IAEA'S ACTIVITIES IN P&T

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Abstract

The paper gives an overview of the IAEA's activities on Partitioning and Transmutation in the Division of Nuclear Power and the Division of Nuclear Fuel Cycle and Waste Technology, carried out since the information provided at the previous Information Exchange Meeting held in 1996.

Introduction

There is considerable interest among a number of Member states in the Partitioning and Transmutation (P&T) of long-lived radionuclides as a potential complement to the reference concept of the closed nuclear fuel cycle comprising: fuel fabrication, energy generation, intermediate storage of spent fuel, reprocessing, plutonium use in fuel and disposal of solidified high-level waste (HLW) in a deep geologic repository. This is the reason why P&T activities have been regularly dealt with in the IAEA Programme of Activities since the International Nuclear Fuel Cycle Evaluation (INFCE), conducted in the late seventies.

The IAEA reports on P&T published between 1982 and 1997 are listed at the end of this paper. Since the first OECD-NEA Information Exchange Meeting in 1990, the IAEA has been reporting on it's P&T activities, which covered at that time mainly non-OECD countries. This paper gives an overview of these activities carried out in the Division of Nuclear Power and the Division of Nuclear Fuel Cycle and Waste Technology, since the previous Information Exchange Meeting held in 1996.

Early 1998, the Director General of the IAEA established a Senior Expert Group (SEG) to carry out an in-depth review of the main IAEA Programme of Activities. In its report to the DG, the SEG identified in the Programme for Nuclear Power and the Nuclear Fuel Cycle specific strategic objectives and recommended adjusting the Programme of Activities, which is expected to be done in 1999. Amongst others, it identified three specific strategic objectives on P&T:

- Further development and introduction of advanced power reactors with inherent safety and passive mechanism and of emerging nuclear energy systems (ADS).
- Potential and development of partitioning and transmutation techniques for high-level long-lived wastes.
- Potential, development and introduction of new proliferation resistant, actinides burning and transmutation fit fuel cycles.

IAEA activities

Status report on actinide and fission product transmutation studies

While intensive R&D programmes in the field of actinide and fission products transmutation are carried in OECD countries, there is a broader international interest in this area. Many non-OECD countries either already rely on nuclear power as a very important source of energy, or consider seriously plans for nuclear development as a way to meet the energy needs of their large and fast growing population (China, India). Two non-OECD states (Russia and China) possess nuclear weapons and face problems connected with the disposal of radwaste of defence nuclear facilities. These factors form an incentive for transmutation related research and at least four non-OECD countries have projects of different scale under way: Czech Republic, China, India, and the Russian Federation.

In view of this, the IAEA has taken an initiative to make a survey of the research activities in non-OECD countries upon recommendation by a Technical Committee Meeting (TCM) held in Vienna in 1994. The report was prepared by a TCM in September 1995 and published in 1997 (IAEA-TECDOC-948).

Accelerator-driven systems: energy generation and transmutation of nuclear waste (status report)

Participants of a Special Scientific Programme on "Use of High Energy Accelerators for Transmutation of Actinides and Power Production" held in Vienna in 1994, in conjunction with the 38th IAEA General Conference recommended the IAEA to prepare a status report on **Accelerator Driven Systems** (ADS). The general purpose of the status report was to provide an overview of ongoing development activities, different concepts being developed and their status, as well as typical development trends in this area and to evaluate the potential of this system for power production, Pu burning and transmutation of minor actinides and fission products. This document includes the individual contributions by the experts from six countries and two international organisations, as well as executive summaries in many different areas of the ADS technology. The document was published and distributed by the IAEA in 1997 (IAEA-TECDOC-985).

Co-ordinated Research Project (CRP) on the potential of Th-based fuel cycles to constrain Pu and to reduce long-term waste toxicities

This CRP started in 1996 with participation of China, Germany, India, Israel, Japan, Republic of Korea, the Netherlands, Russia and the USA with a purpose to examine the different fuel cycle options in which Pu can be recycled with Th to get rid of the Pu, or replace the Pu with materials that are less unacceptable to the public. The potential of the Th matrix will be examined through computer calculations. Each participant would choose his own fuel cycle, and the different cycles will be compared through certain predefined parameters (e.g. annual reduction in Pu inventory). As a final recommendation, the CRP could suggest the demonstration of Th-Pu burning in a reactor in one of the Member states. The toxicity accumulation and the transmutation potential of Th-based cycles for current, advanced and innovative nuclear power reactors including hybrid systems will be investigated.

To achieve the target of the CRP, it was decided to set up three stages. During the first stage, two benchmark exercises should be performed. Benchmark 1 would deal with calculation of the isotopic composition, cross-sections and fluxes for a typical PWR-cell loaded with (Pu-Th)O_2 fuel, as a function of the fuel burn-up. Benchmark 2 would deal with the same calculations, but for PWR lattice. Results of the benchmark exercises were discussed at the first Research Co-ordination Meeting (RCM) held in October 1996. Generally, the benchmark results of the participating countries showed good agreement regarding the destruction of Pu, and the isotopic composition of the remaining Pu. Some discrepancies appeared in the calculated neutron multiplication factor of the fuel, and in the build-up of minor actinides for high burn-up. The results of this stage were reported at the 9th International Conference on Emerging Nuclear Energy Systems (ICENES '98), held in Tel-Aviv, Israel, 28 June – 2 July 1998.

A critical review of the basic data and of the methods were performed during the second stage of the CRP. Participants of the CRP agreed that during the second stage of the CRP, three types of reactors should be investigated in terms of their potential to burn plutonium. The participants were divided into three groups, of which each group would investigate one reactor type. This procedure allowed a comparison of the computed results among several participants investigating the same type of reactor, and thus served as an additional benchmark exercise. The results (Calculations on Burning of Plutonium in LWR, HTR and MSR), obtained during the second stage of the CRP, were presented and analysed at the Second Research Co-ordination Meeting (RCM) held in Tel-Aviv, Israel, from 23-25 June 1998. Generally, the results showed a range of fuelling strategies on the basis of current and near-future-technologies.

For the third stage of the CRP, a Pu generating unit combined with a corresponding Pu burning unit was selected to assure a complete burning of the generated plutonium. A complete Pu-flow cycle will be considered. On the basis of these data, overall radio–toxicities of the combined system of PWRs and Pu burners will be compared with the U-fuelled PWR. The third RCM is planned in April 1999.

CRP on the use of Th-based fuel cycle in Accelerator Driven Systems (ADS) to Incinerate Pu and to Reduce Long-term Waste Toxicities

The purpose of the CRP is to assess the uncertainties of the calculated neutronic parameters of a simple model of Th or U fuelled ADS, in order to get a consensus on the calculation methods and associated nuclear data. Participants identified a number of issues which should be considered to get a better understanding of the ADS and agreed that some points, such as comparison of the different approaches and tools used by the different groups, should be reviewed at a later stage.

The first stage of the ADS benchmark was devoted to neutronics analysis of those ADS which are under development for nuclear energy production with a low long-term radioactivity of waste. As a background of this concept, Energy Amplifier (EA-ADS) simplified model was under inter-comparison.

The first RCM was held in March 1997 in Italy. The purpose of the meeting was to review the results of the first stage of ADS neutronic benchmark and to elaborate a programme for the second stage. Results of this RCM were reported to the IAEA TCM on Feasibility and Motivation for Hybrid Concepts for Nuclear Energy Generation and Transmutation held in Madrid, Spain, 17-19 September 1997.

During the next stage, an inter-comparison of the transmutation potential of ADS: transmutation rates of MA and LLFP, actinide and fission product inventories in a modular fast spectrum ADS, will be investigated. Results of this stage are very important in order to:

- Expand the benchmark option of the CRP to ADS new application.
- Cover the most essential activities (conducted now in many counties) to clarify the potential of ADS in transmutation of long-lived actinide and toxic fission products being produced by nuclear power in using the of U-Pu fuel cycle.
- Find an international consensus on the future role of ADS in a nuclear power scenario.

The second RCM will be held from 2-4 December 1998 in Petten, the Netherlands.

Technical committee meeting on feasibility and motivation for hybrid concepts for nuclear energy generation and transmutation

The purpose of this TCM was to assess the advantages and disadvantages of hybrid concepts for nuclear energy generation and transmutation of minor actinides and their potential role relative to the current nuclear power programmes and potential future direction to promote these concepts world-wide. The TCM was hosted by CIEMAT (Centro de Investigaciones Energeticas Medicamentales y Tecnologicas) and held at its headquarters in Madrid, Spain, on 17-19 September 1997.

Several major programmes/concepts on ADS development were presented:

- CERN Concept of ADS (C. Rubbia).
- OMEGA Programme & Neutron Science Project For Developing Accelerator Hybrid System at JAERI (T. Mukaiyama).
- Los Alamos ATW Programme (F. Venneri).
- Hybrid Systems For Nuclear Waste Transmutation Project In France (M. Salvatores).

The most salient observations resulting from the TCM were:

- Several accelerator systems and sources concepts can be developed for ADS.
- It is however important to have a very reliable source of neutrons coupled to the reactor system.
- The associated sub-critical reactor will likely be liquid lead-cooled (or lead/bismuth cooled), with efforts to use natural convection for lead circulation.
- Effort to develop neutronic benchmarks and codes for ADS should be pursued at the international level under the aegis of the Agency.
- Even if ADS is tentatively presented by some as a way to solve all nuclear waste issues, ADS is not an alternative to geological disposal. However, they have the potential to drastically reduce the waste toxicity, thanks to their capacity to burn minor actinides and fission products. As a reprocessing stage will be required, non-proliferation concerns should therefore be addressed.
- Further development of ADS requires the building of a demonstration device with a thermal power, in the 100-300 MW range. Efforts should be co-ordinated at international level on this matter.
- This pre-industrial test should provide input on the feasibility of the industrial deployment of ADS, including fuel cycle requirements, and a better understanding of the safety issues to be addressed.

Data-base of experimental facilities and computer codes for ADS related R&D

The needs for strengthening international co-operation in the field of the R&D for accelerator-driven systems was emphasised at several international forums:

- Scientific Programme on “Use of High Energy Accelerators for Transmutation of Actinides and Power Production”, Vienna, 21 September 1994 (in conjunction with the 38th IAEA General Conference).
- The Second International Conference on Accelerator-Driven Transmutation Technologies and Applications, Kalmar, Sweden, 3-7 June 1996.
- The 8th International Conference on Emerging Nuclear Energy Systems (ICENES’96), Obninsk, Russian Federation, 24-28 June 1996.

Consultants on Hybrid Concepts for Nuclear Energy Generation and Transmutation held in Vienna, on 16-17 December 1996 noted that:

- An increasing number of groups is entering this field of research.
- Many of these groups are not embedded in wider national activities.
- For these groups there is a need for co-ordinating their efforts and jointly funding projects as also for getting access to information from nationally or internationally co-ordinated activities.

Discussing organisational aspects of a possible IAEA involvement, consultants came to the conclusion that an effective co-ordination would necessitate the creation of an information document on existing and planned experimental facilities which can be used for ADS related R&D. The information would be provided by the Member states and distributed to all interested institutions. To facilitate this recommendation, two consultancies were organised in 1997 to work out and finalise a format of the document.

In June 1998, a draft of the database (DB) was distributed by the Agency to all contributors in the form of working material. A consultancy, was convened from 27-31 July 1998 in Moscow to review the draft.

The consultants made the following recommendations:

- The “hard” copy of the DB should be followed by an “electronic” version of the DB publicly accessible on the Internet or on CD-ROM.
- The IAEA should continue the ADS activities in CRPs and several possible topics for future CRPs have been proposed for consideration.
- The status on ADS should be regularly upgraded in an IAEA TECDOC, accessible to the general public and re-issued every 3-4 years.
- International meetings on ADS R&D need stronger international co-operation and harmonisation. There are already a large number of different international meetings and activities in this area. In this context, it is desirable to harmonise and closely co-ordinate the IAEA ADS activities with OECD-NEA.
- The IAEA co-operation in the preparation of the coming ADTT conference in Prague (June 1999) is highly appreciated.
- To establish an IAEA Advisory Group on ADS Concepts for Nuclear Energy Generation and Transmutation and Related Fuel Cycles for guidance on the above recommendations.

Co-ordinated Research Project (CRP) on Safety, Environmental and non-proliferation aspects of partitioning and transmutation of actinides and fission products

The overall objectives of the CRP are to reduce the long-term hazard arising from the disposal of high level waste. More specifically, the CRP aims to identify the critical nuclides to be considered in a P&T strategy, to quantify their radiological importance in a global nuclear fuel cycle analysis and to establish a priority list of radionuclides according the hazard definition.

During the first Research Co-ordination Meeting, held in October 1996, the Chief Scientific Investigators (CSI) made the following recommendations:

- The CSIs noted that the P&T studies initiated at OECD-NEA have up to now been focused on the development of the P&T processes within France and Japan and those countries (UK, USA) being interested in its evolution or which were engaged in these activities in the past. The OECD-NEA intends to make a system analysis study of the entire P&T field except for some very fundamental issues, e.g.: radionuclide toxicity ranking and influence of the geosphere on the dose-to-man generated by a radionuclide inventory. Keeping these principles in mind it is obvious that the IAEA with a world-wide scope in nuclear matters, will cover those aspects of P&T which are explicitly outside the OECD-NEA area (China, India, Korea, Republic of Russia) or which are not treated in the OECD-NEA system's analysis. In this context the detailed technological process analysis will not be studied within this CRP and the direct safety impact on workers and environment will be restricted to non-OECD countries. The contribution of the IAEA CRP on P&T will focus on the radiological impact of partitioning on the disposal issues.
- The CSIs pointed out that there are still no proposals to cover non-proliferation aspects of P&T processes and suggested to leave this subject out of the scope for the time being.
- The CSIs pointed out that in Russia in August 1996, the first stage of an industrial separation facility started operation at RT-1 in Chelyabinsk. This stage is based on the dicarbollide process and separates Cs and Sr from HLW. The second stage which is under design, will be based on a generic phosphine oxide process to separate actinides and Tc. The main aim of this separation facility is to simplify handling of HLW in Russia. However, the experience with this facility in the future could be useful for the investigation on P&T. This technology could be included in comparative analysis with TRUEX, DIDPA, DIAMEX and others. This facility could also be used to investigate operational safety aspects of partitioning facilities and secondary waste arising in a real process. Therefore, the CSIs proposed to include operational safety aspects in the Russian contribution.
- The CSIs recommended that the Republic of Korea should try to determine the required hazard reduction factor with and without P&T in addition to their proposed work which is relevant to the disposal of spent nuclear fuel.
- The CSIs proposed that in addition to its present work on quantification of radiological source terms and hazard reduction by partitioning of HLW with reference to PHWR fuel arisings, India should evaluate the radiological source terms of the critical nuclides generated in the thorium fuel cycle for their long-term hazard potential.
- The CSIs stressed that up to now the P&T community has considered the critical nuclides from the potential radiotoxicity point of view. In this respect, Pu and Am are the most important hazardous nuclides. However, taking into account the very low solubility of Pu and Am in disposal conditions, it is necessary to review the ranking and to investigate the risk of the nuclides for the biosphere and mankind. Other nuclides, e.g. ^{129}I, ^{237}Np, ^{99}Tc, ^{135}Cs, ^{93}Zr, ^{90}Sr and ^{137}Cs, will be also comparatively studied. In the framework of P&T, recycling of actinides implies an increase of the ^{238}Pu level in the fuel recycling processes and of ^{241}Am, ^{243}Am, ^{244}Cm in the MA recycling. The handling and treatment of industrial quantities puts the ^{238}Pu and ^{244}Cm at a much higher critical level than the Am isotopes in the safety assessment. The CSIs suggested that Belgium and UK should consider these aspects in their contribution to the CRP.

- The CSIs pointed out that the TRPO and DHDECMP-HDEHP processes for separation of MA from HLW are being investigated in China. It could be recommended to compare decontamination factors for both processes and their advantages and disadvantages and include these results in China's contribution to the CRP.

A second RCM is scheduled from 1-4 December 1998, where progress reports will be presented based on the proposals in the research agreements/contracts and the recommendations of the first meeting.

Conclusions

- The IAEA will continue to assist Member states in activities on partitioning and transmutation according to their needs.
- Adjustments in the IAEA programme of activities will be made based on the recommendations of the SEG.
- The IAEA will continue to co-ordinate activities with international organisations such as OECD-NEA and EC.

LIST OF IAEA PUBLICATIONS

[1] "*Evaluation of Actinide Partitioning and Transmutation*", Technical Report Series No. 214, Vienna, 1982, International Atomic Energy Agency.

[2] "*Feasibility of Separation and Utilization of Ruthenium, Rhodium and Palladium from High Level Wastes*", Technical Report Series No. 308, Vienna, 1989, International Atomic Energy Agency.

[3] "*Feasibility of Separation and Utilization of Caesium and Strontium from High Level Liquid Wastes*", Technical Report Series No. 356, Vienna, 1993, International Atomic Energy Agency.

[4] "*Use of Fast Reactors for Actinide Transmutation*", IAEA-TECDOC-693, Vienna, 1993, International Atomic Energy Agency.

[5] "*Safety and Environmental Aspects of Partitioning and Transmutation of Actinides and Fission Products*", IAEA-TECDOC-783, Vienna, 1995, International Atomic Energy Agency.

[6] "*Advanced Fuels With Reduced Actinide Generation*", IAEA-TECDOC-916, Vienna, 1996, International Atomic Energy Agency.

[7] "*Status Report on Actinide and Fission Product Transmutation Studies*", IAEA-TECDOC-948, Vienna, 1997, International Atomic Energy Agency.

[8] "*Accelerator Driven Systems: Energy Generation and Transmutation of Nuclear Waste*", IAEA-TECDOC-985, Vienna, 1997, International Atomic Energy Agency.