Radiation Protection’s Benefits in the Production of Iodine-131


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Abstract. Iodine-131 is being produced in Argentina at the Ezeiza Atomic Center as a by-product of the Molybdenum-99 production process. For this purpose, low enriched uranium-aluminium (LEU) targets are irradiated for around 5 days in the RA-3 reactor core. Once irradiated, the targets are transferred to shielded cells, where they are processed until final product is obtained.

The process comprises several stages associated to the separation and purification of the iodine until a maximum-purity product is obtained, achieving in this way, the quality for its use in nuclear medicine.

This fission Iodine-131 purification method was developed by the staff of the CNEA in 2005, converting Argentina in the first all over the world that produces Molybdenum-99 and Iodine-131 from Low Enriched Uranium targets. In the past, Iodine-131 was produced in Argentina by irradiation of tellurium oxide, and Iodine-131 generated in the irradiation of LEU targets for the Molibdenum-99 production, was considered a nuclear waste.

The old tellurium oxide method basically consisted in the irradiation of tellurium oxide, dissolution of the irradiated material, and finally an acid distillation of the generated iodine. The new process is all carried out in alkaline medium, generating in this way, lower emissions with several times bigger productions, as almost all the iodine remains in the solution.

Main features of both processes and a description of the Radiation Protection benefits achieved with the new method, including the reduction of nuclear wastes and the total iodine emissions, are shown in the paper.

Introduction

Iodine-131 is a radionuclide widely employed in nuclear medicine practices. For this reason, production of fission I-131 has become an important concern in CNEA Radioisotope Production Program.

Fission I-131 is being produced in CNEA of Argentina since September 2005, employing low enriched uranium/aluminide targets [1][2][3][4].

Digestion of the targets is based on the method developed by Dr. Sameh Ali at KfK in Germany for Molibdenum-99 production [5].

Iodine-131 purification method was developed by the staff of CNEA [6].

Fission Isotopes Production Facility

The building is located at Ezeiza Atomic Center, neighbor to RA-3 reactor. Production facility has two groups of four hot cells each. The first group, where digestion of targets is performed, has a shielding of 30 cm of lead. The other group, employed in the purification stages, has 20 cm of lead walls.

All the cells have α β γ tight stainless steel boxes with epoxy cover.

Isotopes Production and Fractionation Facility

The building is located in the same block that the Fission Isotopes Production Facility. A unique cell is used in the conditioning and fractionation of the Iodine. It has α β γ tight stainless steel boxes with epoxi cover and its walls have 10 cm of lead thickness.

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Fission Iodine-131 process description (new method)

Uranium aluminide targets are irradiated in RA-3 reactor core during 110 hours with a neutron flux of about $2 \times 10^{14}$ n/cm$^2$.seg and ten hours of cooling in reactor pool [7][8].

Transportation from RA-3 is accomplished through an internal corridor, with a motorized shielding of 23 cm of lead that has a capacity for carrying up to four targets.

![Picture 1]

Fission Iodine Production

Irradiated plates are dissolved in hot alkaline solution. Hydrogen and fission gases produced are kept in evacuated charcoal filled tanks and, after four weeks of decayment, they are released to the atmosphere.

When dissolution is completed, solution is filtered through a sintered stainless steel plate, leaving non-fissioned uranium and other products in the precipitate. The resulting solution is composed by Iodine and the other fission products soluble in alkaline medium.

As first stage of purification, alkaline solution is fed through a column of anion exchange resin where some fission products, soluble in alkaline medium, pass through. Iodine is retained in this column, together with some other fission products.

Different washing solutions are passed through the column, separating groups of different fission products with each solution, but remaining iodine. Resulting iodine goes to a second purification stage. It is eluted and then loaded in a new column of strong anion exchange resin where iodine is retained again and other fission products passed through. Later, the iodine is stripped from the column and is stored for a period of eleven days to allow the decay of impurities, mainly I-132 and I-133.

Finally, the final solution is delivered to the other facility for final conditioning, quality control, fractionation and dispatch.

Quality control

Typical values of quality control results for Iodine-131 samples produced by this method are shown in table 1.
Table 1: I-131 specification and typical CNEA values.

<table>
<thead>
<tr>
<th></th>
<th>Typical</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiochemical purity</td>
<td>99%</td>
<td>95%</td>
</tr>
<tr>
<td>Radionuclide purity</td>
<td>99.97%</td>
<td>99.9%</td>
</tr>
<tr>
<td>pH</td>
<td>8.5</td>
<td>Between 7-9</td>
</tr>
<tr>
<td>Radionuclide Impurities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nb-95/I-131</td>
<td>&lt; 1.2x10^{-3}</td>
<td>&lt;10^{-3}</td>
</tr>
<tr>
<td>Zr-95/I-131</td>
<td>&lt; 1.4x10^{-3}</td>
<td>&lt;10^{-3}</td>
</tr>
<tr>
<td>Ru-103/I-131</td>
<td>&lt; 1.9x10^{-3}</td>
<td>&lt;10^{-3}</td>
</tr>
<tr>
<td>I-132/I-131</td>
<td>&lt; 1.8x10^{-4}</td>
<td>&lt;10^{-3}</td>
</tr>
<tr>
<td>I-133/I-131</td>
<td>&lt; 4.0x10^{-5}</td>
<td>&lt;10^{-3}</td>
</tr>
</tbody>
</table>

Old Tellurium oxide method

The whole process was carried out in the Isotope Production and Fractionation Facility. The Iodine-131 was obtained by irradiation of tellurium oxide 99.99% purity, and a (n,γ) reaction transform Te-130 into Te-131 and then, by radioactive decayment into I-131.

The irradiation was performed for around one month in RA-3 reactor.
The separation of the iodine from the tellurium began with an alkaline dissolution of the oxide, and then, an acid distillation was carried out.

In that acid medium, it was impossible to retain all the iodine, so part of it went through the ventilation system.

Main Features Comparison

To carry out this comparison we studied 3 different variables related with the production of I-131 between 2001 and 2008.

The first variable analyzed was the total activity dispatch in each period. For a better comparison, a “factor” was created in order to relate each year with 2001. In this way, it is possible to read directly the increases in the dispatches activities compared with the 2001 results.

The factor “f” has the following form:

\[ f_i = \frac{A_i}{A_{2001}} \]

\( A = \) Activity dispatch

\( i = \) number of year considered

Calculating \( f_i \) for each year (Fig.1):
The second variable considered was the emission of I-131 to environment. For this reason we calculated the average emissions in the last 5 years, when we had produced the I-131 with the tellurium oxide method, and the average emission with the new one. It should be clarified that we compared two scenarios, the first one producing fission Mo-99 and I-131 from tellurium oxide method, and the second one producing fission Mo-99 and fission I-131.

In 2008, the months considered were from January to May, but we extrapolated these values to the entire year. The values obtained were the ones showed in the figure 2.

The third variable considered was the generation of liquid nuclear wastes due to the production and purification of I-131.

In this case, we compared the same two scenarios considered before, the first one producing fission Mo-99 and I-131 from tellurium oxide method, and the second one producing fission Mo-99 and fission I-131. As the fission iodine process do not generate an increase in liquid waste activity in the molybdenum fission process, and as we do not need the old tellurium oxide method, we obtained a substantial reduction in the generation of liquid wastes. To have an idea, liquid wastes containing radioactive tellurium has been reduced by around of 6 liters per week. For this reason, there is a huge reduction in the personal dose of all the workers involve in the task.

Conclusions:

The first variable analyzed was the total activity dispatched in each period. When the production of fission I-131 began, the demand was covered part by CNEA’s supply and part by importation. Since
that year, CNEA was increasing the supplied activity to cover, during 2007, the whole national market. Moreover, nowadays there are some foreign countries that import our material. If we observe variability in the produced activity, it is expected that there had been an increase in the emission to the environment. That thing did not happen, mainly due to the alkaline medium that the fission’s iodine process is carried out, as almost all the iodine remains in the solution, and because of the recovery of the fission iodine in the molybdenum process. The reductions of the emissions can be observed in the Figure 3.

**Figure 3:** Comparison of average emissions in both periods

Even more, if we compare the emission in function of dispatched activity, the improvement is even better, as can be seen in figure 4.

**Figure 4:** Comparison of average activities emissions per Curie dispatch in both periods

Other benefits, related with the new process, are reduction of the irradiation cost and raw material.

In every process where radioisotopes are produced by the utilization of open sources, there is an unavoidable dose to the involved workers and eventually, to the most exposed people, called critic group. In the second group, this dose is due to the radioactive effluents that the production method or practice cause.

In our case, if we see the two scenarios, this is before and after the fission iodine process, a great improvement was achieved. A huge reduction of the nuclear wastes activities and the emissions was reached and, in this way, a dose reduction to the staff and the critic group.
If we talk specifically about the critic group and considering the population most exposed and most vulnerable for this type of effluent, a dose reduction of 63% was accomplished (see Fig. 5). The factor that relates the activity of the nuclear effluent with the dose received by the critic group was calculated by the Nuclear Regulatory Authority.

**Figure 5:** Critic group average dose comparison in both periods

![Critic group average dose comparison in both periods](image)

(*a*) Extrapolated first 5 months values to the entire 2008 year

As most people know, the objective of the radioprotection is achieved fulfilling three basics principles. The first one is the justification of the practice, concept easily justified when we talk about medic radioisotopes production. The second one is the dose limits, aspect that is fulfilled effortlessly by CNEA’s staff and the critic group. The third one is the optimization of the task, concept very related with the safety culture. The optimization of the task in the nuclear field is one principles of the radioprotection and CNEA’s staff is committed with this and the others principles of the radioprotection, and we are continue searching for improvement of all our activities.

This fission Iodine-131 purification method was developed by the staff of the CNEA in 2005, becoming Argentina in the first and unique country that produces Molybdenum-99 and Iodine-131 from LEU targets. Argentina is committed with the uranium enrichment minimization and has demonstrated its commitment with facts.

In this paper, after a great effort to carry out successfully the fission iodine process, we can see that not only this great achievement was reach. An important reduction of the nuclear effluents was obtained too, minimizing the radiological risks and the doses but maximization the production and so the benefits to the society.
References


