

IAEA ACTIVITY ON PARTITIONING AND TRANSMUTATION OF ACTINIDES AND FISSION PRODUCTS

A. Grigoriev, V. Arkhipov,
IAEA, Division of Nuclear Power and Fuel Cycle

Abstract

In 1990, the IAEA received a request from Member States to review the status of research and development on partitioning and transmutation of actinides and fission products. In response to this request the Advisory Group Meeting (AG) was held in the fall of 1991. AG advised the Agency to play an active role in coordinating international activities in this area. A series of meetings that followed identified considerable interest among many Member States and international organizations in the P&T options as a potential complement to the reference concepts of the back-end of nuclear fuel cycle. Inherent difficulties for the Agency to actively explore this programme were identified including non-proliferation concerns from some Member States about partitioning technology and possible duplication of effort in other international organizations, especially OECD/NEA. But, there remain fundamental questions to be addressed on the objectives of and motivations for P&T and it is clear that some common international understanding would be necessary. In order to contribute to the solution of this problem, and considering the existence of programmes being implemented by OECD/NEA, the Agency has initiated a CRP entitled "Safety, environmental and non-proliferation aspects of partitioning and transmutation of actinides and fission products" (1995-1998). The documents on accelerator-driven systems and on the status of transmutation studies in non-OECD countries are being prepared.

1. *Introduction*

There is considerable interest among many 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.

P&T is a complex issue involving safety, technological, economic and public acceptance aspects. Until now, there is no clear indication that P&T of actinides and long-lived fission products offers a more safe and effective waste management option. Current national (China, France, Japan, Russia) and international (OECD/NEA and CEU) programmes on P&T tend to be more concerned with the development of techniques for the separation of actinides, preparation of fuel and targets and for transmutation of actinides and long lived-fission products rather than with the studies of safety implications of P&T.

The IAEA's involvement with the problem of partitioning and transmutation of actinides and fission products goes back to 1976 when the Agency carried out a Co-ordinated Research Programme (CRP). The results of the CRP were published in a Technical Report Series No. 214 in 1982. The conclusion of this report on P&T was rather negative. In 1990, the Agency received a request from some Member States to re-activate the programme. The Advisory Group Meeting (AGM) held in the autumn of 1991 advised the Agency to play an active role in coordinating international activities in this area. A series of meetings (two Consultant Meetings (CS) and one Technical Committee Meeting (TCM)) that followed identified considerable interest among many Member States and international organizations in the P&T options as a potential complement to the reference concepts of the back-end of nuclear fuel cycle.

The meetings also gave the opportunity to review the current status and progress of national and international programmes on P&T, to identify the most important directions of national and international co-operation. The meetings provided advice regarding the IAEA programme on P&T.

2. *Main results of IAEA meetings on P&T*

There is a scientific consensus that the current waste management concept provides an adequate protection to the population and the environment by sufficient confinement of radionuclides. According to the experts' opinion the purpose of P&T is to reduce the long-term effects of radiotoxicity of actinides and long-lived fission products but cannot eliminate the need for a geologic repository. In some countries (France, Japan, Russia) it has already received political or institutional backing as a complementary future strategy to the current fuel cycle. The specific role of P&T in the nuclear fuel cycle needs to be defined further within the general trend to minimize waste and the growing concern about a maximum degree of safety in the very long term.

A general guidance with respect to hazard reduction by P&T cannot be given since the local geological, hydrogeological and confinement conditions of proposed repositories vary from country to country. However, qualitative indications will be very useful to establish an order of priority in the radionuclides to be studied regarding the hazard reduction involved.

It was emphasized that from the point of view of potential hazards (potential hazard involves the source term without taking into account the geological barriers), the actinides are the most important nuclides to be investigated in a P&T concept, however, some long-lived mobile fission products constitute the main residual hazard (residual hazard means the radionuclides released to the biosphere) over a long term period of time.

The following are main conclusions of meetings concerning the progress being made in the fields of partitioning, of fuel and target developments and of transmutation.

Partitioning

Two main fields of work are involved in the partitioning of plutonium, minor actinides and long lived radionuclides: wet separation methods that are implemented in association with the PUREX process; pyrometallurgical processes, which may follow the PUREX process or completely replace it.

Significant progress has been achieved in reducing the losses of plutonium from the PUREX process and in the improvement of neptunium and technetium separation through flow sheet alterations. Progress has also been made with the partitioning of other elements.

Fuel and Target Development for Transmutation

The technical feasibility of the use of U-Pu and U oxide fuels for the recycling of minor actinides in a fast reactor has been proven to some extent. Oxide, metal alloy and inert matrix fuels and targets containing MA and Tc-99 are fabricated, at a laboratory scale, and scheduled for irradiation. Concepts of nitride and molten salt fuels have been proposed for the advanced transmutation systems, e.g. actinide burners and accelerator driven systems.

Transmutation

An overall reduction of the radiological hazards requires the development of new technologies, e.g. with an accelerator driven transmutation system. Only with a major break-through in technology are we likely to reach the expected goal.

3. *Role and involvement of IAEA*

The participants of IAEA meetings stressed that OECD/NEA and CEU have managed international P&T programmes. However, a number of countries are not yet covered by these international bodies, therefore the IAEA might play a significant role by coordinating the efforts of these countries with OECD/NEA and CEU countries.

Based on the recommendation of experts from Member States and considering the existence of technologically oriented programmes being implemented by OECD/NEA and CEU, the IAEA established a complementary programme on the safety, environmental and non-proliferation aspects of P&T that could be beneficial in assisting Member States.

A series of topics are to be addressed as:

1. the definition of hazard criteria;
2. the evaluation of hazard reduction;
3. the definition of a priority list of nuclides to be considered.

Since each of the three above-mentioned topics are strongly dependent on the geological nature of the repositories and on their technological implementation it is deemed necessary to widen the scope of the P&T discussion to the general waste management issue involved with such an option. It is, therefore, suggested to associate plutonium and waste management experts in the P&T discussions.

In the mainstream of this programme, IAEA with the P&T, Pu, and Waste Management expert groups will be able to make a comprehensive evaluation of the following tasks:

4. establish a worldwide inventory of the radionuclide source term;

5. identify the possible fundamental safety benefits of a series of P&T options and scenarios;
6. evaluate the waste conditioning processes in the perspective of a future transmutation option;
7. identify the influence of secondary waste arisings on the net safety benefit of the overall P&T processes;
8. examine the non-proliferation implications of an extended fuel cycle activity over a long period of time.

This recommendation became a basis of a CRP on P&T initiated by the IAEA in 1994.

4. *Co-ordinated research programme "Evaluation of the Safety, Environmental and Non-Proliferation Aspects of Partitioning and Transmutation of Actinides and Fission Products", 1994 - 1998*

Scientific scope and programme goals

The CRP will promote the exchange of information on the results gained by different countries in order to clarify the objectives and motivation of P&T and to obtain a common international understanding from the standpoint of safety and non-proliferation. The results of this programme will also give the opportunity to Member States to define the scope of further research and development work required in this field. The intended beneficiaries of the proposed programme are both the policy makers and the research programme managers in the fuel cycle field.

In the framework of the CRP the radionuclides hazard is to be studied in order to identify the critical nuclides to be considered in a P&T strategy and to quantify their radiological importance in a global nuclear fuel cycle analysis. A priority list of radionuclides for P&T is to be established according to the hazard definition.

The necessary extent of P&T for achieving the radiological hazard reduction should be clearly defined. It may turn out that not all long-lived radionuclides will have to be partitioned to the same degree and hence their contribution to the disposed waste will have a different effect on the overall hazard reduction. The achievable goals in hazard reduction by different P&T systems will be examined.

The construction and operation of various nuclear facilities needed for P&T may involve increasing risk for the personnel and additional detriment to the environment. The safety aspects of the modified fuel cycle are to be realistically assessed.

Non-proliferation implications of different P&T systems will be assessed in order to define the most promising and effective schemes in this regard.

Programme Subjects

A list of proposed subjects is given below :

- a) **Critical Radionuclides for P&T**
These studies will define the hazard criteria and consider the hazards of different radionuclides in HLW. As a result of the studies a priority list of critical radionuclides will be established for partitioning and transmutation.
- b) **Radiological Hazard Reduction by P&T**
The aims of the radiological hazard reduction will be defined and the necessary extent of P&T

for achieving the hazard reduction will be studied. Attainable hazard reduction by different P&T systems will be assessed. For different partitioning processes under development, the influence of secondary waste arisings and the quantification of unseparated radionuclides which must be sent to a repository will be evaluated.

c) **Safety assessments of different P&T processes**

These studies will include investigations of the operational safety aspects of different P&T systems including the management of the secondary waste in order to assess the safety of the modified fuel cycle.

d) **Non-proliferation aspects of P&T processes**

These studies will be aimed at the potential of P&T for the technical contribution to the non-proliferation regime.

5. **Status Report on Transmutation of Actinides in non-OECD Countries** (to be published in 1996)

The preparation of a Status Report on Actinide Transmutation in Advanced Nuclear Reactors in non-OECD countries was initiated in 1994. Its objective is to review the status of research activities in non-OECD countries and to discuss relevant programmes on transmutation development in these countries.

Participating Countries: Belgium, China, Czech Republic, France, India, Japan, Republic of Korea, Russian Federation.

6. **Status Report on Accelerator Driven Systems** (to be published in 1997)

The IAEA has also started to prepare a status report on **Accelerator Driven Systems (ADS)**, as recommended by participants of a Special Scientific Programme on "Use of High Energy Accelerators for Transmutation of Actinides and Power Production" held at the Austria Center in Vienna, on 21 September 1994 in conjunction with the 38th IAEA General Conference. The general purpose of the Status Report is to provide, in particular for planners, decision makers, and other parties that are not directly involved in the development of ADS, an overview of on-going development activities, different concepts being developed and their project status, as well as typical development trends.

Participating Countries and Organizations: France, Japan, Russian Federation, Sweden, USA, EC-JRC (Ispra Site), CERN.

7. **Coordinated Research Programme (CRP) on the Potential of Th-based Fuel Cycles to Constrain Pu and Reduce Long-term Waste Toxicities.**

This CRP was established in 1995. It will examine the different fuel cycle options in which Pu can be recycled with Th to eliminate of Pu, or replace Pu with materials that are more acceptable to the public. Potential of Th-matrix will be examined through computer calculations. Each participant can choose his own cycle, and the different cycles can be compared through certain predefined parameters (e.g., annual reduction in Pu inventory). The toxicity accumulation and a transmutation potential of Th-based cycles for current, advanced and innovative nuclear power reactors, including hybrid systems, will be investigated.

The CRP consists of two parts (Benchmarks):

Part 1: Calculation of the isotopic composition, cross- sections and fluxes for a typical PWR-cell loaded with (Pu-Th)O₂ - fuel, as a function of the fuel burnup.

8 countries are participating in the Benchmark.

Data set was distributed by IAEA in 1995 and all participants have already sent us the results of calculations. As all results of calculations are available, RCM is planned to be held in October 1996 in Vienna to discuss the results of calculations and to approve the next stage of the programme.

Part 2: Accelerator Driven Systems (ADS) - Neutronic Calculations

Goal of Stage 1 of this Benchmark was defined as a verification of reactivity swing during burnup, as well as some important reactivity effects for a fast spectrum ADS (²³³U - ²³²Th fuel) with an external (spallation type) neutron source at different subcriticality levels. 9 countries and 1 International Organization (CERN) are participating in this Benchmark. The final data specification was distributed in July 1996 and RCM is planned for February-March 1997.