Radiological Control of Water in Reactor Pond of MR Reactor in NRC "Kurchatov Institute", During Dismantling Work– 13462

Alexey Stepanov, Yury Simirsky, Ilya Semin, Anatoly Volkovich, Oleg Ivanov.
National Research Center "Kurchatov Institute", Moscow, Russia
alexstepanov@lenta.ru

ABSTRACT

The analysis of the activity and radionuclide composition of water from the MR reactor pond for α,β,γ-ray radionuclides was made. To solve this problem we use a wide range of laboratory equipment: gamma spectrometric complex, beta spectrometric complex, vacuum alpha spectrometer, and spectrometric complex with liquid scintillator. The water from MR reactor pond contains: Cs-137 ($2{,}6*10^2$ Bq/g), Co-60(1,8 Bq/g), Sr-90 ($1{,}0*10^2$ Bq/g), H-3 ($7{,}0*10^3$ Bq/g), and components of nuclear fuel (U-232,U-234,U-235,U-236,U-238). Therefore the cleaning water from radioactivity waste occurs to be quite a complicated radiochemical task.

INTRODUCTION

At the moment the NRC "Kurchatov Institute" carry out works on decommissioning and dismantling the multiloop research MR reactor [1]. In the course of dismantling, the test loops and fuel channels were placed in the reactor pond. Some loops were partly destroyed during the research. The analysis of the water in the reactor pond showed high level of the radionuclides Cs-137 and Sr-90. Now we conduct works on cutting and removing the channels from the reactor pond [2]. There is a risk, that nuclear fuel from the damaged loops and channels, will get into the water. Therefore it is necessary to monitor the activity and radionuclide composition of water from the MR pond for α,β,γ-ray radionuclides.

EXPERIMENTAL SECTION

To solve this problem we carried on a complex spectrometric analysis of the water from the MR pond. The concentration of γ-ray radionuclides was estimated using the spectrometric complex ISO-CART of the ORTEC company, that includes a semi-conductor detector from HP Germany GEM40P4. The final spectra are shown on figure 1. The analysis of the gamma-spectrum was made by the ISOPLUS-B32 software and showed that the pond water contains $2{,}6*10^3$ Bq/g of Cs -137 and 1,8 Bq/g of Co-60.

To detect the concentration of Sr-90 we used the scintillation β-ray spectrometer "Progress-beta", with the plastic scintillation detection assembly BDEB-3-2U. The spectra are shown on figure 2. Then we processed the spectra within the range from 0.9 MeV to 30 MeV to verify the assumption that the sample contains K-40 and Sr-90 in equilibrium with Y-90. The processing of the β-spectra with the "Progress-5" software allowed to define concentration of the radionuclide Sr-90 in the water of the MR reactor pond that occurred to be $1{,}0*10^3$ Bq/g.

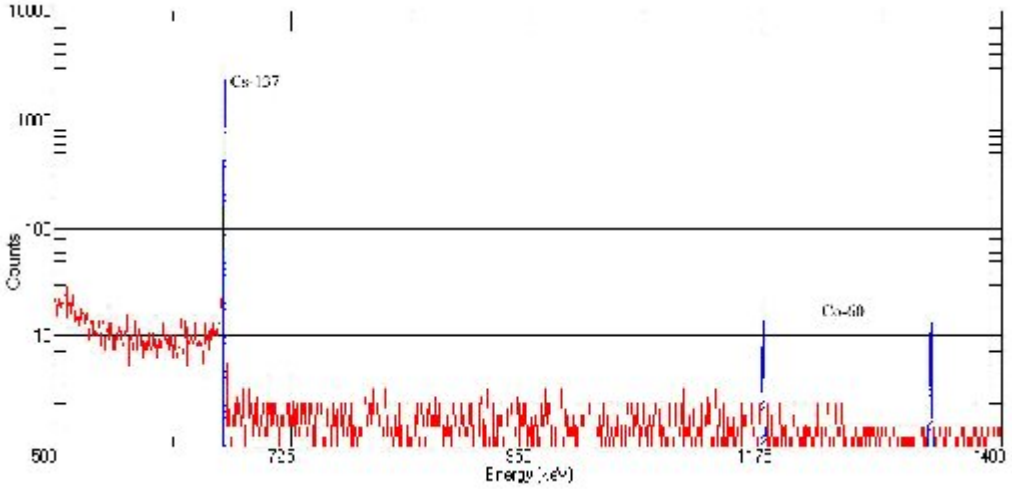

Fig.1 The gamma-spectrum of water from MR reactor pond.

To detect the concentration of Sr-90 we used the scintillation β-ray spectrometer "Progress-beta", with the plastic scintillation detection assembly BDEB-3-2U. The spectra are shown on figure 2. Then we processed the spectra within the range from 0.9 MeV to 30 MeV to verify the assumption that the sample contains K-40 and Sr-90 in equilibrium with Y-90. The processing of the β-spectra with the "Progress-5" software allowed to define concentration of the radionuclide Sr-90 in the water of the MR reactor pond that occurred to be $1{,}0*10^3$ Bq/g.

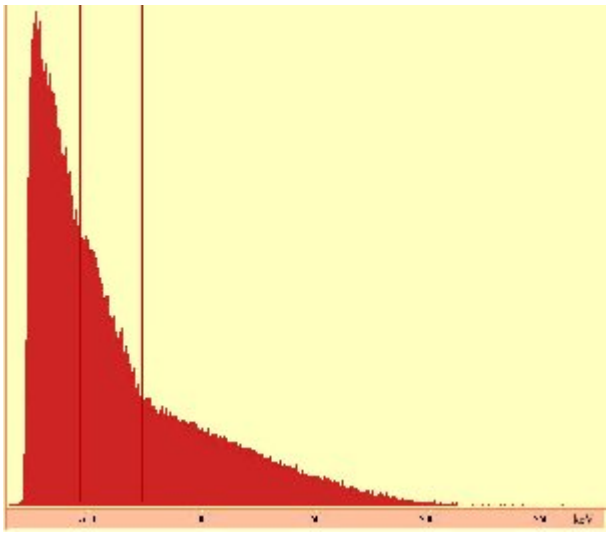

Fig.2 The beta-spectrum of water from MR reactor pond.

Tritium that is a β-ray radionuclide with the particle energy 18 keV was detected by the highly sensitive spectrometric complex SKS-07P-B11 with liquid scintillator ULTIMA GOLD AB. To eliminate from water the other radionuclides, that complicate detection of tritium, we submitted the water to bi-distillation. The concentration of tritium on the water of the MR pool was calculated by the "Liquid Master" software and was $7*10^3$ Bq/g. The spectrum of tritium is shown on figure 3.

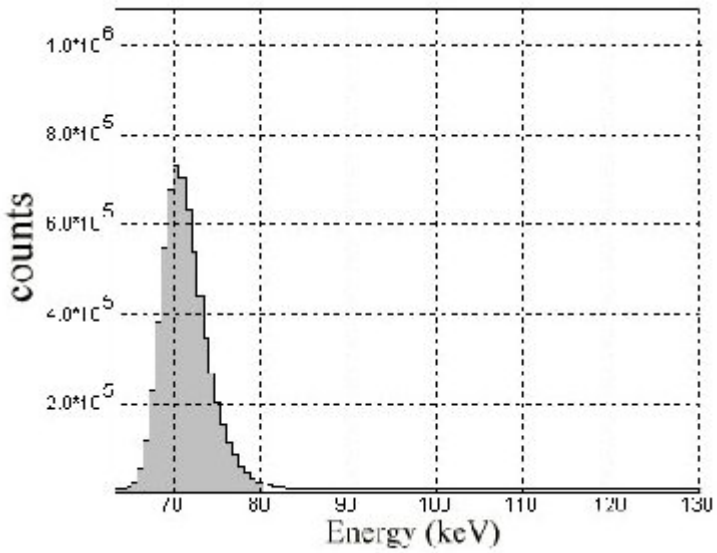

Fig. 3 The beta-spectrum of tritium.

We checked the presence of nuclear fuel components in the water of the pond by detecting radionuclides of uranium. It is quite a complicated problem to detect α-ray radionuclides in water, with high activity of Cs-137 and Sr-90. To separate uranium from other radionuclides and to concentrate it we used the ion-exchange method. 1000 ml of the water were acidified to pH=1 by a mixture of 95 ml of 20% sulphuric acid and 5 ml of 57% nitric acid. The achieved solution we pass through an ion-exchange column filled with ion-exchange resin AB-17 at a speed of 1 g/s. Before work the column was wash by a 1M solution of ammonium nitrate that contained 0,1M of nitric acid. The desorption of uranium were made at the same speed by a 1M solution of ammonium nitrate containing nitric acid. The aliquot of the achieved solution was used to detect uranium by the method of liquid scintillation spectrometry.

Then we evaporate the remained solution. Residue on evaporation we dissolved in 5 ml of a 0,5M solution of nitric acid, added 1 ml of a saturated solution of ammonium oxalate and 1 ml of a 25% solution of ammonium chloride and adjusted pH to 9 by an ammonia solution. The achieved solution was put in an electrolytic cell and uranium was deposed on a stainless steel cathode during 45 minutes under with the current density of 0,3 A/cm^2. During the electrolytic process we kept the pH level on 9 by adding the ammonia solution if necessary. When the

electrolytic process was over we took the aliquot from the cell to define the electrochemical yield of uranium. The cathode was washed by distillate water and the α-spectrum of the prepared target was taken by the vacuum Alpha Analyst Integrated Alpha Spectrometer of the Canberra company with a semi-conductor passivated implanted planar silicon detector. Uranium α-spectra obtain with the aid of a vacuum alpha spectrometer and a liquid-scintillation spectrometer are shown on figures 4 and 5 correspondently.

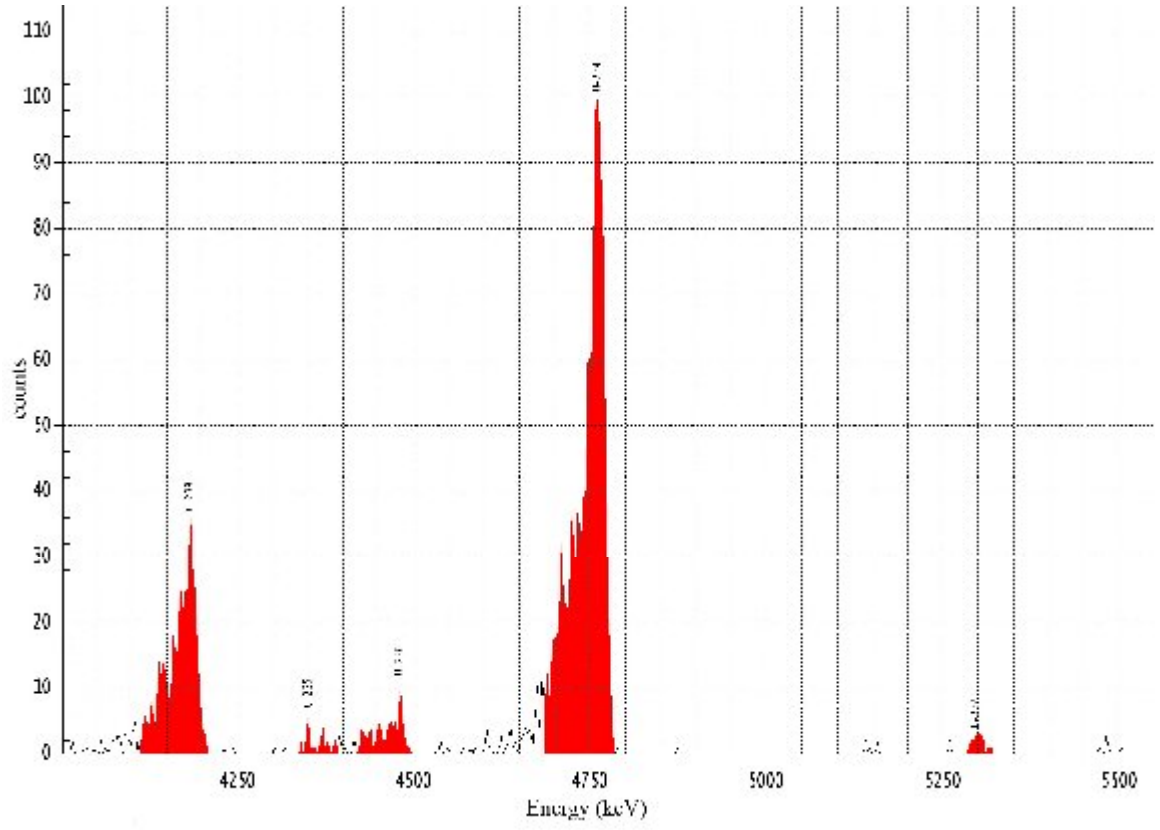

Fig. 4 The alpha-spectrum of water from MR pond, obtain on vacuum spectrometer.

The α-spectra of uranium received by the method of liquid scintillation spectrometry were processed by the Liquid Master software. We defined the limit concentration of uranium in the water of the MR pond that reached $2*10^{-3}$ Bq/g. The analysis of the α-spectra of water from MR pond received by a vacuum spectrometer showed presence of radionuclides U-232, U-234, U-235, U-236 and U-238. That means the water was polluted by components of nuclear fuel elements. The ratio of ^{232}U / ^{234}U / ^{235}U / ^{236}U / ^{238}U is 1 / 61 / 1.4 / 4 / 20.

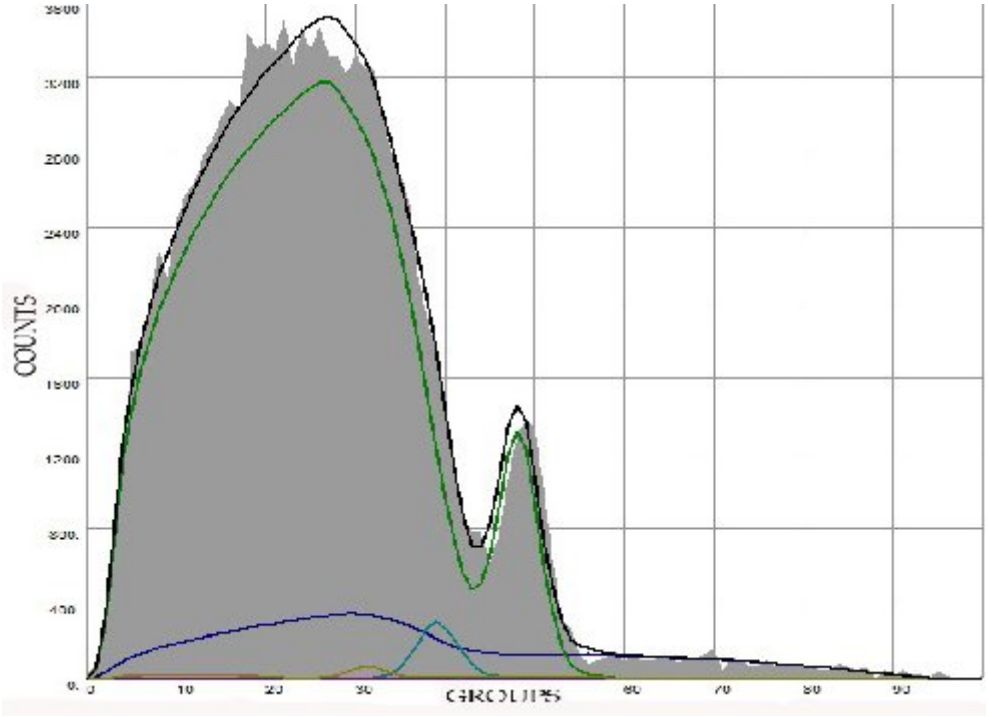

Fig. 5 The alpha-spectrum of water from MR pond, obtained on liquid-scintillation spectrometer and adopted in "Liquid Master" software.

CONCLUSIONS

Basing on the experimental data we can conclude, that the main doze increasing radionuclide in the investigated water is Cs-137. Hence during the dismantling work on reactor it seems reasonable to clean up the reactor pond water from Cs-137, which will decrease external dose of personal. This can be done with the help of filtering containers with a Cs-selective sorbent, for example, a sorbent based on ferrocyanides [3]. To the clean up water from Sr-90 [1] is possible with using selective sorbents, for example zeolite modified by phosphates of alkaline-earth metals. The concentration of tritium in the water pond exceeds seven time the tritium limits in liquid radioactivity waste [4]. Since there is no way to clean up water from tritium its concentration in the reactor pond can be decreased by diluting water with low tritium concentration.

The complex spectrometric analysis of the water in the MR reactor pond showed that the water contains: components of nuclear fuel, uranium radioactive decay product – Cs-137 and Sr-90, a considerable amount of Co-60 as the result of activation of structural materials, and tritium. For

these reasons to decrease the radionulcides concentration in the water, to achieve minimum level of radiation burden for the staff, that dismantling the MR reactor, and to classify it as liquid radioactivity waste occurs to be quite a complicated radiochemical task.

REFERENCES

1. V.G. Volkov, Y.A. Zverkov etc. “Preparation for the decommissioning of research reactor MR in the Kurchatov Institute." Atomic Energy, 2008, v.104, no 5, pp. 259-264.
2. Alexey Danilovich, Oleg Ivanov etc. ”Radiological Survey of Contaminated Installations of Research Reactor before Dismantling in High Dose Conditions with Complex for Remote Measurements of Radioactivity”, WM2012 Conference, February 26 – March 1, 2012, Phoenix, Arizona, USA”, conference proceedings, №12069.
3. Patent RF G21 F2/12 №2118856 from10.09.1998
4. Resolution of the Government RF №1069 from 19.10.12