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Assessment of the increasing in 131-I production due to improved tellurium target in the WWR-c reactor core

O.Yu. Kochnov, V.V. Kolesov*, R.V. Fomin, G.M. Jerdev

Obninsk Institute for Nuclear Power Engineering, National Nuclear Research University "MEPhI".Studgorodok 1, Obninsk, Kaluga region 249020, Russia

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Abstract

Currently, the problem of expanding the production of 131-I radionuclide for medical purposes is still relevant. The main consumer of this product in the European region is the MRRC of the Russian Ministry of Healthcare (Obninsk). 131-I production at the Obninsk Branch ofthe JSC "Karpov Institute of Physical Chemistry" is insufficient and requires additional supplies of 131-I from NIIAR (Dimitrovgrad). On the other hand, due to the fact that the half-life of 131-I is only eight days, its transportation over long distances is not feasible. Therefore, an increase in this isotope production at the Obninsk Branch of the Karpov Institute can bring significant economic benefits.

At present a new design of the target for 131-I production has been developed. However, comparative assessment of standard and modified targets efficiency has not been performed so far.

This paper presents some estimates of 131-I production with both targets which were irradiated in the WWR-c reactor. It is shown that a new target provides a significant (by a factor of three) increase in 131-I production, while specific concentration of 131-I in the initial target is slightly (about 20%) decreased.

We have also investigated replacing aluminum alloy target shell with one made of stainless steel and found a 20% decrease in the 131-I yield.

The comparison between the calculated 131-I yield and the actual 131-I yield testifies that the cumulated 131-I yield can be significantly increased.

Keywords: WWR-c reactor; Tellurium target; 131-I production.

Introduction

Currently, expanding the production of 131-I radionuclide for medical purposes is still relevant. The 131-I radionuclide (T1/2 = 8.02 days, $E\beta = 0.607$ MeV,$E\gamma = 364$ keV with probabilities 89.9% and 82%, respectively) is used as a radioactive marker in wide spectrum of cancer diagnostics (thyroid, liver, heart etc.) as well for treatment for some types of cancer. Development of iodine radiopharmaceuticals production is shown on Fig. 1. The main consumer of this product in the European region is the MRRC of the Russian Ministry of Healthcare (Obninsk). Although production of iodine preparations at the JSC "Karpov Institute of Physical Chemistry" grows, is does not cover the whole demand so that an additional supply of 131-I from NIIAR (Dimitrovgrad) is necessary. On the other side, the half-life time of 131-I is eight days only, meaning that long-distance transportation is not feasible. For this reasons, the on-site generation of this isotope at the Obninsk branch of the JRC "Karpov Institute of Physical Chemistry" may bring significant economic benefit.

Problem statement

131-I production can be increased in several ways:

* Corresponding author.
E-mail addresses: kochnov2000@mail.ru (O.Yu. Kochnov), kolesov@iate.obninsk.ru (V.V. Kolesov), sparck22@yandex.ru (R.V. Fomin), jerdev@ippe.ru (G.M. Jerdev).

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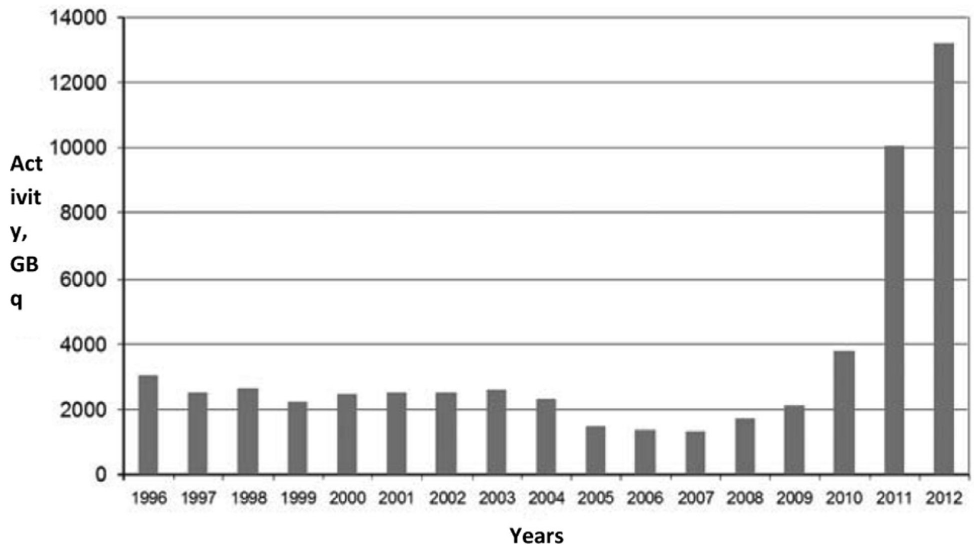

Fig. 1. Production of 131-I radiopharmaceuticals in JSC “Karpov Institute of Physical Chemistry”.

- Increase the amount of irradiated targets together with the number of experimental channels and irradiation chambers in the WWR-c reactor core;
- Irradiate targets in other research reactors (for example IVV-2 M in Zarechny) and nuclear power plants (for example the Leningrad NPP) followed by their return for reprocessing;
- Position targets in regions with higher neutron flux (for example in neutron traps) etc.

All these ways are followed; however each of them has its drawbacks. Major attention can be payed to modify the design of targets positioned in the reactor core technological channels.

In the present work we perform computational study of feasibility of the 131-I target modifications. As a result, the most effective way of production expansion will be clarified to the manufacturer.

The main requirements to the irradiation target are:

- It must fit into a perforated container with inner diameter of 54 mm.
- The target’s diameter is limited by the 30 mm 131-I extraction facility.
- The target is made of pellets sealed intosilica glass ampoules and withstanding irradiation conditions.

The first version of the target design, at the begin of 131-I production, was represented by a set of silica glass ampoules placed in a perforated container. The target was positioned into a blind, passive-cooled vertical experimental channel at the core periphery. This type was not suited for modifications allowing considerable increase of 131-I production, therefore a new improved target design with an increased loading of 130-Te was proposed in 2012, which has led to gain in production by a factor of six or more.

This was insufficient; therefore we also assessed the use of another construction material in the improved target design. The new construction material admits higher temperature of 131-I extraction leading to considerably higher iodine yield (by a factor of two or more) without melting the target cladding. The amount of irradiated material is also increased while silica glass is not needed.

Fig. 3 shows calculation model of the modified target design.

Results of calculations

The WWR-C core model, particularly suitable for calculations of nuclide generation in technological channels, has been presented in [1]. This model can be used to compare 131-I generation in different target designs, using the MCNP [2] and the VisualBunOut [3] computer codes.

We have performed calculations of 131-I yield in the initial (Fig. 2a) and modified (Fig. 3a) targets, placed in in channels 1-1 and 1–4 of the WWR-c core during the reactor campaign.

The WWR-c reactor campaign comprises 100 h per week, followed by shutdown for cooling, fuel and targets reloading and other operations. The target is usually placed in the core during two campaigns; thus the target is irradiated for 100 h in the core channel at the nominal power of 10 MWt, the core is cooled down (the target is positioned in the channels in the absence of neutron flux) for 68 h and then the target is again irradiated for 100 h at the core nominal power. Immediately after that the target is processed.

The major decay chain leading to generation of 131-I is shown on Fig. 4.

Before comparing generated activities in the initial and modified targets, we compare available nuclear data necessary to perform these calculations.

Currently, there are many evaluated data sets that can be used to calculate 131-I yield in the tellurium oxide, irradiated