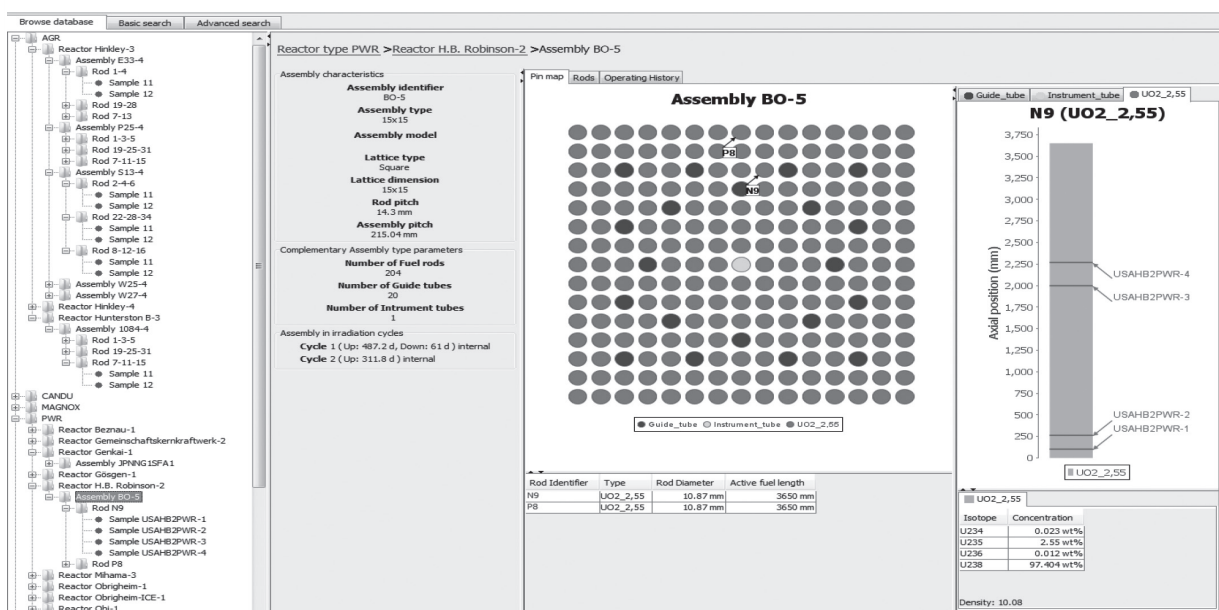


Figure 2: Examples of time-dependent irradiation information, which can be stored in the "Assembly Operational History" section of the SFCOMPO application. From top to bottom: Fuel temperature, power density and soluble boron content.

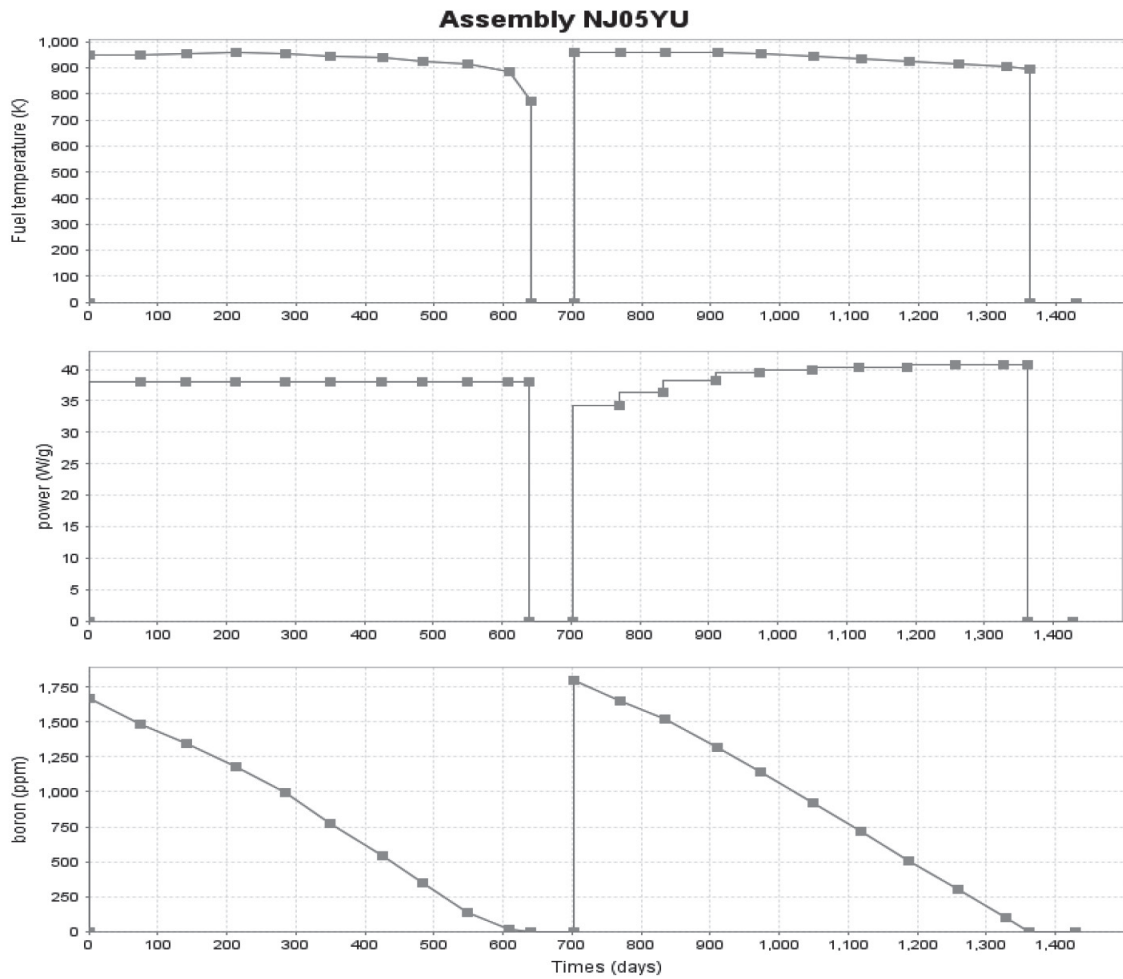
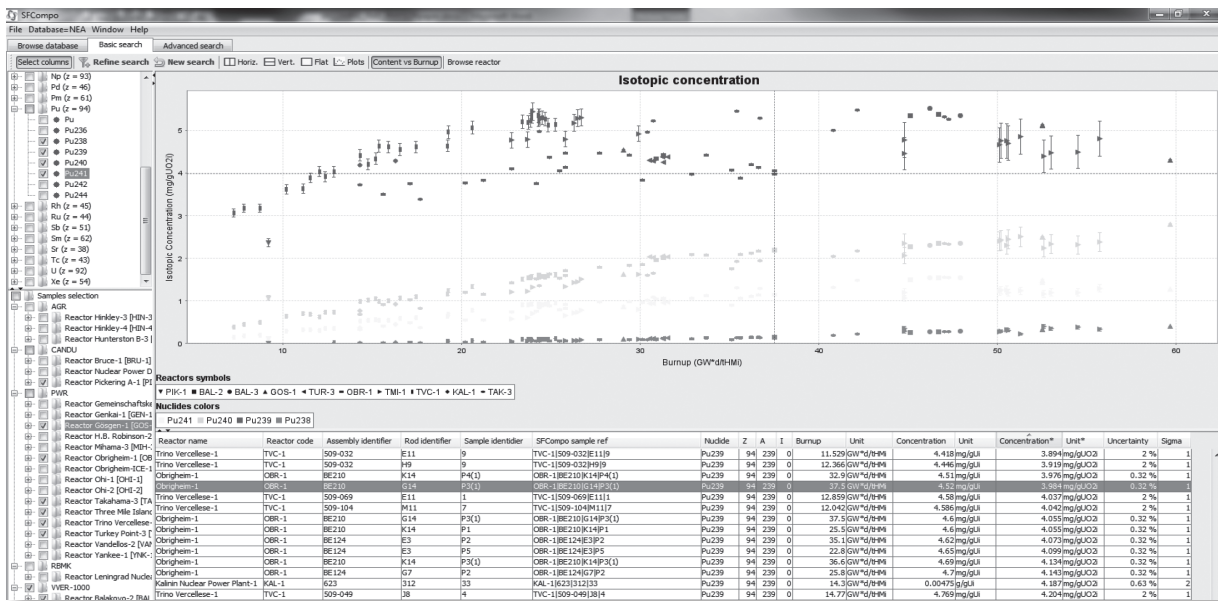


Figure 3: Example of a comparison of plutonium isotopic samples (Pu-238, 239, 240, 241) for a selection of reactors of different types in the database. A graphic plotter allows for visualisation of trends, while a tabular panel provides numerical data.



Trivial conversions between a very large set of SI units are supported by SFCOMPO. Non-trivial conversions of nuclide concentration values normalised at the beginning of irradiation are also supported. In order to accurately perform norm conversions, and in anticipation of more complex unit conversions that may develop in future versions, the SFCOMPO application has access to an internal copy of the NUBASE library (currently supported NUBASE versions are the 1997, 2003 and 2012 editions) of basic nuclear properties data (masses, half-lives). The user can select the library to be consulted by default from a preference menu or can choose to read his or her own nuclear data values through a simple ASCII file.

Currently, the input of new data into the development version of the application is performed by importing a predefined Excel template into the SFCOMPO application. A user who wishes to enter proprietary data into a local installation of the database may do so by filling in the template. A dialog box that summarises errors and warning logs during the data import process is also an essential feature that guides the user in correctly filling out the template and helping with possible format errors.

Users may request the new SFCOMPO Java API (application programming interface) to develop a personal Java programme. The API consists of Java classes for the object model and database connections, and can be obtained from the NEA on a case-by-case request basis.

Conclusions

The widely recognised interest in benchmark data extends to many technical and scientific areas represented at the NEA such as the Working Party on Nuclear Criticality Safety, the Working Party on Scientific Issues of Reactor Systems, the Radioactive Waste Management Committee and the Integration Group for the Safety Case, which are all represented through membership in the EGADSNF. The EGADSNF provides an international framework for compilation and technical review of available assay data for benchmarking purposes.

Oak Ridge National Laboratory and the NEA Data Bank have led the efforts to compile new reactor datasets, which have expanded the representation of reactors in the database to an international selection of designs. This expansion is ongoing and will likely triple the contents of the database in terms of reactors represented. The EGADSNF will progressively review and evaluate the data, with experts from each participating member country reviewing their own national or nationally used reactor designs. SFCOMPO is designed to be the largest, freely accessible evaluated assay database for international reactor designs in NEA member countries.

For further information on the Expert Group on Assay Data of Spent Nuclear Fuel, see www.oecd-nea.org/science/wpncs/ADSNF/.

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A new series of international nuclear emergency exercises (INEX)

by H.B. Okyar, E. Lazo and M. Siemann*

The INEX series of international nuclear emergency exercises, organised under the auspices of the NEA Working Party on Nuclear Emergency Matters (WPNEM), has proven successful in testing, investigating and improving national and international response arrangements for nuclear accidents and radiological emergencies.

The first few INEX exercises focused largely on the national and international aspects of early-phase management of nuclear power plant emergencies. Starting with INEX-3 (2005-2006), the international community began looking at issues in longer-term consequence management. In order to build on the momentum of INEX-3 and the work of various INEX-3 follow-up activities, the INEX-4 exercise was developed in 2008 and conducted during 2010-2011. This exercise focused on issues of consequence management and transition to recovery in response to malicious acts involving the release of radioactive materials in an urban setting. Recognising that the arrangements for managing these events may vary between countries, the goal of INEX-4 was to provide a basis for enhancing emergency management through the exchange of exercise experiences among participating countries and the identification of common issues and good practices.

The INEX-4 exercise assessment was completed with a topical session of the WPNEM in May 2013 and highlighted the need to focus on improving emergency communications, decision making in uncertain circumstances, early availability and sharing of information and accident assessment considerations based on limited, uncertain information. The INEX-4 summary report (available on the NEA website) describes the key outcomes of countries' experiences for future analysis and reporting by the WPNEM.

The Fukushima Daiichi nuclear power plant (NPP) accident occurred during INEX-4 and had a direct impact on NEA technical standing committees' work programmes. The WPNEM played an important role during the emergency, following and studying the insights and ideas that drive nuclear emergency management decision making. It collected crucial information on governmental decisions and recommendations with respect to the accident situation, and implemented a framework study to assist in the collection of NEA member country experiences that would facilitate the identification of commonalities in national assessment approaches and results.

The findings triggered the INEX-5 exercise, which will build upon the experiences and lessons learnt from past nuclear accidents/incidents, and the success of previous INEX exercises. This exercise is intended to test mechanisms for decision making

at the national level, particularly in uncertain circumstances or in the absence of data, to examine arrangements for international co-operation and co-ordination of data and information exchange among countries and arrangements for practical support and assistance between groups of countries or geographical regions. It will also investigate the long-term issues beyond the early response phase.

The WPNEM agreed on a tightly focused scope, which will consist of a tabletop exercise or moderated workshop that is not based on a real time test. The exercise will be a common scenario based on a re-enactment of a nuclear power plant accident, although not the Fukushima accident. It will consider coincident impacts on multiple units and include impacts on other critical national infrastructures using a modular approach to materials.

A planning group was established to develop the technical scenario and other necessary information for use in INEX-5, in line with the above objectives, areas of interest and scope. In addition, the following scenario requirements will frame the exercise:

- The accident will be at an NPP.
- A severe accident scenario will be used.
- The scenario will involve transboundary impacts.
- Exercise play will focus on the intermediate phase.
- A key focus will be on the characterisation of the offsite impact.
- The scenario will result in a large area of impact.
- Participating countries may add national issues of interest.
- National emergency actions taken in the early phase will be supplied in exercise materials and will reflect the procedures of each participating country.

Based on the above information, INEX-5 will address lessons identified and issues raised by the Fukushima response, acting as more of a regional and international exercise than a national one. The WPNEM agreed on a roadmap for the technical development, approval and conduct of the exercise, which is targeted for September 2015 to March 2016, with exercise documents having been made available in October 2014. The INEX-5 exercise will be open to all NEA member and non-member countries and to relevant international organisations.

Note

For more information on the WPNEM and on previous INEX exercises, see www.oecd-nea.org/rp/wpnem/.

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Thermodynamics of Advanced Fuels – International Database Project

by S. Massara and C. Guéneau*

The Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project was established in 2013 under the auspices of the NEA Nuclear Science Committee. The project was designed to make available a comprehensive, internationally recognised and quality-assured database of phase diagrams and thermodynamic properties of advanced nuclear fuels with a view to meeting specialised requirements for the development of advanced fuels for a future generation of nuclear reactors.

Some of the specific technical objectives that this programme intends to achieve are to predict the solid, liquid and/or gas phases formed during fuel cladding chemical interactions under normal and accident conditions, to improve the control of the experimental conditions during the fabrication of fuel materials at high temperature, for example by predicting the vapour pressures of the elements (particularly of plutonium and the minor actinides) and to predict the evolution of the chemical composition of fuel under irradiation versus temperature and burn-up.

This joint project, co-ordinated by the NEA, was established for an initial three-year period among nine organisations from six NEA member countries: Canada (AECL, RMCC, UOIT), France (CEA), Japan (JAEA, CRIEPI), the Netherlands (NRG), the Republic of Korea (KAERI) and the United States (US DOE). It is entirely funded by the nine signatories of the project.

The need for thermodynamic data in nuclear fuel analyses

Detailed modelling of the fuel-cladding system is of major importance for several types of studies related to safety improvements, lifetime extension for generation II-III reactors and for the design of

advanced generation IV systems. Thermodynamic data is needed for various analyses involving nuclear fuel, for example in the design of the fuel elements, in the modelling of the fuel-cladding system under normal conditions in performance codes, in the analysis of fuel and cladding behaviour under severe accident conditions (pre- and post-melting), in the interaction of corium with the vessel (in-vessel) and the concrete (ex-vessel).

These analyses may involve different types of fuel and cladding for generation II-III and generation IV systems:

- oxide, nitride, carbide, metal fuels, fuels with thorium, fuels with minor actinides or fission products;
- zircaloy, SiC, ODS steels, standard and advanced cladding materials;
- structural materials such as concrete, vessels or control rods.

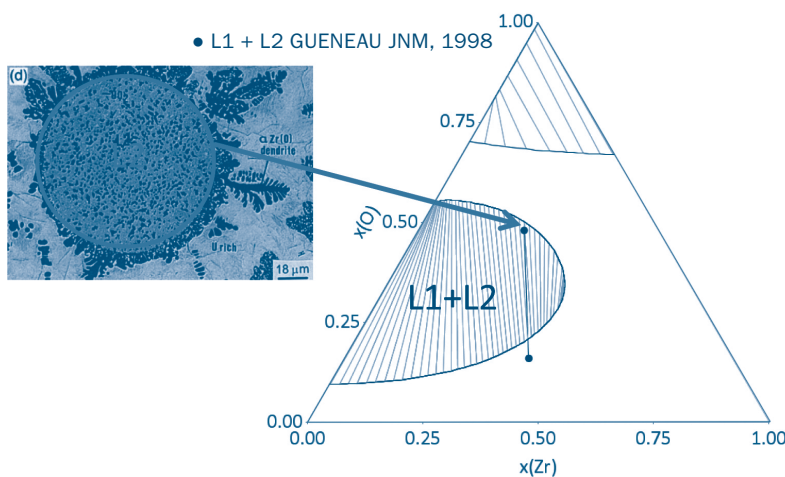
Available tools for thermodynamic calculations

Currently, several tools are used in various laboratories and organisations active in this domain. In Canada, for example, the database on UO₂, developed at the Royal Military College of Canada (RMCC), is used. In France, it is the FUELBASE developed at the Alternative Energies and Atomic Energy Commission that is used. Japan uses a database on metallic fuels developed at the Central Research Institute of Electric Power Industries (CRIEPI) and another one on corium for BWRs developed at the Japan Atomic Energy Agency (JAEA). The Netherlands uses TBASE, developed at the Nuclear Research and Consultancy Group (NRG), and the United States uses several databases developed at the Department of Energy (DOE) at the Oak Ridge National Laboratory (ORNL), the Idaho National Laboratory (INL) and the Lawrence Livermore National Laboratory (LLNL).

Each of these databases can perform studies on only a few of the chemical species described above. The unification of these separate databases would therefore greatly benefit all of these organisations, each of which today solely relies on its own experience, data, know-how and resources for the use, maintenance, development and validation of its database(s).

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A binary ZrO phase diagram



Source: C. Guéneau, Journal of Nuclear Materials (1998).

Development of the TAF-ID database

The TAF-ID database will merge existing databases and those being developed by the signatories of the project. It will be regularly updated with ad hoc models for new chemical systems, through application of the CALPHAD method.

The CALPHAD method allows for the calculation of phase diagrams (the composition and number of the phases) over a large composition, temperature and pressure range, as well as for the calculation of the thermodynamic properties of these phases (heat capacity, enthalpy, activity, partial pressure), which stem from the Gibbs energy of the phases that may form (see above figure). Functions are based on sublattice models derived from the crystalline structure of the different phases (a sublattice corresponding to a crystalline site). The free parameters in the model are optimised using a least-square minimisation method between experimental and calculated data. The experimental data consist of phase boundaries (liquidus, solidus, solubility limit) and/or thermodynamic data (heat capacity, mixing enthalpy, enthalpy of formation, activity). This approach requires a preliminary critical analysis

of all experimental information available on the system prior to the modelling of phases of interest.

The database will be available both in ThermoCalc and FACTSAGE usable formats, two of the most widely available tools for thermodynamic calculations. The project will also identify the need for and encourage the measurement of further experimental data, necessary to establish and validate models for new chemical systems.

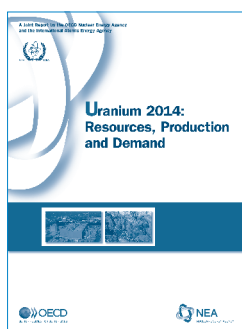
TAF-ID versions

Two versions of the TAF-ID database will be developed. The first is a working version, containing the description of all the systems to be investigated in the framework of the TAF-ID Project. This working version will be accessible only to the signatories of the project. A released version for wider distribution will contain a more limited amount of data – for example, only data which have already been published in the open literature at the time of release. This second version will be managed by the NEA and will be accessible to all NEA member countries, upon request to the NEA and after signature of a non-disclosure agreement.

Uranium 2014: Resources, Production and Demand

by R. Vance*

Since the mid-1960s, with the co-operation of their member countries and states, the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) have jointly prepared periodic updates (currently every two years) on world uranium resources, production and demand. Published by the OECD/NEA in what is commonly known as the “Red Book,” the 25th edition, released in September 2014, contains 45 national reports covering uranium producing and consuming countries and those with plans to do so.



The uranium resource figures presented in the 25th edition of the Red Book are a snapshot of the situation as of 1 January 2013. Resource figures are dynamic and related to commodity prices. Despite less favourable market conditions, continued high levels of investment and associated exploration

efforts have resulted in the identification of additional resources of economic interest, just as in past periods of intense exploration activity.

Total identified resources (reasonably assured and inferred) as of 1 January 2013 amounted to 5 902 900 tonnes of uranium metal (tU) in the <USD 130/kgU (<USD 50/lb U₃O₈) category, an increase of 10.8% compared to 1 January 2011. In the highest cost category (<USD 260/kgU or <USD 100/lb U₃O₈) which was reintroduced in 2009, total identified resources amounted to 7 635 200 tU, an increase of 7.6% compared to the total reported in 2011. The majority of the increases are a result of re-evaluations of previously identified resources and additions to known deposits, particularly in Australia, Canada, the People’s Republic of China, the Czech Republic, Greenland, Kazakhstan and South Africa.

Worldwide exploration and mine development expenditures in 2012 totalled USD 1.92 billion, a 22% increase over updated 2010 figures, despite declining market prices. Production in 2012 increased by 7.4% from 2011 to 58 816 tU and is expected to increase to over 59 500 tU in 2013. This recent growth is principally the result of increased production in Kazakhstan, which remains the world’s largest producer by a large margin. *In situ* leaching (ISL,

sometimes referred to as *in situ* recovery, or ISR) production accounted for 45% of world production in 2012, largely because of increases in Kazakhstan, along with other ISL production in Australia, China, the Russian Federation, the United States and Uzbekistan.

At the end of 2012, a total of 437 commercial nuclear reactors were connected to the grid with a net generating capacity of 372 GWe requiring some 61 600 tU, as measured by uranium acquisitions. By the year 2035, world nuclear capacity, taking into account changes in policies announced in Belgium, France, Germany, Italy and Switzerland following the Fukushima Daiichi accident, is projected to grow to between about 400 GWe net in the low demand case and 680 GWe net in the high case, increases of 7% and 82% respectively. Accordingly, world annual reactor-related uranium requirements are projected to rise to between 72 000 tU and 122 000 tU by 2035.

The currently defined resource base is more than adequate to meet high case uranium demand through 2035, but doing so will depend upon timely investments given the typically long lead times required to turn resources into refined uranium suitable for nuclear fuel production. Other concerns in mine development include geopolitical factors, technical challenges, increasing expectations of governments hosting uranium mining and other issues facing producers in some regions.

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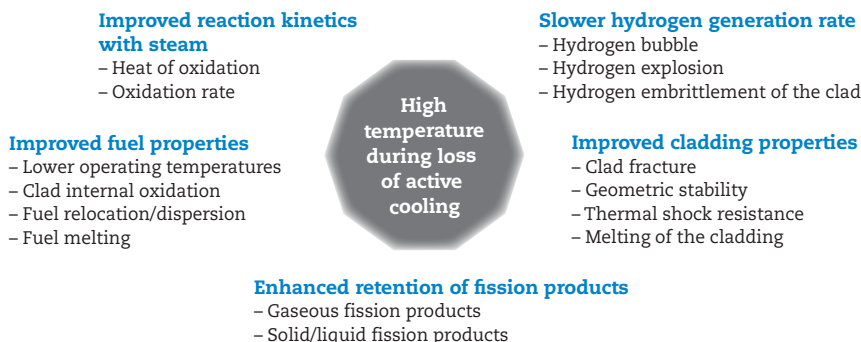
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A new NEA expert group on accident-tolerant fuels

by S. Massara*

After the events at the Fukushima Daiichi nuclear power plant in March 2011, enhancing the accident tolerance of light water reactors (LWRs) became a topic of serious discussion. One outcome of those discussions has been to promote research into the development of advanced fuels and more robust reactor system technologies with improved performance, reliability and safety characteristics during normal operations and under accident conditions. The Fukushima Daiichi accident has highlighted in particular the importance of reducing hydrogen production rates and increasing fission product retention during extended loss of cooling accidents, as illustrated in the following figure.

Major issues in establishing the attributes of accident-tolerant fuels (ATFs)



© US DOE (2012).

In this context, the NEA organised two international workshops to share information and discuss technical and safety issues associated with the development of accident-tolerant fuels (ATFs) for LWRs. Presentations were given by experts from various organisations, industry and regulatory bodies of NEA member countries, as well as from representatives of international bodies. The presentations focused on lessons learnt from the Fukushima Daiichi accident, the desired characteristics of ATFs, potential design options and candidate materials, as well as the current state of the art in related modelling and simulation methods. During discussions following these workshop presentations, delegates agreed to establish a collaborative framework on ATFs within the NEA.

Reporting to the Nuclear Science Committee, the Expert Group on Accident-tolerant Fuels for Light Water Reactors (EGATFL) will define and carry out a programme of work to help advance the scientific

knowledge needed to provide the technical underpinning for the development of advanced LWR fuels with more enhanced accident tolerance compared to currently used zircaloy/ UO_2 fuels. The group will foster information exchange on material properties and relevant phenomenological experiments, carry out state-of-the-art reviews, organise benchmark studies and foster international collaboration in the development of core materials and designs that provide an improved tolerance to accidents.

The start-up meeting for the new expert group was held at the NEA on 28-29 April 2014 and was attended by over 30 delegates from countries representing major LWR operators. It was agreed at this meeting that the programme of work would focus on the following key areas: system assessments, cladding and core materials, and fuel concept development.

As part of the systems assessment programme, analyses will be made using state-of-the-art modelling and simulation methods to establish the most important parameters affecting accident tolerance and to rank the effectiveness of proposed concepts in the form of a performance metric. System performance under normal and accident reactor conditions, the impact on spent fuel management operations and the economic viability of new fuel designs are likely to be among the key components of this metric.

As high-ranked candidate materials and fuel concepts emerge from this process, evaluations will be undertaken on the status of related technical readiness levels, including the availability of the experimental information needed to qualify performance and safety analyses.

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EXFOR: Improving the quality of international databases

by E. Dupont*

The NEA Data Bank is an international centre of reference for basic nuclear tools used for the analysis and prediction of phenomena in nuclear energy applications. The Data Bank collects, compiles, disseminates and contributes to improving computer codes and associated data.

In the area of nuclear data, the Data Bank works in close co-operation with other data centres that contribute to the worldwide compilation of experimental nuclear reaction data in the EXFOR database (NEA, 2012). EXFOR contains basic nuclear data on low- to medium-energy experiments for incident neutron, photon and various charged-particle-induced reactions on a wide range of nuclei and compounds. Today, with more than 150 000 data sets from more than 20 000 experiments performed since 1935, EXFOR is by far the most important and complete experimental nuclear reaction database. It is widely used to further improve nuclear reaction models and evaluated nuclear data libraries. The Data Bank supervises the development of the Joint Evaluated Fission and Fusion (JEFF) file, which is one of the major evaluated nuclear data libraries used in the field of nuclear science and technology.

As part of its mission, the Data Bank works to maintain the highest level of quality in its databases. One method that was proposed to check the mutual consistency of experimental data in EXFOR (see NEA, 2011) is to test for outlier measurements more than a few standard deviations from the mean value as, in principle, several measurements of the same reaction quantity should form a continuous distribution. More recently, another method was developed to crosscheck evaluated and experimental data in databases in order to detect aberrant values (SCM, 2014). It was noted that there is no evidence, on the basis of numerical comparisons only, that outliers represent “bad” data. The fact that such data deviate significantly from other data of the same reaction may, however, be helpful to nuclear data evaluators who focus on one or a few isotopes and may wish to discard such data after a thorough analysis.

The Data Bank also organised a comprehensive review of cross-section data. An efficient review system and associated strategy were developed to systematically compare more than 10 000 cross-section data sets from EXFOR with the corresponding values in the main evaluated nuclear data libraries, including JEFF. The review initially covered all

neutron-induced threshold and activation reactions such as (n,n') , $(n,2n)$, (n,p) and (n,α) (NEA, 2014). The resulting statistical information showed various interesting trends in the data, including a list of suspicious data sets for which the cross-section values deviate greatly from the major evaluated nuclear data libraries and/or other measurements. The original publications associated with these data have also been systematically checked. This work confirmed that most of the experimental data were compiled correctly in the EXFOR database, and it identified a few compilation mistakes that have since been corrected. A second part of the review devoted to the (n,γ) cross-section is underway. This part of the review is challenging because of the large fluctuations of data in the resonance region that make the comparison more difficult. If successful, the review could be completed with other non-threshold cross-sections such as (n,f) , (n,tot) and (n,n) .

All of these initiatives have been very useful to maintain the highest level of quality in the EXFOR database. In addition, future development versions of the JEFF library can be automatically benchmarked against other evaluated libraries and against a more reliable experimental database. Such work will contribute to improving the quality of evaluated nuclear data for the benefit of all users.

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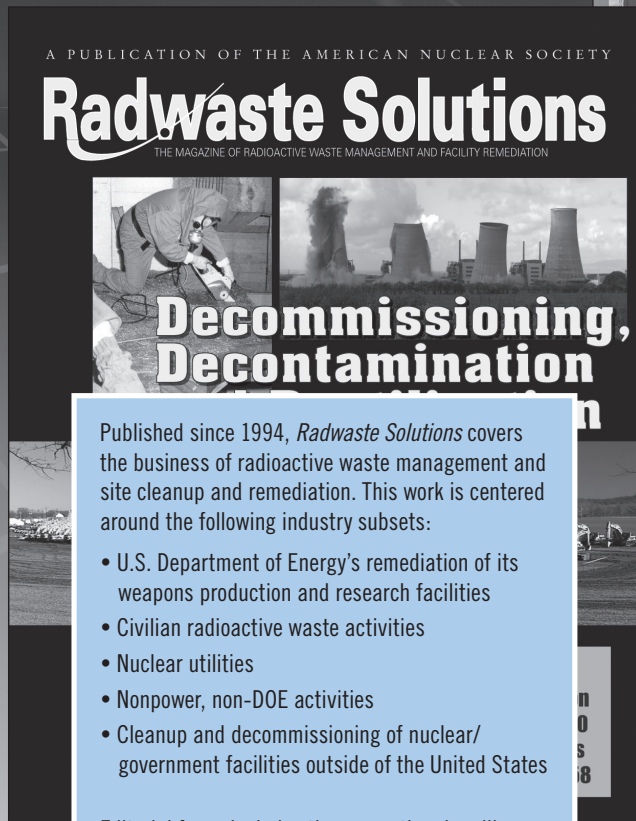
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<p>Behaviour of Iodine Project (BIP) Contact: axel.breest@oecd.org Phase 2 mandate: April 2011-September 2014 Phase 3 under discussion</p>	Belgium, Canada, Finland, France, Germany, Japan, Republic of Korea, Spain, Sweden, United Kingdom, United States.	≈EUR 300 K /year
<p>Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Plant (BSAF) Contact: andrew.white@oecd.org Phase 1 mandate: November 2012-September 2014 Phase 2 under discussion</p>	France, Germany, Japan, Republic of Korea, Russian Federation, Spain, Switzerland, United States.	EUR 160 K
<p>Cable Ageing Data and Knowledge (CADAK) Project Contact: axel.breest@oecd.org Current mandate: December 2011-December 2014</p>	Canada, France, Japan, Norway, Republic of Korea, Slovak Republic, Spain, Switzerland, United States.	EUR 360 K
<p>Cabri Water Loop Project Contact: neil.blundell@oecd.org Current mandate: March 2000-March 2015</p>	Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States.	≈EUR 74 million
<p>Component Operational Experience, Degradation and Ageing Programme (CODAP) Contact: olli.nevander@oecd.org Current mandate: June 2011-December 2014</p>	Canada, Chinese Taipei, Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Slovak Republic, Spain, Sweden, Switzerland, United States.	EUR 130 K /year
<p>Co-operative Programme on Decommissioning (CPD) Contact: inge.weber@oecd.org Current mandate: January 2014-December 2018</p>	Belgium, Canada, Chinese Taipei, European Commission, France, Germany, Italy, Japan, Republic of Korea, Slovak Republic, Spain, Sweden, United Kingdom, United States.	≈EUR 70 K /year
<p>Fire Incidents Records Exchange (FIRE) Project Contact: neil.blundell@oecd.org Current mandate: January 2014-December 2015</p>	Canada, Czech Republic, Finland, France, Germany, Japan, Netherlands, Republic of Korea, Spain, Sweden, Switzerland, United States.	≈EUR 72 K /year

NEA joint projects and information exchange programmes enable interested countries, on a cost-sharing basis, to pursue research or the sharing of data with respect to particular areas or issues in the nuclear energy field. The projects are carried out under the auspices, and with the support, of the NEA.

At present, 17 joint projects are being conducted or completed in relation to nuclear safety, one in the area of nuclear science (advanced fuels), two in support of radioactive waste management and one in the field of radiological protection. These projects complement the NEA programme of work and contribute to achieving excellence in each area of research.

Objectives

- Provide experimental data for resolving key light water reactor (LWR) thermal-hydraulics safety issues related to multiple, high-risk failures, notably those highlighted by the Fukushima Daiichi nuclear power plant (NPP) accident.
- Focus in particular on the validation of simulation models and methods for complex phenomena of high safety relevance to thermal-hydraulic transients in design basis accidents and design extension conditions.

- Obtain a more detailed and mechanistic understanding of iodine adsorption/desorption on containment surfaces by means of new experiments with well characterised containment paints and paint constituents and novel instrumentation (spectroscopic methods).
- Obtain a more detailed and mechanistic understanding of organic iodide formation by means of new experiments with well characterised containment paints and paint constituents and novel instrumentation (chromatographic methods).
- Develop a common understanding of how to extrapolate with confidence from small-scale studies to reactor-scale conditions.

- Analyse the accident progression of the Fukushima Daiichi NPP accident utilising the common information database.
- Improve the understanding of the severe accident (SA) phenomena which occurred during the accident, through comparison with participants' analysis results and with measured plant data.
- Contribute the above results to the improvement of methods and models of the SA codes applied in each participating organisation, in order to reduce uncertainties in SA analysis and to validate the SA analysis codes by using data measured through the decommissioning process.
- Contribute results of the analysis on accident progression, the status in the reactor pressure vessels (RPVs) and the primary containment vessels (PCVs) and the status of debris distribution to a future debris removal plan.

- Establish the technical basis for assessing the qualified life of electrical cables in light of the uncertainties identified following the initial (early) qualification testing.
- Investigate the adequacy of the safety margins and their ability to address the uncertainties.

- Extend the database for high burn-up fuel performance in reactivity-induced accident (RIA) conditions.
- Perform relevant tests under coolant conditions representative of pressurised water reactors (PWRs).
- Extend the database to include tests done in the Nuclear Safety Research Reactor (Japan) on boiling water reactor (BWR) and PWR fuel.

- Collect information on passive metallic component degradation and failures of the primary system, reactor pressure vessel internals, main process and standby safety systems, and support systems (i.e. ASME Code Class 1, 2 and 3 or equivalent), as well as non-safety-related (non-code) components with significant operational impact.
- Establish a knowledge base for general information on component and degradation mechanisms such as applicable regulations, codes and standards, bibliography and references, R&D programmes and pro-active actions, information on key parameters, models, thresholds and kinetics, fitness for service criteria, and information on mitigation, monitoring, surveillance, diagnostics, repair and replacement.
- Develop topical reports on degradation mechanisms in close co-ordination with the NEA/CSNI Working Group on Integrity and Ageing of Components and Structures (WGIAGE).

Exchange scientific and technical information among decommissioning projects for nuclear facilities, based on biannual meetings of the Technical Advisory Group, to ensure that the safest, most environmentally friendly and economical options for decommissioning are employed.

- Collect fire event experience (by international exchange) in the appropriate format and in a quality-assured and consistent database.
- Collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention.
- Generate qualitative insights into the root causes of fire events in order to derive approaches or mechanisms for their prevention and to mitigate their consequences.
- Establish a mechanism for the efficient feedback of experience gained in connection with fire, including the development of defences against their occurrence, such as indicators for risk informed and performance based inspections.
- Record the characteristics of fire events in order to facilitate fire risk analysis, including quantification of fire frequencies.

NEA joint projects

Project	Participants	Budget
<p>Fire Propagation in Elementary, Multi-room Scenarios (PRISME-2) Project</p> <p>Contact: neil.blundell@oecd.org</p> <p>Current mandate: July 2011-June 2016</p>	Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden, United Kingdom.	EUR 7 million
<p>Halden Reactor Project</p> <p>Contact: axel.breest@oecd.org</p> <p>Current mandate: January 2012-December 2014</p>	Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Japan, Kazakhstan, Norway, Republic of Korea, Russian Federation, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States.	≈ EUR 55 million
<p>High Energy Arcing Fault Events (HEAF) Project</p> <p>Contact: neil.blundell@oecd.org</p> <p>Current mandate: July 2012-December 2015</p>	France, Germany, Japan, Republic of Korea, United States.	Costs covered by the US NRC and in-kind contributions.
<p>Hydrogen Mitigation Experiments for Reactor Safety (HYMERES) Project</p> <p>Contact: axel.breest@oecd.org</p> <p>Current mandate: October 2012-September 2016</p>	Canada, China, Czech Republic, Finland, France, Germany, India, Republic of Korea, Russian Federation, Spain, Sweden, Switzerland.	EUR 4 million
<p>Information System on Occupational Exposure (ISOE)</p> <p>Contact: halilburcin.okyar@oecd.org</p> <p>Current mandate: January 2012-December 2015</p>	Armenia, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Lithuania, Mexico, Netherlands, Republic of Korea, Romania, Russian Federation, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States.	≈ EUR 400 K /year
<p>International Common-cause Failure Data Exchange (ICDE) Project</p> <p>Contact: axel.breest@oecd.org</p> <p>Current mandate: April 2011-December 2014</p>	Canada, Finland, France, Germany, Japan, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	EUR 330 K
<p>Loss of Forced Coolant (LOFC) Project</p> <p>Contact: neil.blundell@oecd.org</p> <p>Current mandate: March 2011-March 2016</p>	Czech Republic, France, Germany, Hungary, Japan, Republic of Korea, United States.	EUR 3 million

Objectives

- Answer questions concerning smoke, fire and heat propagation inside a plant, by means of experiments tailored for code validation purposes for fire modelling computer codes.
- Undertake experiments related to smoke and hot gas propagation, through a horizontal opening between two superimposed compartments.
- Provide information on heat transfer to cables and on cable damage.
- Provide information on the effectiveness of fire extinguishing systems.

Generate key information for safety and licensing assessments and aim at providing:

- extended fuel utilisation: basic data on how the fuel performs, both under normal operation and transient conditions, with emphasis on extended fuel utilisation in commercial reactors;
- degradation of core materials: knowledge of plant materials behaviour under the combined deteriorating effects of water chemistry and nuclear environment, also relevant for plant lifetime assessments;
- man-machine systems: advances in computerised surveillance systems, virtual reality, digital information, human factors and man-machine interaction in support of control room upgradings.

Perform experiments to obtain scientific fire data on the high energy arcing faults phenomena known to occur in nuclear power plants through carefully designed experiments:

- use data from the experiments and past events to develop a mechanistic model to account for the failure modes and consequence portions of HEAFs;
- improve the state of knowledge and provide better characterisation of HEAFs in fire probabilistic risk assessment (PRA) and US National Fire Protection Association NFPA 805 license amendment request applications;
- examine the initial impact of the arc to primary equipment and the subsequent damage created by the initiation of an arc (e.g. secondary fires).
- use international collaboration to expand on the pool of available test data and acquire authorship involvement in the development of a new U.S. NUREG that consequently has international standing and applicability.

Improve the understanding of hydrogen risk phenomenology in containment in order to enhance modelling in support of safety assessments that will be performed for current and new nuclear power plants. With respect to previous projects related to hydrogen risk, HYMERES introduces three new elements:

- tests addressing the interaction of safety components;
- realistic flow conditions;
- reviews of system behaviour for selected cases.

- Collect, analyse and exchange occupational exposure data and occupational exposure management experience at nuclear power plants.
- Provide broad and regularly updated information on methods to improve the protection of workers and on occupational exposure in nuclear power plants.
- Provide a mechanism for dissemination of information on these issues, including evaluation and analysis of the data assembled and experience exchanged, as a contribution to the optimisation of radiation protection.

- Provide a framework for multinational co-operation.
- Collect and analyse common-cause failure (CCF) events over the long term so as to better understand such events, their causes and their prevention.
- Generate qualitative insights into the root causes of CCF events which can then be used to derive approaches or mechanisms for their prevention or mitigation of their consequences.
- Establish a mechanism for the efficient feedback of experience gained in connection with CCF phenomena, including the development of defences against their occurrence, such as indicators for risk-based inspections.
- Generate quantitative insights and record event attributes to facilitate the quantification of CCF frequencies in member countries. Use the ICDE data to estimate CCF parameters.

To perform integral tests in the high-temperature engineering test reactor (HTTR) in order to:

- provide experimental data to clarify the anticipated transient without scram (ATWS) in the case of an LOFC with occurrence of reactor re-criticality;
- provide experimental data to validate the key assumptions in computer codes predicting the behaviour of reactor kinetics, core physics and thermal-hydraulics related to protective measures for safety;
- provide experimental data to verify the capabilities of these codes regarding the simulation of phenomena coupled between reactor core physics and thermal-hydraulics.

NEA joint projects

Project	Participants	Budget
<p>Primary Coolant Loop Test Facility (PKL-3) Project Contact: neil.blundell@oecd.org Current mandate: April 2012-December 2015</p>	Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, United States.	EUR 3.9 million
<p>Source Term Evaluation and Mitigation (STEM) Project Contact: axel.breest@oecd.org Current mandate: July 2011-June 2015</p>	Canada, Czech Republic, Finland, France, Germany, United States.	EUR 3.5 million
<p>Studsvik Cladding Integrity Project (SCIP) Contact: axel.breest@oecd.org Phase 2 mandate: July 2009-June 2014 Phase 3 under preparation</p>	Czech Republic, Finland, France, Germany, Japan, Norway, Republic of Korea, Russian Federation, Spain, Sweden, Switzerland, United Kingdom, United States.	≈ EUR 7.7 million
<p>Thermochemical Database (TDB) Project Contact: maria-eleni.ragoussi@oecd.org Current mandate: April 2014-March 2018</p>	Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, United Kingdom, United States.	EUR 1.5 million
<p>Thermodynamics of Advanced Fuels – International Database (TAF-ID) Project Contact: simone.massara@oecd.org Current mandate: January 2013-December 2015</p>	Canada, France, Japan, Netherlands, Republic of Korea, United States.	≈ EUR 112 K /year
<p>Thermal-hydraulics, Hydrogen, Aerosols, Iodine (THAI) Project Contact: neil.blundell@oecd.org Phase 2 mandate: August 2011-July 2014 Phase 3 under discussion</p>	Canada, Czech Republic, Finland, France, Germany, Hungary, Japan, Netherlands, Republic of Korea, Sweden, United Kingdom.	EUR 3.6 million

Objectives

- Investigate safety issues relevant for current PWR plants as well as for new PWR design concepts.
- Focus on complex heat transfer mechanisms in the steam generators and boron precipitation processes under postulated accident situations.

Improve the general evaluation of the source term, and in particular:

- perform experiments to study the stability of aerosol particles under radiation and the long-term gas/deposits equilibrium in a containment;
- conduct a literature survey on the effect of paint ageing;
- perform experiments to study ruthenium transport in pipes.

- Generate high-quality experimental data to improve the understanding of the dominant failure mechanisms for water reactor fuels and devise means for reducing fuel failures.
- Achieve results of general applicability (i.e. not restricted to a particular fuel design, fabrication specification or operating condition).
- Achieve experimental efficiency through the judicious use of a combination of experimental and theoretical techniques and approaches.

Produce a database that:

- contains data for elements of interest in radioactive waste disposal systems;
- documents why and how the data were selected;
- gives recommendations based on original experimental data, rather than on compilations and estimates;
- documents the sources of experimental data used;
- is internally consistent;
- treats all solids and aqueous species of the elements of interest for nuclear waste storage performance assessment calculations.

Make available a comprehensive, internationally recognised thermodynamic database and associated phase diagrams on nuclear fuel materials for the existing and future generation of nuclear reactors. Specific technical objectives this project intends to achieve are:

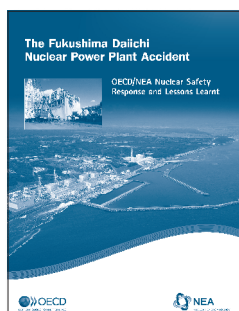
- predict the solid, liquid and/or gas phases formed during fuel/cladding chemical interaction under normal and accident conditions;
- improve the control of the experimental conditions during the fabrication of the fuel materials at high temperature;
- predict the evolution of the chemical composition of fuel under irradiation versus temperature and burn-up.

Address remaining questions and examine experimental data relevant to nuclear reactor containments under severe accident conditions concerning:

- release of gaseous iodine from a flashing jet;
- deposition of molecular iodine on aerosol particles;
- hydrogen combustion during spray operation;
- onset of passive autocatalytic recombiner (PAR) operation under extremely low oxygen conditions.

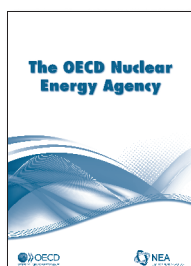
New publications

General interest



The Fukushima Daiichi Nuclear Power Plant Accident: OECD/NEA Nuclear Safety Response and Lessons Learnt

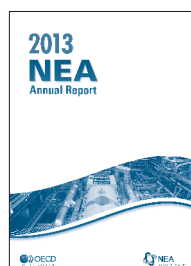
NEA No. 7161. 68 pages.



The OECD Nuclear Energy Agency

8 pages.

Also available in Chinese, French and Russian.



2013 NEA Annual Report

NEA No. 7174. 63 pages.

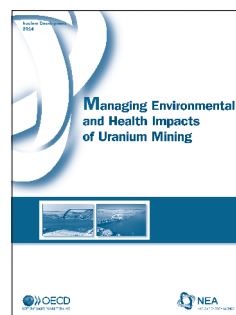
Also available in French.

Nuclear development and the fuel cycle

Managing Environmental and Health Impacts of Uranium Mining

NEA No. 7062. 140 pages.

Uranium mining and milling has evolved significantly over the years. By comparing currently leading approaches with outdated practices, this report demonstrates how uranium mining can be conducted in a way that protects workers, the public and the environment. Innovative, modern mining practices combined with strictly enforced regulatory standards are geared towards avoiding past mistakes committed primarily during the early history of the industry when maximising uranium production was the principal operating consideration. Today's leading practices in uranium mining aim at producing uranium in an efficient and safe manner that limits environmental impacts to acceptable standards. As indicated in this report, the collection of baseline environmental data, environmental monitoring and public consultation throughout the life cycle of the mine enables verification that the facility is operating as planned, provides early warning of any potentially adverse impacts on the environment and keeps stakeholders informed of developments. Leading practice also supports planning for mine closure before mine production is licensed to ensure that the mining lease area is returned to an environmentally acceptable condition. The report highlights the importance of mine workers being properly trained and well equipped, as well as that of ensuring that their work environment is well ventilated so as to curtail exposure to radiation and hazardous materials and thereby minimise health impacts.



Nuclear Energy Data 2014

Données sur l'énergie nucléaire 2014

NEA No. 7197. 96 pages.

Nuclear Energy Data is the OECD Nuclear Energy Agency's annual compilation of statistics and country reports documenting the status of nuclear power in the OECD area. Information provided by member country governments includes statistics on installed generating capacity, total electricity produced by all sources and by nuclear power, nuclear energy policies and fuel cycle developments, as well as projected generating capacity and electricity production to 2035, where available. Total electricity generation at nuclear power plants and the share of electricity production from nuclear power plants remained steady in 2013 despite the progressive shutdown of all reactors in Japan leading up to September and the permanent closure of six reactors in the OECD area. Governments committed to maintaining nuclear power in the energy mix advanced plans for increasing nuclear generating capacity, and progress was made in the development of deep geological repositories for spent nuclear fuel, with Finland expected to have the first such facility in operation in the early 2020s. Further details on these and other developments are provided in the publication's numerous tables, graphs and country reports.

Uranium 2014: Resources, Production and Demand

NEA No. 7209. 504 pages.

Uranium is the raw material used to fuel over 400 operational nuclear reactors around the world that produce large amounts of electricity and benefit from life cycle carbon emissions as low as renewable energy sources. Although a valuable commodity, declining market prices for uranium since the Fukushima Daiichi nuclear power plant accident in 2011, driven by uncertainties concerning the future of nuclear power, have led to the postponement of mine development plans in a number of countries and raised questions about continued uranium supply. This 25th edition of the "Red Book", a recognised world reference on uranium jointly prepared by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, provides analyses and information from 45 producing and consuming countries in order to address these and other questions. It includes data on global uranium exploration, resources, production and reactor-related requirements. It offers updated information on established uranium production centres and mine development plans, as well as projections of nuclear generating capacity and reactor-related requirements through 2035, incorporating policy changes following the Fukushima accident, in order to address long-term uranium supply and demand issues.

Nuclear safety and regulation

福島第一原子力発電所事故 OECD/NEA原子力安全の対応と教訓 要旨

NEA No. 7217. 8 pages.

This report outlines the response of the OECD Nuclear Energy Agency (NEA) and its member countries to the March 2011 accident at TEPCO's Fukushima Daiichi nuclear power plant. All NEA members took early action to ensure and confirm the continued safety of their nuclear power plants and the protection of the public. Consistent with its objective of maintaining and further developing the scientific, technological and legal bases for safe nuclear energy, the NEA has assisted its member countries in their individual and collective responses to the accident. It has also provided direct assistance to the relevant authorities in Japan. These actions are summarised in the report along with lessons learnt thus far. Key messages are offered as a means to help strengthen the basis for nuclear safety and its implementation in all countries using nuclear power.

The Characteristics of an Effective Nuclear Regulator

NEA No. 7185. 32 pages.

Both national and international organisations agree that the fundamental objective of all nuclear safety regulatory bodies – the regulator's prime purpose – is to ensure that nuclear licensees operate their facilities at all times in a safe manner. Much has been written about ways to improve regulatory processes or to improve the effectiveness of a regulatory body, including in previous OECD/NEA regulatory guidance booklets. But until now, none have focused on the characteristics of an effective nuclear safety regulator.

Effective organisations are those that have good leadership and are able to transform strategic direction into operational programmes. Effectiveness is about how well the organisation is achieving its fundamental purpose – in the case of a nuclear safety regulator, ensuring that licensees operate their facilities and discharge their obligations in a safe manner.

This regulatory guidance booklet describes the characteristics of an effective nuclear safety regulator in terms of roles and responsibilities, principles and attributes. Each of the characteristics discussed in this report is a necessary feature of an effective nuclear safety regulator but no one characteristic is sufficient on its own. It is the combination of these characteristics that leads to the effectiveness of a nuclear regulatory body. The report provides a unique resource to countries with existing, mature regulators and can be used for benchmarking as well as training and developing staff. It will also be useful for new entrant countries in the process of developing and maintaining an effective nuclear safety regulator.

Radioactive waste management

Guide for International Peer Reviews of Decommissioning Cost Studies for Nuclear Facilities

NEA No. 7190. 49 pages.

Peer reviews are a standard co-operative OECD working tool that offer member countries a framework to compare experiences and examine best practices in a host of areas. The OECD Nuclear Energy Agency (NEA) has developed a proven methodology for conducting peer reviews in radioactive waste management and nuclear R&D. Using this methodology, the NEA Radioactive Waste Management Committee's Working Party on Decommissioning and Dismantling (WPDD) developed the present guide as a framework for decommissioning cost reviewers and reviewees to prepare for and conduct international peer reviews of decommissioning cost estimate studies for nuclear facilities. It includes checklists that will help national programmes or relevant organisations to assess and improve decommissioning cost estimate practices in the future. This guide will act as the NEA reference for conducting such international peer reviews.

Nuclear Site Remediation and Restoration during Decommissioning of Nuclear Installations

NEA No. 7192. 244 pages.

Decommissioning of nuclear facilities and related remedial actions are currently being undertaken around the world to enable sites or parts of sites to be reused for other purposes. Remediation has generally been considered as the last step in a sequence of decommissioning steps, but the values of prevention, long-term planning and parallel remediation are increasingly being recognised as important steps in the process. This report, prepared by the Task Group on Nuclear Site Restoration of the NEA Co-operative Programme on Decommissioning, highlights lessons learnt from remediation experiences of NEA member countries that may be particularly helpful to practitioners of nuclear site remediation, regulators and site operators. It provides observations and recommendations to consider in the development of strategies and plans for efficient nuclear site remediation that ensures protection of workers and the environment.

R&D and Innovation Needs for Decommissioning Nuclear Facilities

NEA No. 7191. 314 pages.

Nuclear decommissioning activities can greatly benefit from research and development (R&D) projects. This report examines applicable emergent technologies, current research efforts and innovation needs to build a base of knowledge regarding the status of decommissioning technology and R&D. This base knowledge can be used to obtain consensus on future R&D that is worth funding. It can also assist in deciding how to collaborate and optimise the limited pool of financial resources available among NEA member countries for nuclear decommissioning R&D.

Nuclear law

Nuclear Law Bulletin No. 93

Volume 2014/1

NEA No. 7181. 134 pages.

The *Nuclear Law Bulletin* is a unique international publication for both professionals and academics in the field of nuclear law. It provides authoritative and comprehensive information on nuclear law developments. Published free online twice a year in both English and French, it features topical articles written by renowned legal experts, covers legislative developments worldwide and reports on relevant case law, bilateral and international agreements as well as regulatory activities of international organisations. Feature articles in this issue include: "Progress towards a global nuclear liability regime"; "The Convention on Supplementary Compensation for Nuclear Damage and participation by developing countries: A South African perspective"; "Fusion energy and nuclear liability considerations"; and "Nuclear energy and Indian society: Public engagement, risk assessment and legal frameworks".

Nuclear science and the Data Bank

International Handbook of Evaluated Reactor Physics Benchmark Experiments 2014 Edition

NEA No. 7173. DVD.

The International Reactor Physics Experiment Evaluation (IRPhE) Project was initiated as a pilot activity in 1999 by the Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) Nuclear

Science Committee (NSC). The project was endorsed as an official activity of the NSC in June 2003. While the NEA co-ordinates and administers the IRPhE at the international level, each participating country is responsible for the administration, technical direction and priorities of the project within their respective countries. The information and data included in this handbook are available to NEA member countries, to all contributing countries and to others on a case-by-case basis.

This handbook contains reactor physics benchmark specifications that have been derived from experiments that were performed at nuclear facilities around the world. The benchmark specifications are intended for use by reactor designers, safety analysts and nuclear data evaluators to validate calculation techniques and data. Example calculations are presented; they do not constitute a validation or endorsement of the codes or cross-section data. The 2014 edition of the *International Handbook of Evaluated Reactor Physics Benchmark Experiments* contains data from 135 experimental series that were performed at 48 reactor facilities. A total of 131 of the 135 evaluations are published as approved benchmarks. The remaining four evaluations are published as draft documents only. New to the handbook are benchmark specifications for selected measurements from the VENUS-7 series that were performed in the zero power VENUS reactor at SCK•CEN, Mol (Belgium) as part of the “Plutonium Recycle Programme”.

State-of-the-art Report on Innovative Fuels for Advanced Nuclear Systems

NEA No. 6895. 193 pages.

Development of innovative fuels such as homogeneous and heterogeneous fuels, ADS fuels, and oxide, metal, nitride and carbide fuels is an important stage in the implementation process of advanced nuclear systems. Several national and international R&D programmes are investigating minor actinide-bearing fuels due to their ability to help reduce the radiotoxicity of spent fuel and therefore decrease the burden on geological repositories. Minor actinides can be converted into a suitable fuel form for irradiation in reactor systems where they are transmuted into fission products with a significantly shorter half-life. This report compares recent studies of fuels containing minor actinides for use in advanced nuclear systems. The studies review different fuels for several types of advanced reactors by examining various technical issues associated with fabrication, characterisation, irradiation performance, design and safety criteria, as well as technical maturity.

Also available

2013 GIF Annual Report

www.gen-4.org

This seventh edition of the *Generation IV International Forum (GIF) Annual Report* highlights the main achievements of the Forum in 2013, and in particular the progress made in the collaborative R&D activities of the ten existing project arrangements for the gas-cooled fast reactor, the sodium-cooled fast reactor, the supercritical-water-cooled reactor and the very-high-temperature reactor. Progress made under the Memoranda of Understanding (MOU) for the lead-cooled fast reactor and the molten salt reactor, including Russia’s signing of the latter MOU in November 2013, is also reported. The Phase 1 report on safety design criteria for the sodium-cooled fast reactor was published in May 2013, marking an important milestone in the development of safety standards for generation IV reactors. Finally, the *Technology Roadmap Update for Generation IV Nuclear Energy Systems* was completed in 2013, providing both an assessment of progress made in the development of Generation IV systems since the publication of the original *Technology Roadmap* in 2002 and an overview of the GIF’s key objectives for the next ten years.

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