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Review

Production of medical radionuclides in Russia: Status and future—a review

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HIGHLIGHTS

- We analyze current and potential production of medical radioisotopes in Russia.
- All main isotope producers in Russia are listed.
- Potential of new isotopes produced at middle energy accelerators are considered.
- Problems arising in with further progress are considered.

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ABSTRACT

We present a review of reactor and accelerator centers in Russia that produce medical isotopes, the majority of which are exported. In the near future, we anticipate increased isotope production for use in nuclear medicine in Russia. The existing linear accelerator at the Institute for Nuclear Research (Moscow–Troitsk) and several prospective installations are considered to be particularly capable of providing mass production of radionuclides that can substitute, to a certain extent, for the traditional medical isotopes.

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1. Introduction

The production of radionuclides for medicine and other applications is one of the most important directions of nuclear chemistry and the nuclear industry. Russia traditionally plays an important role in supplying isotopes to the world market; its share is estimated to be 22% (Kirienko, 2011), whereas the fraction of medical isotopes it supplies is somewhat less. At the beginning of the atomic era, powerful facilities were created in Russia, which were, for the most part, oriented toward defense and fundamental research. Now, medical applications are assuming greater importance not only in Russia but throughout the world. The world market for medical diagnostics and therapy is reportedly approximately $12 billion and is expected to increase to $68 billion in 2030. However, the consumption of medical isotopes in Russia is low, and approximately 90% of the isotopes are exported (Kirienko, 2011). The government is anticipated to approve a new program for the development of nuclear medicine in Russia, which would greatly increase the consumption of medical isotopes for domestic needs.

Isotopes for medical diagnostics and therapy are produced in several institutions at large nuclear facilities throughout Russia. The primary producers of medical radioactive isotopes and radiopharmaceuticals in commercial amounts are shown in Table 1. There are also other locations where radionuclides are obtained for research.

The production of short-lived cyclotron radionuclides in medical centers for positron emission tomography (PET) (^{18}F, ^{13}N, ^{13}C, ^{15}O) is not included in the present review. Only 10 PET centers are operational in Russia, and not all of them are used efficiently. However, approximately 40 centers are under construction. Royal Philips Electronics, along with the Russian state corporation ROSATOM, have announced plans for the regular manufacturing of PET scanners in Russia in the immediate future.

Providing enough isotopes for medical diagnostics is, in fact, a global problem, and Russia is determined to resolve this issue. The most important radionuclide in single photon emission computed tomography (SPECT) is ^{99m}Tc ($T_{1/2}$=6.0 h), which is generated from ^{99}Mo ($T_{1/2}$=66 h). The largest proportion of ^{99}Mo is produced in nuclear reactors via fission of highly enriched uranium. The total production and consumption of ^{99}Mo (calculated for a 6-day decay) in the world is approximately 400 TBq/week (about 12,000 Ci/week) (consumption in the USA is 180–260 TBq/week (5000–7000 Ci/week), whereas in Russia, the consumption is less than 4 TBq/week (100 Ci/week)). The primary producers of ^{99}Mo in the world are (Service, 2011): Nordion (irradiation at reactor NRU in Canada), Covidien (reactors HFR in the Netherlands, BR-2 in Belgium and Osiris in France), IRE Belgium (the same reactors HFR, BR2 and Osiris), and NTR (Safari reactor, South Africa). Other producers (in Russia, Australia, Indonesia, Argentina, Chile, Poland, Romania, Pakistan, and Egypt) provide only approximately 5% (Hansell, 2008). Japan (2014), China (2015) and South Korea (2016) have ambitious projects to contribute an important fraction of the world production in the near future. Russia would like to play a more important role in producing ^{99}Mo for export in the facilities in Dimitrovgrad and Obninsk (discussed below) using the traditional approach.

Several methods are being developed to meet the increasing demand for isotopes used for diagnostics. The most promising methods seem to be the following.

Table 1
Primary isotope producers in Russia (see references in the text below).

Institution	Location	Facilities	Radionuclide products
Kurchatov Institute	Moscow	30 MeV cyclotron, liquid fuel reactor, hot cells	^{123}I, ^{201}Tl; Under development: ^{99}Mo, ^{89}Sr
Medical Preparations Plant (Burnazyan Center)	Moscow	hot cells	^{67}Ga-citrate, ^{89}Sr, ^{131}I-radiopharmaceuticals, ^{201}Tl; ^{59}Fe (under development)
Research Institute of Atomic Reactors	Dimitrovgrad, Volga region	nuclear reactors, hot cells	^{99}Mo, ^{125}I, ^{131}I, ^{188}W, ^{89}Sr, ^{117m}Sn, ^{153}Sm, ^{153}Gd, ^{177}Lu, ^{192}Ir, ^{131}Cs, actinides; ^{144}Ce-spring microsources
Institute for Physics and Power Engineering	Obninsk, Central region	hot cells	^{32}P, ^{82}Sr, ^{133}Xe, ^{225}Ac; ^{99}Mo/^{99m}Tc-generator, ^{188}W/^{188}Re-generator, ^{90}Sr-microsources for cardio-vascular therapy; ^{225}Ac/^{213}Bi-generator (under development)
Karpov Institute of Physical Chemistry	Obninsk, Central region	nuclear reactor, hot cells	^{99}Mo, ^{153}Sm; ^{99}Mo/^{99m}Tc-generator, ^{131}I- radiopharmaceuticals, ^{188}W/^{188}Re-generator (under development)
Cyclotron Co.	Obninsk, Central region	23 and 14 MeV cyclotrons	^{67}Ga, ^{68}Ge, ^{85}Sr, ^{103}Pd, ^{111}In, ^{195}Au; ^{68}Ge/^{68}Ga-generator
Production Association MAYAK	Ozersk, Ural region	nuclear reactors, hot cells	^{14}C, ^{32}P, ^{35}S, ^{89}Sr, ^{90}Sr
Institute of Nuclear Materials	Zarechny, Ural region	nuclear reactor, hot cells	^{14}C, ^{32}P, ^{33}P, ^{35}S, ^{90}Y, ^{131}Cs, ^{192}Ir
Khlopin Radio Institute	St-Petersburg	cyclotron, hot cells, nuclear reactor of LAES	^{67}Ga, ^{123}I, ^{124}I, ^{125}I, ^{186}Re; ^{99}Mo/^{99m}Tc-generator
Central Research Institute of Radiology and Roentgenology	St-Petersburg	cyclotron, hot cells	^{123}I-radiopharmaceuticals; ^{82}Sr/^{82}Rb-generator, PET-isotopes
Research Institute of Applied Chemistry	St-Petersburg	hot cells	Compounds labeled with ^{3}H, ^{14}C, ^{33}P, ^{125}I
2nd Central Institute of Ministry of Defense	Tver, Central region	30 MeV cyclotron	^{67}Ga
Institute of Nuclear Physics of Tomsk Polytechnic University	Tomsk, Siberia region	nuclear reactor, cyclotron, hot cells	^{67}Ga, ^{123}I, ^{199}Tl; ^{99}Mo/^{99m}Tc-generator
Institute for Nuclear Research of Russian Academy of Sciences	Moscow–Troitsk	linear accelerator	targets containing ^{68}Ge, ^{82}Sr, ^{103}Pd, ^{117m}Sn; Under development: ^{64,67}Cu, ^{72}Se, ^{223}Ra, ^{225}Ac