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Potential of thorium-based fuel cycles to constrain plutonium and to reduce the long-lived waste toxicity

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FOREWORD

An important function of the International Atomic Energy Agency is to "foster the exchange of scientific and technical information" and to "encourage and assist research on, and development and practical application of, atomic energy for peaceful uses throughout the world". For innovative advanced nuclear reactor concepts, IAEA Member States in many cases find it attractive to cooperate internationally in technology development. The IAEA's fast reactor and hybrid systems technology development activities, which are conducted within its Nuclear Power Program, encourage international cooperation through technical information exchange and collaborative research. As regards the latter, Coordinated Research Projects (CRPs) are tools that are effectively used in IAEA's activities both to promote exchange of scientific and technical information, and to implement collaborative. Apart from allowing to share the efforts on an international basis and to benefit from the joint experience and expertise of researchers from the participating institutes, CRPs are fostering international team building.

Large stockpiles of civil plutonium have accumulated worldwide from nuclear power programs in different countries. There is a serious public and political concern in the world about misuse of this plutonium and about accidental release of highly radiotoxic material into the environment. It is therefore necessary to safeguard the plutonium under strong security. One alternative for the management of plutonium is to incinerate it in reactors. However, if the reactors are fuelled with plutonium in the form of U-Pu-mixed oxide (MOX), second-generation plutonium is produced. A possible solution to this problem is to incinerate plutonium in combination with thorium. The thorium cycle produces ^{233}U that, from a non-proliferation point of view, is preferable to plutonium for two reasons. Firstly, it is contaminated with ^{232}U, which decays to give highly active daughter products. This would make handling and diversion difficult. Secondly, in case this is not sufficient a deterrent, the ^{233}U could be denatured by adding some ^{238}U to the thorium. The quantity of ^{238}U could be fine-tuned so as to be sufficient to denature the ^{233}U, but not so much as to produce a significant quantity of plutonium. The thorium option not only produces electricity, but also replaces the plutonium with denatured ^{233}U, which can be used in other reactors at a later date. All this can be done in existing reactors.

In 1995, the IAEA initiated the CRP on "Potential of Thorium-based Fuel Cycles to Constrain Plutonium and to Reduce Long-term Waste Toxicity". The Member States joining into the CRP were: China, Germany, India, Israel, Japan, Republic of Korea, the Netherlands, Russian Federation and the United States of America.

This CRP examined the different fuel cycle options in which plutonium can be recycled with thorium to incinerate plutonium. The potential of the thorium-matrix has been examined through computer simulations. Each participant has chosen his own cycle, and the different cycles are compared through certain predefined parameters (e.g., annual reduction of plutonium stockpiles). The radio-toxicity accumulation and the transmutation potential of thorium-based cycles for current, advanced and innovative nuclear power reactors are investigated. The research program was divided into three stages: (1) Benchmark calculations, (2) Optimization of the incineration of plutonium in various reactor types, (3) Assessment of the resulting impact on the waste radio-toxicity.

The results of the first two stages were presented at ICENES 98, ICENES 2000, respectively; the results of stage three will be presented at PHYSOR 2002.

The present report was prepared by H. J. Rütten, Scientific Coordinator of the CRP, and by IAEA staff on behalf of all the Chief Scientific Investigators of this CRP, namely: Zhu Yongjun (China), R. Srivenkatesan (India), A. Galperin (Israel), Tomohiko Iwasaki (Japan), Won Seok Park (Republic of Korea), H. T. Klippel (The Netherlands), V. Ilynin (Russia), and M. Todosow (USA). The IAEA officer responsible for this publication was A. Stanculescu.

EDITORIAL NOTE

In preparing this publication for press, staff of the IAEA have made up the pages from the original manuscript(s). The views expressed do not necessarily reflect those of the IAEA, the governments of the nominating Member States or the nominating organizations.

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