During its 20-year lifetime, the Connecticut Yankee Nuclear Power Plant in Haddam Neck, (U.S.) has produced more electricity than any other nuclear plant in the United States. The 616 MW plant was for many years the world leader and has only recently been surpassed by a few much larger plants in other countries.

Editorial board: Jacques de la Ferté, Zabel Cheghikian, Roxanne Goldsmith

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The OECD Nuclear Energy Agency (NEA) was established in 1957 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April, 1972, when Japan became its first non-European full Member. NEA membership today consists of all European Member countries of OECD as well as Australia, Canada, Japan and the United States. The Commission of the European Communities takes part in the NEA's work and a cooperation agreement has been concluded with the International Atomic Energy Agency.

The purpose of the NEA is to further the development of the peaceful uses of nuclear energy by sponsoring economic, technical and scientific studies and projects, and by contributing to the optimisation of safety and regulatory policies and practices.

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Prospects for nuclear energy into the 21st century

G. Vendryes

Our planet's population of five billion will double by the year 2050. Even if the population then stabilizes, we face the challenge of enormously improving average living standards. Today's disparities are simply unacceptable. The 10 billion men, women and children of the future must all enjoy living conditions and home comforts at least equal to those now prevailing in the most highly developed countries.

However successful the richest countries are in economizing and conserving energy, there will ineluctably be very substantial growth in world energy demand, continuing throughout the next century. Although vast, the energy resources for meeting this demand are certainly not inexhaustible. Humanity should not renounce the use of any source of energy, provided its cost is reasonable and its risks acceptable. The 21st century will therefore use peaceful nuclear energy on a much larger scale than is presently the case.

Any scenario for the long-term future is debatable and full of uncertainties. However, there are already a number of positive technological factors which favour nuclear energy projects as a solution to the enormous demand for economic growth which is predicted for the first part of the next century.

It is true that the public is consciously or unconsciously afraid of nuclear energy, and this reaction has been sharpened by the Chernobyl accident. While the risks of nuclear power are less well understood and accepted than most, the force of public opinion is determinant in allowing continued use of this source of energy. To overcome this negative attitude may be the greatest challenge of the next decade. Clearly, one of the key elements is to establish an impeccable safety record in all nuclear activities. Enhanced safety and better operating conditions are essential to reduce the probability of accidents.

The passage of time may allow a less impassioned and more objective comparison of the relative benefits of energy sources. Uranium and plutonium fission may then be looked on more favourably with the growing recognition that our planet is, in any case, naturally radioactive and that exploiting other energy sources also involves dangers for human beings and their environment, as indeed for all human endeavours.

Nuclear power prospects for the future

Growth in the use of nuclear power has slowed in recent years but has never stopped. New reactors are being completed and commissioned even in the United States, which probably has the oldest and strongest opposition movement. Plant construction has continued steadily in Eastern Europe, Japan, the United Kingdom and in the Soviet Union. In many countries, the nuclear option is already irreversible. Such is certainly the case in France, where nuclear energy will account for 40 per cent of total primary energy consumption by the year 2000. There is a strong likelihood that this trend will continue and even accelerate under the pressure of economic realities. By the early years of the next century, construction of nuclear power plants will resume on a large scale in many industrialised nations.

On the other hand, medium-term prospects for nuclear plant construction in developing countries seem to be slim. Very few will be making significant use of nuclear power at the beginning of the 21st century, mainly due to lack of financial resources and the necessary industrial infrastructure, as well as insufficiently-developed power transmission and distribution networks. The greatest obstacle in some countries, however, and the last to disappear, will be the fact that nuclear power requires a large pool of highly skilled and trained people at all levels.

Thus there is a very real possibility that, at the dawn of the 21st century, nuclear power may be seen as a privilege reserved for the rich and only a distant dream for poorer countries. This situation is worrying from all points of view and can be remedied only by major efforts on the part of industrialised nations.

In the technical sphere, it seems unlikely that the design of nuclear power plants will change much in the coming years nor that the market will find a place for new reactor systems radically different from those in use today.
Nuclear prospects

On the contrary, utilities will restrict their choice to a very small number of reactor systems. In particular, pressurised water reactors will occupy a growing and finally dominant position throughout the world.

Standardization does not mean absence of progress and the pressurised water reactor will be continually enhanced, often by exploiting advances in non-nuclear areas such as robotics and artificial intelligence. Greater equipment reliability will result in reduced outage time for inspection or maintenance, the service life of reactors will be increased to forty years, higher burn-up limits will extend the residence time of fuel in reactors beyond today's three years, growing use will be made of mixed uranium and plutonium fuels and radiation exposure of plant workers will be even further reduced.

Natural uranium production is not the only part of the nuclear fuel cycle experiencing a worldwide over-capacity. Uranium enrichment is in the same situation and will remain so until the end of the century. However, in line with increasing prospects for nuclear power plant construction, large additional enrichment capacities will have to come on-stream around the year 2000. Several processes are in competition for this future new generation of enrichment plants. And, whereas the market has already chosen the dominant technology for reactors, the enrichment race is still wide open. The current situation may be transformed by breakthroughs in laser enrichment, which is intellectually attractive and holds out hope of a sharp reduction in enrichment costs. In addition, laser enrichment is the key to unlocking the large reserves of residual U-235 in depleted uranium and reprocessed uranium.

New uses for nuclear energy

The early years of the next century will probably also see significant growth in the use by industrialised nations of nuclear energy for purposes other than electricity production in power plants. The application that first comes to mind is production of hot water for district heating or of industrial process steam at various temperatures, by dedicated nuclear reactors or cogeneration plants also supplying electricity. Some countries are already following this path, including the Soviet Union. As the 21st century unrolls, and provided public acceptance increases, nuclear energy could be employed on a very large scale for heat production on the outskirts of towns and cities or close to large industrial complexes.

Uranium fission energy may also find new markets in transportation. However, despite the remarkable success of nuclear-powered submarines and aircraft carriers, it is doubtful that nuclear propulsion will be used in the foreseeable future for large merchant ships. The necessary cost reductions, safety conditions and changes to maritime law are not on the horizon.

On the other hand, the next century will see great expansion in exploration of space, throughout our solar system. The self-contained energy sources for propelling and supplying power to space vehicles will have to be very compact and long-lived, making nuclear fission a favourable solution. This will, of course, be a very special and probably quite small market, but one that will supply future generations of engineers with really exciting and difficult technological challenges.

What will be the consequences of all these developments for the nuclear fuel cycle? It is difficult to be precise about whether our planet's uranium resources can be exploited at a reasonable cost of, say, less than 100 US dollars per pound of U-238, and can meet foreseeable needs. It is likely, however, that future prospection on a much larger scale will identify new reserves and shift the total towards the high end of published estimates.

The future of breeder reactors

Given this possible evolution of the world-wide nuclear energy scene, it is clear that breeder deployment will take place later and more slowly than envisaged even ten years ago. This, of course, does not mean that the need for such reactors and the advantages they offer would be diminished in any way. On the contrary, breeders will remain of major strategic importance for nations that are poor in domestic energy resources.

The use of nuclear fission energy will one day be identified with the use of breeders and this day may come much sooner than many experts believe. Now that we have mastered breeder technologies and demonstrated industrial feasibility, it remains to pursue their development persistently, but without haste, and achieve the cost competitiveness that is already within reach.

Well before breeders are built in large numbers, the industrial use of plutonium will become commonplace as it enters into the fuel of more and more light water reactors. Given its very high energy content, there is a further role for plutonium as fuel during the next century.

This is a strong argument for reprocessing, as is the need to put fission products in the best form for storage or final disposal under optimal safety conditions for future generations. A large expansion in spent fuel reprocessing is therefore to be expected, although perhaps not for twenty years. There will be little incentive to reprocess fuel quickly in the meantime, and we must prepare for extended interim storage of most spent fuel. The few new reprocessing plants decided here and there will be built mainly with an eye on the future, to help the host countries master reprocessing technologies.

What is done with fission products once separated from uranium and plutonium by reprocessing, is one of the most controversial issues today in nuclear power. In fact, these radioactive by-products of nuclear energy will in the future become partly assets instead of pure liabilities.
Human imagination and ingenuity will greatly expand the range of applications for radioisotopes, already widespread in science, medicine, agriculture and industry. A vast market will open up as the cost of separating specific fission products from spent fuel steadily decreases.

Even so, there will be no market for a good proportion of the fission products from reprocessing plants and some means will have to be found for their safe disposal. The only method envisaged at present is to place these highly-radioactive wastes in repositories deep underground in carefully chosen geological structures. This approach can afford adequate guarantees of safety and its choice is by no means a sign of irresponsibility towards future generations.

In conclusion, the choice of energy sources in the next century will be relatively limited and nuclear power, which has achieved an impressive level of safety and reliability, appears as an obvious choice for meeting energy demand. On the other hand, as we have witnessed in the past decade, the development of this energy source is highly dependent on the degree of acceptance by the public and the government decision-makers. In view of this fact, changing the public attitude from scepticism to approval will continue to be one of the main challenges facing the nuclear industry.
Nuclear trade and non-proliferation policies: a historical overview

The NEA is publishing a two-volume study entitled: *The Regulation of Nuclear Trade: Non-proliferation — Supply — Transport*. Volume I deals with the international aspects of nuclear trade, while national legislation is discussed in Volume II. The following text (the first of two parts) is condensed from Chapter One of Volume I. This chapter provides an overview of the stages of development of the law regulating trade in nuclear material, equipment and technologies and places this development within a historical, political and economic perspective. The second part will appear in the Fall 1988 issue of the Newsletter.

**Internationalisation and secrecy: 1945-1953**

When the peaceful uses of nuclear energy were first envisaged in 1944-45, a group of American scientists proposed an international treaty banning nuclear weapons and establishing controls over nuclear energy based on a renunciation of certain sovereign rights. This was followed in November 1945 by the Agreed Declaration on Atomic Energy, issued by the United States, the United Kingdom and Canada, which had co-operated in the development of the nuclear weapon. The Declaration reflected the ambivalent desire for secrecy and internationalisation that was to characterise the early development of atomic energy. On the one hand, it advocated a policy of secrecy, which would later be adopted in the United States' McMahon Act of 1946, and on the other, it contained a proposal for the international control of all nuclear activities.

**The Acheson-Lilienthal Report**

In January 1946, the United Nations General Assembly created the U.N. Atomic Energy Commission (UNAEC) as a dependent body of the U.N. Security Council concerned with the development of atomic energy and the possible elimination of nuclear weapons. In the so-called *Acheson-Lilienthal Report* to this Commission of March 1946, the United States proposed a comprehensive, international regime for control of atomic energy in exchange for giving up its nuclear monopoly.

Since almost all industrial nuclear activity was classified as "dangerous," the Report proposed the internationalisation of all peaceful applications of nuclear power and the transfer to a world organisation of supervisory responsibility for the development of national nuclear programmes. The Report advocated total nuclear disarmament and comprehensive international ownership

laws regulating trade in nuclear material, equipment and technology are strongly influenced by the desire of exporting countries to prevent the spread of nuclear weapons. Because civilian atomic power was originally a spin-off from military programmes, and because some facilities used for nuclear power generation can also be used to produce materials for nuclear weapons, there is a widespread notion that the two facets of nuclear energy cannot be wholly separated. The international rules of the nuclear trade are therefore largely determined by the interaction between civil and military aspects of nuclear energy.

The States which built atomic weapons during World War II were the best placed to capitalise on this experience after the war for the industrial development of atomic energy. But the United States' post-war decision to impose tight secrecy on atomic energy, even towards its former allies, dampened for at least a decade any possibility of co-operation in developing nuclear energy for peaceful purposes.

Much of the information was finally declassified at the first United Nations Conference on the Peaceful Uses of Atomic Energy in 1955. Encouraged by growing public enthusiasm, Canada and Sweden joined the United States, the United Kingdom, the USSR and France in developing nuclear reactor models. By 1964, there were fifteen reactors in operation or completed, using either natural or enriched uranium.

However, the United States retained a monopoly over enriched uranium supplies in the West and was able to insist on verifying, through inspection, that the nuclear material transferred to foreign countries was not diverted to other than peaceful uses. Gradually, other industrialised countries adopted the same position. Nuclear export policies have always vacillated between encouraging access to nuclear technology and restricting the spread of that same technology. The development of nuclear trade regulations is itself a reflection of the difficulty of reconciling these two major interests.
and management of nuclear material; this international authority was to be given a leadership role in the development of nuclear technology.

The Baruch Plan

However, the U.S. Government considered the Acheson-Lilienthal proposal to create a "supranational" body as too idealistic to succeed. The idea of preserving the American military atomic monopoly was revived in a new version of the proposal, now called the Baruch Plan, which was presented to the UNAEC in June 1946 by the United States' Representative, Bernard M. Baruch. The Baruch Plan nevertheless maintained the internationalisation aspects of its predecessor by proposing an International Atomic Development Authority (IADA).

This authority would manage all atomic energy activities potentially dangerous to world security, with emphasis on the necessity for effective control, surveillance and licensing of national activities. In addition, no national governmental veto would be allowed to interfere with IADA's control and inspection missions.

A Soviet counter-proposal demanded a prohibition of nuclear weapons before any discussion of the problems of international control. In the second meeting of the UNAEC, the Soviet Union made clear that it considered the Baruch Plan's proposal for veto-free international intervention in the domestic nuclear sphere as unacceptable.

The Baruch Plan fell victim to the cold war rivalry developing between the United States and the USSR. The long negotiations to achieve international nuclear disarmament and world control over nuclear energy ended in a deadlock in 1948 and were followed by the eventual demise of the UNAEC and its official dismantling in 1952.

The McMahon Act

The failure of the Baruch Plan may have strengthened the United States in its determination to safeguard its nuclear monopoly. The McMahon Act of 1946 prohibited the transfer of any knowledge, technology or materials which could be used to develop nuclear weapons. It nevertheless urged the "dissemination of scientific and technical information relating to atomic energy". All questions relating to atomic energy were to be the responsibility of the United States Atomic Energy Commission (USAECC). This policy prevented neither the Soviet Union nor the United Kingdom from achieving nuclear weapons capability shortly thereafter. At the same time, the United States undertook massive nuclear testing and the build-up of its own nuclear arsenal.

The failure to contain the spread of nuclear weapons by blocking the flow of scientific and technical knowledge made it clear that a comprehensive regime to control the worldwide development of nuclear energy would be almost impossible to achieve.

Openness and international co-operation

The loss of the American nuclear weapons monopoly in the early 1950s, coupled with growing commercial interest in the development of civil nuclear energy, led to the elaboration of a new United States non-proliferation policy. The U.S. Government took several steps to encourage nuclear development at home and abroad, and in November 1958, agreed with EURATOM to promote the export to Europe of light-water reactors fuelled with uranium enriched in the United States.

Atoms for Peace Plan

On 8th December 1953, President Eisenhower officially launched the Atoms for Peace Plan in which the United States for the first time accepted the principle that the civilian and military uses of atomic energy could be technically separated through effective safeguards and inspections. As a result, controls would be required only on certain sensitive nuclear facilities. Such controls would not constitute a disarmament strategy, since only non-nuclear weapon States (NNWS) were to be subjected to it.

Clearly distinct from both disarmament and full internationalisation, the new regime would be limited to a general surveillance system. At the same time, the United States abandoned its earlier policy of denial of information as embodied in the 1946 McMahon Act and launched a new strategy to promote the peaceful uses of nuclear energy under appropriate safeguards, particularly through bilateral agreements on the transfer of nuclear technology.

This policy shift had a major impact on the history of international nuclear relations. Atoms for Peace provided the basis for the growth of nuclear energy programmes throughout the world. The broad international co-operation established was a precursor of the specialised intergovernmental organisations which were to be set up in the nuclear field, the first of which was created within the framework of the United Nations.

Nuclear co-operation organisations

The International Atomic Energy Agency

The Atoms for Peace proposal set forth an ambitious plan to reduce the threat of atomic weapons' development by directing nuclear explosive materials to an international pool of materials to be used solely for peaceful purposes. The plan proposed that States would essentially retain their competence in nuclear affairs while agreeing to participate in an international control system. Nuclear weapon States (NWS) would agree to deposit with a new world agency some of their fissionable materials which had, until then, been earmarked for military uses.
Nuclear trade

Shockproof and fire resistant containers are used to transport highly-radioactive spent fuel by ship. More than 15,000 shipments have been safely made to date.

After four years of negotiations leading to the adoption of the Statute of the International Atomic Energy Agency (IAEA) in 1956, the direct arms control function was dropped entirely, while the new Agency's powers concerning fuel storage and supply were also considerably reduced. The new policy of openness and co-operation in the nuclear field was later to lead, in a more limited geographical framework, to the creation of EURATOM and the European Nuclear Energy Agency of the Organisation for European Economic Co-operation (OEEC).

The European Atomic Energy Community

The European Atomic Energy Community (EURATOM) was established by the Treaty of Rome in 1957 to integrate the nuclear energy sector along the lines of the European Coal and Steel Community which had been launched in 1955. The initiative was partly motivated by the energy problems that arose from the 1956 Suez crisis. The EURATOM project contemplated the regrouping of the European nuclear industry and its development in close co-operation with the United States, which strongly supported this initiative.

The founding fathers of EURATOM hoped that the new organisation would restart the process of political integration by resolving the problem of nuclear weapons in Europe and regrouping the nuclear energy programmes of its Member States. The Treaty finally concluded did not go this far but a number of provisions reflected this initial intention.

The European Nuclear Energy Agency

The European Nuclear Energy Agency (ENEA) was created within the OEEC on 1st February 1958, one month after EURATOM. It was given wide statutory responsibilities, including the harmonisation of the scientific and industrial programmes of its Member countries; the establishment of joint undertakings; a security control
function and the development of national legislation in the
peaceful uses of nuclear energy, particularly in the field of
nuclear third party liability.

To promote technical and industrial co-operation,
the ENEA created three joint undertakings: EUROCHE-MIC, in 1957; HALDEN, in 1958; and DRAGON, in 1959.
Later, these objectives were to evolve towards more
traditional co-operation activities looking at all aspects of
nuclear power, with emphasis on nuclear safety and
technology. The Agency remained essentially a European
venture until 1972, when Japan became a member and the
Agency’s name was changed to the OECD Nuclear Energy
Agency (NEA). Eventually Australia, Canada, Finland and
the United States also became Members.

US-USSR consensus on
non-proliferation

Despite a high level of international co-operation,
great differences remained between the United States and
the USSR on the concept and modalities of international
inspections. Competition between the superpowers in the
peaceful uses of nuclear energy led both countries to share
nuclear technology with friendly nations, with the
United States intensifying its nuclear energy aid through
the use of bilateral agreements.

Both the United States and the USSR had, at one
point, shared the view that internationalisation should be
opposed and that nuclear aid and trade should follow a
bilateral pattern. Yet the United States had progressively
come to accept a multilateral safeguards system, while the
USSR maintained its opposition to IAEA safeguards.
Following its rupture with China at the end of the 1960s,
the Soviet Union reassessed its nuclear export policy and
revised its attitude towards the IAEA’s safeguards function.

Thus a unified safeguards system became feasible
in 1963, when the Soviet Union reversed its position and
accepted the principle of international inspections. This
policy shift laid the ground for placing national nuclear
programmes and technology under the surveillance of a
world authority. This new regime was achieved with the
transfer of bilateral safeguards agreements to the competen-
tce of the IAEA and, ultimately, its automatic application
to all nuclear transactions.

Adoption of the Treaty on the
Non-Proliferation of Nuclear Weapons

The Treaty on the Non-Proliferation of Nuclear
Weapons (NPT) was opened for signature on
1st July 1968; among the sixty-two signatories were three
nuclear weapon States — the United Kingdom, the United
States and the USSR. The Treaty divided countries into
two categories, the nuclear weapon States (NWS) and the
non-nuclear weapon States (NNWS). The NNWS would
receive the benefits of peaceful nuclear technology by
renouncing nuclear weapons in the hopes of consolidating
world peace. They pledged to allow international inspec-
tion of their nuclear plants to guarantee their compliance
with the agreement. The NWS, for their part, undertook to
allow equal access to nuclear technology for all and to
pursue negotiations for ending the nuclear arms race and
for general and complete disarmament.

Among the NWS, both France and the People’s
Republic of China refused to sign the Treaty. So did some
NNWS more advanced in nuclear technology, such as
Argentina, South Africa, India and Israel. These abstentions compromised the universality of the NPT. Neverthe-
less, the Treaty entered into force in 1970, and the IAEA
began negotiations with the Contracting Parties for the
application of safeguards on their territories. The first
global regime for control of the peaceful uses of nuclear
energy was gradually put in place. (To be continued.)
Nuclear risks and public information

J. de la Ferté

For several years, public authorities and industry have paid increased attention to the need to inform the public about preventive and remedial actions against technological hazards which could affect health and safety or the environment. Many steps have already been taken in this field, in particular following several major industrial accidents which considerably affected the general public (oil spills, Bhopal, pollution of the Rhine, Chernobyl, etc.).

The right of the public to be informed of the technological risks to which it may be exposed has been stated in many national laws and in official declarations adopted at the international level (e.g., the final Declaration of the United Nations Conference on the Human Environment in 1972, declarations by the OECD Member countries in 1979 on anticipatory environmental policies, and the Seveso Directive in 1982). More recently, following the 1988 OECD Conference on Accidents Involving Hazardous Substances, a draft Council Act of the OECD was drawn up with a view to formalising general principles on public information and public participation in decision-making.

While this policy is widely backed in industrialised countries, it raises many practical difficulties, not least because it hinges on the development of new methods and structures better adapted to rapidly changing information techniques. It has been observed, in particular, that the complex scientific and technical concepts which the public must assimilate to obtain a correct picture of the risks arising from a modern industrial activity are now increasingly conveyed through mass audiovisual means, and much less by conventional written materials which allow a more thorough presentation of this type of information.

The nuclear industry has had to come to grips with this information problem for many years. In all OECD countries with nuclear power programmes, specific measures have been implemented by the public authorities and industry as well as by utilities, and further action is still being taken as regards public consultation and information on plant siting, construction and operation. Considerable experience has therefore been acquired in this field*, although the outcome has not always fully met expectations.

The Chernobyl lesson

The accident at the Chernobyl power plant in April 1986 put existing information mechanisms to the test. For the first time in the history of nuclear power, the national authorities of many countries, especially in Europe, were confronted with a crisis of wide international scope which required urgent replies to the public’s questions. Although they did not have full details about the circumstances of the accident, they had to assess risks rapidly and accurately, give advice on the precautions to be taken, implement necessary safety measures and dispel ungrounded fears. This situation generally raised considerable difficulties and revealed a number of deficiencies, such as the absence of suitable liaison at the international level to obtain reliable source information, inadequate harmonization of the criteria used by national authorities for triggering any prevention and safety measures required, leading to unwarranted discrepancies in the way the situation was handled, insufficient training of crisis teams and poor co-ordination of information services.

In view of the speed at which information (and also rumors) can circulate, and the interdependence of countries in the face of a major event, it was soon obvious that there was little room for manoeuvre when it came to preventing misunderstandings and extreme reactions likely to cause public distress.

By bringing into the open public information difficulties in an emergency, the Chernobyl crisis stimulated efforts toward better preparedness for this type of situation. These have resulted in the development of improved strategies for the communication of information, renewed international co-operation in order to promote rapid circulation of information in the event of an emergency, and studies on suitable methods for communicating to the public complex concepts such as those relating to the safety of nuclear installations, radiation protection and risk perception.

Information in a crisis situation

All countries conducting nuclear power plant programmes and their neighbours have local and national emergency plans, which are either “comprehensive” or specifically designed for a nuclear emergency. Although most of these plans clearly identify responsibilities at the local level in the event of an emergency, experience shows

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* See also “Nuclear Power and Public Opinion”, an article published in the December 1984 issue of the NEA Newsletter.
that, in a crisis, it is necessary to be equally well organised at the national level, including in countries with a federal structure, and also to ensure that action taken at the different levels is co-ordinated in an effective way. This applies a fortiori to communication with the public. The idea of a crisis information unit, co-ordinating action taken by the different regulatory and technical authorities involved at the national level, is therefore of special interest.

Much care should be taken to select the members and working methods of this crisis information unit, since the information supplied to the public must be credible and issued at the right time; it must also be honest, accurate and easily understood by all. In several countries, for instance, one or more communications experts and a media representative will be included in the information unit, as their skills would be useful for drafting the communiques. Similarly, the best ways to ensure effective mobilisation of the unit members in the event of an emergency and special training in communication are being studied.

However, the circulation of information from a recognised national source must take into account the local population’s natural tendency to turn to familiar and trusted sources in order to check or supplement “official” information. Recognition of the growing role of information channels, not only local media but also social and professional bodies — doctors, teachers, trade associations and trade unions, etc. — which are in frequent contact with the public, suggests that they should be more closely integrated into the process of communicating information and should be prepared to assist when appropriate. Action is being taken in several countries along these lines.

Preparing the public to receive information (or instruction) in an accident situation is a difficult task which cannot be performed properly unless prior steps have been taken during normal times. Many countries are already issuing leaflets to the population living near power plants on how to respond in the event of an accident. However, the possibility of extensive contamination warrants the circulation of this type of information throughout
Public information

the country. Some governments are already doing this by including the information in public telephone directories.

Under normal circumstances, it is admittedly difficult to sustain public awareness of the possibility of an accident, and it is hardly practicable to run frequent emergency exercises involving the general public. In the long term, continuous provision of information on safety and radiation protection issues may improve public understanding of emergency instructions and thereby assure a more rapid response in the event of an accident.

For example, in France, a national electronic magazine on nuclear information has recently been introduced through the Minitel network. Under the name of Magnus, it may be consulted at any time to obtain radioactivity levels in the different regions, information about operating conditions at nuclear installations and answers to basic questions on safety. Magnus is also designed for the rapid transmission of information to the public in the event of an accident.

International co-operation

Recent accidents with transfrontier implications have confirmed the value of promoting information exchanges among countries on the siting and operation of hazardous industrial installations and on assistance and emergency plans. In the nuclear field, there are many bilateral agreements between neighbouring countries to provide early notification of any abnormal situation. Several international agreements have also been concluded following the Chernobyl accident, such as the IAEA (International Atomic Energy Agency) Convention on Early Notification of a Nuclear Accident, already signed by 72 countries, or the European Community System of Rapid Exchange of Information in Cases of Abnormal Levels of Radioactivity or of Nuclear Accidents. It should be noted that the latter stipulates that the notifying State will communicate to the other EC Member States the arrangements it has made to ensure public information.

While such international agreements represent a significant step forward and are a prerequisite for rapid transmission of information to the public by the national authorities of the countries concerned, difficult problems continue to exist in transmitting information to those living in border areas. In the same way that radioactive contamination can spread beyond frontiers, emergency information issued by the press, radio and television broadcasting systems in one country can be immediately picked up by the public in a neighbouring country and cause confusion if the content does not tally with that issued by local authorities. On-going liaison between public information officials in neighbouring countries should help to foresee — and attenuate — public response to unverified information coming from foreign countries.

By removing major differences in the way countries interpret and apply international radiation protection standards, much will be done to prevent public concern about discrepancies in the emergency measures taken in a neighbouring country. The work currently underway to harmonize intervention levels on an international scale, in particular through the NEA*, is a step in the right direction. It should be noted that the Council of Ministers of the European Communities has recently adopted a regulation laying down maximum permitted levels of radioactive contamination of foodstuffs following a nuclear accident or any other radiological emergency.

Communication with the public

The third type of problem highlighted by recent events — although these are long-standing problems which are not specific to the nuclear industry — concerns communication difficulties between scientific experts and the public. Many surveys have confirmed that the explanations given by the experts on the consequences of the Chernobyl accident were not understood by the public, and scientists are indeed often ill-prepared to communicate their information in accessible terms to the public at large.

As a rule, the public does not readily understand scientific ideas and is usually reluctant to consider complex technical subjects unless they are of immediate concern. On the other hand, recent surveys have shown that the public does not feel sufficiently informed about the risk of accidents at nuclear power plants, their implications and planned safety measures.

Modern communication methods which are already being applied in many different fields (consumer education, politics, etc.) are equally essential to help the public understand the complex scientific concepts relating to nuclear technology, safety and emergency response during an accident situation. Close co-operation between nuclear experts and “communicators” is therefore vital.

Communication with the public is an on-going process and the type of information required depends on the circumstances and the groups to which it is addressed. Persons in the industry, who already have some scientific or medical knowledge, require different information from that required by most members of the public. The information must also be tailored to other groups with specific responsibilities (political leaders, trade union representatives, officials, environmentalists etc.).

Regardless to whom it is addressed, the information must be clear, easy to understand, not unduly simplified, and “true” even if it is not reassuring. For instance, it is advisable to keep the number of measurement units quoted to a minimum (becquerel for activity levels and millisievert for doses) and to relate them to familiar

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* See the next article, which concerns a report by NEA experts on Intervention criteria following a nuclear accident (p. 14).
concepts. Comparisons should be given in order to explain abstract or unfamiliar ideas. For instance, the doses which the public might receive through the activities of the nuclear power industry should be compared to those from natural radiation or medical exposure to radiation.

In line with this objective, the public authorities in France have recently decided to introduce a severity scale for assessing the seriousness of nuclear accidents along the same lines as the Richter scale for earthquakes. The main purpose is to prevent misunderstandings and to clarify, for the general public, the relative importance of a nuclear incident or accident by enabling it to form an opinion quickly on the actual risks entailed.

Conclusions

Policies aimed at better controlling major industrial risks are helping to put nuclear power into a broader industrial context. Severe accidents which have occurred in other industries and those — fortunately few — in the nuclear power industry have spurred efforts to improve communication with the public in the event of an emergency. The progress made in this connection, for instance, in the chemical industry, matches that made in the nuclear industry following Chernobyl. Nevertheless, much work still remains to be done before communication mechanisms under accident conditions are fully mastered.
NEA Update

Intervention criteria following nuclear accidents

L. Chamney

The release of radioactive material resulting from the Chernobyl accident of April 1986 caused widespread environmental contamination, particularly in Europe. The protective measures taken in OECD countries included restrictions on the consumption and distribution of food and cleaning of contaminated areas. However, considerable differences were apparent in the establishment and application of intervention criteria, even taking into account the understandable differences in contamination levels, environmental features, living habits and diets and national regulatory approaches.

To help improve international harmonisation of the principles and criteria for the protection of the public in the event of a nuclear accident, the NEA Committee on Radiation Protection and Public Health requested an Expert Group to consider the whole question of intervention levels for nuclear emergencies, based on a critical review of the Member countries' responses to the Chernobyl accident [1]. The Expert Group has recently completed its review, and a report documenting their observations, conclusions and guidance will be published shortly [2].

Intervention Criteria

**Intervention levels (ILs)** are values of radiation dose which are used as a threshold for initiating a given set of protective measures. They normally are specified in terms of projected dose to individuals over a given period of time. It is generally recognised that the risks and difficulties associated with implementing the various measures can vary widely, depending on the particular circumstances of the accident, and thus the level of dose at which a given protective measure should be introduced is influenced by such considerations. Consequently, international recommendations call for a dose range to be established, for each protective measure, between two dose levels—a lower level, below which introduction of the protective measure is not likely to be warranted on the basis of radiological protection, and an upper level, above which the protective measure should almost certainly be implemented.

**Derived intervention levels (DILs)** are secondary criteria, usually specified as the concentration of activity of a given radionuclide within a given food or environmental medium, which, on the basis of specific assumptions on transfer to humans, corresponds to the relevant IL. The DILs can be compared directly to measurements of activity in the environment or in food, and thus can be used to provide a timely determination of the need for implementing protective measures.

International guidance

International guidance on emergency response planning existing prior to the Chernobyl accident [3,4] was mainly developed in the context of accidents of relatively short duration, where protective measures would usually be considered for an area close to the site of the accident (i.e., the near-field). (Table 1 shows existing intervention levels for various protective measures.) As such, the guidance does not appear to have given complete or adequate consideration to the issues and problems posed by Chernobyl-type accidents, involving distribution of radionuclides far from the accident site (i.e. the far-field) and over an extended period of time. Variable interpretations of how to apply the international guidance to the far-field situations which existed in OECD Member countries led to a certain degree of disharmony in their responses.

International guidance therefore needs to be expanded or clarified, primarily to indicate how criteria mainly derived for planning and response to near-field accidents should be adapted to respond appropriately to impacts in areas remote from the site and to long-term contamination problems. This applies in particular to the basic principles for planning and accident management provided in Publication 40 of the International Commission on Radiological Protection (ICRP) [3]. The rationale for such reconsideration involves the need to place more emphasis on control of the collective detriment in the far-field, and to establish an individual-related criterion based on acceptable risk. These issues should be given further consideration by the relevant international organisations.

Mr. Larry Chamney is a member of NEA's Radiation Protection and Waste Management Division.
The definition of DILs

One of the principal problems in the use of intervention criteria in the various countries concerns the diversity of values that were adopted for the Derived Intervention Levels (DILs) (see insert). The DILs for the various exposure pathways were identical in certain countries but significantly different in others. For example, in many cases, broad ranges were noted for specific controls on food consumption and distribution (see Table 2). Some of this diversity can be explained by differences in the intended application of the DILs, or by objective differences in environmental characteristics, contamination levels, and dietary and living habits. However, variations in methodologies and assumptions used in DIL modelling, as well as the often-hidden influence of considerations other than strict radiological criteria, also played a substantial role.

Given this considerable potential for differences in establishing DILs, even when they have been based on the same intervention level of dose, a more systematic and harmonised approach to their definition should be developed at the international level.

As a perspective, Table 3 shows the intervention criteria which have been adopted recently by the Commission of the European Communities (CEC). These values are intended for control of food placed on the market in the CEC Member countries following any future nuclear accident or other type of emergency which may lead to significant radioactive contamination of foods [5].

As already mentioned, in the OECD Member countries, the exposure pathway of most concern following the Chernobyl accident involved the ingestion of contaminated food, and most DILs adopted by authorities therefore concerned control levels for food consumption and distribution. However, other routes of radiation exposure also exist, for example contamination of surfaces and large areas (e.g., fields, buildings, roads), requiring extensive decontamination, and contaminated sewage sludge resulting from processes of nuclide concentration in sewage treatment plants, which may require special considerations related to its handling, disposal and use as fertiliser. The establishment of DILs for these and other potential routes of exposure needs to be considered further.

Table 1
Existing International Guidance on Intervention Levels (mSv)

<table>
<thead>
<tr>
<th>Protective Measure</th>
<th>Whole Body or Dose Equivalent</th>
<th>Single Organ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Sheltering</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>Stable Iodine Administration</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Evacuation</td>
<td>50</td>
<td>500</td>
</tr>
<tr>
<td>Relocation</td>
<td>50</td>
<td>500</td>
</tr>
<tr>
<td>Control of Food</td>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: References [3] and [4].

Table 2
Range of DILs Adopted in OECD Member Countries during the Chernobyl Accident for Controls on Food Consumption and Distribution (Bq/kg or Bq/l)

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Drinking Water</th>
<th>Milk/Dairy Produce</th>
<th>Vegetables</th>
<th>Meat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine-131</td>
<td>1.5 - 11 000</td>
<td>10 - 2 000</td>
<td>70 - 110 000</td>
<td>70 - 1 000</td>
</tr>
<tr>
<td>Caesium-134 and -137</td>
<td>50 - 51 000</td>
<td>50 - 8 900</td>
<td>100 - 190 000</td>
<td>100 - 6 000</td>
</tr>
</tbody>
</table>

Source: Reference [2].
Note: In many cases, the large range in DIL values is due to the differing assumptions used in their derivation and in their application. Detailed observations are provided in Reference [2].
Table 3
Intervention Criteria Adopted by the CEC for Controls on Marketing of Food* (Bq/kg or Bq/l)

<table>
<thead>
<tr>
<th></th>
<th>Milk/Dairy Produce</th>
<th>Other Produce (Meat, Vegetables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strontium Isotopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e.g. Strontium-90)</td>
<td>125</td>
<td>750</td>
</tr>
<tr>
<td>Iodine Isotopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e.g. Iodine-131)</td>
<td>500</td>
<td>2 000</td>
</tr>
<tr>
<td>Alpha-emitting Isotopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e.g. Plutonium-239, Americium-241)</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>Other Long-Lived Nuclides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e.g. Caesium-134, Caesium-137)</td>
<td>1 000</td>
<td>1 250</td>
</tr>
</tbody>
</table>

Source: Reference [5].
* These values represent maximum permitted levels for food placed on the market within CEC Member countries following any future nuclear accident or other radiological emergency.

International harmonisation of intervention criteria

The work of the NEA in identifying relevant issues and problems in the area of intervention criteria should be seen as a contribution to other international organisations examining the means for achieving a better international harmonisation of the principles and criteria for protection of the public in the event of an accident. Following publication of the Expert Group report, the NEA will continue to address specific issues in this field, and will follow closely the progress of national and international activities aimed at harmonising the development and application of intervention criteria.

References

NEA Update

Uranium supply and demand: a recent NEA review

Over the past few years, declining estimates for the use of nuclear power by the year 2000 have stabilised uranium prices at a low level and reduced exploration programmes. The NEA has just published a review of uranium supply and demand in the World Outside Centrally Planned Economies Area (WOCA) which contains updated information on uranium exploration activities, resources and production for some 46 countries during 1985 and 1986.

Expenditures on uranium exploration have remained stable since 1984 at the relatively low level of $120-150 million per year, compared with $760 million in year-of-expenditure dollars in 1979. Exploration expenditures by countries outside their territory also stabilised at around $70 million, compared to $158 million in 1979. No significant discovery of new deposits has been reported since 1984, although ongoing exploration in Canada has led to an increase in resource estimates of more than 50 000 tonnes of uranium.

As shown in the figure below, uranium production declined from 38 800 tonnes in 1984 to 34 900 tonnes in 1985, but recovered to 37 100 tonnes in 1986. Production remained 1 200 tonnes below reactor requirements in 1985 and 2 100 tonnes below in 1986. Total production in Australia returned to 1984 levels in 1986, following a temporary decline, and production capability has increased. Domestic production in the United States increased slightly and is expected to increase significantly by 1988, due to in situ leaching projects. Canada maintained its position as WOCA’s leading producer in 1985-1986 and also has new production prospects for 1988. Production in Africa has continued to decline since 1984.

Uranium supply and demand

Although the progression of nuclear electricity generating capacity has slowed substantially in the past fifteen years, the growth in nuclear capacity is expected to
rise from 235 GWe in 1986 to 342 GWe in 2000. Normally this should stimulate an increase in uranium production. However, during the period 1970 to 1987, an estimated 145 000 to 150 000 tonnes of uranium were produced in excess of requirements, equivalent to between three and four years of projected reactor needs. As this is higher than the desired inventory needs, some utilities will meet part of their requirements by drawing down these inventories, leaving actual production levels below requirements until an appropriate level of stocks is reached.

Depending on whether uranium production centres rely only on low cost resources (i.e., $80/kg or less) or on both low and higher cost resources ($130/kg or less), production from existing and committed centres would be sufficient until the early to mid-1990s. Additional production from planned or prospective centres could satisfy requirements until about the end of the century, whereupon utilities will have to rely either on new discoveries or on development of other substantial known resources. Given a lead time of about 10 years from start of exploration until first production from successful discoveries, current uranium exploration efforts may have to be intensified. These efforts could be stimulated by an increase in the price of uranium.

**Impact on long term production**

Factors which will have the greatest impact on the long term development of uranium resources are the rate of nuclear power growth and technological developments. Nuclear power growth will be affected by economic growth and the resulting changes in energy demand, the relative economies of nuclear and fossil fuels in generating electricity, environmental considerations (including the problems of acid rain and the "greenhouse effect") and public acceptance, especially in light of the Chernobyl accident.

On the technological side, several techniques have been developed which, to different degrees, economise on the use of uranium. Several of these, including more efficient fuel designs for light water reactors, the use of mixed oxide fuel (plutonium and uranium oxides) in light water reactors and advanced enrichment techniques, could significantly lessen future uranium requirements. In the longer term, fast breeder reactors using plutonium for fuel may become a viable economic alternative to conventional reactors.
International standard problems: a convenient tool for nuclear safety assessments

R. Caruso

Assessing the safety of a nuclear installation requires the use of a number of highly specialised tools, including computer codes, experimental facilities and their instrumentation, special measurement techniques, and methods for testing materials and components. These may nonetheless vary to some extent among the different countries. They can also be extremely complex and costly to produce and use, and in such cases, assessing their validity can also be difficult. The OECD countries have developed an effective method to increase confidence in the validity and accuracy of such tools by the use of International Standard Problem (ISP) exercises. Problems for the ISP programme conducted by the Nuclear Energy Agency are selected — and results evaluated — by the NEA Committee on the Safety of Nuclear Installations (CSNI).

The ISP programme involves the comparison of predictions of different computer codes for a given physical problem against one another or against an agreed standard. To date, 19 ISPs have been completed and documented. Six more are in various stages of completion, and new ones are proposed each year to the CSNI. Most of the problems so far have involved predicting the results of thermal-hydraulic tests designed to simulate transient conditions in nuclear power plants. The transients represent abnormal operating conditions that may occur during the operating life of a power plant. They include relatively straightforward conditions, such as a rapid reactor shutdown, and more serious conditions, up to and including the case of a full rupture of the largest pipe in the reactor coolant system. The most serious transients are known as Design Basis Accidents (DBAs), because they produce the most severe conditions which the power plant safety systems are designed to mitigate.

The experimental facilities which are the object of ISP exercises are located in many OECD countries. The LOBI test rig is operated by the Commission of the European Communities in Ispra, Italy. It simulates the primary and secondary system of a large pressurised water reactor (PWR), and was designed to investigate transient thermal-hydraulic behaviour during loss-of-cooling accidents (LOCA).

The Loss of Fluid Test (LOFT) facility, located in the United States, includes a volumetrically scaled, operating pressurised water reactor and is the only test facility which used actual nuclear heat sources for its experiments.

Some of the tests have also involved calculations of containment performance during accidents, for both DBAs and more severe accidents. One recent ISP involved the interaction between molten nuclear fuel material and concrete during severe accidents. Another required the calculation of a transient involving the rupture of a steam generator tube at the Doel Nuclear Power Station in Belgium, and it is anticipated that more transients involving actual events at operating power plants will be evaluated in this way.

The HDR facility, in the Federal Republic of Germany, is being used to investigate phenomena associated with reactor containment buildings. It was designed as an actual containment building for a small nuclear power plant, which was completed but never operated commercially. It is about 1/6 the size of containment buildings for large power plants, and is used to study phenomena associated with pipe ruptures and other situations, such as fires, which could occur inside reactor containments.

ISPs are performed as open or as blind problems. In an open problem, the results of an experiment are available to the participants before the experiment is evaluated. In a blind problem, the actual results are not made known until after delivery of the calculated results to the comparison organisation. Depending on the kind of experiment and its objectives, certain boundary and initial conditions of the experiment are communicated to the participants before they begin their calculations. This is necessary where it is difficult to guarantee the reproducibility of the experiments. The specification of initial and boundary conditions ensures that all models begin the experiment from the same point and model the same sequence of equipment operation. All ISP participants are provided with a complete description of the experimental facility. In some cases, where the test facility is new and no results of any other tests are available, double-blind ISPs are run to see how well the behaviour of the system can be modeled without tuning. Tuning refers to the adjusting of a computer model to account for specific characteristics of the test facility that have been observed in past exercises. Double-blind ISPs are especially challenging, to both the codes and the code users, and are correspondingly more valuable in assessing code performance.

The predicted results for the experiment are collected by a lead country and a report comparing the predictions to the actual data is prepared. This document is distributed to each participating organisation and discussed at a subsequent workshop.
The ISPs serve several objectives: 1) they contribute to a better understanding of postulated events; 2) they compare and evaluate the capability of best estimate computer codes to predict controlled experiments, and thus improve the confidence in them as assessment tools for safety issues; 3) they suggest necessary improvements in the codes; 4) they improve the ability of the code users; and 5) they provide information for quantifying safety margins in current design or licensing criteria. The ISP programme has contributed significantly to the nuclear safety field by accomplishing these objectives.
The feasibility of disposal of high-level radioactive waste into the seabed

B. Rüegger

The NEA will publish in the near future an evaluation of the technical feasibility and radiological safety of radioactive waste disposal into the seabed. Seabed burial is a multibarrier concept for the disposal of packaged high-level wastes or spent fuel within the geological structures which are found beneath the oceans. Seabed disposal is an alternative to geological disposal on land for such waste, and one which has been studied at an international level.

The eight volumes of the report present the results of more than eleven years of research conducted by the NEA Seabed Working Group* which was created to answer the following three key questions:

1) Are there locations under the oceans which have the geological stability and barrier properties suitable for disposal?

2) Is it possible to implant waste-filled canisters in the seabed sediments and what effect does this emplacement have on the barrier properties of the containment system?

3) What are the radiological consequences of seabed burial?

Research included technical feasibility, geological and physical processes, oceanography and biology, and a radiological safety assessment put all these aspects into perspective. The main findings of the report are summarised briefly below.

The disposal site

A subseabed disposal site would, in principle, be located at 4000 to 6000 meters below sea level, away from the edges of tectonic plates where seismic or volcanic movements could disrupt the repository and expose canisters, and away from areas of potential mineral and biological resources. The site would be chosen for the ability of the sediment formations to contain radionuclides if the canister fails through corrosion.

Research has been conducted to see if sites with such promising features can, in fact, be located in the oceans. The properties studied include the seafloor slope, sediment thickness, stratigraphy, tectonics, volcanism, seismicity, movement of water in the sediment (pore water advection), sorption capacity, degree of oxidation of the sediment (redox conditions), presence of erratic boulders, sand layers, and disturbance of the sediments by marine organisms (bioturbation).

Five locations in the North Pacific and ten in the North Atlantic have been evaluated. Some locations have been studied in detail while, in others, only one or two reconnaissance cruises were performed to supplement a limited data base. Two Atlantic sites have been used as reference sites for the radiological assessment.

Implantation of the waste

Wastes could be implanted at a depth of 50 to 70 meters into the sediments with a penetrator technique. Canisters, each weighing a few tons, would be allowed to fall through the water column to gain enough momentum to imbed themselves deep into the sediments, which immediately close in and seal dynamically. The properties of the sediments appear to be unaffected.

Wastes could also be implanted using deep sea drilling equipment based on that which has been used by the oil industry for the last 20 years. By this method, stacks of canisters would be placed in deep holes which would then be back-filled, with the uppermost canister at about 100 to 200 meters below the ocean floor.

The cost of high-level radioactive waste disposal in the seabed would depend on the method used but it is estimated to be less than 1 per cent of the cost of generating electricity.

Radiological assessment and results

The primary concern for radioactive waste disposal is the health risk to man by exposure to radionuclides escaping from the repository. The core of the evaluation is a calculation of the radiation exposure which humans would receive from a subseabed repository. The base case, which considers wastes buried 50 meters deep in the North Atlantic Ocean, describes what is thought to

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Mr. Bertrand Rüegger is a member of NEA’s Radiation Protection and Waste Management Division.

* Members of the NEA Seabed Working Group are Belgium, Canada, France, the Federal Republic of Germany, Italy, Japan, the Netherlands, Switzerland, United Kingdom, United States, and the Commission of European Communities.
Conclusions

The composite conclusion which can be drawn from the work of the Seabed Working Group is that seabed burial appears to be a technically feasible and economical method of disposal of high-level radioactive waste or spent fuel. Some of the specific conclusions which may be drawn from the substantial body of information available to characterise seabed disposal are:

- Sites have been found in both the North Atlantic and North Pacific oceans which, based on current guidelines and available data, appear suitable for disposal.

- Two options, penetrator emplacement and drilled emplacement, have been found to be technically and economically viable for the emplacement of waste canisters into sediments at required depths.

- Extrapolations from laboratory tests indicate that waste packages could be made to survive from a few hundred to as much as a few thousand years after burial. The conditioned waste would slowly release radioactivity over another few thousand years but the primary sediment barrier would contain most of the radionuclides until they have essentially completely decayed.

- The maximum dose to individuals or the population due to radionuclides which would eventually escape the sediment formation into the ocean would be infinitesimally small relative to natural background radiation and would be many orders of magnitude below present standards for human health protection.

- There would be insignificant risk to the deep sea environment from seabed disposal.

Although the general feasibility of seabed disposal has been established, the Seabed Working Group suggests that further research on sediment properties, deep-sea biology, and some engineering aspects would be needed to reduce the residual uncertainties, and should be conducted before a decision could be made to use seabed disposal for high-level wastes.

Obviously, legal and institutional aspects of seabed disposal would also have an important role to play in such a decision. This subject is currently under review by the Contracting Parties to the London Dumping Convention which agreed at their 8th Consultative Meeting in 1984 that "no such disposal should take place unless and until it is proved to be technically feasible and environmentally acceptable, including a determination that such wastes and matter can be effectively isolated from the marine environment, and a regulatory mechanism is elaborated under the London Dumping Convention to govern the disposal into the seabed of such radioactive wastes and matter."

In the meantime, it would be desirable to continue research activities in order to strengthen the data base and increase the amount of experience needed to decide whether such a disposal option is acceptable.
An international research project has recently been initiated under the auspices of the NEA to gain further insight into the long-term physical and chemical processes likely to influence the transport of radionuclides through rock masses. The research will involve the study of geochemical and hydrogeological processes acting upon the Koongarra uranium ore deposit in the Alligator Rivers region located in the Northern Territory of Australia which may resemble those processes acting upon a high-level radioactive waste disposal facility; hence the term "natural analogues".

The project, which builds on research carried out at the site since 1981, will include six technical sub-projects, the results of which should serve to increase the confidence placed in predictions of the safety of potential disposal sites:

- Modelling of radionuclide migration
- Hydrogeology at Koongarra
- Uranium/thorium disequilibria studies
- Colloid and groundwater studies
- Production and dispersion of naturally-occurring fission products
- Production and dispersion of naturally-occurring trans-uranic radionuclides.

Emphasis will be placed on validating the mathematical models used to assess the safety of potential sites for radioactive waste disposal by testing these models against field observations made at Koongarra. For example, large-scale hydrogeological models will be compared with regional data obtained from the area around Koongarra, and detailed geochemical models describing the behaviour and migration of radionuclides through rock will be compared with field and laboratory measurements.

Participants in the project are the Australian Nuclear Science and Technology Organisation (ANSTO), the Japanese Atomic Energy Research Institute (JAERI), the Swedish Nuclear Power Inspectorate (SKI), Her Majesty's Inspectorate of Pollution, the U.K. Department of the Environment (HMIP / DOE), the U.S. Nuclear Regulatory Commission (NRC) and, as an associate participant, the Power Reactor and Nuclear Fuel Development Corporation of Japan (PNC). The three-year programme will be managed by ANSTO and will cost about $A 2.6 million ($1.85 million).

Cross-section of Koongarra ore body

This uranium ore body lies near a fault between sandstone and quartz chlorite schist, and a strong groundwater flow crosses it. Experiments will measure the concentrations of uranium and its daughters on samples of rock and groundwater.
The nuclear power situation in OECD countries

1987 Situation

During 1987, nuclear electricity generation in OECD countries rose by 5.9 per cent from 1.240 terawatt hours (TWh) to 1.313 TWh. Nuclear power provided 22 per cent of electricity generated in the OECD area. The number of nuclear power plants connected to the grid in Member countries rose to 312, with some 15 new reactors coming on line. The total installed nuclear power capacity also increased by around 8 per cent to 240 GWe.

<table>
<thead>
<tr>
<th>Country</th>
<th>Units</th>
<th>Capacity (GWe)</th>
<th>Nuclear electricity generation (TWh)</th>
<th>Nuclear share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>7</td>
<td>5.5</td>
<td>39.6</td>
<td>66.1</td>
</tr>
<tr>
<td>Canada</td>
<td>18</td>
<td>11.8</td>
<td>72.9</td>
<td>15.1</td>
</tr>
<tr>
<td>Finland</td>
<td>4</td>
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<td>18.5</td>
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<td>France</td>
<td>53</td>
<td>49.7</td>
<td>251.3</td>
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<tr>
<td>Germany, F.R.</td>
<td>19</td>
<td>18.9</td>
<td>122.6</td>
<td>31.3</td>
</tr>
<tr>
<td>Italy</td>
<td>3</td>
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</tr>
<tr>
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<td>106</td>
<td>94.4</td>
<td>455.3</td>
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<tr>
<td>Total OECD</td>
<td>312</td>
<td>240.1</td>
<td>1312.6</td>
<td>22.4</td>
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</tbody>
</table>

Data as of 20th May 1988

Estimates of nuclear electricity capacity to the year 2000

<table>
<thead>
<tr>
<th>Country</th>
<th>1990 Net GWe</th>
<th>Nuclear Share (%)</th>
<th>2000 Net GWe</th>
<th>Nuclear Share (%)</th>
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<tr>
<td>Belgium</td>
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<td>17.3</td>
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* Secretariat's estimates
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URANIUM — Resources, Production and Demand
(A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, March 1988.)

Nuclear power-generating capacity will continue to expand albeit at a slower pace than during the past fifteen years. This experience must be matched by an adequately increasing supply of uranium. This report compares uranium supply and demand data in free market countries with the nuclear industry's natural uranium requirements up to the year 2000. It also reviews the status of uranium exploration, resources and production in 46 countries.

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All steps of the nuclear fuel cycle, as well as industrial and medical uses of radionuclides, generate low- and medium-level wastes. Repositories for disposal of these radioactive wastes near or deep below the ground surface already exist or are being planned in most of the OECD Member countries. Assessment of the processes and phenomena influencing the possible release of radionuclides from the repository environment, as discussed in these proceedings, is the first step in the analysis of the long-term safety of this form of disposal.

ISBN 92-64-03060-3
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Including the Index of information published in the first 40 issues
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Nuclear Waste Bulletin No. 2.

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Editor's note

Radiological impact of the Chernobyl accident in OECD countries

On 15th January 1988, the NEA issued a press release concerning the publication of its report on The Radiological Impact of the Chernobyl Accident in OECD Countries. Included in the press release was a map showing estimates of the average individual dose received in each OECD country. The NEA did not ask Member countries to provide these estimates directly. Instead, the authorities of Member countries provided collective dose estimates from which the NEA derived indicative average individual doses by dividing the total collective dose by the population of the country*. Owing to the low deposition levels observed in Spain, the authorities there did not consider it useful to calculate a collective dose and therefore, no individual dose estimate could be given for Spain. The NEA did not intend to imply, in its press release, that the impact of the Chernobyl accident was not evaluated in Spain, and in fact, several other parts of the report give data on the radiological impact of this accident on Spain. The NEA regrets any misunderstanding caused by the selection of this map for the press release.

The report The Radiological Impact of the Chernobyl Accident in OECD Countries is available from all OECD Sales Agents in Member countries, as well as from the OECD Publications Office, 2 rue André Pascal, 75775 Paris Cedex 16, France. [ISBN 92-64-13043-8; US$ 31.00].

* All dose estimates except the average doses were provided officially to the NEA.
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