Mo-99 2013 TOPICAL MEETING ON
MOLYBDENUM-99 TECHNOLOGICAL DEVELOPMENT

April 1-5, 2013
Embassy Suites Downtown - Lakeshore
Chicago, Illinois

Production of ^{99}Mo at IPEN-CNEN/SP-Brazil

João A. Osso Jr., Carla R.B.R. Dias, Tania P. Brambilla, Rodrigo Teodoro, Marcela F. Catanoso, Josiane Zini, Regina R.L. Bezerra, Luiz A. Villela, Jeremias L. Correia, Evandro Ivanov, Fatima M.S. Carvalho, Lorena Pozzo, Peterson L. Squair, Jair Mengatti
Radiopharmacy Department
Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN/SP), Avenida Prof. Lineu Prestes 2242, 05508-000 – São Paulo, SP – Brazil

ABSTRACT

The most widely radioisotope employed in Nuclear Medicine diagnosis in Brazil is ^{99m}Tc. The ^{99}Mo-^{99m}Tc generators are solely produced at IPEN-CNEN/SP since 1981. The Brazilian demand reaches out 385 generators per week with a total activity of about 16.7 TBq nowadays. The recent ^{99}Mo supply crisis deeply affected the distribution of generators in Brazil because ^{99}Mo was imported only from Canada. A short term solution was achieved with the purchase of ^{99}Mo from Argentina and more recently from South Africa. The midterm project consists on the production of (n,γ) ^{99}Mo using the existing IEA-R1m Reactor with the distribution of ^{99m}Tc to hospitals in Sao Paulo. The long term project deals with the production of ^{99}Mo through the fission of LE^{235}U targets using the new Brazilian Multipurpose Reactor with a 30 MW power. This work gives an up-to-date on the projects aiming the nationalization of the ^{99}Mo production.

1. Introduction

Technetium-99m (^{99m}Tc) is the workhorse of diagnostic nuclear medicine and used for approximately 20–25 million procedures annually, comprising nearly 80% of all diagnostic nuclear medicine procedures. Its excellent nuclear and chemical characteristics enable high quality images with low radiation doses to patients and make it very versatile for attaching to different chemical substances. Nuclear Medicine applications in Brazil have been widely growing in the past few decades, following the world trends. [1, 2].

^{99m}Tc (half-life: 6 h) is produced by the decay of molybdenum-99 (^{99}Mo) (half-life: 66 h) and supplied via a ^{99}Mo-^{99m}Tc generator.

The Brazilian demand, attended solely by IPEN-CNEN/SP, reaches out more than 385 generators per week with a total activity of about 16.7 TBq (450 Ci), which corresponds to

4% of the overall ^{99}Mo global demand at an importation cost of US$20 million/year. Up to 2009 ^{99}Mo was solely imported from Nordion, Canada.

The shutdown of the NRU reactor in Canada in 2009 has triggered a global shortage in nuclear medical isotopes, which has made the situation particularly problematic from a medical standpoint. This recent ^{99}Mo 'crisis' deeply affected the distribution of generators in Brazil.

This work describes the efforts taken by IPEN-CNEN/SP to overcome the recent ^{99}Mo supply shortage and an up-to-date on the projects aiming the nationalization of the ^{99}Mo production.

2. Description of the actual work

The Radiopharmacy Center of IPEN-CNEN/SP has an established radioisotope production program to supply radiopharmaceuticals to the Nuclear Medicine community in Brazil. These radiopharmaceuticals are prepared with radioisotopes produced in both a Nuclear Reactor and two Cyclotron accelerators. IPEN has a Research Reactor, so called IEA-R1m that nowadays operates at 5.0 MW for 64 hours continuously.

The strategies for overcoming the ^{99}Mo shortage are divided into 3 categories: short, mid and long term projects.

Mid term and long term projects are under way aiming the nationalization of the production of ^{99}Mo. The long term solution will use the recently approved new Brazilian Multipurpose Reactor (BMR) that will be built near São Paulo city and will have a 30 MW power.

Short term project

A short term solution was achieved with the purchase of ^{99}Mo from Argentina, South Africa, Canada and more recently from IRE (Belgium).

Mid term project

The mid term project consists on the production of (n,γ) ^{99}Mo using the existing IEA-R1m Reactor. The methodology employed is the separation of ^{99m}Tc from ^{99}Mo through the solvent extraction technique with metilethylketone (MEK). The ^{99m}Tc will then be distributed to the clinics near IPEN, in Sao Paulo city, and later monodoses will be prepared by labeling the lyophilized kits with ^{99m}Tc. Figure 1 represents the mid term strategies for the production of ^{99}Mo via neutronic activation based on early experiences. Future perspectives on the development of mid term actions would be mainly dependent on the new configuration of IEA-R1m Nuclear Reactor (i.e, if the reactor power is upgraded from 4.0 MW to 5 MW) and also the use of the new Reactor.

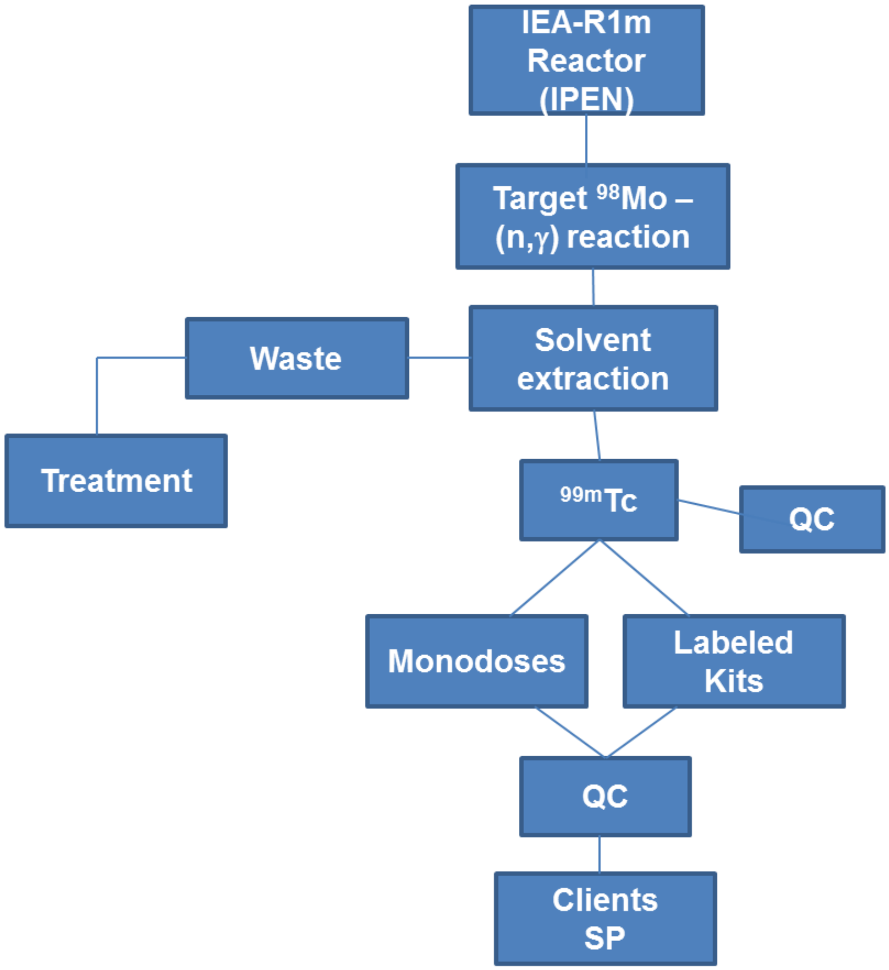

Fig 1. Mid term strategies for the production of ^{99}Mo and distribution of ^{99m}Tc.

Long term project: new Brazilian Multipurpose Reactor (BMR)

The long term project deals with the production of ^{99}Mo through the fission of ^{235}U using LEU targets. Due to the international concerns about the proliferation of weapons-usable uranium and eventually eliminating the use of HEU (>20%) the International Atomic Energy Agency (IAEA) initiated a program of developing techniques for production of ^{99}Mo using low enriched uranium (LEU). The substitution of HEU to LEU requires a modified technology. The approach to be adopted by IPEN would be largely dependent on the reactor features and the economic viability of the process employed. Two different approaches are being studied, the more conventional basic dissolution of UAlx targets and the modified Cintichem method that employs the acid dissolution of metallic U targets. This last method is being promoted by IAEA through the CRP: T1 2018 - Developing Techniques for Small Scale Indigenous Molybdenum-99 Production Using Low Enriched Uranium (LEU) Fission or Neutron Activation.

Figure 2 shows the strategies for the production of ^{99}Mo through the fission of ^{235}U. It can be seen that the aim of the project is also the production of fission ^{131}I.

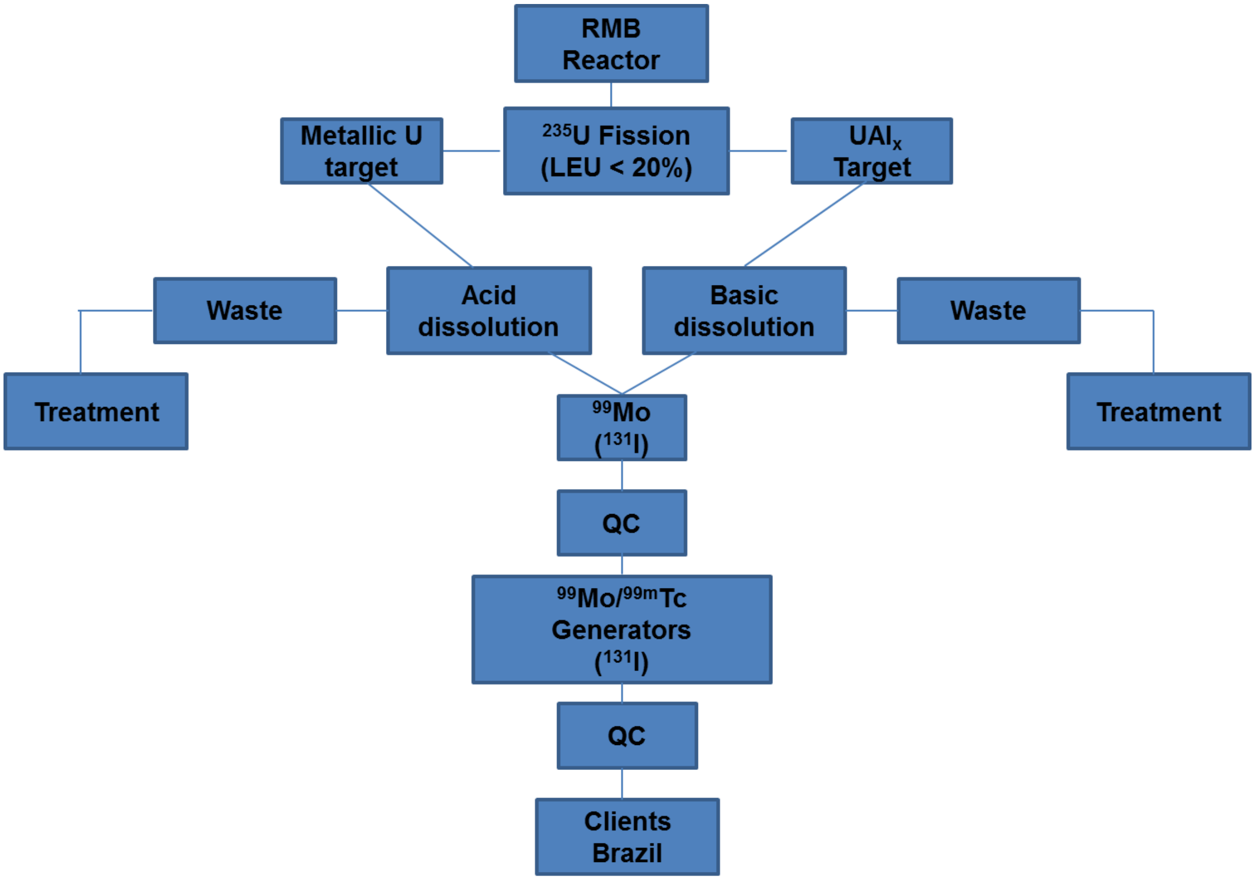

Fig 2. Long term alternatives for the production of ^{99}Mo and distribution of ^{99m}Tc via LE^{235}U in the BMR

3. Results

Short term project

In 2009, actions have been taken to overcome the shortage of ^{99}Mo supply by the main Brazilian supplier (MDS Nordion). The straight forward short term action included the purchase of ^{99}Mo from Argentina and South Africa and also the distribution of ^{99}Mo/^{99m}Tc generators from Israel and Belgium (IBA). Besides, an adequacy of the Brazilian market (i.e., from 16.7 TBq ^{99}Mo/week to nearly 14.8 TBq ^{99}Mo/week) took place. A change of trend happened; there was a higher demand for low activity generators compared to the pre-crisis higher demand for high activity generators. Another interesting point was that the nuclear medicine physicians started to employ less ^{99m}Tc activity in the exams, leading to a better use of the generators. Nowadays ^{99}Mo is being imported from Argentine, South Africa, Canada and Belgium and the generators are being produced 3 times per week.

Figure 3 shows the demand for ^{99}Mo in Brazil since 2000 highlighting the effect of the ^{99}Mo supply crisis and the recovery of the market.

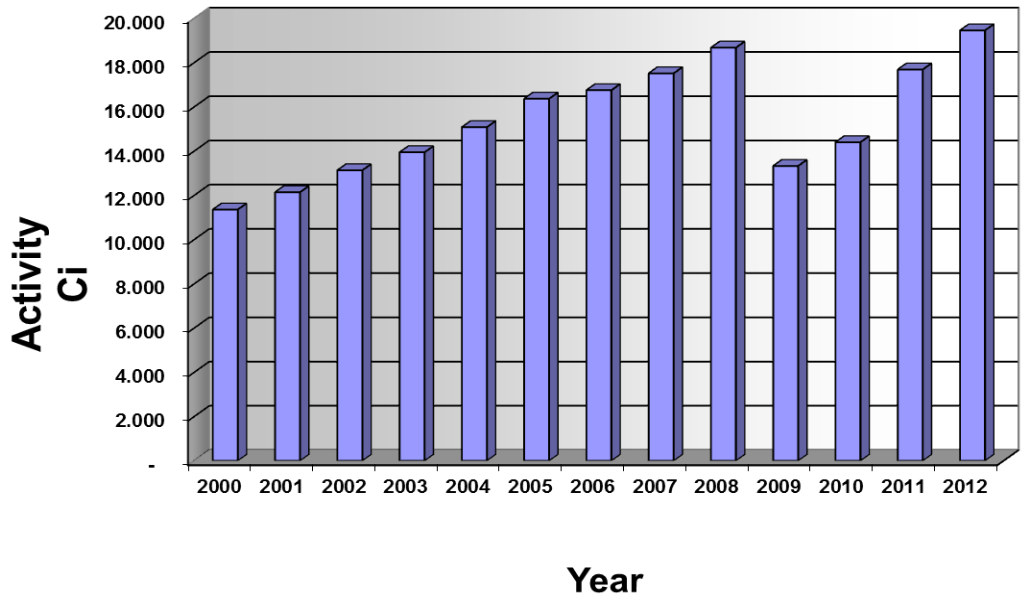

Fig. 3. Demand of ^{99}Mo in Brazil

Mid term project

In the past, IPEN has developed the route for producing ^{99}Mo by neutron activation of Mo targets in the IEA-R1m Research Reactor through the ^{98}Mo(n,γ)^{99}Mo reaction and developed the MoZr gel generator technology. This technology is limited so the mid term project will employ the solvent extraction principle. Experiments are under way using the solvent extraction of ^{99m}Tc with MEK and the preliminary results showed a separation yield higher than 85% for ^{99m}Tc with adequate purity for posterior labeling. The production hot cell is being assembled and the production is expected to start in the end of 2013. The total activity of ^{99m}Tc expected to be delivered is between 0.5 TBq (13 Ci) and 1.3 TBq (35 Ci) of ^{99m}Tc (Monday morning calibration) depending on the operation schedule of the Reactor. These activities represent 17 % and 50 % of the ^{99m}Tc demand in the city of Sao Paulo, respectively.

Long term project: new Brazilian Multipurpose Reactor (BMR)

Due to the increasing needs of the nuclear medicine in Brazil and the world shortage of ^{99}Mo observed since 2008, IPEN decided to develop its skills for producing ^{99}Mo through the route of ^{235}U fission. This decision was based on: (i) the well-established laboratory for producing ^{99m}Tc generators already in operation in IPEN and responsible for the Brazilian market supply; (ii) the availability of LEU (20 wt%) by the Brazilian Enrichment Laboratory; (iii) the established capacity to prepare targets of UAlx; (iv) the availability of some human resources in uranium chemistry; (v) the possibility of operating the IEA-R1 for at least ten years more; and (vi) the recent intention of the CNEN to construct a new Brazilian multipurpose research reactor (BMR).

Studies are under way on both routes, i.e., the basic dissolution of UAlx targets and acid dissolution of metallic U targets, always using LEU targets. The conception design project was completed for the building that will contain the ^{99}Mo processing installation. The chemical processing studies are under way together with the LEU targets preparation and the waste management.

4. Conclusions

Several actions have been taken to overcome the ^{99}Mo supply crisis and also to underline the efforts towards the nationalization of ^{99}Mo production. The long term project is only possible with the construction and operation of the new Reactor, the BMR.

5. Acknowledgements

The authors wish to thank IAEA for the Brazilian participation in the CRP: T1 2018 - Developing Techniques for Small Scale Indigenous Molybdenum-99 Production Using Low Enriched Uranium (LEU) Fission or Neutron Activation. The authors also want to thank CNPq for granting the fellowships for this project.

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