NEA News

2000 – No. 18.2

In this issue:

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NUCLEAR • ENERGY • AGENCY

NEA News

contents

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All correspondence should be addressed to:

The Editor
NEA News
OECD Nuclear Energy Agency
12, boulevard des Îles
92130 Issy-les-Moulineaux
France
Tel.: +33 (0) 1 45 24 10 10
Fax: +33 (0) 1 45 24 11 10

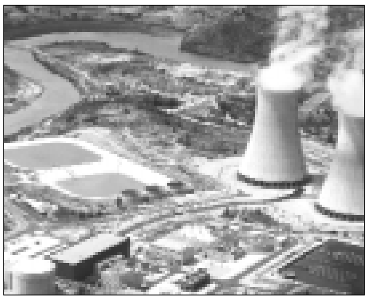
The OECD Nuclear Energy Agency (NEA) was established in 1958 as the OEEC European Nuclear Energy Agency and took its present designation in 1972 when its membership was extended to non-European countries. Its purpose is to further international co-operation related to the safety, environmental, economic, legal and scientific aspects of nuclear energy. It currently consists of 27 Member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The European Commission takes part in the NEA's work and a co-operation agreement is in force with the International Atomic Energy Agency.

For more information about the NEA, see:

www.nea.fr

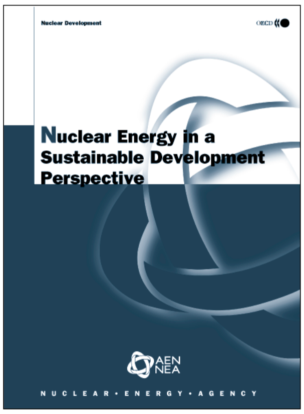
Cover page: The Loviisa nuclear power plant in winter. Credit: Fortum, Finland.

Facts and opinions

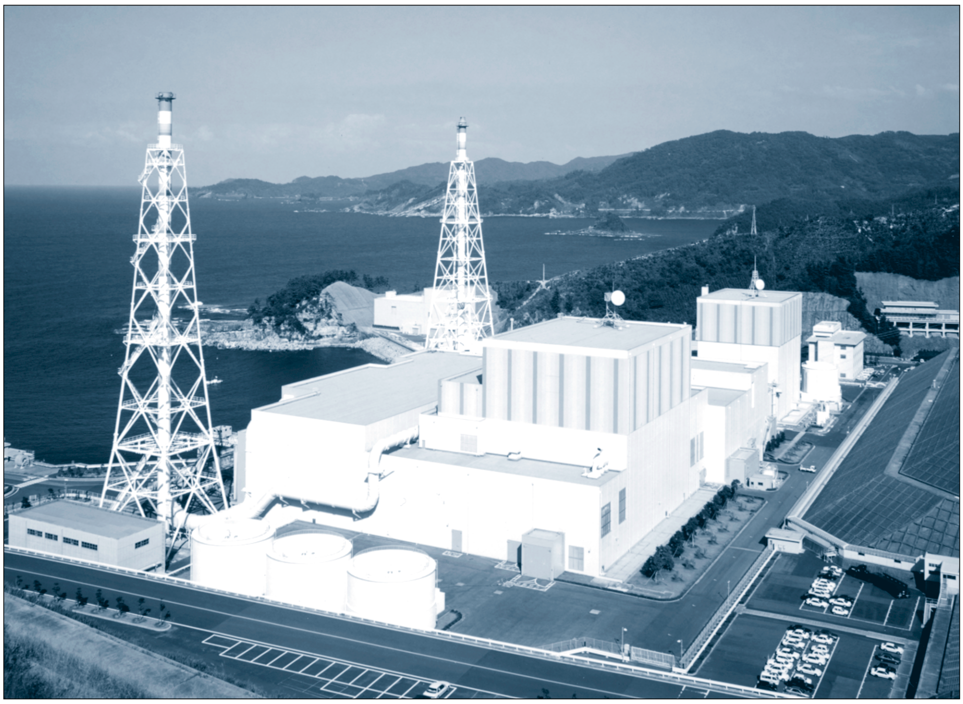


NEA updates

News briefs



editorial



Chugoku Electric Power Co., Japan

Considering future generations

As we reach the end of the 20th century, it is an appropriate time to consider some of the major challenges that will continue to face our "blue planet" in terms of economic growth, human health, natural resources, environment and, ultimately, social welfare.

The century which is ending saw unparalleled industrial development and technological innovation and the emergence of a certain form of human prosperity in the developed world based upon quantitative growth. The realisation that this pathway was not necessarily to the advantage of the world at large led to the search for a more qualitative approach to development, and the reliance on responsible industrial and social policies based on which today's society would leave an undiminished potential for progress and welfare to later generations.

The "Bruntland report" of 1987, appropriately entitled "Our common future", defined sustainable development as "development that meets the needs of the present, without compromising the ability of future generations to meet their own needs", and pointed out its three inter-related economic, social and environmental components. In this context, energy appears as a critical commodity. Meanwhile, signs of world climate change and the role of anthropogenic releases in this phenomenon are a cause of mounting concern, and reasonable solutions must be found to minimise these releases or at least to curb their progression. While the poor results of the just-completed COP-6 testify to the complexity of the task, the publication by the European Commission of the EU Green Paper on security of energy supply illustrates inter alia the importance for industrialised countries of relying on energy mixes that contribute to meeting Kyoto targets for reducing greenhouse gas emissions.

The role of the Nuclear Energy Agency is to assist its members in maintaining and further developing the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy. Identifying the impacts of nuclear energy in a sustainable development perspective, outlining factors to be considered in assessing the contribution that nuclear energy can make to sustainable development goals, as well as pointing out the challenges that must be overcome to achieve this contribution, are priority objectives for the NEA. A new NEA report just published addresses this issue.

Nuclear energy and the scientific knowledge, institutional infrastructure and operational experience that support it can represent an asset for present and future generations, in line with sustainable development goals. Without prejudging the policies that our Member countries may choose in order to meet their energy needs, it is highly important for the international community to face its long-term responsibilities.

C. Picot, T. Lazo, C. Pescatore, J. Royen*

Nuclear energy and civil society

Involving the public in government decision making on major technological activities and projects is no longer a desired attribute or ideal, it has become a necessity for effective governance. Policies that lack public support are policies that risk failure. For this reason both the OECD and the NEA are closely examining the role of civil society in public decision-making processes.

Society is increasingly concerned about human activities that impact the well-being of mankind, including public health and the environment. The nuclear industry is one such activity with which are associated certain concerns and issues that impact policy and decision making in relation to risk assessment and management. In today's world of deregulation and globalisation, government policy often requires broadly based assessments of benefits, risks and costs as part of decision-making and regulatory processes. Such processes work very effectively for most situations, with regulatory authorities establishing regulations and making decisions based on existing laws and government policy guidelines. This is the case with the nuclear industry.

However, in some cases, the societal concern over a particular risk may not be fully reflected in government policy. Emerging risks from new technologies, such as the genetic modification of foods, or from discovered risks, such as bovine spongiform encephalopathy (BSE), are examples. Similar risks exist in the nuclear industry, such as those occurring in unexpected locations (e.g. a radiological contamination of an old industrial site), or those associated with new practices (e.g. the release of metals containing small but measurable quantities of radioactivity for unrestricted use). In some situations involving risks caused by regulated industrial activities, affected populations may have views that legitimately differ from those of the industry producing the risk. In these situations, the social component of regulatory judgement and government decision making is in the limelight. Indeed, the social value attached to risks tends to become a major element in the decision-making process. These types of situations can arise very quickly, with the "discovery" and vast coverage of a risk by interest groups or the media, and with government and regulatory bodies often pressured to react.

With today's modern communication tools, governments and citizens are generally better and more quickly informed than before. However, because the flow of information is not subject to quality controls, some of it may be incomplete or misleading. In addition, with the growing competition for catching the public's attention, certain media have at times succumbed to the temptation of adopting the "sensational sells" approach. On technical and sensitive issues such as nuclear energy, this can lead to problematic situations.

* *Mrs. Cynthia Picot is a member of the NEA Central Secretariat (e-mail: cynthia.picot@oecd.org). Dr. Ted Lazo (lazo@nea.fr) is Deputy Head and Dr. Claudio Pescatore (pescatore@nea.fr) is a member of the NEA Radiation Protection and Radioactive Waste Management Division. Dr. Jacques Royen is Deputy Head of the NEA Nuclear Safety Division (jacques.royen@oecd.org).*

From the perspective of deregulation, governments and regulatory authorities are also feeling pressure to improve their processes. In this case, governments are pressed to better assess such aspects as the costs that are imposed by policy decisions and regulations; the equity with which industries in a particular sector, such as energy production, are treated; and the equity with which risks, for example from exposure to various carcinogenic agents released to the environment by different industries, are assessed and managed.

In the context of these diverse pressures, governments are re-examining decision-making processes, and the roles and expectations of all participants in those processes. Governments increasingly realise that they will not be able to effectively implement policies, as good as they may be, if their citizens do not understand and support them. A current focus of work at the OECD and the NEA is to share experience among governments and regulatory authorities in dealing with and involving the public, to draw from this experience examples of good practice, and to reach consensus on ways to move forward. In this regard, areas of particular interest to the NEA are radioactive waste management, nuclear safety regulation and radiation protection.

Radioactive waste management

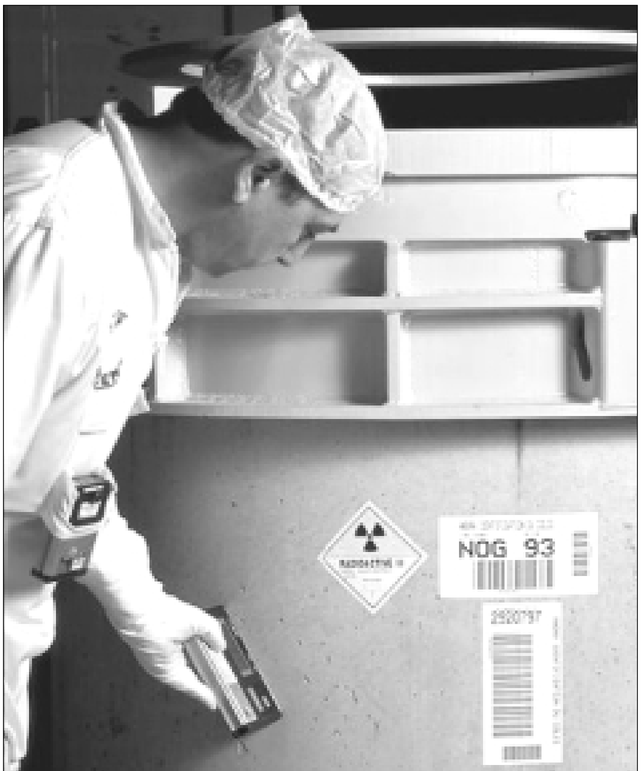
Issues of confidence and public perception have been critical in gaining approval of the development of repositories for long-lived radioactive waste at specific sites. In recent years, radioactive waste management institutions have become increasingly aware that technical expertise and technical confidence in the safety of geologic disposal, alone, are insufficient to justify to a wider audience geologic disposal as a waste management solution. It is important to note that the process by which proposals are brought forward must be trusted, and decisions need to be made with sensitivity to stakeholders, particularly the public in the vicinity of a proposed repository. The needs of these audiences may not always be anticipated and a dialogue with stakeholders needs to be sought, so that the public is afforded opportunities to interact as early as possible in the process of repository development.

In most countries, the local communities have a strong position with respect to the siting of a repository, sometimes with a right to veto. Only in a few countries (notably Finland and Sweden) have the programmes moved forward more or less as originally planned, and with public consent. In other countries (such as Germany and the UK),

site selection programmes have been delayed or halted, often due to insufficient attention having been given to public concern. Examples also exist where severe problems have resulted in a complete re-evaluation and a new approach in the national programme.

The NEA examined the question of radioactive waste management and public confidence in detail in August 2000 when it launched the first-ever "International Forum on Stakeholder Confidence".[1] The Forum is intended to facilitate the sharing of experience in addressing the societal dimension of radioactive waste management, to explore means of ensuring an effective dialogue with the public, and to consider ways to strengthen confidence in decision-making processes.

One of the trends that clearly emerged from these first discussions was that the time is over when exchanges between nuclear energy institutions and civil society were confined to rigid mechanisms provided by the law. There is recognition that a more complex interaction is now taking place among players at national, regional and especially at local levels, as large industrial projects are highly dependent on siting and other local considerations. A broader, more realistic view of decision making, encompassing a range of actors in civil society, is emerging.[2]



Pierre Berenger, EDF, France

Safety check of the radioactivity of a spent fuel cask at the Nogent-sur-Seine NPP, France.

Nuclear safety and regulation

One of the key issues in the area of nuclear safety and regulation is ensuring effective communication programmes and dialogue with the public. In many countries, however, there is little or no interaction between regulatory or safety authorities and the public. Where there is interface with the public, public participation varies widely from one country to another.

The NEA Committee on Nuclear Regulatory Activities (CNRA) is currently concentrating on the issue of accountability of, and trust in, nuclear regulatory bodies. In November 2000, it organised an international workshop on "Investing in Trust: Nuclear Regulators and the Public"[3] in order to exchange information and views on how regulatory authorities organise or plan to expand interface with the public. The workshop confirmed that one particularly important factor is the attitude of the safety authorities and the regulators with regard to their own participation in public dialogue. Experience has shown that active regulator involvement is needed, and that this is also possible without endangering the regulator's independence and integrity as a licensing body. A gradual evolution can be seen from a situation of "isolated regulators" to active ones increasingly perceived as the "people's experts".

It has been recognised that in order to interface with the public, it is necessary to define both the nature and role of the regulator and also the composition and characteristics of discrete groups making up the "public". It is also necessary to clarify where to draw the line between the regulatory role and what is demanded from regulators by different groups within the public.

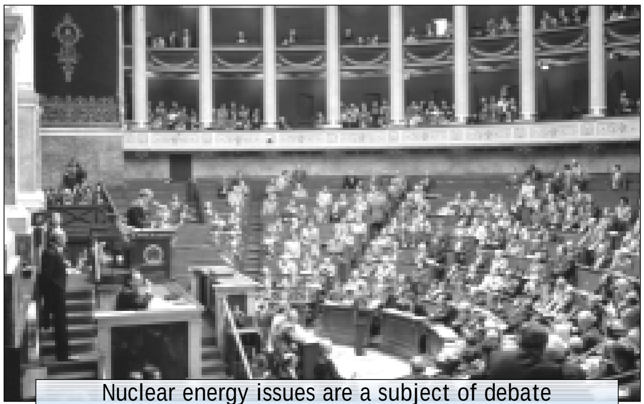
In general, it is believed that providing the public with adequate information will require increasing resources in the future. There is consensus that regulatory bodies are responsible for informing the public about their role in ensuring nuclear safety. However, they should remain neutral and refrain from the temptation to educate the public about nuclear energy, which could be misinterpreted as promotional.

Radiation protection

Radiation protection is a subject that attracts considerable public attention and generates extensive debate. The system of radiation protection has provided high-quality protection against harmful exposures to ionising radiation over the past several decades. It has evolved, however, into a system that is riddled with complex technical definitions and inconsistencies as compared with regulations governing "naturally induced" exposures to radiation. For example, the public, the media, industry and government regulators are sometimes at a loss when trying to explain or understand why one set of exposure levels declared "unsafe" in an industrial context is reported to be totally safe in other contexts. The result can be confusion, if not outright dismay.

From its inception, the system of radiation protection, as defined by the International Commission on Radiological Protection (ICRP), was developed by a fairly closed circle of scientists and academics. The technical rationale and terms that they use no longer seem sufficient to explain radiation protection theory and practice in today's social context. The scientific community has acknowledged that the system needs to be reviewed and has begun defining the task that lies ahead. It is clear that in order for the system to gain public support, including from both individuals and industry, these stakeholders will need to be consulted during the review and decision-making process.

The radiation protection community is pursuing two parallel paths. First, the system of radiation protection is itself being examined to see how it can be made more clear and coherent, and can better respond to modern societal needs. The NEA has recently published *A Critical Review of the System of Radiation Protection*, providing its first reflections on how the system of radiation protection should evolve. Second, the process of making decisions in situations of radiological risk is being examined. This includes pursuing better communication of theory and practice to a wider audience, the clarification of stakeholder roles, and improved understanding of the role of technical experience and knowledge in societal decision-making processes. It will also be necessary to look at whether protection against ionising radiation should be treated differently than protection against other hazards and toxic agents. These are some of the issues that will be considered at "The Second Villigen Workshop: Better Integration of Radiation Protection in Modern Society"[3] being organised by the NEA in January 2001 in Switzerland. It is expected that the workshop will contribute to the analysis and understanding of the socio-political-economic framework of modern decision making in pluralistic, educated and democratic societies.


The National Assembly, France

Nuclear energy issues are a subject of debate in many national parliaments.

Conclusions

Overall, the main issue emerging from the "Nuclear Energy and Civil Society" debate is the need to obtain a thorough understanding of the policy and decision-making processes, and the roles of the various participants. It is also necessary to characterise the relative importance of common social values, of trust in authorities, and of risk perceptions in reaching credible and acceptable decisions. To accomplish this, it will be necessary to identify and analyse the key social and political values and behaviour patterns that affect scientific, technical and economic decision making in the nuclear energy field. These are some of the subjects likely to be taken up in the months to come by the NEA.

The NEA, as a forum for regulators and government experts, offers a unique setting for sharing experience, comparing best practices and developing new strategies. Based on the ongoing work in the areas of radioactive waste management, nuclear regulation and radiation protection, it is intended that the NEA will be in a better position to develop a broad-based view of commonalities in the processes of developing publicly supported policies, decisions and regulations in the field of nuclear energy. ■

Notes

1. The proceedings entitled *Stakeholder Confidence and Radioactive Waste Disposal* are available free of charge from the NEA.
2. For a more detailed discussion of this issue see *Progress Towards Geologic Disposal: Where Do We Stand?* (NEA, 1999).
3. Proceedings of the workshop will be published by the NEA.

H. Riotte, T. Lazo, S. Mundigl*

Radiological impacts of spent nuclear fuel management options

A recent NEA study finds that the difference in the radiological impacts of the reprocessing and non-reprocessing nuclear fuel cycles does not provide a compelling argument in favour of one option or the other.

An important technical study on radiological impacts of spent nuclear fuel management options, recently completed by the NEA, is intended to facilitate informed international discussions on the nuclear fuel cycle. The study was prepared at the request of the OSPAR Commission, established under the international Convention for the Protection of the Marine Environment of the North-East Atlantic.

The study compares the radiological impacts on the public and on nuclear workers resulting from two approaches to handling spent fuel from nuclear power plants:

- the reprocessing option, that includes the recycling of spent uranium fuel, the reuse of the separated plutonium in MOX fuel, and the direct disposal of spent MOX fuel; and
- the once-through option, with no reprocessing of spent fuel, and its direct disposal.

Based on the detailed research of a group of 18 internationally recognised experts, under NEA sponsorship, the report concludes that:

- The radiological impacts of both the reprocessing and the non-reprocessing fuel cycles studied are small, well below any regulatory dose limits for the public and for workers, and insignificantly low as compared with exposures caused by natural radiation.
- The difference in the radiological impacts of the two fuel cycles studied does not provide a compelling argument in favour of one option or the other.

The study also points out that other factors, such as resource utilisation efficiency, energy security, and social and economic considerations would tend to carry more weight than radiological impacts in decision-making processes.

Scope and analytical approach

The study addresses all parts of both fuel cycle options that are relevant to the comparison of radiological impacts, including uranium mining, fuel fabrication, power production and reprocessing, as well as transportation and waste. It evaluates the radiological impacts to populations living near nuclear facilities, to the general public and to workers based on the system of radiation protection recommended by the ICRP in its Publication 60 (1991).

In order to assess the radiological impacts of the two fuel cycles, the radioactive releases considered were based on normalised, actual radioactive releases from real reference facilities, carefully

* *Mr. Hans Riotte is Head (e-mail: hans.riotte@oecd.org), Dr. Ted Lazo, Deputy Head (e-mail: lazo@nea.fr), and Mr. Stefan Mundigl, member (e-mail: mundigl@nea.fr), of the NEA Radiation Protection and Radioactive Waste Management Division.*

selected to reflect current good practice in radiation protection. Generic models, using stylised assumptions to characterise the populations exposed to the radioactive discharges, were then used to calculate population doses. It is important to note that these calculations, based on simplified fuel-cycle scenarios, were validated against actual results from a few real facilities. In addition, calculated radiological impacts were supplemented by results of studies carried out by other national and international organisations.

One of the strong points of the report is that actual data from reference facilities is in reasonable agreement with the modelled results from the stylised cycles studied. The reference facilities were chosen according to several criteria:

- The facilities were of industrial scale.
- They had been operating for some time.
- They had involved the use of current technology and current practice in radiation protection complying with existing standards.
- They had been able to supply appropriate recent data representing the past several years of operational history.

In developing the study, the following assumptions were made:

- Both cycles assumed simplified fuel cycles for 1 000 MW(e)-class pressurised water reactors (PWRs).
- The long-term stability of tailings from mining and milling was maintained.
- There was no extensive use of depleted uranium from enrichment, and no use of separated uranium from reprocessing, in either option.
- For both options, all waste and spent fuel were disposed of in a repository.
- For the reprocessing option, all uranium oxide spent fuel was reprocessed; all plutonium recovered from reprocessing of uranium oxide fuel was recycled as MOX fuel only once; and all waste, including vitrified high-level waste and spent MOX, was disposed of in a repository.

As regards impact on the environment, the Expert Group felt that it was appropriate to follow the current recommendations of the International Commission on Radiological Protection (ICRP), which state that if man is adequately protected, the environment will also be adequately protected. The Expert Group noted, however, that the ICRP is reviewing this position in the light of current scientific knowledge.

Results

The study found that the radiological impacts of the two fuel cycles studied were low in absolute terms (1.6 manSv/GWa[1] and 2.6 manSv/Gwa, respectively for once-through versus reprocessing options). Furthermore, the impact of either fuel cycle was very low compared with natural background exposure, and with the radiological impact of the use of coal to generate electricity (approximately 20 manSv/GWa, according to the UNSCEAR 93 publication).

The two fuel cycles studied differed the most in terms of public exposure from mining and milling activities, and from reprocessing activities. It was assumed, and current site practices confirm, that good practice in mining and milling would result in tailing piles that were stable in the long term. Although the Expert Group believed this to be a reasonable assumption, it was recognised that many studies have shown the degradation of tailing pile covering (with time, erosion, etc.) to result in significant additional releases of radon gas – the most significant source of exposure from mining and milling. As an example, a factor of ten increase in radon emissions would result in a factor of ten increase in the doses modelled by the study, and would result in the total dose due to the once-through cycle being higher than that of the reprocessing cycle. Although the Expert Group believed that such increases were not likely, the small absolute value of the results, together with the sensitivity to this particular assumption and the limitations inherent in the generic calculations more generally, led the Group to conclude that

Aerial view of the Tokai Works spent fuel reprocessing facility in Japan.

PNC, Japan

the radiological impacts of the two cycles were not significantly different. The numerical results of the study are presented in the table.

When considering the data, it is instructive to note that, overall, public exposures in both options are low compared with the pertinent regulatory limits, and also insignificantly low compared with exposures caused by natural background radiation (the worldwide average annual individual dose from natural background radiation is 2.4 mSv).

Uncertainties

This study recognises that inherent uncertainties associated with the assumptions made to calculate public exposures are large. In particular, public exposures from mining and milling showed great sensitivity to the study's assumptions that current good practice and technology are applied, and that tailing piles will be stable in the long term. Good practice in the management of mine and mill tailing

Summary table of dose estimation for the public and workers from major fuel cycle stages of each option

(Note: Collective doses in this table are used only in a comparative fashion.)

Fuel cycle stage	**Public (generic calculations)**			**Workers (operational data)**	
	Collective dose truncated at 500 years (manSv/GWa)		**Average annual individual dose to the critical group** (mSv/a)	**Annual collective dose** (manSv/GWa)	
	Once-through	**Reprocessing**		**Once-through**	**Reprocessing**
Mining and milling	1.0(5) *(1-1 000)*(3)(4)	0.8(1)(5) *[0.8 x(1-1000)]*(3)(4)	0.30-0.50 *(0.020-0.940)*(3)	0.02-0.18	0.016-0.14(1)
Fuel conversion & enrichment	0.0009		0.020 *(10^{-6})*(3)	0.008-0.02	0.006-0.016(1)
Fuel fabrication				0.007	0.094(2)
Power generation	0.6	0.6	0.0005-0.0008	1.0-2.7	1.0-2.7
Reprocessing, vitrification	Not applicable	1.2(1) *(0.6)*(3)	0.40 *(0.005-0.059)*(3)	Not applicable	0.014(1)
Transportation	Trivial	Trivial	Trivial	0.005-0.02	0.005-0.03
Disposal	(6)	(6)	(6)	Trivial	Trivial
Total	**1.6(5)**	**2.6(5)**	**Not applicable**	**1.04-2.93**	**1.14-2.99**

1. Collective doses for the reprocessing option have been scaled down by the ratio of mined natural uranium needed for the two options (179.3 t and 141.7 t).
2. Weighted by UO_2 and MOX-fuel amounts (21.1 t and 5.5 t).
3. Site-specific assessment values are given within brackets. They provide an indication of the sensitivity of results to assumptions about population distribution, habits of individuals and characteristics of the environment in which they live, and about conditions of releases.
4. The range refers to the sensitivity discussed in other studies (UNSCEAR, SENES, EC) using longer integration times.
5. Collective doses from mining and milling could be a few tens of manSv in case of poor tailing-pile maintenance.
6. No releases of radionuclides are expected within the first 500 years after placement of waste and spent fuel in a final repository.

piles has been demonstrated to result in fairly low emission rates for radon gas, and, consequently, low population exposures. Data from previous studies have indicated that these tailing piles can emit tens to hundreds of times more radon than assumed in this study, if not managed by current standards. While actual data from existing, well-run mines in Canada and Australia indicates that the assumption of the application of good practice is reasonable, numerical results were affected by these uncertainties. In addition, further uncertainties arise because some elements of the simplified fuel cycles adopted for this study are not yet fully established operationally.

The OSPAR Commission

The OSPAR Commission was established under Article 10 of the 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic, which replaced both the 1972 Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft and the 1974 Paris Convention for the Prevention of Marine Pollution from Land-based Sources. The Contracting Parties[2] are committed to taking all possible steps to prevent and eliminate pollution, and to take the necessary measures to protect the maritime area. Hence they seek to adopt scientific and technical research programmes, harmonise their environmental policies and strategies, and ensure the application of the best available techniques and the best environmental practice in their measures and programmes.

In 1998 the OSPAR Commission agreed on a strategy for radioactive substances. The objective of the strategy is to prevent pollution from ionising radiation through progressive and substantial reductions of discharges, emissions and losses of radioactive substances. The ultimate aim is to achieve concentrations in the environment near background values for naturally occurring radioactive substances, and close to zero for artificial radioactive substances.

The OSPAR Commission asked the NEA to perform this study in order to receive an independent technical input to its work. Since the NEA is well-recognised for its active programmes in radiation protection and waste management and has good experience in environmental assessment of radioactive discharges, it is well-suited to undertake authoritative scientific and technological studies in these technical areas.

ERA – Energy Resources of Australia Ltd., Australia

Mill tailings processing plant at the Ranger mine in Australia.

At its annual meeting in June 2000, the OSPAR Commission discussed and welcomed the NEA report entitled *Radiological Impacts of Spent Nuclear Fuel Management Options: A Comparative Study*.[3] The OSPAR Commission considered that this comprehensive and authoritative study was scientifically sound and based on internationally accepted methodology. The OSPAR Commission recognised that the study is a source of scientific knowledge and provides an important input to future OSPAR work on radioactive substances. The findings of the study will assist the Commission in the implementation of the OSPAR Strategy with regard to Radioactive Substances. ■

Notes

1. Man-Sieverts per gigawatt per year.
2. Current Contracting Parties are: Belgium, Denmark, the European Commission, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.
3. The report was published under the title *Radiological Impacts of Spent Nuclear Fuel Management Options: A Comparative Study*, ISBN 92-64-17657-8.

Y.-E. Jung, G. Alfors*

Electricity market deregulation and its impact on the nuclear industry

Electricity has traditionally been supplied in OECD countries by state-owned facilities, or state-protected monopolies with regulated pricing. More recently, however, several countries have deregulated their electricity markets, thus opening the door to competitive supply and pricing. Deregulation of electricity markets is a trend that is expected to be followed by many countries, and can have a significant impact on the future of nuclear power programmes.

Recognising the importance of deregulation in the electricity sector for nuclear power, the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) conducted a study that reviews and analyses its potential impact on existing and future nuclear power plants. The results of the study were recently published in a 62-page report entitled *Nuclear Power in Competitive Electricity Markets*.[1] The report is intended to assist policy makers and nuclear electric utilities in identifying potential impacts of deregulation on their particular situations and in planning for the future. It provides an overview of the status of electricity market deregulation, briefly reviews related aspects of privatisation of electricity supply, and examines generic and specific issues concerning nuclear power in a deregulated market.

In a deregulated, economically competitive market, power generators want to invest in profitable options that have relatively well-known technical, economic and political risks. In such a market, nuclear power might be at a disadvantage, since it may be considered to be encumbered with political risks (such as those arising from public opposition), technical risks related to waste disposal issues, and economic risks associated with liabilities arising from eventual decommissioning and dismantling of nuclear power plants. On the other hand, nuclear power does have important environmental advantages, in particular practically zero emissions of greenhouse gases, particulate and other atmospheric pollutants. All of these characteristics specific to nuclear power, both positive and negative, may be important in assessing the competitiveness of nuclear power in a deregulated electricity market. High capital cost, long construction time and the need for operation at high capacity factors are relevant to nuclear power, but they apply to certain other power technologies as well.

Impacts on current nuclear power plants

For existing nuclear power plants, the determining costs in a competitive market are the marginal costs of operation, i.e. operating and maintenance costs, including repair and refurbishment expenses. Plant investment costs are important to the company and stockholders, but they have already been paid and, therefore, can be considered as sunk costs with respect to economic decisions on the continued operation of a nuclear power plant. However, low electricity prices in a competitive market could pose a problem for nuclear electric

* *Mr. Young-Eek Jung was, at the time of writing, a consultant in the NEA Nuclear Development Division. He is presently Quality Assurance Manager, Kori Nuclear Power Plant, Korea Electric Power Corporation, Republic of Korea (e-mail: yejung@kepco.co.kr). Mr. Gunnar Alfors is Director of Production, Vattenfall AB, Generation, Asset Management, Sweden (e-mail: gunnar.alfors@generation.vattenfall.se).*

utilities, since they might, in some cases, not be high enough to cover both the marginal costs of operation and the investment costs of nuclear power plants which are still to be amortised.

The impact of electricity market deregulation on the performance of existing nuclear power plants is expected to be positive. Increased competition tends to bring about staff reductions, productivity increases, and availability improvements for nuclear power plants, the sum of which improves economic performance. In some OECD countries, nuclear power plants are already operating effectively in competitive electricity markets.

Capacity factors for US nuclear power plants have increased and the average nuclear generation cost has fallen in recent years, thus making nuclear power more competitive. US nuclear power plants are on average competitive in terms of production costs. In the United Kingdom, nuclear power plants have performed well under deregulation. Availability has improved and output has increased through the improvement of refuelling operations, reduction of outage times and the increase of power levels. Nuclear power plants in Finland and Sweden have been operating successfully within the Nordic electricity market, and Spanish, German and Dutch nuclear power plants have successfully performed in the competitive markets that were introduced at the beginning of 1998.

The cost of extending the life of a nuclear power plant is expected to be less than that of building a new power plant of any kind for base-load electricity supply. It is expected, therefore, that competition will increase the chances of life extension of effectively operated nuclear power plants.

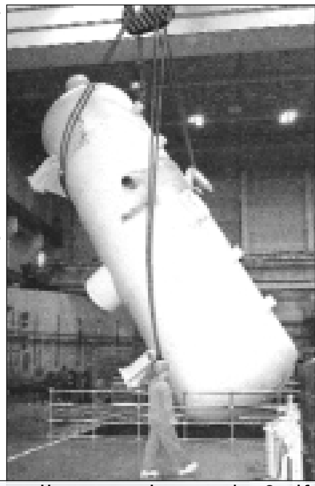
Nuclear facilities are generally well run, not only because of regulatory requirements but also because of economic incentives to be competitive with other energy sources. Some concerns have, however, been expressed that too much emphasis on economic competitiveness might have a negative impact on nuclear safety. Nevertheless, there are indications that economic competitiveness and safe operation are fully compatible, and that nuclear safety will not be affected negatively by electricity market deregulation.

Impacts on nuclear liabilities and insurance

Competition will put pressure on power generators to clearly identify and quantify future economic liabilities of nuclear power plants, and to include them in electricity prices. In competitive electricity markets, changes in regulatory requirements may also have to be considered. However, current liabilities of nuclear power and associated insurance schemes, whose costs are rather well established, are not likely to change in a deregulated market.

Decommissioning and waste management liabilities may be the most important of the various economic risks of nuclear power in competitive electricity markets. The associated concerns include accuracy of the estimated future costs, adequacy and availability of funding provisions to meet those costs, and stability of regulatory requirements that impact on the costs.

Energiewerke Nord GmbH, Germany



Dismantling operations at the Greifswald nuclear power plant in Germany.

There is a risk of shortfalls in funds for decommissioning and waste disposal in a competitive environment due to early plant closures, or not having a guaranteed volume of electricity for sale. Approaches for making up these shortfalls, if they arise, could include an increase in electricity prices, nuclear plant owners bearing the costs, or government funding.

Intensity of competition in the nuclear decommissioning and waste management market will increase and likely lead to reduced prices. Complete privatisation of waste management and decommissioning might be an outcome. Some governments already have assigned full responsibility for waste management and decommissioning to nuclear power plant owners, with the government retaining an overview and safety regulation role.

Iberdrola-Generación S.A., Spain

Aerial view of the Cofrentes nuclear power plant in Spain.

Impacts on the structure of the nuclear power sector

Competition is likely to have an impact on the structure of the nuclear power industry, including nuclear research activities. Ownership consolidation or cost-sharing partnerships of nuclear generators are expected in competitive markets in order to obtain the benefits of economies of scale and to achieve greater competitiveness in providing base-load electricity to customers. Nuclear vendors, equipment suppliers and engineering companies will consider global alliances and joint ventures in order to achieve a sharing of the risks in the new market environment and to obtain the benefits of synergy.

Restructuring of the nuclear fuel cycle industry is expected, including vertical integration of the front-end fuel cycle industries, vertical integration between front-end and back-end fuel cycles, and horizontal integration within each fuel cycle stage. In the back-end of the fuel cycle, traditionally run by state-owned companies, the emergence of private suppliers is expected. Renewed interest in international solutions for radioactive waste disposal can also be expected if cost pressure on the back-end of the fuel cycle increases.

Government funding of R&D for nuclear power has declined and this trend is expected to continue as electricity market deregulation increases. Utilities may tend to reduce R&D expenses in order to reduce costs and their efforts will likely focus on applied research aimed at performance enhancement. Although support from utilities for fundamental nuclear research activities will decrease, competition is likely to stimulate and reward initiative and innovation. The benefits of competition can include relief from some regulatory requirements that are not cost-effective, and a certain freedom to be innovative in ways that will lower cost. Competition is also creating opportunities for innovations in generating technology aimed at improving efficiency and reliability of power plants.

Impacts on new nuclear power plants and competitiveness

The competitiveness of new nuclear power plants has decreased substantially in recent years, particularly when compared to gas-fired plants. A recently published NEA/IEA joint study on *Projected Costs of Generating Electricity* concludes that nuclear power is seldom the cheapest option for plants to be commissioned by 2005-2010.

In a competitive market, it will be more difficult to predict electricity prices over a long period. Therefore, nuclear power plants, that require relatively longer construction times and higher investment costs, may have greater investment risks than other power plants. On the other hand, nuclear power has advantages of low fuel prices and lower risks of fuel price escalation.

Investment decisions for new nuclear power plants will depend upon expected profitability. The prospects for building new nuclear power plants in competitive markets are not clear. Although sound arguments can be made that justify building new nuclear power plants in these markets, decisions in many countries are likely to be influenced by public opinion, political will, and the pace of implementation of spent fuel and other high-level waste disposal facilities. Safety regulations and the ways in which they are implemented can also have a significant impact on nuclear generation costs and the competitiveness of nuclear power.

Other factors, such as the environmental benefits of nuclear power, could help in promoting its development. The competitiveness of nuclear power could also improve if external environmental costs, e.g. related to greenhouse gases and other pollutant emissions from coal and gas plants, were taken into account in market prices. In the longer term, stabilising the emission of greenhouse gases worldwide probably will require the use of nuclear power, since it is one of the least costly alternatives among non-carbon energy sources. ■

Note

1. *Nuclear Power in Competitive Electricity Markets* is available free of charge from the NEA Publications Section (neapub@nea.fr).

C. Viktorsson, B. Kaufer*

Regulatory effectiveness

Ensuring public health and safety has been and will continue to be the cornerstone of nuclear power regulation. The organisations, structures and processes of regulatory authorities have evolved over the past decades, with major changes occurring mainly due to events such as the Three Mile Island and Chernobyl accidents. More recently, however, factors other than events have begun to impact how regulatory authorities function.

Economic factors, deregulation, technological advancements and government oversight are some of the elements that are leading regulatory bodies to review their effectiveness. Seeking to enhance the present level of safety by continuously improving the effectiveness of regulatory bodies is seen as one of the ways to strengthen public confidence in the regulatory systems.

Regardless of the reason, most regulatory authorities in NEA Member countries have begun to realise that, in the near future, they will need to further improve their effectiveness. The first step taken by the NEA Committee on Nuclear Regulatory Activities (CNRA) was to hold in June 1999 an international workshop on "Developing and Measuring Regulatory Effectiveness". Nuclear regulators, industry representatives, and governmental and public experts participated. The main objectives were to improve knowledge about regulatory effectiveness in relation to nuclear installations, to establish a better understanding of how regulatory effectiveness may be measured, and to share experience in enhancing regulatory effectiveness.

* *Mr. Christer Viktorsson is Deputy Director-General, Office of Reactor Safety, Swedish Nuclear Power Inspectorate (SKI), Chairman of the CNRA Task Group on Regulatory Effectiveness and a member of the CNRA Bureau (e-mail: christer.viktorsson@ski.se). Dr. Barry Kaufer is a member of the NEA Nuclear Safety Division (e-mail: barry.kaufer@oecd.org).*

From left to right: G. Frescura, Head of the NEA Nuclear Safety Division (NSD), B. Kaufer, NSD member, J. Laaksonen, Chairman of the CNRA and C. Viktorsson, Chairman of the CNRA Task Group on Regulatory Effectiveness.

A key conclusion was that more effort is needed regarding communication issues and how the regulator can best establish and maintain a dialogue with the public. The need to be both credible and open while maintaining a non-advocacy role was stressed by many of the participants. The issue of maintaining a dialogue with the public was addressed in a second international workshop organised by the CNRA in November 2000 on "Investing in Trust: Nuclear Regulators and the Public". Other issues such as internal quality assurance, the continuing need for international exchanges among regulators to ascertain whether regulatory effectiveness can actually be measured and provide meaningful results, and the concept of regulatory independence were also regarded as significant issues.

In order to address these and other issues, the CNRA set up a task group of senior-level regulators to take an in-depth look at the basic concepts underlying regulatory effectiveness, advances being made and future requirements. Of utmost importance in this work was the need to establish a consensus on what regulatory effectiveness actually means. A key attribute of any effective organisation is its ability to maintain competence.

The group concluded that the regulatory body is effective when it:

- ensures that an acceptable level of safety is being maintained by the regulated operating organisations;
- develops and maintains an adequate level of competence;
- takes appropriate actions to prevent degradation of safety and to promote safety improvements;
- performs its regulatory functions in a timely and cost-effective manner as well as in a way that ensures the confidence of the operating organisations, the general public, and the government; and
- strives for continuous improvement in its performance.

These objectives can only be accomplished, however, if the regulator has the necessary authority and resources.

Consideration was also given to how effectiveness and efficiency are defined in relative terms. It was noted that in many instances these terms are used interchangeably, but they actually have quite different meanings. Participants generally agreed that the following simple definitions are adequate:

Regulatory effectiveness means "to do the right work", whereas regulatory efficiency means "to do the work right".

These definitions imply that one has to analyse effectiveness first, based on well-defined mission objectives of the regulatory body. Having done that, one can then work to improve efficiency. Setting goals that are possible to follow up is very important.

Having established a clear definition, the group has moved forward in several areas. One key concept is how to model regulatory effectiveness to provide a means for both assessing and measuring regulatory effectiveness and efficiency. Several countries have or are developing effectiveness models and a model was developed for assessing and measuring regulatory efficiency and effectiveness. This model, which is based on those primarily used for managing the safety of nuclear installations and the quality of the regulatory body, is depicted in Figure 1. It includes conventional management wisdom as well as modern business practices adapted to governmental organisations.

It is important to note that priorities within a specific block may differ between countries for each of these items. The task group is proceeding

Figure 1: A model for assessing and measuring regulatory efficiency and effectiveness

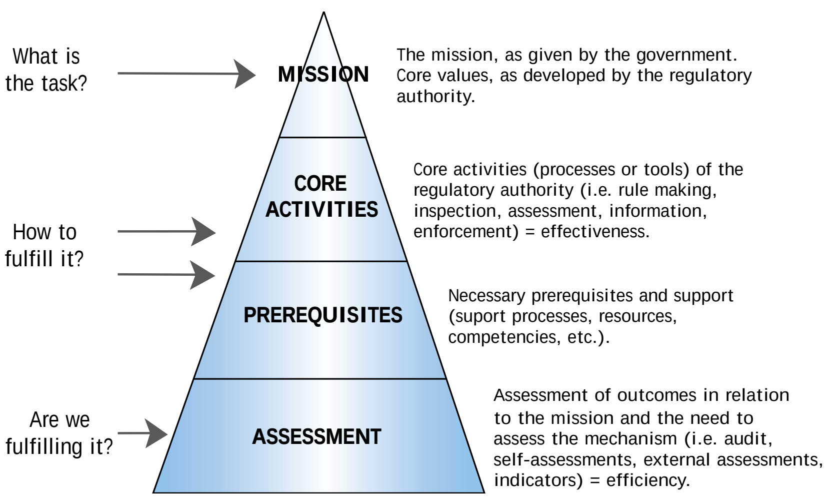
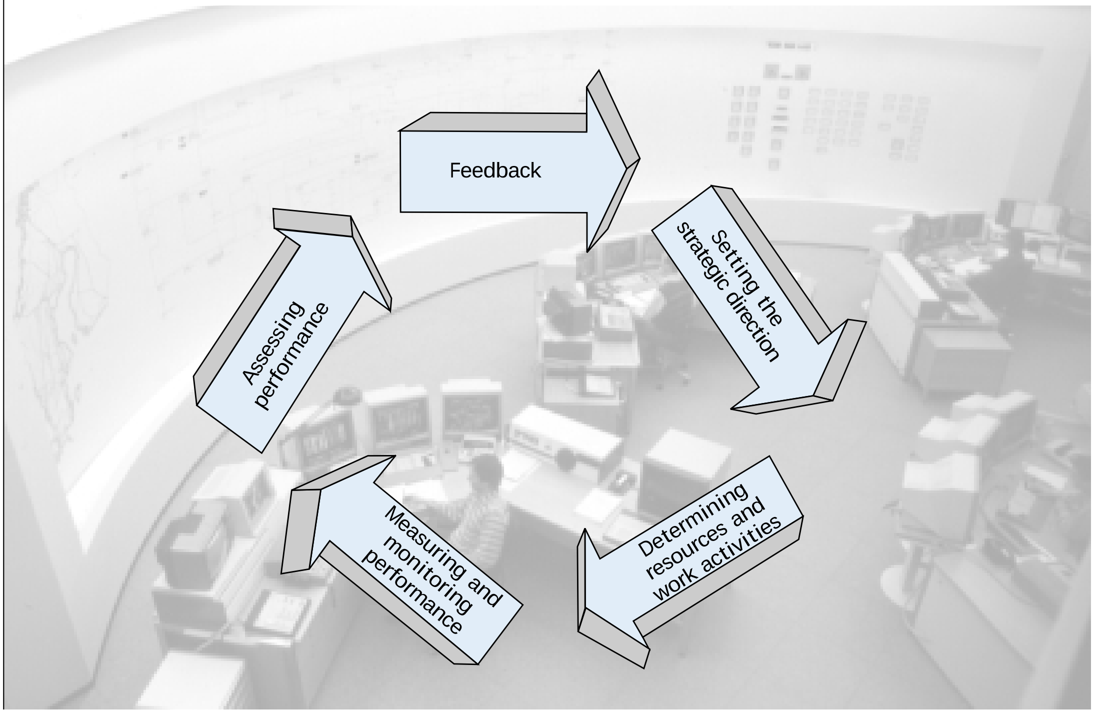


Figure 2: The concept of the "learning organisation"



with several case studies applying this model to their own specific situations.

Another important task is to establish a means of quantifying performance through the use of sets of indicators. While the calculation of an indicator value, such as radioactive releases, may be simple, the interpretation of trends can be complex. The group is looking into indicators that are simple, useful, relevant and can be used to measure and report regulatory effectiveness.

Participants felt that the dynamics of an organisation need to be stressed, in particular the need for continuous improvement in performance. The concept of the "learning organisation" was also emphasised and supported. Steps include: identifying issues; setting objectives to solve the problems; designing solutions; implementing solutions; evaluating solutions; tracking success; identifying issues, etc. Figure 2 shows the basic steps towards continuous improvement.

Finally, regulatory organisations are increasingly looking at the quality of the work they perform through quality assurance programmes. The adoption of quality assurance by the regulatory body has the potential to contribute both to regulatory effectiveness (i.e. doing the right work), and to regulatory efficiency (i.e. doing the work right). Quality assurance for the regulator implies having the right systems covering all aspects of regulatory work, applying those systems, checking their application through a feedback and review process, improving the systems over time and adhering to them.

As Dr. Agnes J. Bishop, President of the Canadian Nuclear Safety Commission noted "...it is often difficult to attribute good industry performance to the actions of the regulator. Is the industry doing well because of the regulator, or despite the regulator? Is a particular licensee performing well because it is a good operator, or because it is well-regulated?" The continually improving performance of the industry along with results of numerous recent reviews show that regulators are effective and efficient; but Dr. Malcolm Knapp, former Deputy Executive Director at the US Nuclear Regulatory Commission, has also pointed out that "our efforts towards regulatory effectiveness are very much a work in progress".

The CNRA Task Group on Regulatory Effectiveness is continuing its work. A comprehensive report on "Improving Regulatory Effectiveness" will be issued by the CNRA in 2001. ■

D. Metcalfe, C. Pescatore, J. Andersson, T. Sumerling*

Regulatory reviews of safety assessments of deep geologic repositories

The safety of underground repositories for radioactive waste must be demonstrated to the satisfaction of the implementing organisations, the regulatory bodies, the wider scientific and technical community, political decision makers and the general public. In particular, convincing arguments are required that engender confidence in the safety of the proposed repositories, taking into account the uncertainties that inevitably exist in forecasting the behaviour of complex natural and engineered systems over long periods. During the development of repositories, integrated performance assessments (IPAs) are normally carried out at key stages by the implementing organisation and reviewed by the regulatory authorities.

The NEA "IPAG-2" study was carried out in order to examine the experience of peer reviews of IPAs, and especially reviews performed in support of regulatory assessments, from both the implementer and regulator points of view. Seventeen organisations, representing a wide spectrum of national programmes and stages in repository development (see table), participated. The results of the study were published this year under the title *Regulatory Reviews of Assessments of Deep Geologic Repositories: Lessons Learnt*. Summary observations and recommendations of the study are presented below.

The conduct of reviews

Dialogue between the implementer and regulator

Dialogue is important and of benefit to both implementers and regulators at all phases of the performance assessment preparation and review process. Implementers and regulators should discuss approaches for maintaining a dialogue that benefits the process and, at the same time, preserves independence. Making the written records and documentation from the dialogue available to the public could enhance the overall credibility of the process and public acceptance.

IPAs and stepwise repository development

A stepwise process is necessary to develop a repository concept and to prepare incrementally a convincing case for long-term safety and compliance with regulatory requirements. Such a process is consistent with the legal and regulatory frameworks in most countries. The implementer and regulator should establish a structured framework for IPA contents and reviews early in a repository programme.

* *Mr. Doug Metcalfe is the Chairman of the NEA Working Group on Integrated Performance Assessments of Deep Repositories (IPAG) (e-mail: metcalfe@cnsc-ccsn.gc.ca). Dr. Claudio Pescatore is a member of the NEA Radiation Protection and Radioactive Waste Management Division (e-mail: pescatore@nea.fr). Dr. Johan Andersson (e-mail: johan.andersson@streamflow.se) and Mr. Trevor Sumerling (e-mail: trevor@sam-ltd.decom.co.uk) are consultants to the NEA.* *The authors acknowledge the contribution of all IPAG-2 participants to the success of the initiative. This article illustrates the results of their joint efforts.*

Integration of performance assessment and repository safety

There are two broad aspects to making a safety case for a repository. The first is the selection of a site and development of a design that possesses "intrinsic or inherent quality" with respect to safety, e.g. the site displays long-term geological stability and the engineered barriers use materials with well-understood properties. The second is provided by the IPA itself, which involves the acquisition of information relevant to the repository site and design, and the development and application of methods and models to assess this information. While the IPA provides a vehicle that illustrates why a particular site and design should function so as to provide the required level of safety, it is the quality of the selected site and design that provides that safety. A safety case should clearly and convincingly document the factors that give confidence in the intrinsic quality of the selected site and design, as well as the technical demonstration of safety provided by quantitative PA analyses.

Independent assessment or calculations by regulators

It is the responsibility of the implementer to produce a complete analysis of repository safety, but independent calculations by the regulator can

Organisations participating in IPAG-2; the IPAs reviewed; and the purpose of the IPAs and reviews

Implementer	Reviewer	IPA	Purpose of the IPA and review
Ontario Hydro[1], Canada	AECB, Canada	AECL EIS on the concept for disposal of Canada's nuclear fuel waste.	Safety and acceptability of AECL's concept for disposal. A federal review panel made recommendations on the future steps to be taken with respect to the management of nuclear fuel waste in Canada.
NRI, Czech Rep.		EIA documentation.	Feedback to R&D at an early stage of development.
VTT[2], Finland	STUK, Finland	TVO-92 and TILA-96 on spent fuel disposal in crystalline rock.	Background for selection of sites for more detailed investigation. Feedback to R&D.
BfS, Germany	GRS, Germany	Konrad repository for LLW and ILW.	Part of the license application of the repository.
PNC[3], Japan	ACRWM of AEC[4], Japan	H3 study: updated knowledge on Japan's geologic environment, the technology of geologic disposal and the performance assessment of the multi-barrier system.	A basis for further research and development with the objective of confirming scientific and technical feasibility of the geologic disposal concept in Japan.
SKB, Sweden	SKI, Sweden	SFR repository for operational waste (LLW and ILW).	To permit full-scale operation. (Operational license had stipulations.)
Nagra[5], Switzerland	HSK, Switzerland	Repository for LLW and ILW at Wellenberg.	Application for general license (site selection and general outline of project) and Cantonal concession for the use of the underground.
UK Nirex, UK	UKEA, UK	NR 337 study, a preliminary assessment of the post-closure performance of a potential deep waste repository at Sellafield.	HMIP (now UKEA) undertook a review of the Nirex documents to test and develop its regulatory assessment capabilities.
DOE/WIPP, USA	US EPA[4], USA	Compliance Certification Application (CCA) for the WIPP repository for TRU-waste.	The IPA served as the basis in the CCA for demonstrating compliance with the quantitative requirements of the EPA's regulations, 40 CFR 191 and 194.
DOE/YM, USA	USNRC, USA	TSPA-95 evaluation of the potential Yucca Mountain repository.	Aid regulator and applicant to prepare for licensing. TSPA-1995 focused on components determined by previous analyses to be most significant.

1. The IPA was prepared by AECL. 2. On behalf of Posiva, the Finnish implementer. 3. "Implementer" role through the year 2000 only. 4. Did not participate in IPAG-2. 5. On behalf of GNW.

benefit both the regulator and the review process. Some regulators consider that having and using an independent PA capability is also important for establishing confidence in the regulator on the part of the public and other stakeholders.

The safety case

Technical issues and concerns

Although many technical issues are site- or design-specific, responses to the IPAG-2 questionnaire revealed some generic concerns. Important examples are insufficient integration of site investigation and integrated PA programmes and results, the adoption of potentially non-conservative assumptions in modelling, and insufficient analysis of potential evolution scenarios and their attendant uncertainties. The fact that these concerns were common to several reviews indicates that performance assessment methods may still need improvement in these areas.

Multiple lines of reasoning

Multiple lines of reasoning are valuable in building confidence in the results of an IPA, although there are different opinions on their importance in developing the overall safety case. Some regard the main technical analysis as the essential aspect in demonstrating regulatory compliance, with other lines of evidence providing only ancillary support. Others consider that alternative lines of reasoning should play a more important role, especially in view of the need to provide convincing demonstrations of safety to a range of audiences. Few existing IPAs have made use of multiple safety indicators, but this may be a fruitful area for continued international work.

Variety of assessment techniques

Differences in opinion remain on the relative values of various modelling and calculation techniques and approaches in IPAs. It is accepted, however, that there is a role for a variety of techniques and approaches in performance assessment, and that these can be used in a complementary manner. Some IPAs may focus on particular techniques for pragmatic reasons but, in general, the intent has not been to exclude other approaches.

Qualitative and quantitative information

Scientists and engineers sometimes view qualitative, or "soft", information as of less value than "hard", quantitative information. Qualitative information is, however, essential in long-term safety assessments, and thus it would be useful to explore ways to better use this information. Rather than viewing qualitative information as being inferior to quantitative information, it should be considered as a different type of information that can be used for different purposes in an IPA. Consideration should be given both to presenting qualitative arguments and information in the safety case, and to increasing their value in the decision-making process.

Meaning of the multi-barrier system

The multi-barrier concept is one of the key bases for the long-term safety of deep geologic disposal systems, and is important for overall confidence building. Non-technical stakeholders may consider, however, that the realisation of the multi-barrier concept in a repository system falls short of their expectations if they start from the premise that barriers can and should be completely redundant and independent. Further work is necessary to develop a definition of the multi-barrier concept that describes it in the context of what is achievable and necessary in a deep geologic disposal system.

Traceability and transparency

The IPAG-2 study concludes that IPAs prepared for licensing purposes need to be traceable, transparent, reproducible and publicly available.[1]

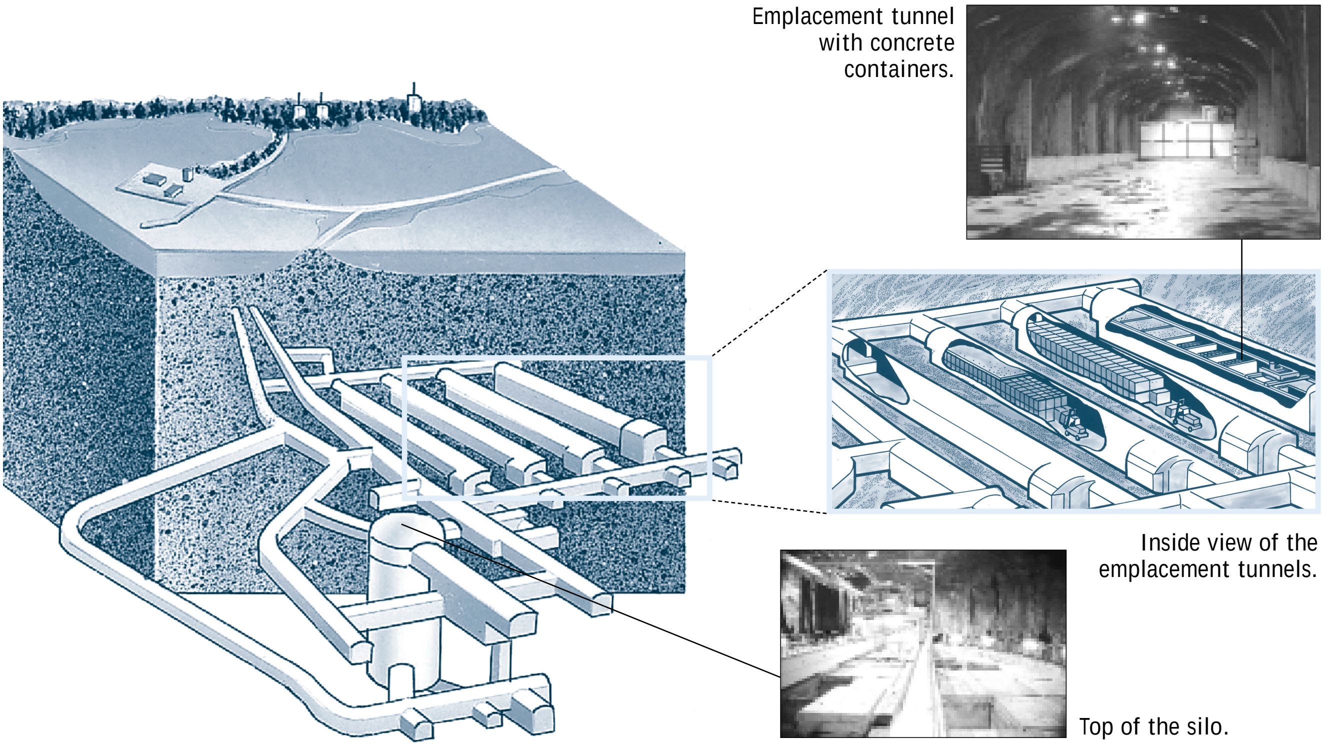
Achieving the desired level of traceability and transparency for regulators

Regulators and their technical reviewers are the primary audiences of most IPAs. However, many regulators continue to have difficulties tracing the results and logic of these assessments, even though implementers have increased efforts in building traceability into IPAs. At least one aspect of developing traceability and understanding between the implementer and regulator is consistency of the methods used and documentation structure and style.

Implications for other stakeholders

Other, non-technical stakeholders also review IPAs, and have different needs with regard to traceability and transparency. These stakeholders generally approach IPAs from different viewpoints and make judgements using different value

The SFR repository in Sweden for operational waste (LLW and ILW)



SKB, Sweden

systems. Interactions with these stakeholders are becoming increasingly more important as potential repository sites are selected, and regulatory decisions are made for those sites. The NEA should explore in greater detail the approaches and techniques used for addressing the needs of the public and other non-technical stakeholders in IPAs.[2]

Regulatory guidance

Regulatory guidance should clearly state the requirements and expectations for demonstrating compliance with regulatory criteria in order to define the task to be undertaken by the implementer, as well as enhance transparency and credibility of the review process. Regulatory guidance may be developed in a stepwise manner, consistent with the stepwise development of national repository programmes, and should be reviewed at strategic points to ensure its continuing applicability.

International consistency is desirable in regulatory guidance, and organisations such as the IAEA, the ICRP and the NEA contribute significantly to such harmonisation. The importance of national factors should not be overlooked, however, and it is important that regulatory guidance reflect the concerns of stakeholders.

Conclusions

The IPAG-2 study was the first of its kind to survey and compare international experience of peer reviews of integrated performance assessments (IPAs) of deep geologic repositories for radioactive waste. It was based on real experience and documents, representing both the reviewer and reviewee points of view. Important lessons were learned during the study that will be useful for NEA Member countries in developing repositories. The information obtained can help improve IPAs, thus facilitating their review and ultimately helping improve confidence in the feasibility and safety of the project. Overall, the study underlined the importance of dialogue across institutional and cultural boundaries. ■

Notes

1. See also *Lessons Learnt from Ten Performance Assessment Studies*, NEA, 1997.
2. A new NEA initiative, the Forum on Stakeholder Confidence, has since been launched (see page 6).

E. Sartori, B.-C. Na*

Use of mixed-oxide fuels

There are two main types of fuel used in nuclear power plants: uranium-oxide (UO_2) fuel and mixed-oxide (MOX) fuel. The burning of UO_2 fuel produces plutonium, which in spent fuel can be directly disposed of as nuclear waste or, after reprocessing, can be used in MOX fuel. One of the advantages of recycling is to limit the total amount of plutonium being produced. Surplus plutonium from defence programmes, which has grown to 68 metric tons in the framework of disarmament agreements, can also be recycled in MOX fuel.

Several OECD countries use plutonium recovered from spent fuel in the form of MOX fuel in existing power plants. In France, 16 pressurised water reactors (PWRs) utilise MOX fuel and it is planned to introduce MOX fuel progressively in 4 more in coming years. Germany and Switzerland have experience in using MOX both in PWRs and boiling water reactors (BWRs). France and Japan also have experience in using MOX fuel in fast reactors and advanced thermal reactors. All of these countries report that the operation of existing reactors with MOX fuel is satisfactory and that MOX core behaviour is equivalent to that of conventional UO_2 core behaviour from the standpoints of operation and safety.

Specificities of MOX fuel and limitations of its use

Plutonium has been used in the current generation of reactors for many years, and its technology is well-understood. This practice is, however, still limited.

Because plutonium strongly absorbs thermal (soft) neutrons, the neutron spectrum is depleted in that energy range and thus becomes harder in MOX-fuelled systems compared with UO_2-fuelled systems. This leads, in turn, to a reduction of (safety) control material effectiveness. In the case of a voiding of the reactor coolant, the fast neutrons from fission find insufficient moderator materials to slow them down and the neutron spectrum maintains an additional hard component, leaving a relatively small thermal neutron population. Therefore, the capture of neutrons by the non-fissile plutonium isotopes (i.e. ^{240}Pu and ^{242}Pu) diminishes. The system thus becomes more reactive and these isotopes contribute to the degradation of the coolant void reactivity coefficient, which affects the safety margins. In addition, an increased proportion of plutonium content in the reactor core diminishes the delayed neutron fraction, an important parameter for reactor operation. In other words, the higher the plutonium content and the poorer the plutonium quality (i.e. containing smaller fractions of fissile plutonium), the smaller the safety margins.

In the multi-recycling of plutonium in PWRs, the quality of plutonium degrades as there is an accumulation of non-fissile plutonium isotopes (^{240}Pu and ^{242}Pu) and the concomitant production of minor actinide isotopes (e.g. neptunium, americium, curium). This reduces the availability of neutrons for the fission process and would force the use of more highly enriched plutonium fuels. For these reasons, current plutonium recycling in PWRs is limited to one or two generations.

The power level of MOX assemblies in current core loading is higher than that of UO_2 assemblies, and the difference between them is called power peaking. MOX assemblies are designed to minimise power peaking.

All these specific phenomena related to the use of plutonium in light water reactors (LWRs) do not cause any problems for the safe and effective operation of reactors using current technology. Loading of plutonium assemblies in current PWR cores is recommended up to 30% of the total to avoid any problems which might be caused by power peaking or degradation of safety parameters.

* *Dr. Enrico Sartori (e-mail: sartori@nea.fr) and Dr. Byung-Chan Na (e-mail: na@nea.fr) are members of the NEA Nuclear Science Section.*

Current NEA activities

More advanced techniques being investigated in Member countries for managing the stockpile of plutonium are currently being reviewed by the NEA.

If plutonium is to be used up faster than the current rate, multiple recycling and high burn-up of plutonium in LWRs is an obvious and convenient option. In order to introduce this option the computational tools and associated basic data need to be verified and validated to test their predictive power and the confidence level that can be placed in them. In addition, possible improvements in nuclear data and physics modelling methods should be identified. For this purpose, the NEA Working Party on the Physics of Plutonium Fuels and Innovative Fuel Cycles (WPPR) has in recent years commissioned theoretical physics benchmarks relating to multiple recycling of plutonium in PWRs and BWRs, and burning/multi-recycling of plutonium in fast reactors.[1]

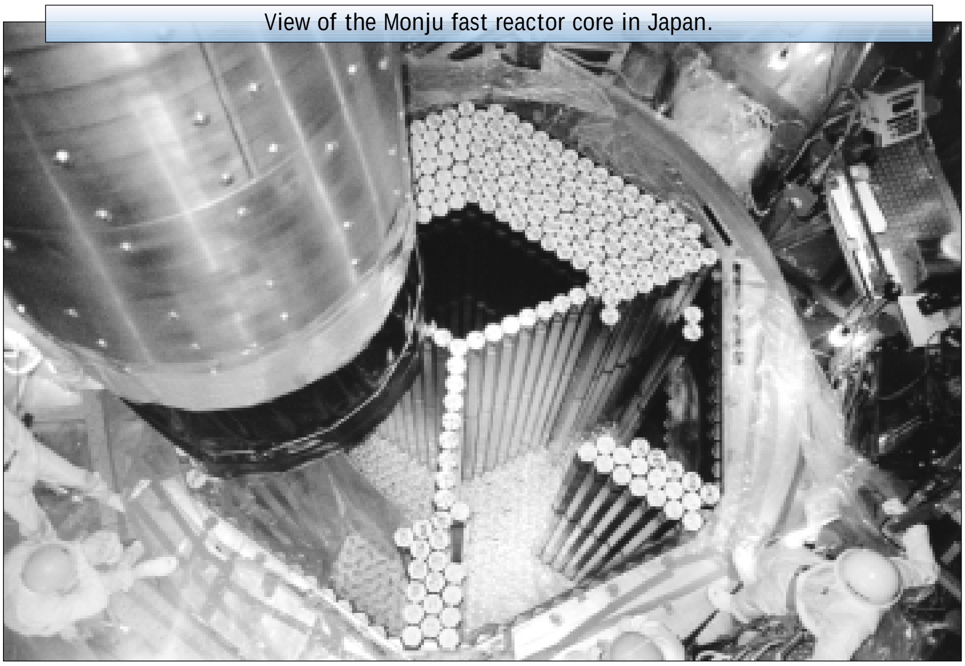
In the PWR benchmarks, various realistic and more challenging situations were considered. Since the first benchmark, considerable progress has been made in nuclear data and calculational methods. The discrepancies caused by the different nuclear data and methods applied to multi-recycling in PWRs are generally within reasonable bounds. Nevertheless, multi-recycling plutonium in conventional PWRs would be limited to the second generation, mostly due to a possible positive void coefficient. Beyond that, it would be necessary to develop advanced PWR concepts such as highly moderated reactors and uranium-free reactors using materials like inert matrices.

Although the motivating factor for PWRs, namely the consumption of plutonium arising from reprocessing, applies to BWRs, MOX utilisation in BWRs is not as widespread. One reason for this is that the nuclear design of BWR cores is more complex than that of PWRs, due to the presence of the water gaps between BWR assemblies, water channels inside assemblies and the complex spatial distribution of steam void. Accordingly, in 1998 the WPPR conducted a physics code benchmark test for a BWR assembly.

In fast reactors, the physics of plutonium recycling is quite different from that in LWRs. Taking advantage of the good neutron economy in fast reactors, they can be used for recycling plutonium (even of low quality) and in restricting the production of, or even in burning, minor actinides at the same time. Moreover, once the problem of surplus plutonium stocks will have been resolved, fast reactors can become conventional plutonium breeders just by adding axial and radial breeder blankets.

In the fast reactor benchmark, the fuel cycle performance and toxicity behaviour of a metal-fuelled fast burner was evaluated in a closed fuel cycle for cores in which plutonium burning achieved ranges from half the initial inventory

View of the Monju fast reactor core in Japan.



PNC, Japan

JNC, Japan

Fugen nuclear power plant in Japan, which uses MOX fuel on a full core scale.

to maintaining it (conversion ratio between 0.5 and 1.0). The nuclear and safety characteristics of these systems were also analysed. The results of the study indicate that low-conversion fast reactors are practicable for plutonium multi-recycling and can significantly reduce the radiotoxicity of waste products destined for final disposal.

Many improvements and clarifications in nuclear data libraries and calculation methods have been achieved from the results of theoretical benchmarks performed. But, it was felt that there was a need to relate these findings to data from experiments. The two-dimensional VENUS-2 MOX core experimental data have been released for this purpose by SCK•CEN, Mol, Belgium. The VENUS facility is a zero power critical PWR mock-up. This benchmark exercise was a blind test, and hence the measured fuel pin power values at specified VENUS-2 locations were not revealed to the participants. Ten institutions worldwide participated in the benchmark. The calculated pin power distributions using combinations of codes and methods were compared with the experimental results. In general, the calculated power levels in the fuel pins are slightly higher than the measured values for the MOX regions and lower for the UO_2 regions. Core design calculations for commercial cores with MOX fuel should take account of the effect. The full results are published in an OECD/NEA report.[2] Furthermore, a series of experimental measurements in the KRITZ 2 reactor at Studsvik, in Sweden, has been released. These experiments were performed at temperatures up to 245°C and fission rate distributions were measured. The experimental results will be used for a benchmark calculation which would allow a thorough investigation of temperature effects.

Recently, the USA and the Russian Federation have declared portions of their weapons-grade plutonium stockpiles surplus to their national defence needs. This fissile material now requires disposal. Countries in Europe and Japan have experience in using plutonium as MOX fuel in civil nuclear reactors. Such experience is relatively scarce or dated in countries possessing excess weapons plutonium. International co-operation and sharing of technical knowledge on MOX physics and fuel performance in reactors will be greatly beneficial for speeding up the disposal process. Therefore, a workshop on the “Physics and Fuel Performance of Reactor-based Plutonium Disposition” was held in Paris in September 1998 to exchange information on experience and ongoing research activities relevant to reactor-based, weapons-grade MOX fuel issues. A Task Force on Reactor-based Plutonium Disposition (TFRPD) was then set up in 1999 to deal with the status and trends of reactor physics, fuel performance, and fuel cycle issues related to the recycling of weapons-grade plutonium in MOX fuel and regulatory requirements for this fuel as well. The Task Force concluded that licensing issues for loading MOX assemblies are, in general, of the same nature as those for loading new types of UO_2 assemblies.

Concluding remark

Although the current technology for using plutonium in LWRs is well-established, the quantity and the quality of plutonium which can be used in present systems are limited. Therefore, the efficiency of plutonium use as nuclear fuel requires further improvement. Benchmark studies performed so far confirm that the fast spectrum systems such as fast reactors have an advantage not only for plutonium utilisation in multi-recycling, but also for the reduction of the toxic potential introduced into the waste stream. More recently, the potential of accelerator-driven, fast spectrum, sub-critical systems for such applications has been highlighted, and numerous R&D activities on these systems are ongoing in national programmes as well as in international organisations. As regards long-term energy resources, fast spectrum systems used in the closed fuel cycle would enable a better exploitation of uranium resources over many centuries.

Notes

1. “The Physics of Plutonium Fuels - A Review of OECD/NEA Activities”, *Nuclear Technology*, Vol. 131, September 2000, pp. 385-394.
2. “Benchmark on the VENUS-2 MOX Core Measurements”, OECD/NEA report, NEA/NSC/DOC(2000)7.

L. Carlsson*

The international common cause failure data exchange

The International Common Cause Failure Data Exchange (ICDE) project was established by several NEA Member countries in order to encourage multilateral co-operation in the collection and analysis of data relating to common cause failure events. Common cause failure events occur when two or more structures, systems or components within a nuclear power plant fail to operate due to a single specific event or cause. Countries participating in the project include Canada, Finland, France, Germany, Spain, Sweden, Switzerland, the United Kingdom and the United States. Other countries have recently expressed their interest in participating.

The project was initiated in August 1994 in Sweden, and initially supported financially by SKI, Sweden and GRS, Germany. As of April 1998, the project is formally operated by the OECD/NEA Working Group on Operating Experience.

Objectives and scope of the ICDE Project

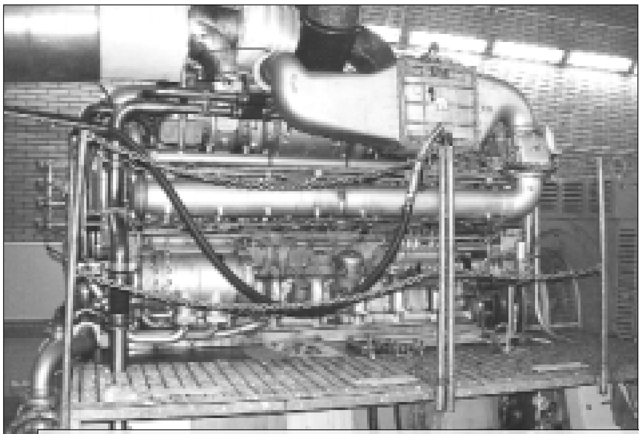
The specific objectives of the ICDE project are:

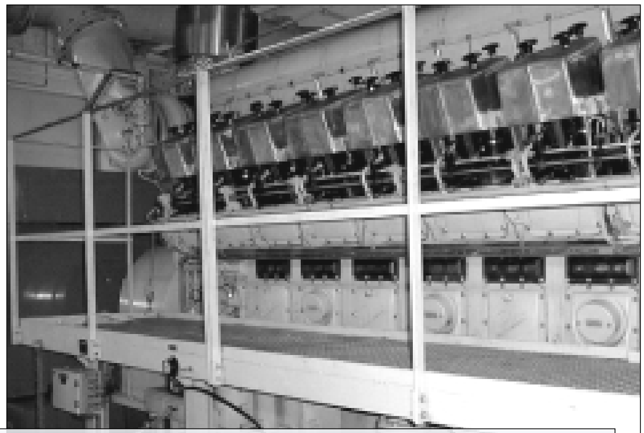
- to collect and analyse common cause failure (CCF) events over the long term so as to better understand such events, their causes, and how to prevent them;
- to generate qualitative insights into the root causes of CCF events, which can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences;
- to establish a mechanism for the efficient feedback of experience gained on CCF phenomena, including the development of defences against their occurrence, such as indicators for risk-based inspections.

The ICDE Project has been designed to include all possible events of interest, including complete, partial and incipient CCF events, called “ICDE events” for this purpose. ICDE events have been defined as the impairment of two or more components (with respect to performing a specific function) that occurs over a relevant time interval and is the direct result of a shared cause. The project covers the key components of the main safety systems, such as centrifugal pumps, diesel generators, motor-operated valves, power-operated relief valves, safety relief valves, check valves, reactor protection system circuit breakers, batteries and transmitters. These components have been selected because several probabilistic safety assessments have identified them as major contributors to risk in the case of common cause failures. In the long term, a broad basis for quantifying CCF events could be established should participating organisations wish to do so.

The data collected in the clearinghouse database are password-protected and are only available to ICDE participants who have provided data. Procedures for protecting confidential information have been adopted. The co-ordinators in the participating countries are responsible for maintaining proprietary rights.

* *Dr. Lennart Carlsson is a member of the NEA Nuclear Safety Division (e-mail: lennart.carlsson@oecd.org).*


Barsebäck Kraft, Sweden


Ringhals, Vattenfall AB, Sweden

Diesel generators at Barsebäck and Ringhals nuclear power plants in Sweden.

Data collection and insights gained

The project has developed guidelines for the collection of common cause failure data. However, specific information is needed for each component group. In order to define component boundaries and other characteristics, a trial data collection is carried out. Component-specific guidelines are then finalised and the data exchange can take place. An important activity for the clearinghouse is quality control according to the guidelines. Each data record is stored in the participating country data replica and sent to the clearinghouse to be merged with other data. The final step in one data exchange is to write a report to the NEA Committee on the Safety of Nuclear Installations (CSNI) on qualitative insights gained from the data exchange. Examples of insights are given below for diesel generators.

Diesel generators

Nuclear power plants have on-site emergency power systems to cope with the loss of station power. Usually the source of emergency power comes from redundant diesel generators. The generators are redundant to the extent that they do not all need to work in order to provide the safety function. The events in which there is common cause failure for all of the diesel generators are of most concern. Statistics were collected for a period of five years and are summarised in the table.

Complete CCFs are mostly detected by testing. The largest set of complete failures occurs in the fail-to-start group.

The most likely root cause is design, manufacture, or construction inadequacy (43%). Most of the design faults are in the instrumentation and control subsystem, which contributes a significant portion of its CCFs to the fail-to-start mode.

Human performance is also worth mentioning. The instrumentation and control subsystem is especially vulnerable to CCF due to the human factor. This is related to the complexity and the function of instrumentation and control. Procedural, maintenance and operational errors all contribute to this root cause. For complete CCF events, human errors are the largest contributor.

Conclusions

The procedure for collecting common cause failure and exchange data has been established with the ICDE project. The basis for better understanding common cause failure events is now available to participating organisations. It has already been possible to conclude that human performance plays an important role for most of the identified complete CCFs. Data exchange and analysis can provide input to research and help promote changes in operating procedures so as to enhance the reliability of safety systems. More countries should therefore be encouraged to participate in the exchange of common cause data.

Summary statistics for diesel generators

Event reports received	Total	Degree of failure observed		
		Partial	Almost complete	Complete
ICDE events:				
Failure to start	45	22	11	12
Failure to run	61	46	10	5
Total	**106**	**68**	**21**	**17**

News briefs

Radioactive waste and sorption in natural systems

All countries operating nuclear power plants devote substantial resources to developing safe and final solutions for the disposal of waste, particularly high-level radioactive waste. The solution currently preferred by specialists consists in the emplacement of wastes in a deep and stable geological setting (granite, clay, tuff, salt formations) that has remained virtually unchanged for millions of years. The aim is to ensure that such wastes will remain undisturbed for the few thousand years needed for their levels of radioactivity to decline to the point where they no longer represent a danger to both present and future generations.

As a general rule, the natural security afforded by the geological formation chosen is enhanced by means of additional precautionary measures: wastes are immobilised in an insoluble form, in blocks of glass for example, and then placed inside corrosion-resistant containers; spaces between waste packages are backfilled with highly pure, impermeable clay; and the repository may be strengthened by means of concrete structures. These successive barriers are mutually reinforcing and together ensure that wastes can be contained over the very long term.

The safety authorities responsible for licensing the construction of waste repositories require that the operator perform a detailed analysis of what might happen were an unforeseen series of events to occur and, in particular, if the integrity of the containment system were to be breached, for example by an earthquake opening up fractures in the rock formations and resulting in the gradual flooding of the repository with groundwater. There are two major processes that need to be taken into account in the event of water entering into contact with waste products, namely, the leaching of radioactive products and the subsequent transport of radionuclides by the water through the various barriers mentioned above (i.e. the container, the layer of clay surrounding the waste packages and the geological formation containing the repository) to the biosphere. The leaching of radioactive products into the water would be an extremely slow process since wastes are immobilised in a form that is, in principle, insoluble; the barriers that the products would subsequently have to penetrate would considerably delay the physical movement of contaminated water; and, in addition, these barriers would in many cases be capable of partly removing the contamination from the water. This decontamination capability is attributable to a number of processes, the most important of which is referred to by scientists as "sorption".

Sorption is a major factor in the assessment of the safety of a radioactive waste repository. It is therefore important to develop mathematical models capable of predicting the level of sorption, as well as the degree to which it might vary, in the event of leakage from a repository.

To be credible, a model must obey the laws of science and chemistry and must be based on a

Geological and hydrogeological exploration of a mesozoic clay formation (opalinus clay) in Benken, Switzerland.

Comet Photo, NAGRA, Switzerland

large volume of experimental evidence. However, sorption is generally a complex phenomenon that cannot readily be investigated and that is influenced by a wide range of parameters. The precise conditions that prevail at great depths below the earth's surface are not easily reproducible in the laboratory, and identifying the chemical species present in the vicinity of the absorbing surface requires extensive investigative facilities. Measuring sorption is, therefore, a long and costly exercise. For many years scientists contented themselves with measuring the "overall" level of sorption in simple systems, the results of which were then extrapolated to the conditions actually prevailing in the environment.

The increased interest now being taken in ecological issues, and, in particular, the growing awareness of the scale of the problems posed by industrial pollution with regard to the management of drinking water supplies, have spawned a large number of university research programmes in recent years. Major progress has been made in basic research into sorption processes. Many of the results that have been obtained can be applied to the particular problems of concern to the nuclear industry. At present, scientists have a good understanding of the processes at work in simple chemical systems and scientifically verifiable models have been developed which can be used to produce credible extrapolations of experimental results and predict how sorption will vary in response to changes in the physical and chemical conditions in a given system.

The problem facing safety analysts in the case of radioactive waste repositories is the complexity of natural systems. Since scientists know how to model the sorption of a chemical compound by a single mineral, the next logical step is to consider natural rocks composed of several different minerals; that is to say, to develop a model for all the different types of complex systems that can occur in nature.

Several modelling approaches, and even a number of models, have been proposed as part of an initial description of sorption in natural complex systems. In view of this diversity, it might well be thought that much work still remains to be done. Yet the successful results announced in the increasing number of papers presented at scientific conferences would seem to suggest that the modelling of sorption has now reached a certain degree of maturity. It should now be possible to work towards securing a broader international consensus on the most appropriate approaches for incorporating sorption into the long-term safety analysis of radioactive waste repositories.

Under the aegis of the NEA, which has substantial experience in this area, twelve organisations from ten NEA Member countries have decided to take part in an international comparative exercise. The aim is to attempt to demonstrate the predictive capabilities of various existing models by using them to interpret sorption measurements carried out on complex materials. Participants will be given a restricted amount of data to configure their models, which will then be run "blind" to predict the sorption in similar systems for which experimental results already exist. These predictions will then be compared with the measured data. Once the exercise has been completed a performance assessment will be made of the various modelling approaches proposed, in which the degree of accuracy of each approach will be compared with its intrinsic complexity, and the results published in a report.

The Sorption II project, which is self-financed by participants, was formally launched on 28 September 2000 at the inaugural meeting of its Management Board and is expected to run for two years. ■


Comet Photo, NAGRA, Switzerland

NAGRA's Grimsel underground site in Switzerland, used for geological and hydrogeological tests related to the disposal of radioactive waste.

International nuclear emergency exercise INEX 2000

Since the beginning of the 1990s, the NEA has regularly organised international nuclear emergency exercises (INEX) in order to help improve, at the international level, the efficiency and effectiveness of nuclear emergency policy, planning, preparedness and management.

Based on lessons learned from INEX 1 and INEX 2 exercises and their associated workshops, the NEA initiated follow-up work that included the publication of *Monitoring and Data Management Strategies for Nuclear Emergencies*. The overall objective of these new strategies is to assist the decision maker by improving the selection of data to be transmitted during an emergency as well as the transmission and reception methods (e.g. using secure worldwide web technologies), and by defining emergency monitoring and modelling needs. To test the validity and usefulness of the strategies, the NEA has launched INEX 2000, which will be similar in scope to the INEX 2 exercises.

For the first time in the INEX series, INEX 2000 will address questions regarding civil liability. The exercise will be performed in two phases. In the first phase INEX 2000 will be a command-post exercise testing objectives similar to those of the INEX 2 exercises, and adding features of the new NEA Monitoring and Data Management Strategies for Nuclear Emergencies. This phase could last 36 hours. The second phase of INEX 2000 will concentrate on decision making in later phases of an accident, and focus on the international aspects of civil liability after a nuclear emergency. This might include consideration of mechanisms for the implementation of existing conventions on third-party liability, such as the Paris Convention on Third-Party Liability in the Field of Nuclear Energy and the Brussels Supplementary Convention. This second phase will be performed as a workshop, to be held a few weeks after the first phase, and to take account of the scenario and decisions taken at that time.

In the planning phase of an international nuclear emergency exercise, the Inter-Agency Committee for Response to Nuclear Accidents (IACRNA), for which the International Atomic Energy Agency (IAEA) serves as Secretariat, co-ordinates the different objectives from various international organisations within the United Nations (UN) family, such as the IAEA, FAO, UN-OCHA, WHO and WMO.

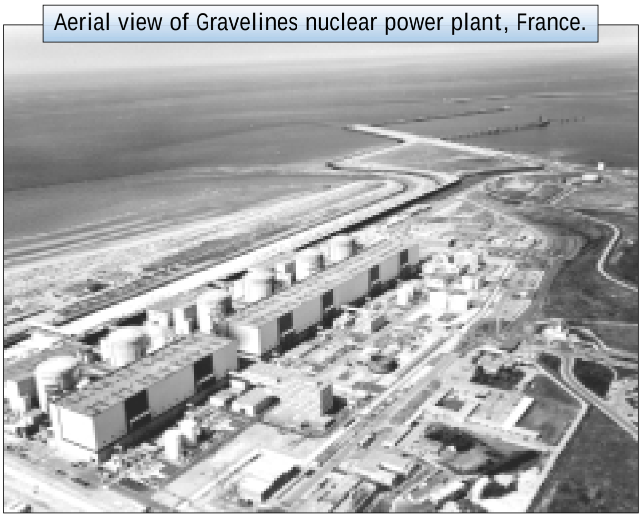
The objectives of INEX 2000 are:

- to test features of the Monitoring and Data Management Strategies for Nuclear Emergencies such as the effectiveness of the developed data matrix and the effectiveness of proposed communication strategies employing new technologies;
- to test the co-ordination of media information between various participants;
- to test the mechanisms for the implementation of the conventions on third-party liability; and
- to identify how participants incorporated the lessons learned from INEX 2 exercises.

France has offered to host the INEX 2000 exercise, which is scheduled for May 2001. The exercise will be based on a simulated reactor accident at the Gravelines nuclear power plant in the north of France, near the Belgian border.

The evaluation of the INEX 2000 exercise will be performed under the auspices of the NEA Working Party on Nuclear Emergency Matters and will be presented in a follow-up meeting as well as an OECD/NEA publication. ■

Aerial view of Gravelines nuclear power plant, France.



EDF, France

New publications

General interest

Geologic Disposal of Radioactive Waste in Perspective

ISBN 92-64-18425-2 – 62 pages – Price: FF 130, US$ 20, DM 39, £ 12, ¥ 2 050.

One of the challenges facing the continued availability of nuclear energy is that of ensuring the safe, environmentally acceptable and economic management of the waste generated during its production. There is a broad scientific and technical consensus that disposal of high-level, long-lived radioactive waste in deep geologic formations is an appropriate and safe means of isolating it from the biosphere for very long time scales. There have, however, been setbacks in the disposal programmes in many countries, primarily due to the failure of the waste management community to win sufficient public and political support. This report reviews the progress to date in this field and the further steps that may be required to implement geologic disposal, taking into account both the technical and regulatory requirements, and the need to achieve an appropriate level of societal acceptance. This book should be of interest to government and industry decision makers, academics and all those eager to better understand what is at stake in this widely debated subject.

Catalogue of Publications 2000

Free: paper or web versions.

Economic and technical aspects of the nuclear fuel cycle

Nuclear Energy in a Sustainable Development Perspective

ISBN 92-64-18278-0 – 62 pages – Free: paper or web versions.

The concept of sustainable development, which emerged from the report of the 1987 World Commission on Environment and Development (the Brundtland report), is of increasing interest to policy makers and the public. In the energy sector, sustainable development policies need to rely on a comparative assessment of alternative options, taking into account their economic, health, environmental and social aspects, at local, regional and global levels. This publication investigates nuclear energy from a sustainable development perspective, and highlights the opportunities and challenges that lie ahead in this respect. It provides data and analyses that may help in making trade-offs and choices in the energy and electricity sectors at the national level, taking into account country-specific circumstances and priorities. It will be of special interest to policy makers in the nuclear and energy fields.

Beneficial Uses and Production of Isotopes

2000 Update

ISBN 92-64-18417-1 – 80 pages – Price: FF 160, US$ 22, DM 48, £ 15, ¥ 2 450.

Isotopes, radioactive and stable, are used worldwide in various applications related to medical diagnosis or care, industry and scientific research. More than fifty countries have isotope production or separation facilities operated for domestic supply, and sometimes for international markets. This publication provides up-to-date information on the current status of, and trends in, isotope uses and production. It also presents key issues, conclusions and recommendations, which will be of interest to policy makers in governmental bodies, scientists and industrial actors in the field.

Nuclear Education and Training: Cause for Concern?

ISBN 92-64-18521-6 – 120 pages – Price: FF 210, US$ 31, DM 63, £ 19, ¥ 3 300.

Mankind now enjoys many benefits from nuclear-related technologies. There is, however, growing concern in many OECD countries that nuclear education and training is decreasing, perhaps to problematic levels. This publication conveys the results of a pioneering survey on nuclear education and training in almost 200 organisations in 16 countries. It presents the current situation and examines causes for concern. It also provides recommendations as to the actions governments, academia and industry must take in order to ensure that crucial present requirements are met and future options are not precluded.

A Summary Report

ISBN 92-64-18260-8 – 35 pages – Free: paper or web versions.

Nuclear Power in Competitive Electricity Markets

ISBN 92-64-18262-4 – 62 pages – Free: paper or web versions.

Economic deregulation in the power sector raises new challenges for the prospects of nuclear power. A key issue is to assess whether nuclear power can be competitive in a deregulated electricity market. Other important considerations include safety, nuclear liability and insurance, the nuclear power infrastructure, and health and environmental protection. This study, conducted by a group of experts from twelve OECD Member countries and three international organisations, provides a review and analysis of these issues, as related to both existing and future nuclear power plants. It will be of particular interest to energy analysts, as well as to policy makers in the nuclear and government sectors.

Nuclear Power Plant Life Management in a Changing Business World

Workshop Proceedings, Washington DC, United States, 26-27 June 2000

ISBN 92-64-18429-5 – 150 pages – Price: FF 375, US$ 53, DM 112, £ 35, ¥ 5 680.

Nuclear power plant life management (PLIM) has become an important issue in the context of changing business circumstances caused by regulatory reform of the electricity market. Specifically, the economic aspect of PLIM is being closely investigated as part of the search for greater competitiveness. It was in this light that the NEA organised an international workshop on “Nuclear Power Plant Life Management in a Changing Business World”. The objective of the workshop was to examine the status of PLIM activities in OECD Member countries and to develop a set of recommendations through separate working groups focusing on technology, regulation and business. The workshop also provided an opportunity to exchange information on lessons learned from past successes and failures. These proceedings will be of particular interest to those playing a policy role in the nuclear industry and those in a position to shape future PLIM strategies.

Uranium 1999: Resources, Production and Demand

A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency

ISBN 92-64-17198-3 – 340 pages – Price: FF 510, US$ 77, DM 152, £ 48, ¥ 8100.

In recent years, the world uranium market has been characterised by an imbalance between demand and supply and persistently depressed uranium prices. World uranium production currently satisfies between 55 and 60 per cent of the total reactor-related requirements, while the rest of the demand is met by secondary sources including the conversion of excess defence material and stockpiles, primarily from Eastern Europe. Although the future availability of these secondary sources remains unclear, projected low-cost production capability is expected to satisfy a considerable part of demand through to 2015. Information in this report provides insights into changes expected in uranium supply and demand over the next 15 years. The "Red Book", jointly prepared by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, is the foremost world reference on uranium. It is based on official information from 49 countries and includes compilations of statistics on resources, exploration, production and demand as of 1 January 1999. It provides substantial new information from all of the major uranium producing centres in Africa, Australia, Eastern Europe, North America and the New Independent States. It also contains an international expert analysis of industry statistics and worldwide projections of nuclear energy growth, uranium requirements and uranium supply.

Radiation protection

A Critical Review of the System of Radiation Protection

First Reflections of the OECD Nuclear Energy Agency's Committee on Radiation Protection and Public Health (CRPPH)

ISBN 92-64-18554-2 – 30 pages – Free: paper or web versions.

The need to address and communicate radiation protection theory, practice and the decision-making process to a wider audience has given rise to numerous debates and led the radiation protection community to revisit the framework of the system of radiation protection. This report is the summary of the NEA's first reflections in this area, and describes those aspects of the current international system of radiation protection that could be improved. Suggested directions for improvement are provided. It is hoped that this material will help guide the international community towards consensus and provide valuable input to the development of new recommendations by the International Commission on Radiological Protection.

Occupational Exposures at Nuclear Power Plants

Ninth Annual Report of the ISOE Programme, 1999

ISBN 92-64-18270-5 – 88 pages – Free: paper or web versions.

The ISOE Programme was created by the OECD Nuclear Energy Agency in 1992 to promote and co-ordinate international co-operative undertakings in the area of worker protection at nuclear power plants. The programme provides experts in occupational radiation protection with a forum for communication and exchange of experience. The ISOE databases enable the analysis of occupational exposure data from the 429 commercial nuclear power plants participating in the programme (representing some 90 per cent of the world's total operating commercial reactors). The Ninth Annual Report of the ISOE Programme summarises achievements made during 1999 and compares annual occupational exposure data. Principal developments in ISOE participating countries are also described.

Second International Nuclear Emergency Exercise INEX 2

Final Report of the Finnish Regional Exercise

ISBN 92-64-08580-7 – Bilingual – 98 pages – Price: FF 150, US$ 21, DM 45, £ 14, ¥ 2 250.

The NEA initiated its programme of International Nuclear Emergency Exercises (INEX) by a table-top exercise (INEX 1) which allowed the 16 participating countries to examine how their response mechanisms addressed the international aspects of a large-scale nuclear emergency. Based on the experience thus gained, a series of more realistic exercises, INEX 2, was organised. These exercises used as a basis a national-level emergency exercise at an existing power plant, and aimed to achieve three international objectives: the real-time exchange of information, public information and decision making based on limited information and uncertain plant conditions. This report summarises the experience gained and lessons learned during the second INEX 2 regional exercise which took place in Finland.

Radioactive waste management

Stakeholder Confidence and Radioactive Waste Disposal

Workshop Proceedings, Paris, France, 28-31 August 2000

ISBN 92-64-18277-2 – 166 pages – Free: paper or web versions.

Any significant decisions regarding geologic disposal of radioactive waste will need a comprehensive public review and a thorough involvement of all relevant stakeholders, such as waste generators, waste management agencies, regulatory authorities, local communities and elected officials. The participation of non-technical stakeholders will become increasingly important as more countries move towards siting and implementing geologic repositories. The decision-making process and avenues for stakeholder involvement differ from country to country, but it is important to identify similarities and differences, understand the key concerns of the various stakeholders, and develop means to interact effectively. The Nuclear Energy Agency recently set up a Forum on Stakeholder Confidence charged with distilling the lessons that can be learnt from national and international experience. These proceedings of the Forum's first workshop held in August 2000 provide an overview of OECD countries' experience in the field of stakeholder confidence and radioactive waste disposal.

Porewater Extraction from Argillaceous Rocks for Geochemical Characterisation

Methods and Interpretations

ISBN 92-64-17181-9 – 186 pages – Price: FF 380, US$ 60, DM 113, £ 37, ¥ 6 350.

The definition of the chemical and isotopic composition of the groundwater present in argillaceous formations, which are considered as potential host rocks for radioactive waste disposal, is crucial for establishing their barrier properties. Therefore, a critical review of the relevant literature on the current methods applied to extract water and solutes and on the various approaches to the interpretation of their results was commissioned to the *Laboratoire d'hydrologie et de géochimie isotopique (Université de Paris-Sud*, France). The present document provides a synthesis of available extraction methods, assesses their respective advantages and limitations, identifies key processes that may influence the composition of the extracted water, describes modelling approaches that are used to determine *in situ* porewater composition, and highlights, wherever possible, some of the unresolved issues and recommendations on ways to address them.

SR 97: Post-closure Safety of a Deep Repository for Spent Nuclear Fuel in Sweden

An International Peer Review

ISBN 92-64-18261-6 – 50 pages – Free: paper or web versions.

This report presents the common views of the International Review Team established by the NEA Secretariat on behalf of the Swedish Nuclear Power Inspectorate (SKI) to perform a peer review of a post-closure safety study of a deep repository for spent nuclear fuel in Sweden, *Safety Report 97*, produced by the Swedish Spent Fuel and Waste Management Company (SKB).

Features, Events and Processes (FEPs) for Geologic Disposal of Radioactive Waste

An International Database

ISBN 92-64-18514-3 – 88 pages – Price: FF 150, US$ 24, DM 45, £ 15, ¥ 2 900.

Safety assessments of disposal sites for radioactive waste involve analyses of potential releases of radionuclides from the disposed waste and subsequent transport to the human environment. An important stage of assessment is the identification and documentation of all the features, events and processes (FEPs) that may be relevant to long-term safety. This report provides an international compilation of FEPs as well as a basis for selecting the FEPs that should be included in safety analyses.

The CD-ROM version of this report is a unique source of key information. It includes both the report and a database.
ISBN 92-64-16791-1 – Price: FF 400, US$ 58, DM 119, £ 37, ¥ 6 250.

Nuclear law issues

Nuclear Law Bulletin

No. 66 + Supplement (December 2000)

ISBN 92-64-17571-7 – 90 pages (+ 16 pages for the Supplement): FF 280, US$ 50, DM 85, £ 29, ¥ 5 750.
ISSN 0304-341X – 2000 Subscription (2 issues + supplements): FF 460, US$ 80, DM 140, £ 48, ¥ 9 550.

Considered to be the standard reference work for both professionals and academics in the field of nuclear law, the *Nuclear Law Bulletin* is a unique international publication providing its subscribers with up-to-date information on all major developments falling within the domain of nuclear law.

Nuclear Legislation: Analytical Study

Regulatory and Institutional Framework for Nuclear Activities

ISBN 92-64-17676-4 – 586 pages – Price: FF 950, US$ 143, DM 283, £ 89, ¥ 15 050.

This analytical study on nuclear legislation provides comprehensive information on the regulatory and institutional framework governing nuclear activities in each OECD country. It is organised on the basis of a standardised format for each chapter in order to facilitate the search for, and comparison of, information. It is a useful tool for students and practitioners alike, carrying out research of an academic nature or looking for practical information on nuclear legislation.

Nuclear Legislation in Central and Eastern Europe and the NIS

2000 Overview

ISBN 92-64-18525-9 – 194 pages – Price: FF 220, US$ 32, DM 66, £ 20, ¥ 3400.

This publication examines the legislation and regulations governing the peaceful uses of nuclear energy in eastern European countries. It covers 11 countries from Central and Eastern Europe and 11 countries from the New Independent States (Albania, Armenia, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Former Yugoslav Republic of Macedonia, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Poland, Republic of Moldova, Romania, Russian Federation, Slovak Republic, Slovenia, Ukraine, Uzbekistan). The chapters follow a systematic format making it easier for the reader to carry out research and compare information. This study will be updated regularly.

Nuclear safety

Assuring Nuclear Safety Competence into the 21st Century

Workshop Proceedings, Budapest, Hungary, 12-14 October 1999

ISBN 92-64-18517-8 – 246 pages – Price: FF 340, US$ 50, DM 101, £ 31, ¥ 5300.

Irrespective of current views on the future of nuclear power programmes, concerns are arising with respect to the long-term ability to preserve safety competence because student enrolments in nuclear engineering are decreasing rapidly and experienced staff are reaching retirement age. "Assuring Nuclear Safety Competence into the 21st Century" was discussed in depth by workshop participants. The need for a long-term strategic view was emphasised, and policy recommendations were made. These proceedings will be of particular interest to those playing a policy role in the nuclear industry, regulatory bodies and the education sector.

Nuclear science and the Data Bank

3-D Radiation Transport Benchmarks for Simple Geometries with Void Regions

ISBN 92-64-18274-8 – 38 pages – Free: paper or web versions.

Industry requires well-validated computation methods and computer codes for its nuclear applications. The predictive power of such tools must be established and users must be confident of their results. Model refinement requires that increasingly sophisticated tools be used. Moreover, the computing power available today no longer justifies a number of geometrical simplifications. This report describes the results of challenging international benchmarks in three-dimensional radiation transport that contribute to the evaluation and validation of state-of-the-art computation methods and computer codes. It will be of particular interest to reactor physicists and radiation shielding specialists.

Benchmark Calculations of Power Distribution Within Fuel Assemblies

Phase II: Comparison of Data Reduction and Power Reconstruction Methods in Production Codes

ISBN 92-64-18275-6 – 234 pages – Free: paper or web versions.

Systems loaded with plutonium in the form of mixed-oxide (MOX) fuel show somewhat different neutronic characteristics compared with those using conventional uranium fuels. In order to maintain adequate safety standards, it is essential to accurately predict the characteristics of MOX-fuelled systems and to further validate both the nuclear data and the computation methods used. A computation benchmark on power distribution within fuel assemblies to compare different techniques used in production codes for fine flux prediction in systems partially loaded with MOX fuel was carried out at an international level. It addressed first the numerical schemes for pin power reconstruction, then investigated the global performance including cross-section data reduction methods. This report provides the detailed results of this second phase of the benchmark. The analysis of the results revealed that basic data still need to be improved, primarily for higher plutonium isotopes and minor actinides.

Benchmark on the VENUS-2 MOX Core Measurements

ISBN 92-64-18276-4 – 196 pages – Free: paper or web versions.

The plutonium produced during the operation of commercial power plants and made available from the dismantlement of nuclear weapons needs to be properly managed. One important contribution to the management process consists in validating the calculation methods and nuclear data used for the prediction of power in MOX-fuelled systems. A series of theoretical physics benchmarks and multiple recycling issues of various MOX-fuelled systems have been studied by the NEA. This led to many improvements and clarifications in nuclear data libraries and calculation methods. The final validation requires linking those findings to data from experiments. Hence, the first experiment-based benchmark using the two-dimensional VENUS-2 MOX core measurement data was launched in May 1999. This report provides an analysis of the results supplied by 12 participants from 10 countries. The comparison of the latest nuclear data libraries and of different calculation methods – including stochastic Monte Carlo and deterministic transport/diffusion methods – is presented.

Evaluation and Analysis of Nuclear Resonance Data

JEFF Report 18

ISBN 92-64-18272-1 – 126 pages – Free: paper or web versions.

Nuclear data are fundamental to the development and application of all nuclear sciences and technologies. Preserving nuclear data knowledge in a field from which a large number of specialists have recently retired is also important, and this report aims to help the preservation effort. The report provides a comprehensive presentation of the nuclear data evaluation process in the resonance energy range. The mathematical basis and the physical theories necessary for the experimental data analysis are presented in detail. This report will be useful for experimentalists and evaluators involved in the preparation of nuclear data.

International Evaluation Co-operation

Volume 14: Processing and Validation of Intermediate Energy Evaluated Data Files

36 pages – Free: paper or web versions.

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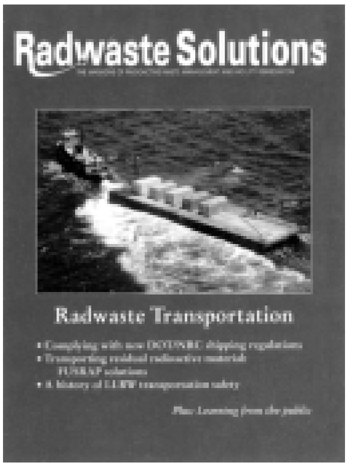

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PRINTED IN FRANCE
(68 2000 02 1 P) ISBN 92-64-17573-3 – No. 51633 2000
ISSN 1605-9581