ON THE MANAGEMENT OF RADIOACTIVE WASTES IN THE COMMUNITY OF INDEPENDENT STATES; PROBLEMS OF LONG-LIVED NUCLIDES AND PARTITIONING

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ABSTRACT

The accidents at NPPs Three-Mile-Island and particularly Chernobyl have drastically slowed down the practical development of nuclear power.

However in the world and in our countries, there is growing confidence in expediency of nuclear power as one trend of energetics in the near future, being ecologically safe and economically practical.

SIGNIFICANCE OF THE PROBLEM, ORGANIZATION OF ACTIVITIES

In 1989-90 the decisions were made to stop construction of NPPs in Rostov, South-Urals, Crimea, Tatarstan, Gorky and other nuclear power plants, but in 1991 the conceptual design of new NPPs has been started for Kazakhstan, Kolskii peninsula, Far East sea-side and Irkutsk region; it was also decided to keep constructing the Voronezh NPP and to replace run-out capacities at St. Petersburg NPP by new power units etc.

In spite of hard economical conditions, the development of new nuclear installations of higher reliability is continued by scientific and design organizations of Russia Ministry of nuclear power and industry.

Beside the improvements in reliability and safety of NPPs, the development of nuclear power is hindered by another very important problem of final disposal and containment of radioactive wastes. Much more public attention has been given to this problem in the last years. In the CIS countries this attention is even considerably superior to the real contribution of radioactive factors as compared with general technical ones into the overall adverse effect.

In the field of radioactive waste containment, the consolidation of all scientific and technical activities takes place as from 1991 with the aim of practical solution of the problem.

Great amounts of radioactive wastes have been already accumulated in the Community countries, primarily in Russia and Ukraine.

First, this concerns the waste from NPPs. Late in 1991, about 200 mln. Curies were accumulated in spent WWER fuel assemblies and 800 mln. Curies in those from RBMK NPPs. The total amount of plutonium accumulated in NPP fuel is estimated as high as 50 t. At nuclear power plants liquid radioactive wastes, for the most part of low activity (135000 m^3), solidified wastes (8000 m^3, 800 Curies) and 100000 m^3 of solid contaminated by radioactive substances (equipment, debris a. o.) are stored.

Secondly, the wastes arising within the frames of defense programs should be noted. At radiochemical plants of the Ministry about $1.2 \cdot 10^9$ Curies of liquid radioactive wastes are stored in special containers. $1 \cdot 10^6$ Curies of solid wastes are stored in near-surface facilities.

In the recent years and particularly as from 1992, a further problem arises from the fact that dismantling of nuclear weapons would result in accumulation of a few tens of tons of weapon-grade plutonium and some hundreds of tons of highly-enriched uranium. These materials should be placed into special interim storage facilities which are not constructed in Russia yet. However it is implied a temporary storage, and I would like to consider this problem elsewhere.

Thirdly, the wastes arising in industry, agriculture and medicine from the use of different ionizing radiation sources are to be managed. For storage and disposal of these wastes, there were constructed regional burial sites, among these are 16 sites in Russia, 5 in Ukraine.

Finally, the wastes from contaminated territories of nuclear industrial objects and those contaminated as a consequence of accidents and emergency discharges.

By tradition, in Russia scientific-research institutes are engaged in scientific and technical problems of waste containment. Among these are:

Research Institute of Inorganic Materials (Moscow), Scientific-Production Association "V. G. Khlopin Radium Institute" (St. Petersburg), Research and Design Institute of Industrial Technology (Moscow). Many R & D are carried out by Research Institute of Nuclear Power Plants (Moscow) and Research Institute of Chemical Technology (Moscow). Scientific-Research Institute of Energetic Technology (St. Petersburg) is involved with designing in this field and transplutonium of radioactive materials; Research Institute of Chemical Machinery (Ekaterinburg) has to do with construction of facilities.

In the last years some other organizations have joined in the solution of these problems; among them are: Institute of Geology, Ore-Deposits, Petrography, Mineralogy and Geochemistry, Academy of Sciences; Scientific-Engineering Centre of Ecological Safety, Urals Branch of Academy of Sciences; Institute of Theoretical and Experimental Physics a. o.

Problem of radioactive waste containment is of international character in terms of its scales and significance.

Therefore, it is evident that closer cooperation of scientific and technical organizations should take place, primarily between the nuclear states.

With great satisfaction we would like to emphasize that concrete results could also be expected in this field. For example: besides the generally accepted international discussion of waste containment problems, in compliance with the program of scientific-technical cooperation between US DOE and Russia Ministry of nuclear power and industry in the field of environmental restoration and waste management for 1991-1992, some specific scientific-technical questions were posed for joint solution at the seminar in October 1991.

We wish that such practice on development of joint projects-programs would be considerably extended. For multilateral joint investigation the following problems could be proposed: waste partitioning, transmutation, possible removal of some waste into outer space, utilization of military nuclear materials on nuclear power, conceptual aspects of different radiation dose impact on flora and fauna and comparison of effects of different technical factors etc. Bilateral joint projects may be no less important, but more specific; for example, Russia and the USA could develop processes for liquid wastes accumulated in containers or for burial of wastes from restoration of contaminated soils.

In 1992 the development of a Russian State program for radioactive waste containment should be completed. It is based on the branch program of 1989-1990.

The programs involve elaboration of legal, administrative and economic standard documents. A database is created on quantities, characteristics and arisings of wastes at installations of the branch. Laws of nuclear power, radiation safety and radioactive wastes are under preparation.

The program envisages the extension of scientific-research and design works just as in the field on conceptual studies, so in applied, practical and search alternative trends.

The development of several test and industrial facilities for waste processing, solidification and disposal is also contemplated.

It should be well to point out a commercial facility for HAW processing at Production Association "Mayak" in Chelyabinsk-40. In the period from July 1991 to February 1992 there were vitrified 220 tons of waste with activity 35 mln. Curies. Throughput of the facility was recently about 280 1/hour with specific activity of glass 900 Ci/1 (330 Ci/kg). In the total there are stored 380 t of vitrified HAW containing about 35 mln. Curies.

Our designs of plants for vitrification of HAW are based on two options: 1) stage process of glass-boiling with remotely dismantable electrofurnace and 2) stage process with induction melting in cold crucible equipped also by remotely dismantable apparatur.

The progress in the field of partitioning, new denitration technologies (plasma-chemical method) and high-temperature synthesis of minerals (induction melting in cold crucible, isostatic pressing) makes it possible to extend our investigations of compounds of zircon group, granate, cubic zirconium oxide and different modified materials of Synrock type which was first proposed by Australian specialists headed by Ringwood.

We are planning to act at better pace in the field wherein we do not keep up with world standards, i. e. searching the sites for final disposal of solidified radioactive wastes in deep geological formations and construction of an underground laboratory for the study of future processes.

ON HAW PARTITIONING

Closed fuel cycle for the most types of fuel elements in our branch is already an actual indication of the beginning with HAW partition. So, the recovery of plutonium as one of the most ecologically hazardous radionuclide and its separate fate suggests the reduced volume of HAW to be disposed of. Recycle of unburnt uranium and energetic plutonium as nuclear fuel enables to decrease mining of natural uranium and thereby to reduce the Earth's ecological problems.

However it seems to us that the degree of waste partitioning should be increased from the standpoint of waste volume and grade.

The problem of final disposal of long-lived radionuclides with lifetime over 1000 years is most difficult to forecast.

Therefore, the partition of radionuclides into short-lived (half-life up to 30-35 years) and long-lived (half-life over thousands years) one could facilitate the technology of solidification of most wastes and the choice of sites for disposal and storage of different wastes.

Separation of wastes into long- and medium-lived ones may be conducted by method of purifying their sum from long-lived nuclides, primarily from transuranium elements, and by method of producing the individual fractions of medium-live nuclides, such as strontium-90 and cesium-137. In our opinion, the second way seems to be easier. But in all cases the permissible contents of long-lived isotopes in solidified fractions of medium-lived ones should be established best on the basis of intergovernmental multilateral estimates.

Hence, we do not consider partitioning in the frames of closed cycle development as an alternative to isolation of radioactive wastes into geological formations.

We do not want that in the community of scientists and practical workers engaged in such enormous problem as isolation of radioactive wastes a war would start between the Big-Indians and the Little-Indians as in Jonathan Swift's "Gulliver's Travels to Lilliput". We desire merely to minimize the wastes to be disposed off in various ways, best suited to one or another region, to one or another country.

We have much to say about the developed partitioning processes and the methods for solidification of different fractions, but this is better to report at section meetings. The chief thing is that the partitioning problems could be solved jointly more reliable.

As for the fate of long-lived wastes, one cannot but return to the problem of weapon plutonium. Now it is considered as waste arising from weapons which are already needless.

Practical realization of the Treaty between our country and the USA on the elimination of intermediate-range missiles and conclusion of the Agreement on the elimination of tactic nuclear weapon and limited reduction of strategic nuclear weapons have posed the program of the fate of nuclear warheads to be dismantled.

Among the variants of reliable and as much as possible fast elimination of nuclear charges as an aspect of providing the safeguards against the proliferation of nuclear weapons over the world, the disposal of weapon-grade plutonium in appropriate geological formations with preliminary dissolution and transformation into a stable mineral-like or ceramic matrix seems to be promising due to relative technical

simplicity. So, it is expected that the disposal is possible without any probability of arising a nuclear hazardous situation in underground storage facility in any natural or technogeneous emergency case.

Such approach appears to us as unacceptable, although it is now one of the simplest technically feasible methods for solving the problem of non-proliferation of plutonium which becomes available in the disarmament process.

Plutonium, without a decision about its fate, should not be stored in special facilities. So, in the USA the law prohibits construction of a regional storage facility for spent fuel assemblies: the problem of their disposal should be solved previously in order that the interim storage does not become a final one.

In our country the population also protests against the construction of such storage facilities before the decision of plutonium fate. The solution of this problem is of importance for the whole world from the political viewpoint.

On the other hand, plutonium is an expensive product; it has put our people to great expenses and undermined the health of thousands of professionals. Such a product should not be destroyed with no benefit from it.

The calculations have shown that in the CIS countries on realizing the closed nuclear fuel the use of energetic plutonium would provide annual average decrease of 12% in uranium demand (for 2025 on nuclear power capacity up to 300 GW); recycle of recovered uranium and plutonium would decrease annual average demand in the period end by 23%. Capital costs would also drop as compared with open cycle.

The use of weapon plutonium seems to be still more advantageous, if the states grant it for utilization at "zero" cost. Firstly, its radiation characteristics facilitate transportation and loading of fuel assemblies; secondly, radiochemical reprocessing of weapon plutonium is reduced as compared with energetic plutonium.

The problems of burning poison could be solved in our opinion, without great difficulties by addition of ^{152}Gd isotope.

Russia is now in severe economical conditions. If the American party, perhaps in cooperation with other countries, helps in investment crediting for reconstruction of MOX fuel workshop with possible use of weapon plutonium, credits will be reimbursed as MOX assembles. These production facilities could be used as well for reprocessing of American weapon plutonium, as the organization of production capacities in the USA for small amounts of the latter may be not justified from economical standpoint.

Thus, it is again a problem which could be best solved in cooperation and on the basis of our technologies to be improved jointly; new technologies will provide fabrication of nuclear fuel of guaranteed quality for both countries.

TRANSMUTATION OF LONG-LIVED RADIONUCLIDES

Careful separation into individual fractions is also required in the case of transmutation method, i. e. nuclear transformation of long-lived radionuclides into short-lived or stable ones.

Early in the eighties, the IAEA drew negative conclusions concerning the expediency of this program. Late in the eighties, interest in nuclear transmutation of long-lived radionuclides was shown again. This results in the development of "OMEGA" program (Japan) and other national programs.

At the IAEA consultative meeting in October 1991, the representatives of 13 countries supported the developments in the field of partition-transmutation of long-lived radionuclides. Attractiveness of transmutation concept for its followers is caused by different reasons. Some followers consider this alternative as a way for persuasion of public opinion in acceptability of nuclear power, other followers - as a basis for improvement of radioactive waste management; the thirds have difficulties with the choice of final disposal sites, the fourths regard it as a basis for passing development of new technologies.

In our country which adheres to the position of closed fuel cycle, the R & D in partition-transmutation are considered as an integral part of a long-term program on radioactive waste management. The development program of partition-transmutation includes the most important aspects, from radioecological substantiation of enumeration of radionuclides, calculation or radiotoxicity indices, substantiation of necessary recovery, elaboration of transmutation techniques to economic estimation of the program costs which should incorporate not only expenses for the program realization, but also take into account prevented damage to the next humanity generations.

Among the most hazardous long-lived nuclides which make the main contribution to the impact on the biosphere (isotopes of plutonium, curium, americium, neptunium-237, iodine-129, carbon-14, technetium-99, cesium-135, zirconium-93), plutonium, americium and curium isotopes should be considered as real candidates for transmutation in existing types of fast reactors.

In the Institute of theoretical and experimental physics (Moscow), the conceptual fundamentals were elaborated for using the facility with high neutron flux from blanket on the basis of accelerator technics.

Participation of Los Alamos Laboratory (USA) and Research Institute of Experimental Physics (Arzamas, Russia) in designing the facilities for transmutation could do much toward realizing the transmutation concept.

REMOVAL OF LONG-LIVED RADIONUCLIDES INTO SPACE

Basically, for final isolation of the most hazardous wastes from the earth's biosphere, outer space could also be used. Long-term astrophysical forecast of waste fate is more reliable than the similar forecast for geological formations which vary with time.

Space isolation could be proposed for such long-lived radionuclides as technetium-90, neptunium-237, iodine-129, zirconium-93. Moderate gamma-activity and rather small volume of these nuclides make it possible to use the available technical systems for removal into outer space.

Among the variants of space isolation of radioactive wastes, both delivery of containers to the orbits in the near Sun space removal from the Sun system by using the available carrier rockets of the type "Zenith" and "Energy" are discussed.

Analysis of real reliability of rocket-space systems with due regard for many years' operating experience has shown that the required safety could be in principle achieved on multi-level countering the abnormal situations.

In connection with the specificity of this method, besides the substantiation of its economic reasonability and solution of all technical programs, the fate of the method will depend on sufficient demonstration of its reliability. Wide public opinion seems to be formed under conditions of a priori denial of such a way. This is confirmed by a rather restrained reaction of participants at the International forums where we had reported about our program.

We understand that the realization of this program requires many R & D in existing and new radiochemical technologies for separation of the most hazardous radionuclides in concentrated form with following capsulation. The wastes placed in special containers should pass standard load tests on transporting, as well as accident effects when entering into the dense atmospheric layers, impact on rock ground, explosion of carrier-rocket and fire on start.

Containers with waste simulators (without any radioactive materials) are now prepared to testing under accident conditions.

In our opinion, the program of waste removal into space could be carried out only in the frames of frank and agreed international cooperation, which would enable to choose the most safe site for starting complex and to gain all advantages from technical and economic collaboration between interested countries, including the international examination of projects.

On summarizing the foregoing about the concepts of long-lived technogeneous radionuclides, it should be noted that these concepts are not opposed. According to our position, reasonable combination of the method based on different concepts seems to be the optimum solution of the problem.

CONCLUSIONS

On the basis of original concept for isolation of radioactive waste and elaborated projects of national program for such isolation, with combined effort of scientists to solve the waste problem, the nuclear industry of Russia in cooperation with some other branches must cope with this complicated task.

However, taking into account that the problem of radioactive waste isolation in many respects is common to nuclear countries, it is necessary to organize bilateral or multilateral collaboration within the framework of specific projects and promising programs.

Such programs and projects are outlined and discussed by the scientific community.