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New Biosafe Nanocomposite Polymer Sorbent (BNPS) for Isotopes Sr and Cs Sorption and for Decontamination Highly Radioactive Water in Solid Phase

Elena V. ORLOVA*, Roman S. FADEEV, Eugene I. MAEVSKY

Institute of Theoretic and Experimental Biophysics (ITEB) RAS, Institutskaya, Pushchino, Moscow district, Russia
*Corresponding author: eaglson@mail.ru

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Abstract It was *de novo* obtained the means of a specific structure designed and the method for the selective binding of Sr and Cs radionuclides in order to decontamination of highly radioactive water in the process of nuclear power stations, as well as under anthropogenic and natural disasters, accompanied by ejection Sr and Cs radionuclides in the environment.

Keywords: *nanocomposite polymer sorbent, decontamination highly radioactive water in solid phase, radionuclides Sr and Cs*

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1. Introduction

Removing slowly decaying radionuclides, particularly Sr and Cs, from water and soil, plants and animals, contaminated nuclear waste is a problem lasting more than 70 years. Increasing problem due to the predominance of the "peaceful atom" in energy, unfortunately, is permanent and requires a serious decision because of the inevitability of early failures and accidents anthropogenic and natural origin. There have been proposed many different, but not radical solutions. There are several basic types of radionuclide sorbents in the form of the sorption matrix of inorganic salts - complexons such as tetra borate [1], acrylates [2], acetates [2], silicates [3,4] and zeolite modification, recently developed at NIMS, Japan (National Institute for Materials Science) [5], strontium-based chelator diazo-complex and silicon zeolite matrix [6], aluminosilicates, aluminasilicium alums [7], orthophosphate [8]. General shortcomings of the above compounds is the complexity of their synthesis, toxicity and rather low sorption capacity.

In order to achieve a high and specific sorption capacity, subject to the requirements of biocompatibility and safety of for various biological objects we have developed the biosafety nanocomposite polymer sorbent for selective sorption of the isotopes of Sr and Cs from liquid media, which has a uniquely high sorption capacity.

2. Materials and Methods

1. Biosafe nanocomposite polymer sorbent (BNPS) was synthesed by the original method [Patent issued from 19.06.2012] [9,10].

2. Saturated aqueous $Sr(NO_3)_2$ and $Cs(NO_3)$ salts solutions were taken in the amount of 5 ml in each. Sorbent samples (2g) were dissolved in these solutions. 15 minutes later the sorbent hydrated all liquid phase and increased in volume. Then the sorbent was separated from the water and atomic absorption spectrophotometry (AAS) investigation was carried out.

3. Determination of the radiation stability of polymer sorbent structure to the absence of radiation crosslinks. BNPS sample was subjected to high irradiation for 24h it is resistant to high doses of radiation and then NMR spectra was determined. UO_{2}. source: α =80000 particals/sm^2/sec (80kBq); β= 26000 particals/sm2/sec (26kBq); γ = 76 roentgen/h , exposure time= 24h. : α =1920 kBq, β= 624kBq, and that full dose on γ = 15.86mSv.

4. Keratinocyte-derived A431cells were obtained from the Russian Cell Culture Collection (Institute of Cytology, Russian Academy of Sciences, St. Petersburg). Fetal bovine serum was from Gibco; culture medium DMEM, acridine orange, hoechst 33342, crystal violet, and other chemicals for cytotoxicity tests were purchased from Sigma Chemical Co.

5. Cytotoxicity Assay. A431 cells were grown in Dulbecco's modified Eagle's medium (DMEM) supplemented with 10% (w/v) fetal bovine serum, 40 mg/L gentamycin, 35 mM sodium bicarbonate, and 20 mM HEPES at 37°C in an atmosphere of 5% CO2. For the cytotoxicity assay, cells were seeded in 96-well microplates or culture dishes (Corning, USA) at a concentration of 2,5 × 10^4 cells/cm^2. Freshly prepared solution of BNPS was added to culture medium 24 h after seeding the cells. Cytotoxicity was evaluated using the crystal violet assay from the ratio of optical densities at 560 nm in treated and untreated (control) cultures at 24 h after adding the agents [11]. The optical density value was in direct proportion to the number of viable cells. Each experiment was performed at least three times. All of the values represent the means (SEM). The statistical significance of the results was analyzed using Student's t test.

6. Confocal microscopy. For imaging, A 431 cells were seeded in 8-well Lab-Tek Chamber Slide system (Nalge Nunc International, USA) at a concentration of 2,5 × 10^4 cells/cm^2. Freshly prepared solution of BNPS was added to each well 24 h after seeding the cells. At 24 h after adding the BNPS, cells were washed three times with ice-cold PBS and stained with acridine orange(1 mkg/ml) and hoechst 33342 (1 mkg/ml) for 25 minutes at 37°C. Images obtained using the confocal system Leica TCS SP5 (Leica, Germany).

3. Results and Discussion

It was *de novo* obtained the means of a specific structure designed and the method for the selective binding of Sr and Cs radionuclides in order to decontamination of highly radioactive water in the process of nuclear power stations, as well as under anthropogenic and natural disasters, accompanied by ejection Sr and Cs radionuclides in the environment (see Figure 1).

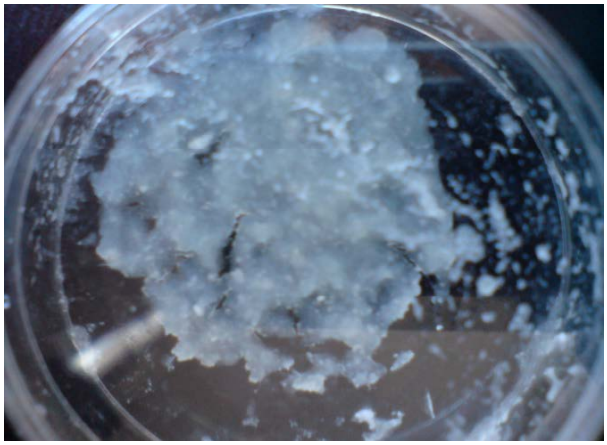

Figure 1. *De novo* obtained biosafe nanocomposite polymer sorbent (BNPS) for selective sorption of Sr and Cs isotopes

In order to achieve a high and specific sorption capacity, subject to the requirements of biocompatibility and safety for various biological objects we have developed the biosafety nanocomposite polymer sorbent for selective sorption of Sr and Cs isotopes from liquid media, which has a unique high sorption capacity. For example, 73kg of this polymer sorbent can decontaminate 1ton of highly radioactive water (in solid phase) (Table 1).

Table 1. Table of comparison BNPS *vs* HOM (high-ordered mesoporous) sorbent

	BNPS	HOM (high-ordered mesoporous)
Specific sorption capacity: 90Sr	3.7TBq (330mg of Sr2+ per 1g sorbent	65GBq (13 mg Sr2+ per 1g HOM)
137Cs	1.12TBq (105g 137Cs per 1g sorbent	Not binding
Biosafe and non-toxic	yes	No
Simplicity of utilization	Yes (by the method [12])	No
Sorbent weight per 1 ton of highly radioactive water **cleaning (in thin-layer filters)**	15kg	225kg
Sorbent weight per 1 ton of highly radioactive water decontamination and following **conversion into amorphous** state	25kg	No
Sorbent weight per 1 ton of highly radioactive water decontamination and following **conversion into hard solid state**	73kg	No
Simplicity of the synthesis	Yes	No

By the AAS investigation it was shown that 2 g of the sorbent can bind Sr - 22% by weight, and Cs-25% by weight. This means that under these conditions the hydrated form of the sorbent has a specific sorption capacity 330mg of Sr^{2+} can be collected and removed with 1g of hydrated sorbent. The resulting specific capacity of the sorbent is higher than NIMS' created equivalent HOM (high-ordered mesoporous) of 25 times (13 mg per 1g). Our sorbent binds 3.7TBq ^{90}Sr (while HOM only 65GBq). At the same time our hydrated sorbent also binds Cs (but HOM doesn't) and has a sorption capacity under these conditions for Cs^{2+} 105g per 1g of hydrated sorbent or for radioactive isotope ^{137}Cs in the number of 1.12TBq (Table 1).

It was shown that when this polymer sorbent sample was subjected to high irradiation for 24h it is resistant to high doses of radiation with the absence of radiation crosslinks in its structure as evidenced by the identity of the NMR control spectra (see Figure 2) *vs* experiment (see Figure 3) samples as well as the complete identity of the two starting from right hydrogen triplet peaks.

Saving of such particular specificity as a triplet form in the NMR spectrum after radiation exposure shows a strong stability of the complete structure of the polymer and its inertness to high dose of radiation.

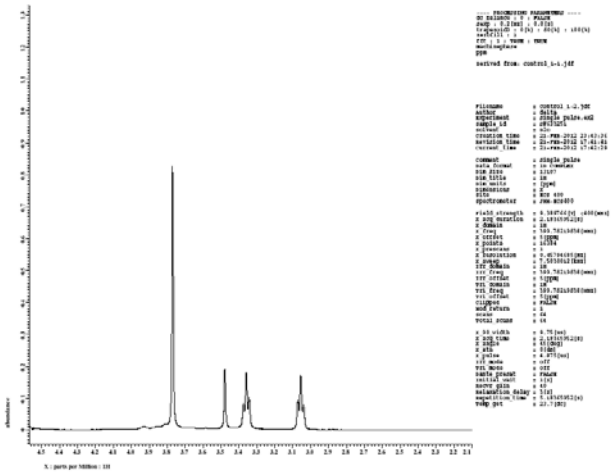

Figure 2. Control BNPS sample

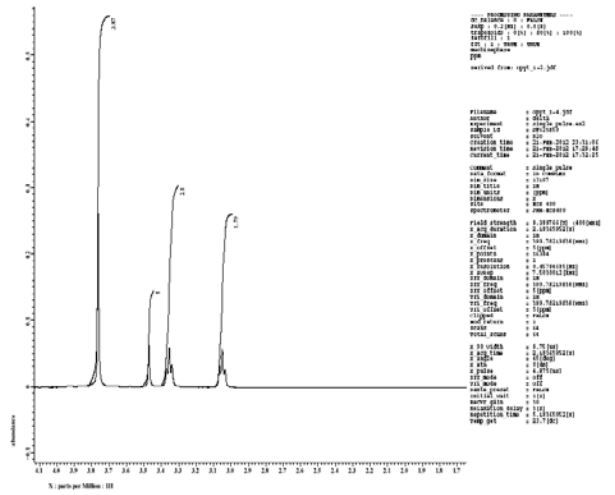

Figure 3. Irradiated BNPS sample

Saving of such particular specificity as a triplet form in the NMR spectrum after radiation exposure shows a strong stability of the complete structure of the polymer and its inertness to high dose of radiation.

Also there were proofed BNPS nontoxic and biosafe properties on human keratinocyte- derived A431cells (Figure 4, Figure 5, Figure 6).

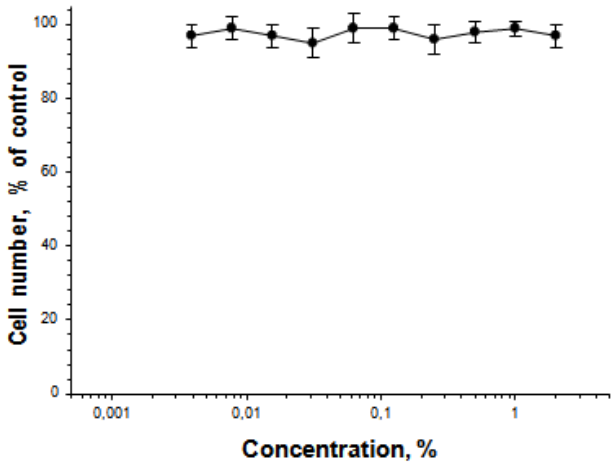

Figure 4. Concentration dependence of cytotoxicity against A 431 cells, evaluated using the crystal violet assay for BNPS

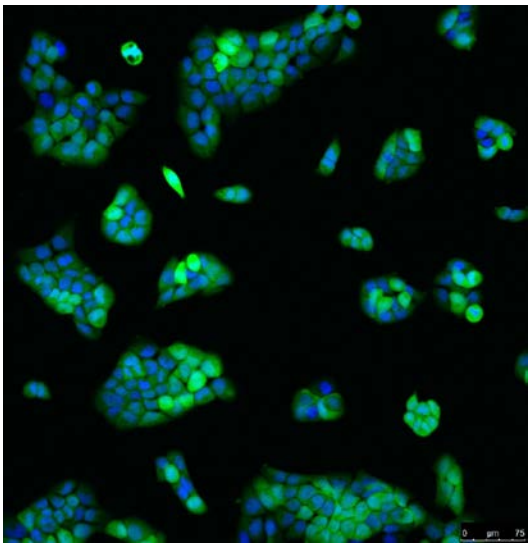

Figure 5. control

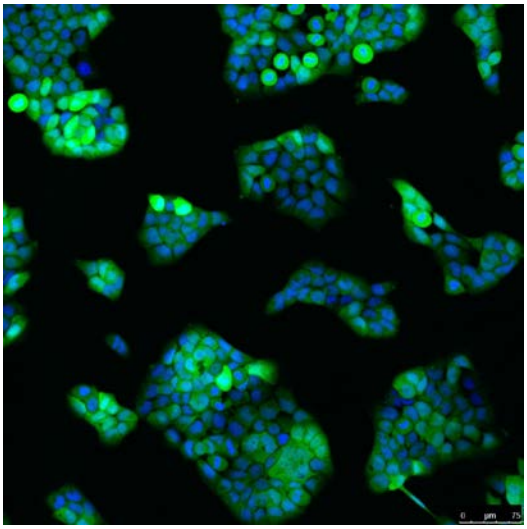

Figure 6. experiment

4. Conclusions

Thus, BNPS can be used: for decontamination (in solid phase) of highly radioactive water from

reactors; for radioactive fuel binding (hydration) for subsequent safe removal from the reactor; a filler for portable and industrial filters for purification of highly radioactive liquids; as enterosorbent because of its biosafe properties. It can be used in various industries, nuclear plants, agriculture and medicine.

Acknowledgement

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