Nuclear fuel cycle training for developing countries

Programmes are being improved based on lessons from the past

by J.L. Zhu, A. Nechaev, and M. Tauchid

Training requirements for the various activities in support of the nuclear fuel cycle depends on the role of each government in relation with its nuclear power programme and the magnitude of such a programme. Activities in the different parts of the fuel cycle represent an industry in itself. Such activities require a large investment and a long lead time. Therefore, IAEA assistance in these fields is generally limited to the introduction and upgrading of the required knowledge and technology including the setting up of the basic infrastructure to initiate the necessary research or investigation.

Type of training

Training in fields of the nuclear fuel cycle provided through the Agency's programme seeks to train scientists or engineers on current technology in accordance with the country's on-going or planned programme. IAEA trains scientists and engineers on certain types of activities in the nuclear fuel cycle to prepare them as active and knowledgeable counterparts to foreign contractors and suppliers of nuclear power facilities. Senior managers are exposed to a number of centres and facilities for their general awareness of the varieties of approaches used by different organizations or countries with similar objectives, as well as an appreciation of the magnitude and required infrastructure for each operation.

Such training is provided through training courses (interregional, regional, national), study tours, individual fellowships abroad, and scientific visits (individual, group). An effective method of training is carried out through the fielding of short- and long-term experts who provide on-the-job training in the country within the framework of the Agency's technical co-operation programme or through long-term projects financed by the United Nations Development Programme (UNDP).

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Nuclear fuel cycle

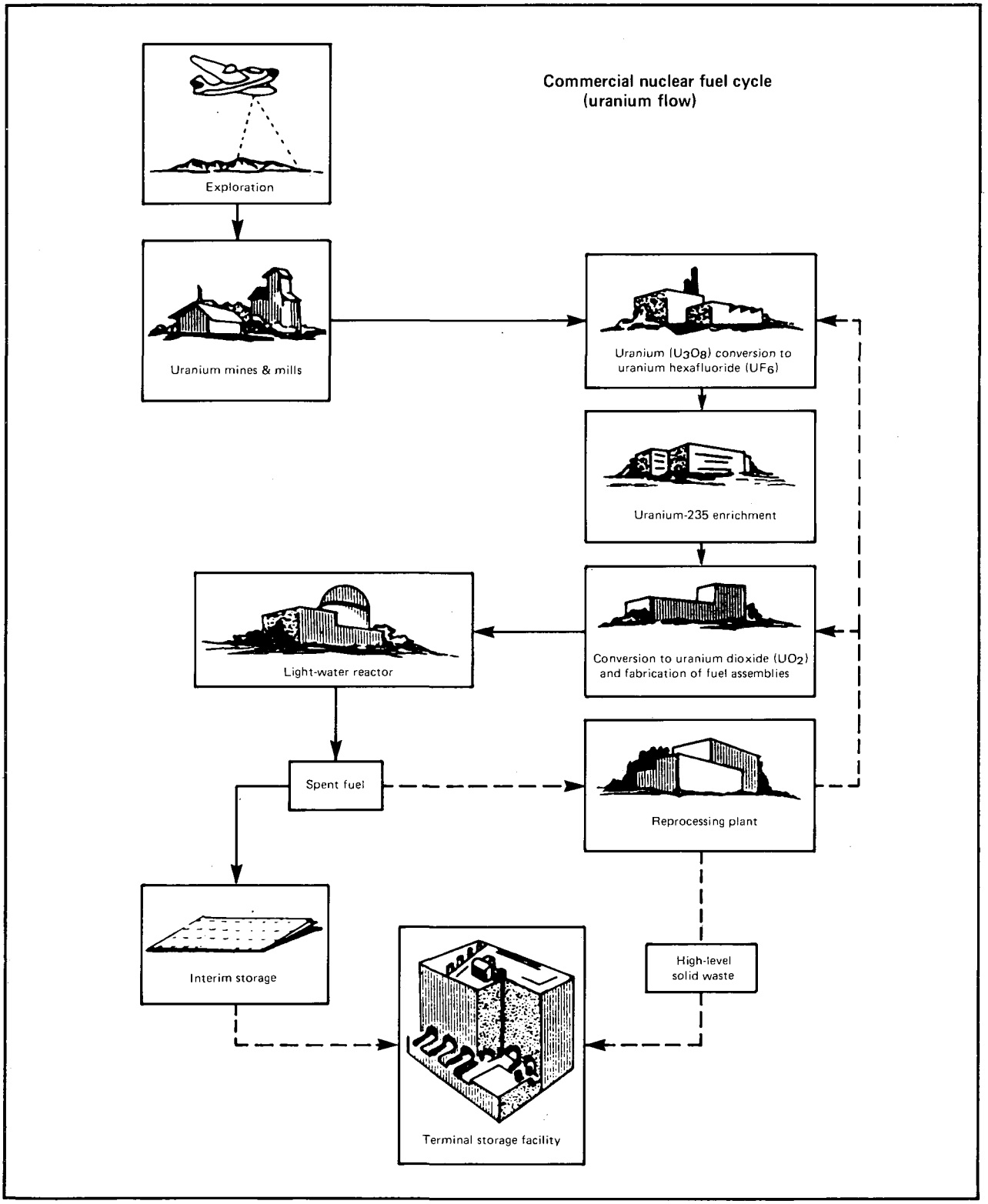
The term "nuclear fuel cycle" is used to describe all operations required to provide a nuclear reactor with fresh fuel and to take care of used fuel. In an open or once through fuel cycle strategy, the fuel passes through the reactor once; there is no reprocessing of the spent fuel and consequently the unused uranium-235 and plutonium-239 that has been produced is not recycled. In such cases, the spent fuel is stored and ultimately disposed of as waste. In a closed cycle, unburned fissile material is recovered in a reprocessing plant for recycling to fuel thermal or fast reactors. *(See accompanying figure.)*

Training in support of this field may be in one of the various activities that are parts of the fuel cycle, which are divided into the front-end and the back-end of the fuel cycle.

Activities that constitute the front-end of the fuel cycle include uranium exploration, to find adequate reserves of uranium ore; mining of the uranium ore; milling and refining of the ore, to produce uranium concentrate (yellow cake); production of uranium hexafluoride; isotopic enrichment of uranium hexafluoride to attain reactor enrichment requirements; and fabrication of nuclear reactor fuel. Fabrication includes the conversion of uranium hexafluoride to uranium oxide; pelletization of uranium oxide; encapsulation of uranium oxide pellets in fuel rods; and assembling fuel elements.

Activities in the back-end of the fuel cycle include temporary or long-term spent fuel storage; spent fuel reprocessing with recovery of plutonium and uranium for recycling; mixed oxide fuel fabrication; radioactive waste management including treatment, conditioning, storage, and disposal; and transportation activities associated with moving radioactive materials to and from each operation.

The first three, and sometimes five, activities in the front-end of the fuel cycle represent the uranium industry. The remaining are normally activities of the nuclear power industry (utilities) of the country.



Past training in nuclear fuel cycle technology

Since 1969, the Agency has organized 14 interregional and regional training courses and one study tour in the various fields of the nuclear fuel cycle. *(See accompanying table.)* Almost without exception, these courses were over-prescribed, particularly in the uranium exploration field. Early courses covered activities in the front-end of the cycle, in particular uranium exploration, evaluation, and ore processing. As activities in many developing countries evolved into more advanced stages in the fuel cycle, so did the Agency's courses. Certain activities in the fuel cycle, however, have not received adequate attention.

For the past 5 years, a new approach has been implemented. National training courses were organized

as a component of on-going Agency technical co-operation projects. Today, five courses have been organized in uranium exploration and evaluation (Indonesia in 1984, Syria in 1985, Turkey in 1986, China in 1987, and Jordan in 1988). Depending on the subject matter, the number of invited lecturers or demonstrators vary from one to six for the 2–4 week courses. This approach is effective as more people can be trained at the same time, especially at a time when placement of fellows abroad is becoming difficult.

A large part of training was carried out through the Agency's fellowship and scientific visit programme. The number of applicants for training abroad under this field of activities ranges from 50-80 annually; more than two-thirds are generally in the areas of uranium exploration, mining, and ore processing. One main difficulty in trying to implement this programme is the limited number of willing host organizations for the increasing number of candidates. This problem is becoming critical in the uranium field as exploration and development in traditionally active countries has been drastically reduced in recent years. Priority selection through stricter screening by the applying organization is essential.

Future programme

One of the best measures to judge the training requirements of the Agency's developing Member States is through the survey of the number of fellowships and applicants for scientific visits, as well as the type of new requests for technical co-operation projects. *(See accompanying charts.)* The majority of these applications and requests are in the field of uranium exploration, geology, mining, and ore processing, indicating that a large number of Member States are still active in these areas. The relatively large number of active technical co-operation projects in these same fields confirms such an assumption. Courses in these activities are therefore justified. Over-prescriptions in past training courses also provide an indication that there is a high demand for such courses.

Looking back at past courses, most covered a rather broad topic. *(See accompanying tables.)* Almost without exception, they contained a strong emphasis on technology rather than planning and management. Most notable is the lack of courses on some of the activities in the nuclear fuel cycle chain, such as uranium mining and fuel fabrication. These observations indicate that future courses should shift in emphasis to a more specialized field of training. All activities in the nuclear fuel cycle have their own technical and economic justifications, prerequisites, and (normally heavy) financial commitments. Therefore, courses or seminars on these matters for the country's planners and decision makers deserve high priority. Equally important are courses covering neglected areas of the fuel cycle mentioned earlier, particularly fuel fabrication. The Agency has supported 10 technical co-operation projects in this field.

Nuclear fuel cycle training courses

Year	Region	Host Country	Description
On nuclear fuel cycle in general			
1980	Interregional	France	Nuclear fuel cycle management (in French)
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On the front-end of the fuel cycle			
1969	Latin America	Argentina	Uranium exploration and evaluation (in Spanish)
1970	Interregional	Spain	Uranium ore analysis (in English)
1974	Asia	India	Uranium exploration and evaluation (in English)
1975	Interregional	Austria	Geochemical prospecting for uranium (in English)
1977	Interregional	Yugoslavia	Geochemical prospecting for uranium (in English)
1978	Interregional	USA	Uranium exploration and evaluation (in English)
1981	Latin America	Bolivia	Uranium exploration methods (in Spanish)
1981	Interregional	Yugoslavia	Uranium ore processing (in English)
1982	Interregional	Madagascar	Uranium exploration methods (in French)
1982	Interregional	Spain	Uranium ore analysis (in Spanish)
1983	Interregional	Yugoslavia	Uranium deposit evaluation (in English)
1983	Interregional	Spain	Uranium ore processing (in Spanish)
1984	Interregional	France	Processing of uranium—from mining to fuel fabrication (in French)
1985	Interregional	Brazil	Exploration drilling and ore reserve estimation (in English)
On the back-end of the fuel cycle			
1986	Interregional	UK, Sweden, Czechoslovakia, Germany, F.R. of, France	Study tour on spent fuel management (in English)

Similarly, to date, not enough attention has been given to training in the area of spent fuel management (mostly to storage of irradiated fuel rods) from both power and research reactors. A seminar on this subject is planned for 1990. More frequent training in this field is needed.

In the past few years, there have been inquiries and requests for assistance from the Agency on the evaluation, processing, environmental impact, and economics of tin tailing containing minerals with various concentrations of thorium, uranium, and rare earth elements. There is a great deal of misinformation on these subjects. As this problem is mainly confined to tin producing countries in Southeast and East Asia, a regional seminar on these subjects is appropriate. Similarly, the recovery of uranium from phosphoric acid is of interest to limited countries in North Africa and the Middle East. Regional seminars on this topic would be of value to the region.

The IAEA has developed or identified computer software for use in geological and mineral resources databases, processing of geochemical survey data, and on ore reserve estimation. Courses on the use of the software are also planned.

Need for education, training

Nuclear fuel is a principle basis of electricity generation and a source of advantages and potential deficiencies of nuclear power. The knowledge of the main properties of nuclear (fissile) materials, reactor fuel, the main principles of fission, "nuclear" heat generation, and radiation emission is a necessary requirement for those who are involved in design, construction, operation, economics, licensing, and any other activities related to nuclear electricity production. It is also desirable for public media, particularly in those countries which have or plan to develop nuclear power. Dissemination of modern knowledge on nuclear materials and reactor fuel are not restricted to those with narrow professional interests. The creation of a "nuclear culture" can be assured, which in turn, could be the best guarantee for successful and safe use of nuclear energy for peaceful purposes.

The IAEA's mandate "to accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world" does not mean that the Agency is a tool for imposing nuclear power programmes on Member States. The IAEA seeks to facilitate the creation of conditions which could reliably guarantee the safe and economical development of nuclear science and technology in those countries which choose to do so. The first and most important condition for the safe introduction and evolution of nuclear power (or nuclear applications) is the high level of "nuclear" education and professional qualification, not only among selected individuals. This precondition helps to avoid dangerous mistakes and unpredictable accidents and guarantees safety for the country and the world. Increasing the "nuclear culture" in developing countries is a vital problem for the world community. The IAEA system of technical co-operation is one of the best mechanisms to combat this problem. Training is one of the most important and fruitful parts of this activity, and requires constant attention and improvements.