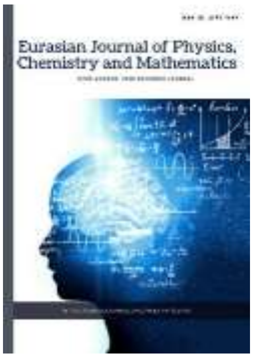

Improving Teaching "Nuclear Energy" on the Example of Nuclear Fuel Cycles in Universities

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ABSTRACT

This article analyzes and discusses the technical features of nuclear fuel cycles in specialized universities. The nuclear fuel cycle is a set of methods for the extraction and production of fuel for nuclear reactors, its preparation for use and disposal. The term "fuel cycle" refers to the fact that spent or irradiated nuclear fuel (SNF), after special processing, can be reused.

To date, the key problem of nuclear non-proliferation is a fairly simple transition from the peaceful use of atomic energy to the military.

Keywords: problem, technical features, nuclear fuel cycle, nuclear fuel, special processing, a set of methods of extraction, fuel production

The use of atomic energy requires the use of various enterprises. Each of these objects is dangerous. These include radioactive dust in uranium mines, potential and actual radiation problems even during normal operation of the facilities, and accidents both with personnel maintaining nuclear installations and with people living nearby, ending in possible contamination of groundwater in a repository for radioactive waste.

The necessary steps for uranium to become a fuel element are shown in the following illustration. After the use of uranium fuel in a nuclear power plant and its exposure in the pool, there are two possible ways to process SNF (spent nuclear fuel). The first way is direct burial, the second is to recycle. Reprocessing means separating the uranium from the plutonium in spent nuclear fuel, making new fuel elements with this material, and reusing it in a nuclear reactor. Most countries using nuclear energy do not reprocess spent nuclear fuel. More information on recycling is given in the next chapter.

Enrichment leads to the appearance of a large amount of depleted uranium (so-called tails). Each enrichment plant produces several thousand tons of this material per year. For economic reasons, the further fate of this material is not determined. It may be that only a small part will be used (outside the nuclear fuel cycle), and the rest will need to be disposed of completely.

Radioactive waste is produced in every nuclear facility. Waste can be classified as low level (LLW), medium level (ILW) and high level (HLW). Compared to other categories, high-level waste is small in volume but contains the majority of the radioactivity.

The main types of high-level waste are: spent fuel subject to "direct" disposal, vitrified radioactive waste (RW) obtained in the process of processing, as well as radioactive materials located inside the reactor. There is a wide variety of low and intermediate level waste. The amount of waste depends on the type of reactor and waste management requirements, including disposal; these factors differ from country to country. For example, a 1300-megawatt pressurized water reactor in Germany produces approximately 60 cubic meters of low and intermediate level waste and about 26 tons of SNF each year. After the decommissioning of a nuclear power plant, such a reactor generates 5,700 cubic meters of low-level waste. For Germany, it is calculated that using nuclear power, based on a reactor lifetime of 35 years, approximately 300,000 cubic meters of waste for disposal will be produced.

With or without reprocessing, a repository for the final disposal of nuclear waste is necessary. This is true not only for large quantities of low and intermediate level waste, but also for spent fuel because, for example, spent mixed oxide fuel is not reprocessed on an industrial scale. The exception is France, where a small amount of such fuel has been reprocessed. There are no repositories (final disposal sites) for high level waste and spent fuel in the world. Repositories for low and intermediate level waste operate in some countries with nuclear programs. It is necessary that the repository appears as soon as possible. If the disposal site is chosen and designed correctly, then the repositories can reduce the risk compared to all other options for radioactive waste management. It is necessary to manage the negative effects of nuclear energy.

A characteristic feature of nuclear materials is the circumstance that, along with the global spread of peaceful nuclear energy, nuclear materials themselves are not subject to free distribution. This controversial feature of nuclear materials is at the heart of the so-called non-proliferation problem. That is, the safety of nuclear materials from the point of view of society is the provision of their exclusively peaceful use.

During the Cold War, there was a certain nuclear world order based mainly on the mutual nuclear deterrence of the two superpowers. Fragile though he was, he still maintained a certain degree of stability in the world. The end of the Cold War and the destruction of the bipolar structure of the world have increased the number of factors influencing the stability of the nonproliferation regime. One of these factors is the illegal circulation of nuclear materials. Theft and smuggling of nuclear materials can be carried out for the following purposes:

• commercial - resale to third parties for the personal enrichment of the kidnapper;

• terrorist - the use of stolen nuclear material for terrorism or blackmail;

• development of the state nuclear program in circumvention of the NPT.

The use of nuclear materials for criminal purposes can assist individual states or terrorist groups in their efforts to circumvent the carefully designed controls of the international non-proliferation regime and allow them to develop nuclear or radiological weapons. If in the 60-70s of the last century, the creation of a nuclear explosive device required the efforts of an entire state, an expensive large-scale program, at present, scientific and technological progress, the dissemination of knowledge and technology have made this process more accessible.

The aggravation of the threat of nuclear proliferation in recent years is caused by the following reasons:

• the release of a significant amount of weapons-grade nuclear material as a result of the nuclear arms reduction process;

• complicating the conditions for obtaining materials for the development of such programs for non-nuclear-weapon states developing their own nuclear programs in connection with the strengthening of the international system of export control;

• an increase in the number and growth of influence and financial opportunities in international relations, terrorist groups, transnational organized criminal communities, separatist movements on religious grounds, religious sects.

The problems of international and domestic terrorism are relevant for many countries with developed nuclear energy. For example, the explosions of residential buildings in Moscow and other cities of Russia, the terrorist attacks of September 11, 2001 in the

United States and October 23, 2002 in Moscow show the seriousness of the intentions of terrorist organizations. According to the media, the terrorist organization Al Qaeda, headed by Osama bin Laden, conducted research on the creation of weapons of mass destruction, including nuclear weapons. To this end, contacts have been made with some nuclear scientists in Pakistan. The Japanese sect "Aum Senrikyo", with the help of members of their organization, acquired plots of land with deposits of uranium ore in Australia, this may indicate a desire to create or acquire nuclear weapons.

In the modern world, the nuclear non-proliferation regime, despite the difficulties that arise, has become an integral part of the legal infrastructure and security of each country.

Some Problems Encountered on the Way of Development of the Nonproliferation Regime.

1. The obligation of the nuclear powers to develop the process of nuclear disarmament has turned out to be one of the weakest links in the non-proliferation regime. Nuclear disarmament is a complex and lengthy process.

2. Currently, a group of countries is outside the nuclear non-proliferation regime - Israel, India and Pakistan. These states have nuclear weapons, although they refrain from deploying them in combat.

3. In 1991, as a result of the collapse of the Soviet Union, the huge nuclear economy of the Soviet Union collapsed. The disintegration was a colossal blow and a problem for the world nuclear non-proliferation regime.

The solution of nonproliferation problems lies in the way of creating international and national systems of nonproliferation guarantees.

The threat of proliferation of nuclear materials is a problem for all states on whose territory nuclear weapons or nuclear fuel cycle facilities are located. The international community is now facing a difficult choice: how to proceed - to try to improve the existing system of restrictions, which is based on principles developed during the Cold War, or to take the most developed national principles and systems and adapt them to global realities.

The effectiveness of nuclear non-proliferation measures in states depends on the awareness of the vital importance of the problem of non-proliferation by all sections of society. Understanding the importance of this problem in society, including representatives of the authorities of various countries, determines its public rating and the corresponding material support for its solution. That is why the activities of organizations promoting the ideas of nuclear non-proliferation among the country's population are so important. A number of organizations around the world are engaged in this important activity. These organizations publish popular magazines, books, hold scientific conferences to which representatives of the general public are invited.

Categorization of nuclear materials: The second very important principle is the categorization of nuclear materials. For nuclear materials, the basic concept is the accounting category of the material. If the material falls under an accounting category, then certain accounting and control rules should be applied to it. If the material does not fall under the accounting category, then such strict rules do not apply to it. Moreover, nuclear materials are subject to state accounting and control if the values of their masses located at the enterprise are equal to or exceed the minimum quantities that are defined in state-level regulatory documents.

The fourth fundamental feature of modern accounting and control systems is the maximum use of access control tools. The accounting and control systems for nuclear materials in all developed countries, including ours, are based on the principle of a measured material balance. At the same time, the procedure for measuring available nuclear materials is, in fact, a serious physical experiment. It must be borne in mind that the measurements of nuclear materials themselves are a relatively lengthy and unsafe procedure (especially when it comes to plutonium). Therefore, every effort is made to reduce measurements of nuclear materials to the necessary minimum. And the continuity of knowledge regarding the state of nuclear materials is ensured through the use of access control tools (ACS) to NM.

Access controls include two classes of measures: surveillance and conservation. The simplest and most commonly used is visual observation. This is the continuous presence of a certain number of persons. When working with nuclear materials, the rule of two is used persons. The most important operations with nuclear materials are carried out by at least two people. When working with weapons materials, the three-man rule may apply.

Thus, a nuclear reactor is an energy device in which a controlled chain reaction of nuclear fission of a fissile material is carried out and the resulting thermal energy is removed. This definition of a nuclear reactor is of the most general nature and reflects only the physical essence of the reactor. There are other definitions of a nuclear reactor that describe this object in terms of its design, its purpose, etc.

In terms of nuclear export control regimes, the definition of a nuclear reactor should presumably cover reactor systems, devices and components that are subject to export controls in accordance with legislation, and should also define what a complete nuclear reactor is, since this heading is indicated in the control list.

Based on these requirements and based on the physical definition of a nuclear reactor, it is necessary to supplement it as follows: The reactor includes components located inside its vessel and directly attached to the vessel, as well as equipment necessary for its normal safe operation, emergency cooling and emergency protection, and the equipment that controls the power level in the core, and those parts of it that contain the primary coolant, come into contact with it, control and regulate it. Nevertheless, it is apparently impossible to exhaustively accurately outline the composition of the design of any reactor by any general definition, since, according to the existing rules, the boundaries of the reactor plant are specified for each NPP by the Chief Designer and General Designer. Thus, the determination of the belonging of one or another unit of reactor export to a nuclear reactor, which is necessary when analyzing a product for belonging to the indicated items, may in a specific case be the prerogative of technical expertise.

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