Vysotskii, V., et al. *Successful Experiments On Utilization Of High-Activity Waste In The Process Of Transmutation In Growing Associations Of Microbiological Cultures*. in *Tenth International Conference on Cold Fusion*. 2003. Cambridge, MA: LENR-CANR.org. This paper was presented at the 10th International Conference on Cold Fusion. It may be different from the version published by World Scientific, Inc (2003) in the official Proceedings of the conference.

Successful Experiments On Utilization Of High-Activity Nuclear Waste In The Process Of Transmutation In Growing Associations Of Microbiological Cultures

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The problem of utilization of high-activity waste by effect of nuclear transmutation in growing associations of microbiological cultures was studied. For the first time we have observed utilization of several kinds of highly active isotopes in the volume of distilled water extracted from the first contour of water-water atomic reactor convert to non-radioactive nuclei.

1. The model and the foundation of the effect of transmutation of radioactive waste in biological systems

In the work, the process of direct utilization of highly active waste and its transmutation into non-radioactive isotopes by microbiological systems has been studied for the first time.

Beside generating heavier stable isotopes from light, medium and heavy stable isotopes on the basis of synthesis reactions [1], there is also the possibility of utilization of light, medium and heavy radioactive isotopes (for example, components of spent nuclear fuel or isotopes used in metrology) by the way of their transformation into stable isotopes of chemical elements. The microbe cultures produce elements essential to their own survival.

The effect of transmutation of isotopes in bacterial cultures, stable in extremely high levels and doses of ionizing radiation, provides hope that solutions to the problem of radioactive waste solution may be found in the use of biological systems [1].

In contrast with classical chemical processes, growing microbiological systems can provide an extremely high selectiveness and completeness of extraction of various chemical elements (including isotopes) from different media. The phenomenon of low temperature transmutation can allow transformation radioactive isotopes, absorbed by a bacterial culture, into stable isotopes of other chemical elements. Naturally, for obvious reasons, we are not considering large or industrial-scale processing of spent nuclear fuel (SNF) and highly radioactive waste with microbiological systems yet, at this preliminary stage in the research, but in the long term such systems may be possible.

In our opinion, the prospects of using bacterial cultures depend upon:

1. Fine purification of regenerated uranium on the final stages of its separation from products of decay to a level, allowing it to be used for refabrication of HPE's without using heavy chambers and remote controls.

2. Purification of gaseous exhausts of NPP's and other facilities, processing SNF, from isotopes of noble gases and products of their decay (mainly, iodine).

3. Purification of low radioactive waste to a level, providing a possibility of their burial, as non-radioactive waste, i.e. to the level of natural radioactive background (8–40 mkr/hr).

4. Purification of sewage and drain waters of NPP's and other facilities, processing SNF to the level of natural background.

Apart from using processes of transmutation (and microbiological systems in general) in purification procedures of various substances and materials from radioactive waste, another potential use of transmutation in production or selective extraction of certain radioisotopes with a very high degree of radiochemical (and chemical) purity — to be used in medicine, for example — such as isotopes of technetium, gallium, iodine and others, production of which is currently quite expensive due to the need of high degree of radiochemical purity in some radioisotopic materials, also appears quite promising.

The process of extraction and separation of certain kinds of highly active isotopes of low concentration from multi-component radioactive waste during the process of growth of maximally radiation-resistant microbiological cultures like *Deinococcus Radiodurans* (capable of sustaining normal metabolism at radiation levels of over 1–10 Mrad), as well as cultures, capable of withstanding considerably lower doses, but nevertheless reaching 30 Krad and more) is based on the fact, that the chemical characteristics of different isotopes of the same element and their ability to participate in vital processes are practically indiscernible.

Because of that, a growing culture can use radioactive isotopes, present in the nutrient medium, to sustain its vital activity (its metabolism).

Moreover, there is information suggesting an important role of radioactive elements in metabolism of live objects. Such hypothesis was offered for the first time by Vernadsky, and was later corroborated by modern studies.

Thus, in the work [2] the ability of micromyces to use such seemingly inert substratum as highly radioactive reactor-grade graphite in constructive metabolism was convincingly demonstrated. The use of uranium as the donor of electrons in energetic metabolism of *Thiobacillus ferrooxidans* has been experimentally proven [3]. This proves, among other things, the importance of selecting a specific microelementary content of an environment (medium) for the process of sustaining normal vital activity of biological systems.

2. Experimental investigation of utilization of high-activity waste in growing associations of microbiological cultures

Nuclear transmutation of several kinds of radionuclides by a special MCT ("microbial catalyst-transmutator") stable compound has been investigated. The "microbial catalyst-transmutator" represents special granules that include: concentrated biomass of metabolically active microorganisms, sources of energy and N, C, P etc., and gluing substances which keep all components in the way of granules stable in water solutions for a long period of time at any external conditions.

The base of the "microbial catalyst-transmutator" are microbe syntrophin associations that contain many thousands kinds of different microorganisms that are in the state of complete symbiosis. These microorganisms appertain to different physiological groups that represent practically whole variety of the microbe metabolism and relevantly all kinds of microbe accumulation mechanisms. The state of complete symbiosis of the syntrophin associations results in the possibility of maximal adaptation of the microorganisms' association to any external conditions changes (including effect of highly active ionizing irradiation).

Microorganisms' interaction with metals is manifested through its final result as mobilization (transformation of metals into a dissolved state) or to the opposite as immobilization — accumulation (transformation of metals into a insoluble state or their tying by cells).

Apparently the radio nuclides just as non-radioactive metals will form sulphides of metals during biogenic sulphate reduction. In other words, radioactive metals (radio nuclides) should be regarded first of all as elements reacting with microorganisms in the same manner and through the same mechanisms as non-radioactive metals.

Typical reaction of the association for such aggressive effects demands the existence of some time for internal adaptation. This time is necessary for mutagene change of 5-10 generations that corresponds to several days. During this time, a purposeful synergy process of stimulation of the mutant formation of such microorganisms occurs, which is maximally adapted to the changed aggressive conditions. This "microbial catalyst-transmutator" is able to develop actively, for example, in water with very high specific activity [4], while ordinary, not radioactively stable monocultures die in such an environment very rapidly.

The research has been carried out on the basis of distilled water from first contour of water-water atomic reactor of Kiev Institute of Nuclear Research. The water with total activity about 10^{-4} Curie/L contained highly active isotopes (e.g., Na^{24}, K^{40}, Co^{60}, Sr^{91}, I^{131}, Xe^{135}, Ba^{140} , La^{140}, Ce^{141}, Np^{239}) was extracted from the active zone (see Fig.1).

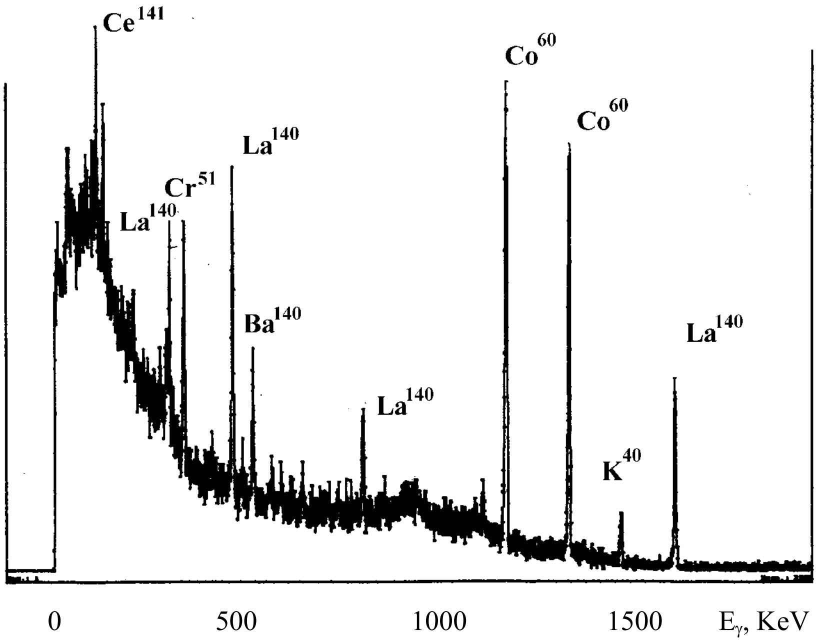

Figure 1. Spectrum of gamma-radiation of distilled water from first contour of water-water atomic reactor (10^{th} day after extraction from the active zone).

In our experiments "microbial catalyst-transmutator" with mass about 1 g was placed in the glass flasks with 10 ml of water from the atomic reactor.

In control experiments the same radioactive water but without "microbial catalyst-transmutator" was used.

The cultures were grown at the temperature 25° C. Activity of all flasks has been measured during 30 days every 5 days.

For the first time we have observed fast utilization of several kinds of highly active isotopes to nonradioactive nuclei in the flasks that contained "microbial transmutator". The results of investigation of the activity Q(t) of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experiment on transmutation (activity is $Q_{cultures}$) and in the control one ($Q_{control}$) are presented on the Fig. 2.

Studied La^{140} isotope has short life-time τ_{La} = 40.3 hours and is nonstable daughter isotope of Ba^{140} radioactive isotope that has life-time about τ_{Ba} = 12.7 days:

$$Ba^{140} \rightarrow La^{140} + \beta^-.$$

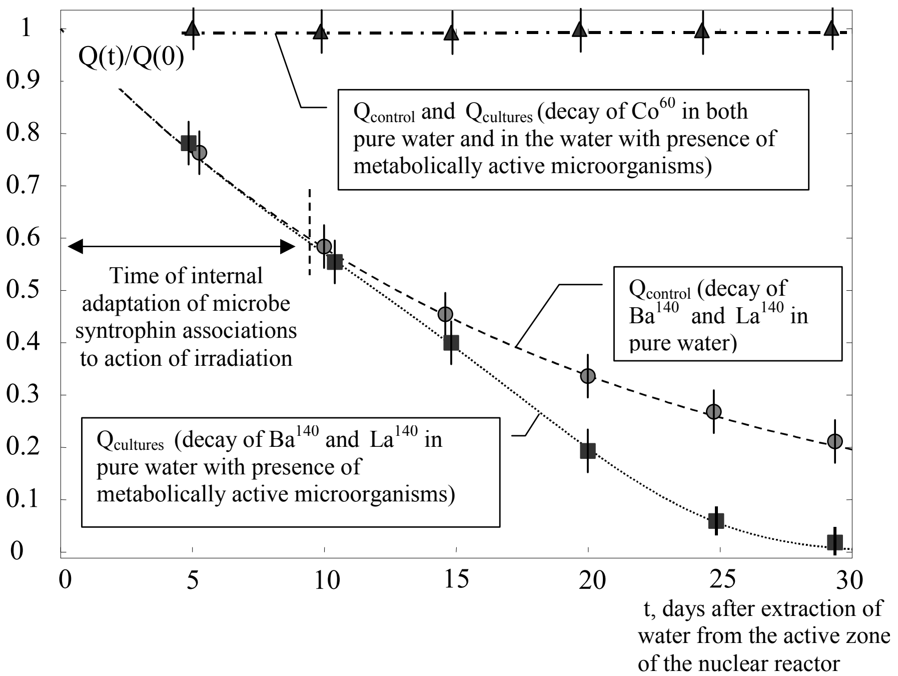

Figure 2. Activity Q(t) of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experiment on transmutation (activity $Q_{cultures}$ in pure reactor water with presence of metabolically active microorganisms) and in the control one (activity $Q_{control}$ in the same pure reactor water without microorganisms)

Initial activities of the Ba^{140} and La^{140} isotopes (on the 10^{th} day after extraction of water from the active zone of the nuclear reactor) were Q_{Ba-140} =1.46.10^{-7} Curie/L and Q_{La-140} =2.31.10^{-7} Curie/L.

The possible way of radioactive Ba^{140} isotope transmutation to the stable state is

$$Ba^{140} + C^{12} = Sm^{152} + \Delta E$$

These reactions are energy favourable (ΔE = 8.5 MeV is positive).

The Sm^{2+} and Ca^{2+} ions are chemically alike and have the approximately same ionic radiuses of divalent state ($R_{Sm} \approx 1.2$ A, $R_{Ca} \approx 1.06$ A). Substituted element Ca is among several vitally necessary elements. Ions of created Sm^{2+} elements can substitute Ca^{2+} ions while microbiological cultures are growing [5].

The probability of such substitution during the process of growing of a biological culture is high because the initial concentration of Ca element in MCT is low.

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